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USSR Report

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

(FOUO 20/81)

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USSR REPORT

CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY

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FOR OFFICIAL USE ONLY

SIGNAL PROCESSING

PUBLICATIONS

OPTICAL PROCESSING

UDC 621.396

RADIOHOLOGRAPHY AND OPTICAL INFORMATION PROCESSING IN MICROWAVE TECHNOLOGY

Leningrad RADIOGOLOGRAFIYA I OPTICHESKAYA OBRABOTKA INFORMATSII V MIKROVOLNOVOY TEKHNIKE in Russian 1980 (signed to press 24 Oct 80) pp 2-4, 181-183

/Annotation, foreword and abstracts from book "Radioholography and Optical Information Processing in Microwave Technology", edited by L.D. Bakhrakh, corresponding member, USSR Academy of Sciences, and A.P. Kurochkin, candidate of technical sciences, Izdatel'stvo "Nauka" (Leningrad Branch), 2,150 copies, 184 pages/

/Text/ ANNOTATION

In the articles in this collection, there is a discussion of the use of holography and optical information processing in microwave technology: the methods and equipment for visualizing microwave fields and obtaining images of objects; the holographic method for determining antenna parameters in the near zone; questions concerning the construction and special operating features of acoustico-optical devices for processing radio signals; an investigation of the correlational optical identification of space images.

FOREWORD

The articles presented in this collection encompass the following themes: holographic methods and equipment for the visualization of microwave and acoustical fields, as well as producing images of objects irradiated by waves in the microwave band; different aspects of the holographic method of determining the parameters of microwave antennas in the near zone; the optical processing of signals from antenna arrays; questions concerning the construction of acoustico-optical devices for processing radio signals.

Questions on the construction of high-speed complexes of equipment for producing microwave and acoustic holograms and images are the subject of the articles by A.V. Avrorin and coauthors and L.I. Bayda and coauthors.

In their article, A.S. Klyuchnikov and P.D. Kukharchik investigate a new type of display for holograms in the millimeter and submillimeter bands: films of different liquids.

The article by O.V. Bazarskiy and Ya.L. Khlyavich is devoted to an analysis of the generalized criterion for evaluating the resolution of radioholograms.

A.I. Balabanov and coauthors present the results of experimental investigations of the correlational optical identification of space objects.

The subject of the articles by A.G. Buday and coauthors and Yu.V. Sysoy. is the development of a holographic method for determining antenna parameters in the near zone.

The next group of articles encompasses various questions concerning the optical processing of signals from antenna arrays and radio-frequency radiation sources. In two theoretical articles, A.Yu. Grinev and coauthors analyze signal processing algorithms and evaluate the parameters of radio-optical antennas with different configurations.

N.A. Yesepkina and coauthors propose and investigate a hybrid opticodigital system for processing the signals received from pulsars.

The collection concludes with articles by Ye.T. Aksenov and coauthors and S.V. Kulakov that are devoted to acoustico-optical devices for processing information on the basis of nonlinear acoustic interaction and an investigation of the effects of elastic wave attenuation and light modulator nonlinearity on the parameters of acoustico-optical correlators.

The editors hope that the works presented in this collection will attract the attention of specialists and contribute to a further improvement in and practical use of the methods of holography and optical information processing in microwave technology.

ABSTRACTS

UDC 778.4:534.6

LONG-WAVE HOLOGRAPHY IN REAL TIME

/Abstract of article by Avrorin, A.V., Breytman, B.A., Volkov, Yu.K., Votentsev, V.N., Gruznov, V.M., Kopylov, Ye.A., Korshever, I.I., Kotlyakov, M.I., Kuznetsov, V.V., and Remel', I.G./

/Text/ The authors discuss questions concerning the creation of high-speed devices for recording long-wave holograms and recovering images in the centimeter band of radio and acoustical waves. The results of experimental investigations of discrete holographic systems that they present show that with the use of certain methods for the processing and digital recovery of images, practically maximum spatial resolution that is close to a single wavelength is achieved. They also discuss plans for constructing matrix systems for the recording of acoustical and superhigh-frequency holograms, and give a description of a specialized computer system for controlling multichannel information collection and image recovery devices. The authors also point out ways of increasing the operating speed of these systems. Figures 9; references 23.

UDC 621.396.671

ELECTRONIC EQUIPMENT FOR RECORDING THE AMPLITUDE-PHASE DISTRIBUTIONS OF ACOUSTICAL FIELDS

/Abstract of article by Bayda, L.I., Belash, G.P., Valyayev, A.I., Kachanov, Ye.I., and Yurkov, Yu.V./

/Text/ The authors investigate the special features of the construction of measuring devices operating under the conditions of the near field of acoustical antennas. They describe the structures of electronic measuring devices that provide for the processing of signals with a broad dynamic range and discuss the special features of their operation and sources of errors that limit the accuracy of the measurements. Some attention is given to the development of compatible devices that make it possible to connect a measuring unit to a computer and carry out machine processing of the near field's measured amplitude-phase distribution. The authors also present the results of experiments in producing unidimensional holograms of different types of antennas. They show that such measurements of the near field are of independent value for analyzing the special features of antenna characteristics. Figures 6; references 8.

UDC 621.396

INTERFERENCE-HOLOGRAPHIC METHODS OF VISUALIZING MICROWAVE FIELDS

/Abstract of article by Klyuchnikov, A.S., and Kukharchik, P.D./

/Text/ The authors discuss a method for visualizing superhigh-frequency fields in the millimeter and submillimeter bands when using displays based on thin films of liquid. The proposed displays do not require thermal stabilization and sensitizing, make it possible to use the recording medium repeatedly, and expand the area of utilization of microwave holography. On the basis of the display that has been developed, the authors propose a technique for visualizing the spatial polarization structure of the emissions from diffraction radiators of different shapes. Figures 6; references 8.

UDC 621.382.049.77

RADIOHOLOGRAM RESOLUTION AND WAYS OF IMPROVING IT

/Abstract of article by Bazarskiy, O.V., and Khlyavich, Ya.L./

/Text/ On the basis of statistical decision theory, the authors have constructed a generalized Rayleigh resolution criterion that takes into consideration not only the diffraction limitations of shaping apertures, but also the signal-to-noise ratio in an image and the probability of making a correct decision about the number of sources being resolved. They find conditions for the resolution of elongated sources that insure both their individual observation and accurate reproduction of their dimensions. They also analyze the possibility of improving the resolution of forming apertures above the classic Rayleigh limit on the basis of an analytical prolongation and compression of the spatial spectrum. Figures 6; references 14.

UDC 621.396.671

REPRODUCING AN ANTENNA'S RADIATION PATTERN ON THE BASIS OF MEASUREMENTS OF THE NEAR FIELD ON A CYLINDRICAL SURFACE

/Abstract of article by Buday, A.G., Bulkin, V.M., Kolosov, Yu.A., Kremenetskiy, S.D., Kurochkin, A.P., and Litvinov, O.S./

/Text/ The authors discuss questions concerning the measurement of an antenna's near field on the surface of a cylinder, as well as the realization of an algorithm for converting the field from the near zone into the distant zone. They discuss the results of a numerical modeling of the problem of recovering the radiation pattern of an antenna with large electrical dimensions and a low side lobe level. Figures 10; references 12.

UDC 621.396.67.012.12

QUESTIONS ON THE REALIZATION OF THE RADIOHOLOGRAPHIC METHOD OF DETERMINING ANTENNA RADIATION PATTERNS

/Abstract of article by Sysoyev, Yu.V./

/Text/ The author proposes a technique for the quantitative evaluation of the required degree of orthogonality of the channels of correlation measuring circuits for the radioholographic method of determining the radiation patterns of antennas. He presents the results of an experimental investigation of the random errors occurring during measurements by this method, and demonstrates the possibilities of a complex of graphic FORTRAN (GRAFOR) programs for constructing plane projections of antenna radiation patterns. Figures 14; references 4.

UDC 621.396.677.49

PLANE RADIO-OPTICAL ANTENNA ARRAYS

/Abstract of article by Grinev, A.Yu., Voronin, Ye.N., and Kurochkin, A.P./

/Text/ The authors discuss the power, accuracy and dispersion characteristics of linear and plane antenna arrays with coherent optical processing in various spatio-temporal light modulators. They propose a reduction of an optical processor that has a number of advantages (in particular, elimination of bearing ambiguity in connection with dipole signal input into the processor). They also evaluate the processor's diffraction efficiency, the pupil effect of the modulator's channels, and the mutual effect among them. Figures 10; references 17.

UDC 621.396.677.49

NONPLANE ANTENNA ARRAYS WITH FORMATION OF THE RECEIVED BEAMS BY METHODS OF COHERENT OPTICS

/Abstract of article by Grinev, A.Yu., and Voronin, Ye.N./

/Text/ The authors describe methods for synthesizing coherent-optic processors of nonplane antenna arrays operating in the parallel scanning mode. Along with a general approach, they also discuss special cases: piecewise plane, cylindrical and annular antenna arrays. They also study effects causing the pattern-forming properties of processors to deteriorate, as well as ways of eliminating these effects. Figures 10; references 14.

UDC 523.84:534.535

A HYBRID OPTICODIGITAL SYSTEM FOR PROCESSING PULSAR SIGNALS

/Abstract of article by Yesepkina, N.A., Bukharin, N.A., Kotov, B.A., Kotov, Yu.A., and Mikhaylov, A.V./

/Text/ The authors present the results of an experimental investigation of an experimental model of an acoustico-optical correlator with temporal integration. They show that the use of such a device for the processing of pulsar signals makes it possible to eliminate the effect of the interstellar medium's dispersion and improve the parameters of existing radiometers. In the investigated correlator, the gauges of instruments with a charge coupling and an addition "Elektronika-100" computer buffer memory are used as the multielement photoreceivers and storage capacity. Figures 2; references 11.

UDC 523.84

MEASUREMENT OF THE COORDINATES OF REFERENCE POINTS IN AN AREA AND DETERMINATION OF THE MAGNITUDES OF CLOUD FORMATION DISPLACEMENTS WITH THE HELP OF AN OPTICAL HETERODYNE CORRELATOR

/Abstract of article by Balabanov, A.I., Korbukov, G.Ye., Feoktistov, A.A., and Tsvetov, Ye.R./

/Text/ The authors explain the results of experimental investigations of the possibility of using an optical heterodyne correlator to measure the coordinates of reference points in an area and cloud formation displacements in photographic space images of the Earth's surface. They show that, providing there has been a preliminary approximate correction of the geometric distortions, fragments of images of an area can be tied in by correlation identification, with a degree of error that is less than the size of an element of resolution. The displacement of cloud formations is determined quite well by a correlation comparison of images obtained by geostationary satellites at 30-minute intervals. Figures 15; references 5.

UDC 534/535.241:621.371

ACOUSTICO-OPTICAL INFORMATION PROCESSING DEVICES BASED ON NONLINEAR ACOUSTIC INTERACTION

/Abstract of article by Aksenov, Ye.T., Yesepkina, N.A., and Shcherbakov, A.S./

/Text/ The authors discuss the possibility of creating a new class of acoustico-optical devices utilizing the nonlinear interaction of elastic waves. They present the results of an experimental investigation of prototypes of such devices, based on lead molybdate and gallium phosphide crystals, that realize signal bias, convolution, correlation and controlled delay. The investigation was conducted at frequencies of 80-500 MHz, using both continuous and pulsed signals. For an input electrical power of up to 0.5 W, the relative efficiency of the devices reached several percent. Figures 5; references 3.

UDC 621.317.757

EFFECT OF ELASTIC WAVE ATTENUATION ON THE OUTPUT SIGNAL OF AN ACOUSTICO-OPTICAL CORRELATIONAL ANALYSIS DEVICE

/Abstract of article by Kulakov, S.V./

/Text/ The author investigates the effect of attenuation on the shape of the shape of the signal in an acoustical light modulator and the output signal of an acoustico-optical correlational analysis device. He presents relationships that make it possible to select the acoustico-optical interaction medium according to the permissible energy of the error. Figures 10; references 9.

UDC 621.317.757

EFFECT OF NONLINEARITY OF ACOUSTICAL LIGHT MODULATORS ON THE CORRELATIONAL PROCESSING OF NARROW-BAND SIGNALS

/Abstract of article by Kulakov, S.V., and Bragina, L.P./

/Text/ The authors produce nonlinear, determinstic models of an acoustico-optical correlational processing device for narrow-band input signals and Raman-(Nat) and Bragg diffraction modes. References 3.

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CSO: 1863/206

UDC 778.4:534.6

LONG-WAVE HOLOGRAPHY IN REAL TIME

Leningrad RADIOGOLOGRAFIYA I OPTICHESKAYA OBRABOTKA INFORMATSII V MIKROVOLNOVOY TEKHNIKE in Russian 1980 (signed to press 24 Oct 80) pp 5-26

/Article by A.V. Avrorin, B.A. Breytman, Yu.K. Volkov, V.N. Votentsev, V.M. Gruznov, Ye.A. Kopylov, I.I. Korshever, M.I. Kotlyachkov, V.V. Kuznetsov and I.G. Remel' from book "Radioholography and Optical Information Processing in Microwave Technology", edited by L.D. Bakhrakh, corresponding member, USSR Academy of Sciences, and A.P. Kurochkin, candidate of technical sciences, Izdatel'stvo "Nauka" (Leningrad Branch), 2,150 copies, 184 pages/

/Text/ Introduction

The creation of high-speed devices for recording holograms and reproducing acoustic- and radio-wave images offers the prospect of numerous applications of the principles of holography in different branches of science and technology /1-3/. The authors of this article have conducted research for the purpose of creating such devices that will operate in the centimeter wavelength band. Preliminarily, we selected a version in which holograms are recorded by multichannel discrete devices, while images are reproduced by a digital method. Despite their technical complexity, such systems are capable -- to the highest degree -- of satisfying the basic practical requirements for operating speed, resolution and the possibility of processing input and output information.

During our research, we solved problems related to improving the quality of the images and testing the hologram and image processing algorithms, and also developed equipment for the rapid recording of holograms and reproduction of images. The results of the experiments are presented in Section 1. A description of the high-speed devices, the design of which is proposed on the basis of the research we performed, is given in Sections 2 and 3.

1. Experimental Investigation of Discrete Holographic Systems

The mathematical apparatus of linear scalar diffraction theory gives rather simple expressions for calculating images and evaluating the resolving power of holographic systems in the absence of noise and interference /4/. For image calculations, the expression most often used is Fresnel's approximation, presented in the form

$$U(x_0y_0)=\frac{1}{i\lambda z}\iint\limits_{\Omega} U(x_1y_1)\exp\left[\frac{ik}{2z}(x_1^2+y_1^2)\right]\times\exp\left[\frac{ik}{z}(x_0x_1+y_0y_1)\right]dx_1dy_1, \quad (1)$$

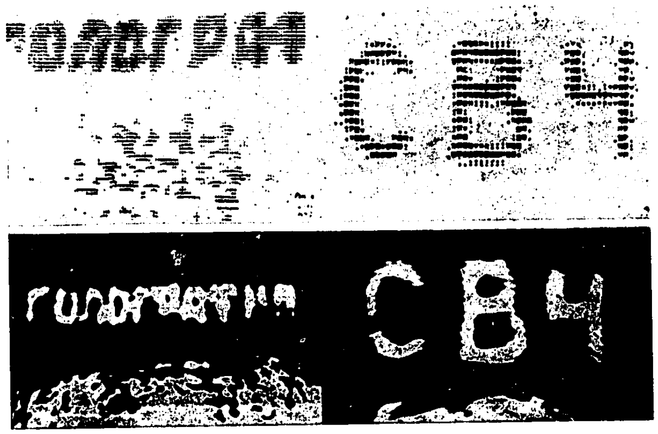

Figure 1. Superhigh-frequency hologram images of objects, as reproduced by digital and optical method.

where $U(x_1y_1)$ is the hologram transmission function. Formula (1) was derived on the condition of smallness of the ratio of the sizes of the receiving aperture and the object (d) to the distance to the object (z). However, if we formally make use of the condition of correctness of the approximation presented in /4/, for aperture and object sizes d = 30λ we obtain the following relationship:

$$z^3 \gg \frac{\pi}{4\lambda} [(x_0 - x_1)^2 + (y_0 - y_1)^2]^2, \quad z \gg 130\lambda, \quad z \gg 4d. \qquad (2)$$

In this case, an estimate according to Rayleigh's formula limits the minimum resolvable interval to a value of 4λ. In most introscopy problems in centimeter waves, such resolution is inadequate. As experiments have shown, however, formula (1) can be used even in the case of d/z = 1 and spatial resolution no worse than for optical reproduction can be obtained. Under real conditions there inevitably appear equipment distortions of the information at the system's input and output that can reduce its resolving power considerably. Within the framework of linear diffraction theory, allowing for the set of factors resulting in information distortions is practically impossible. Therefore, the authors conducted a series of experimental investigations with simple holographic devices that, during the course of the investigations, were made more complicated in the direction of a maximum approximation to systems corresponding to the requirements formulated for resolution and image production time.

The first holographic devices were built according to the traditional plan, with mechanical scanning of a rectangular grating by a single-channel receiver. In most cases the experimental results were evaluated by visual comparison of the reproduced object images.

Various hologram recording systems /5-7/ were tested during the experiments. The optical and digital methods of reproducing images were compared. Different methods for processing holograms and images for the purpose of improving their quality were also investigated.

Figure 1 shows reproduced object images in the form of the words "holography" and "SVCh" /superhigh frequency/. The holograms of these objects were synthesized by mechanical scanning of a grating by a combined source and receiver in the SVCh band, on a wavelength of 3.2 cm. The field values were recorded on the basis of a synchronous signal from a coordinate sensor, at 128 points in the horizontal and on 128 lines in the vertical direction, with an identical spacing of 0.85 cm. Inclination of the reference wave's plane was simulated by introducing phase-modulated reference signals into the coherent receiver, which was based on a balanced circuit, so that only the interference component of the signal was isolated. The signals were then suppressed in the device in order to modulate the light flux, with subsequent recording of it on photographic film /5/ or were converted into a digital 8-bit binary code and entered in a computer memory for digital reproduction /8/. The upper half of Figure 1 shows the images recovered by the digital method, while in the lower half are those reproduced by the optical method, with the usual procedure of optical reduction of the frame and reproduction in the light of a supermode laser.

The digital images were computed according to a program that realizes the Fresnel transformation. A certain amount of processing of the holograms and images was performed during the computation process. The constant component was subtracted from the hologram; the addition of zeros to the hologram (the Fourier interpolation method) doubled the number of readings in the reproduced image; by changing the inclination of the reproducing wave, the images were obtained in the center of the grating. The contrast and density of the printed image were selected when they were being reproduced by an alphanumerical printer.

The spatial resolution in the images presented is on the order of a single wavelength over the entire field of view. In the case of the digital reproduction, the spatial resolution is a littler better. The letters were made from metal foil. In the word "holography," the height of the letters is 3λ and the distance between them is 0.5λ. The distance between the letters "SVCh" is 1.5λ and the width of the strips is 2 cm.

In the optical image of the object "SVCh" (the lower row in Figure 1), we see obvious defects that are related to interference of the light scattered on the optical elements with the reproducing beam and the imposition of a "zero" light beam on the image. Because of the absence of these defects and the processing that was done, the quality of the digital images is better than that of the optical ones.

High spatial resolution can be obtained only by implementing special measures to eliminate interference during the registration of the holograms. Interference can arise because of a connection between the receiver and the emitter, or striking of the receiver by radiation scattered by surrounding subjects and parts of structures, or as the result of direct striking of the receiver by radiation when the hologram of an object is being registered in transient radiation. Interference can be weakened considerably by equipment means: measures to isolate the receiver from the emitter, the use of echoless chambers, the use of receivers and emitters with the narrowest possible radiation patterns. However, when recording weakly scattering objects these measures can prove to be inadequate. As an additional means of weakening interference, it is possible to use subtraction methods if the interference is additive.

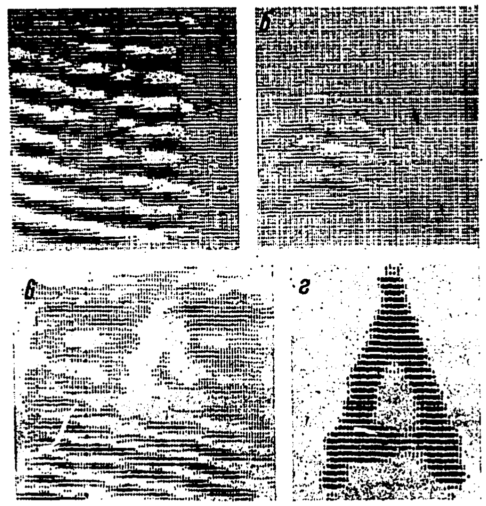

Figure 2. Subtraction of acoustic holograms: a. original hologram; b. difference hologram; c. image obtained from original hologram; d. from difference hologram. The width of the elements of the letter A is 2λ.

Figure 2 is a demonstration of the effectiveness of one of the methods for weakening interference: digital subtraction of holograms [9]. A textolite object in the form of a letter A was placed on a translucent barrier in an air medium. The hologram of the object and the barrier was recorded by an acoustical device on a wavelength of 2.1 cm, with identical quantification spacing of 1 cm along the x and y axes at a distance of 70 cm from the object. The modulus of the barrier's reflection coefficient was 0.26 and the transmission coefficient's modulus was 0.83. A second hologram, of the barrier alone, was made under the same conditions. The holograms were entered successively in a computer memory, after which the operation of element-by-element subtraction took place. In the image reproduced from the difference hologram, the intensive interference caused by the barrier was almost completely eliminated.

The use of the operation of digital subtraction of holograms makes it possible to not have to work in echoless chambers. This is especially useful in the case of hologram recording with a combined source and receiver if the direct striking of the field from the source into the receiver is greater than the permissible level. The method demonstrated above, for eliminating the effect of barriers, can be modified in order to study mediums with a strongly reflecting boundary. For example, when investigating dielectrics it is possible to subtract acoustical and SVCH holograms recorded on the same wavelength. Acoustic waves do not penetrate a medium and carry information only about the shape of the surface. Because of the reflection of the SVCh waves from the boundary, in this case the same information is interference and can be weakened by hologram subtraction.

Figure 3. Phase object image reproduced by the optical method.

The operation of digital subtraction of holograms cannot be used when the interference is very strong, because of the limited dynamic range of the recording devices. In this case it is necessary to carry out analog subtraction at the system's input, since the dynamic range of acoustical and SVCh receivers is greater than that of photographic materials or analog-to-digital converters. In particular, analog subtraction was used to isolate only the interference component of the hologram in the SVCh device. The squares of the amplitudes of the reference waves and those scattered by the object were subtracted in the receiver, which was based on a balance circuit.

The subtraction of additive interference can be accomplished if the distribution of the compensating field created in the plane of the receiving aperture has the same amplitudinal distribution as the interference field but is opposite in phase at every point in the aperture. Such fields will be subtracted when dedektirovaniye /translation unknown/ is carried out in a coherent receiver. The compensating distribution of the field is created in a multichannel array by the introduction of compensating signals into the channels if the interference is created because the transmitting and receiving elements are interfering with each other.

In the case where holograms of objects are recorded in transient radiation and interference can be created as the result of the source's field striking the receiver directly, a compensating distribution of the field can be created with the help of a compensating source /7/. This method is especially useful when investigating thin phase objects. Figure 3 consists of photographs of images of a phase object in the form of the letter Σ that were reproduced by the optical method. The hologram of the object was recorded by a single-channel device operating in the SVCh band on a wavelength of 3.2 cm. The object was made of foam plastic and was 10 cm thick. The transverse dimensions (in millimeters) are indicated in photograph a of the object. Photograph b shows the object image that was recovered with compensation of the source's field, while photograph c shows the image that was recovered when compensation was carried out. Despite the fact that it was not possible to compensate the source's field completely during recording of the hologram, the background created by the source's field striking the receiver directly was quite heavily weakened.

The results of experiments with single-channel holographic devices demonstrated the possibility of obtaining spatial resolution close to the theoretical limit by using additional facilities for eliminating additive interference. Multichannel devices for recording holograms have their own specific shortcomings, such as mutual interference of the channels and nonidentity of their characteristics. Both factors lead to the appearance of multiplicative interference in a hologram, for the elimination of which it is necessary to have more complicated signal processing equipment than was previously used, as well as more processing time. In order to avoid this, the magnitude of the multiplicative interference must not exceed some threshold value determined by the requirements for the quality of the recovered images.

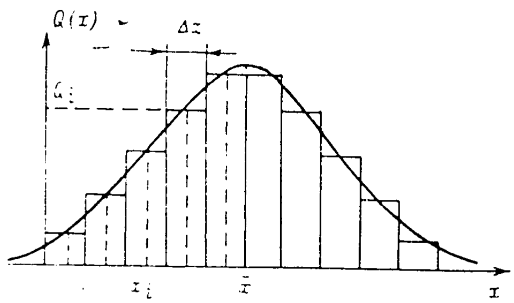

Figure 4. Bar diagram of normal distribution law.

The effect of multiplicative interference on image quality was investigated experimentally with a multichannel holographic device operating in the centimeter acoustic wave band in an air medium. Each of the 64 channels consisted of an acoustic receiver, a band-pass amplifier and an amplitude-phase detector. The acoustic receivers were arranged in a single line. The interval between the receivers was 1.5 cm. A plane hologram was synthesized from 64 x 64 readings by moving the receivers' straightedges in a direction perpendicular to the line in which they were arranged. Nonidentity of the channels was assigned with the help of the appropriate amplification adjustments b(x), fixed bias at the detectors' outputs V(x), and phase delays in the channels $\varphi_H(x)$. Deviation of the values of these parameters from their average values was assigned according to the normal distribution law. In order to do this, the normal distribution function (Figure 4) was approximated by a bar diagram with spacing Δx equal to $0.2\bar{x}$ in the interval of parameter values from 0 to $2\bar{x}$, where $\bar{x}$ is the parameter's average value. Further, the number of channels n_i in which parameter x has the value x_i was determined by rounding off to a whole number the value $64 \cdot Q_i / \sum_{i=1}^{10} Q_i$. The random sequence of the channel numbers for all x_i values of the parameter was then determined according to a table of uniformly distributed random numbers /10/.

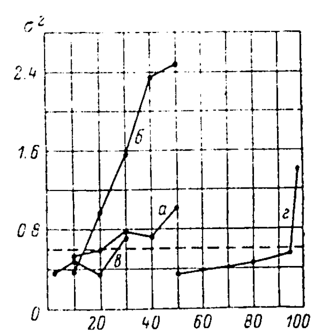

Figure 5. Results of calculation of dispersion σ^2: a. as a function of P_b; of $P_{\varphi H}$; c. of P_V; d. of D.

A quantitative evaluation of the effect of the parameters listed above on image quality was then obtained by computing the average value of the square of the difference of the intensities of distorted and standard images: σ^2. The intensities were first normalized, each to its own average value. The calculated dependences of dispersion σ^2 on the parameters of a multichannel unit are presented in Figure 5 in the form of graphs with coordinate axes σ^2 and P. The relative root-mean-square deviation of a variable parameter was plotted, in percentages, along the P axis. Its dependence on the dynamic range D of the signals at the output of the amplitude-phase detectors was also plotted

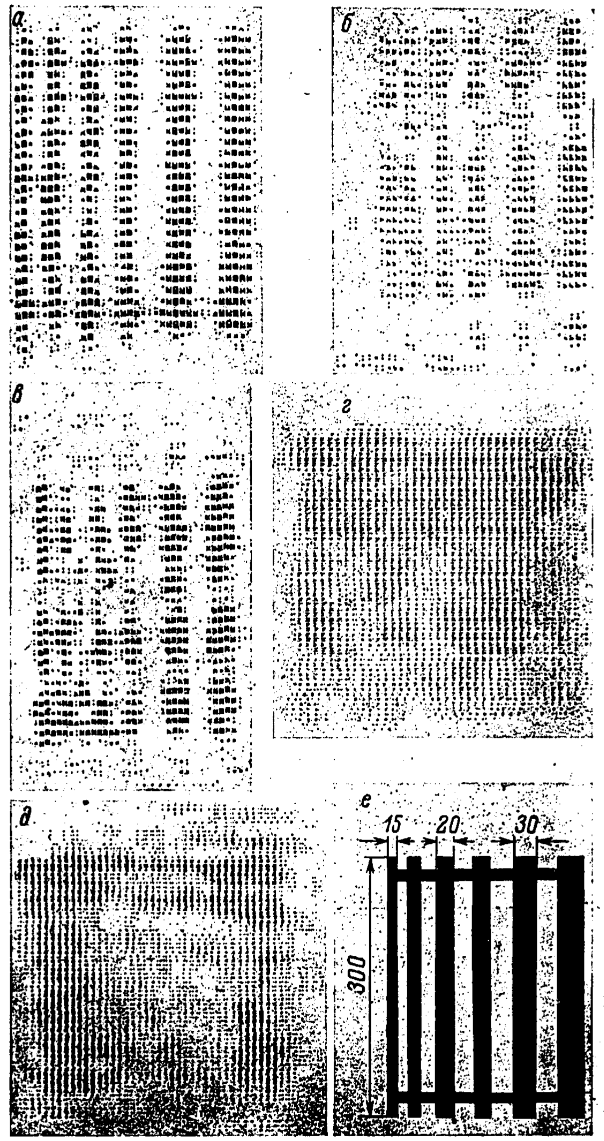

Figure 6. Acoustical images of test objects: a. standard image of a mira /translation unknown/; b. mira image for $P_{\varphi H}$ = 40 per-cent; c. mira image reproduced from phase hologram; d. plate with dimensions of 10 x 10 λ; e. plate image reproduced from phase hologram; f. dimensions of mira test object (in millimeters).

(graph d). The difference in the phases of the reference signal $\pi/2$ between adjacent channels was taken as the phase's average value, while the average value of D was 30 dB. The dependence of dispersion σ^2 on one of the parameters was determined for fixed (minimal) root-mean-square deviations of the other parameters. Each value of σ^2 in the graphs was calculated by averaging four or five values obtained for different realizations of the uniform law of distribution of the variable parameter by channels. The area below the dotted line corresponds to an image quality level that differs insignificantly from the standard when a visual evaluation is made.

The standard image of an object (Figure 6a) was recorded for P_b = 2 percent, P_{φ_H} = = 5 percent, P_v = 1 percent, $D = D_0$. The object was made of plastic 0.1λ thick (λ = 2.1 cm). Its dimensions are shown in Figure 6f. Figure 6b shows the image reproduced for P_{φ_H} = 40 percent.

From the graphs in Figure 5 it follows that nonidentity of the channels with respect to phase characteristics causes the strongest distortion of the distribution of the intensity in the image.

The results that were obtained make it possible to determine the permissible differences in the parameters of a holographic system's channels for a given dispersion σ^2. For instance, if $\sigma^2 = 0.5$, the conditions $P_b \leq 20$ percent, $P_{\varphi_H} \leq 10$-12 percent and $P_v \leq 25$ percent must be fulfilled.

Multiplicative interference can be caused not only by equipment errors, but also by nonlinear hologram recording methods. For instance, by using linear acoustic receivers it is possible to form a "pure" phase diagram /11/ by normalizing the object wave's amplitude to unity. The interest in such phase holograms is caused by the fact that the requirements for the dynamic range of the devices used to form and record the holograms are reduced considerably. A phase hologram can be expressed in terms of a normal hologram by introducing multiplicative interference $f = 1/a(x,y)$, where $a(x,y)$ is the amplitude of the subject signal.

The authors have conducted an experimental investigation of phase holograms for the following type of f_1 function:

$$f_1 = \begin{cases} \dfrac{1}{a(x,\ y)}, & a \geq U_{thr}, \\ 0 & a < U_{thr} \end{cases}$$

for a ratio of the maximum value of the subject signal's amplitude to the amplitude of the threshold voltage (U_{thr}) equal to 100. Figure 6c shows the image of an object in the form of a mira reproduced from a phase hologram. The distortions in this image are noticeable when it is compared to the standard image in Figure 6a, but they are not significant. For example, elements in the object that are 1.5λ wide are reproduced quite well. Figures 6d and e are normal and phase images, respectively, of a mirror-type reflecting plate with dimensions $10\lambda \times 10\lambda$. In comparison with a normal image, in the phase image a decrease in intensity in the central part and an increase around the edges can be seen. Experiments have shown that phase holograms can be used when investigating objects with a diffused type of scattering.

The results that were obtained were used to create a laboratory complex, a description of which is given in /12/. The complex includes multichannel devices for

Figure 7. Images obtained with the holographic complex: a. radio image of an object with strip widths $\lambda = 3.2$ cm; b. acoustic image of an object with strip widths 2λ ($\lambda = 2.1$ cm); c. radio image of an object with strip widths $\lambda/3$ and minimum and maximum distances between strips of 0.8 and 2 cm ($\lambda = 3.2$ cm).

recording acoustic and SVCh holograms in the centimeter wave band, single-channel devices operating on a wavelength of 0.8 cm, and a single-channel device for recording ultrasonic holograms in liquid mediums. The complex is controlled by a small "Elektronika-100" computer. A specialized computing system was included in the complex in order to speed up the computation operations. The results of the computations were displayed on the screen of a video monitoring unit (VKU). The system's software utilized previously used algorithms for processing holograms and images, as well as digital filtration and two-dimensional convolution programs, which made it possible to expand the processing capabilities considerably and, in particular, to realize rapid image reproduction according to Kirchhoff's formula.

Figure 7 contains photographs of test object images taken from the VKU's screen. The holograms of the objects were synthesized by shifting the unidimensional arrays of the transceiving modules (straightedges). In the SVCh device, which operated on a wavelength of 3.2 cm, along the array the antennas were switched into a common waveguide with the help of SVCh switches. In the acoustic device, the detectors' outputs were switched into the computer communication link. The images were reproduced with the help of the specialized computing system. The spatial resolution in the images was on the order of one wavelength. The total recording and reproduction time was about 10 s.

The devices' high operating speed made it possible to perform a large cycle of model experiments that, with due consideration for previously obtained results, led us to the following conclusions: 1) in order to insure good spatial resolution and image quality in multichannel systems with digital reproduction of the images, it is necessary to take measures insuring a reduction in the level of additive interference under different experimental conditions; 2) variations in the channels' characteristics must be reduced to the recommended levels; 3) Fresnel's approximation is usable for reproducing object images with maximum spatial resolution when the ratio of the aperture's size to the distance to the object is unity: 4) in the case of image processing that includes several integral transformations of the Fourier type, for image reproduction it is more advisable to use Kirchhoff's transformation; 5) in addition to the basic operations of direct and inverse Fourier transformations and Fresnel's transformation, another set of operations can be recommended: addition and subtraction of holograms; subtraction of the constant component; standardization of the data masses; computation of the square of the modulus of complex values and the logarithm of the square of the modulus; a change in the contrast and density of the derived image; convolution of two-dimensional masses; auto- and cross-correlation; multiplication by a weighting function; filtration; Fourier interpolation; introduction of a phase wedge for shifting images; operations making it possible to introduce the recording devices' parameters: wavelength, the number of elements, the quantization steps along the x and y axes, the distance to the object; 6) for the purpose of insuring the best image quality and improving the spatial resolution, the principle of joint scanning with the receiver and transmitter should be used.

The following sections contain descriptions of devices for recording holograms and reproducing images, in the design of which the recommendations and conclusions presented above were used to a considerable degree.

2. Multichannel Hologram Recording Devices

Acoustic Devices. Acoustic long-wave holograms can be recorded in several milliseconds only by devices with a two-dimensional matrix and parallel channels. For aperture dimensions of 30 x 30 λ and maximum spatial resolution, the holographic device must contain several thousand channels. The creation of such a system is a complicated technical problem, and its successful solution depends on the correct choice of the system's structure. Let us discuss several block diagrams of individual channels. The block diagram of a channel containing a receiver, an amplifier and an amplitude-phase detector is widely used in systems with series-parallel scanning /3,12/. A signal equal to the cross-correlation function of the reference and subject signals is formed at the amplitude-phase detector's output. Therefore, the amplitude-phase detector can be constructed according to one of the correlator arrangements that gives unskewed and independent evaluations of correlation functions, such as that of a functional correlator (a balanced ring mixer), a relay correlator, or a correlator based on remultipliers.

From the viewpoint of dynamic range and output voltage levels, the most promising one is a relay correlator with clipping (quantification with respect to two levels) of the reference signal. Such a channel can be simplified by the introduction of subject signal clipping, by changing over to the registration of "purely" phase holograms.

We have recently seen the beginning of the development of dynamic methods of acoustic holography /13/ in which what is recorded is not the averaged field formed by reference and subject wave interference, but an instantaneous sampling of the subject field. Practically, this means that the hologram recording time must be considerably less than the acoustic field's period of oscillation. In the general case, the structure of a channel for recording a dynamic hologram must include an amplifier and then an analog memory unit or an analog-to-code converter and a subsequent digital memory unit. This channel arrangement differs fundamentally from that of a correlational channel in that it does not have a narrow-band filter. In order to reduce additive random noise, several dynamic holograms recorded over time intervals that are multiples of the period of the irradiating oscillations should be averaged. This function can be performed by a synchronous adder that is included in each channel.

For multichannel systems, special importance is attached to such channel characteristics as temporal stability, identity of the parameters and technological properties. The use of digital instead of analog (amplitude-phase detector, analog memory) elements in the channels can insure stability and identity of the conversions of signals after their preliminary amplification. In addition, from the economic point of view it is advisable to be oriented on a more general-purpose digital element base when creating multichannel devices.

Devices for Recording SVCh Holograms. The basic assembly in the suggested multichannel system design is a linear commutation scanning device (LKSU) consisting of a series of antenna elements that are arranged in a single line and assembled into a common waveguide /14/. The antenna elements are waveguide segments in which commuting p-i-n-diode SVCh switches are installed. On one of the ends of the segment there is an emitter, while the other is connected to the common waveguide through a coupling aperture. Transmission of the switching pulses from the electronic channel commutator (KK) to the SVCh switches' control inputs is accomplished by sequential connection of the antennas to the common waveguide. If one of the antennas' straightedges is a transmitter and the other is a receiver, at the input of the receiver connected to the common waveguide there is interference along with the signal received by the open antenna element. This interference is caused by the fact that the SVCh switches do not provide complete uncoupling of the closed antenna elements from the common waveguide.

The required uncoupling value can be evaluted with the formula /14/

$$R \geqslant N \cdot 2^{q},$$

where N = number of commuted elements; q = number of characters when the output signal is converted into binary code.

A two-dimensional array for recording holograms is created with a set of identical LKSU's (Figure 8). At the input of the common waveguide of each straightedge there is an electromagnetic oscillation generator G, while at its output there is a diode mixer S. The generators for the straightedges with odd numbers are tuned to frequency ω_1, while those with even numbers are tuned to ω_2, it being the case that

$$|\omega_2 - \omega_1| = \Omega_{if}.$$

Each generator's energy is distributed in the following manner: half of it is emitted through the open antenna element toward the object, while the rest passes along the common waveguide and enters the diode mixer.

Let us discuss the phenomena taking place in straightedges Nos 1 and 2. The energy from both generators is emitted toward the object and scattered by it. If frequencies ω_1 and ω_2 are close together, the complex amplitude of the scattered field is identical for both frequencies and equals ae^{i} . The two signals -- with frequency ω_1 and frequency ω_2 -- are received by the same antenna elements and simultaneously pass along the common waveguide toward the diode mixers of both the first and secone straightedges. However, the only signal amplified by intermediate frequency amplifier UPCh is the one with the frequency that has been shifted by Ω_{if} relative to the oscillations already existing in the mixer and functioning as heterodyne oscillations. It should be kept in mind that the frequency of the second straightedge's heterodyne oscillations is higher than that of the signal being converted, while in the first straightedge it is lower by the amount Ω_{if}. As is known, when signals are converted there is a change in the sign of the phase-modulating function if the heterodyne's frequency is higher than that of the signal. In

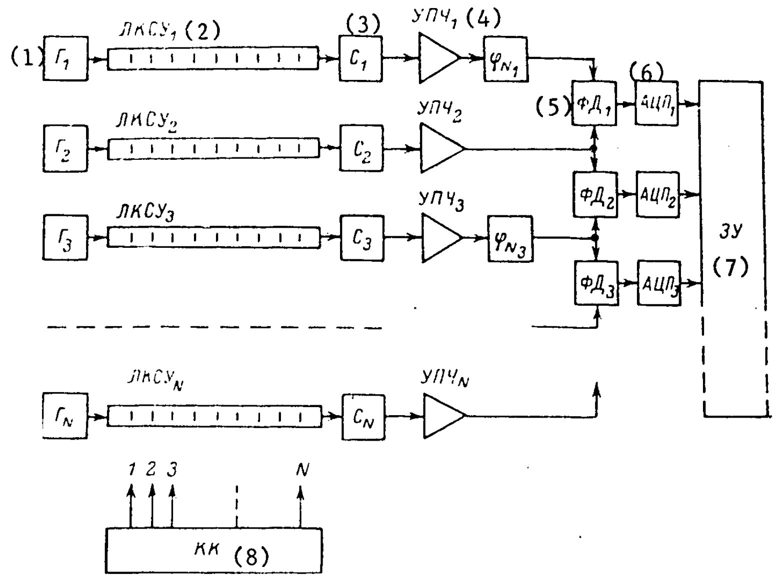

Figure 8. Functional diagram of a two-dimensional array for recording SVCh holograms.
Key:
1. Electromagnetic oscillation generator
2. Linear commutation scanning device
3. Diode mixer
4. Intermediate frequency amplifier
5. Phase detector
6. Analog-to-digital converter
7. Digital memory
8. Channel commutator

accordance with this, we can write expressions for for the intermediate frequency signals acting on the first and second straightedges' UPCh outputs:

$$U_{if\,1} \sim a \exp\{i(\Omega_{if} t + \varphi)\},\quad U_{if\,2} \sim a \exp\{i(\Omega_{if} t - \varphi)\}.$$

In these expressions, a and φ depend on the straightedge channel's number.

For amplitude and phase discrimination, signals U_{if1} and U_{if2} enter phase detector FD, with one of them passing through a phase-shifting circuit and acquiring phase shift φ_N. The phase detector's output signal has the form

$$U_{FD} \sim a\cos(2\varphi - \varphi_N).$$

From this follows the conclusion that when scanning, from the phase detector's output a unidimensional SVCh hologram with a doubled phase value can be recorded. In some cases this can improve the hologram's resolution. Registration is accomplished by entering the signal value in a cell of digital memory ZU.

An analogous discussion can be conducted for straightedges Nos 2 and 3, by combining their outputs in a common phase detector, then the same for straightedges Nos 3 and 4, and so on.

In addition to the useful coherent components, at the phase detector's inputs there is interference that is the sum of the noncoherent signals emitted by all the other generators in the array and received by the straightedges that are connected to the phase detector under discussion. The contribution made to the phase detector's output signal by the interference must be reduced by a low-frequency filter to the necessary level; for example, this means below the value of the quantization step in analog-to-digital converter ATsP. The array's operating speed T will be determined by the filter's time constant in this case, and can be evaluated with the formula

$$T = \frac{N^3 \cdot 2^{2q}}{8\sqrt{2\pi}\sqrt{D_f}},$$

where D_f = dispersion of the random deviation of the SVCh generator's frequency from the average value; N = number of channels in a straightedge; q = number of binary digits in the ATsP.

This evaluation is made providing that filtration takes place in the phase detector only because of noncoherence of the straightedges' independent generators. The random function of the deviation of a generator's frequency from the average value is known. Assuming that the root-mean-square value of this deviation is $5 \cdot 10^6$ Hz, the number of straightedges in the array is 32 and the dynamic range of the phase detector's input signal is 4 binary digits, we obtain an estimate for the array's operating speed of $80 \cdot 10^{-3}$ s. In some applications, a higher operating speed is needed. In order to achieve this, the phase detector's frequency band should be broadened, with simultaneous expansion of the dispersion of the SVCh generators' frequency deviation, or a change should be made to array layouts operating only on the reception of scattered radiation when there is a single irradiating SVCh generator /3/.

The design of the two-dimensional array is relatively simple. It consists of identical straightedges that are not connected to each other by high-frequency circuits. The electrical processing of the signals takes place in comparatively low-frequency circuits that have technically been developed quite well. Special attention should be given to the rational selection of the radiating antenna elements' design for the purpose of reducing their intercoupling. The presence of coupling leads to the appearance of signals, in the absence of an object, that are received by the system as additive interference. The coupling can be reduced, for example, by installing a compensating quadripole between the elements.

The array's merits are the high temporal stability of its parameters because of the switch-type operation and doubled resolving power, caused by the synchronous and joint displacement of the signal emission and reception points. This phenomenon is to the improvement in resolving power in holographic systems with simultaneous scanning by the emitter and the receiver /15/.

3. Devices for Rapid Image Reproduction

As a rule, experiments in the field of digital holography are being conducted according to the classical plan for processing the results of an experiment /16,17/: collect and prepare the information for input, perform calculations with a general-purpose computer, readout and interpretation of the results of the calculations in the laboratory. If these stages are not combined by common facilities, real-time image reproduction is not achievable.

The authors set themselves the problem of creating a complex of automated equipment that would make it possible to reproduce images at the same speed at which the information is supplied by a high-speed recording device.

Modern systems for the automation of physical experiments are constructed on the basis of small computers with limited computation capacities, although -- in contrast to general-purpose computers -- their architecture is maximally adaptable to control conditions /18/. In order to increase a small computer's computation capacity, a specialized processor is added to the system. Modern vector and matrix processors that are adaptable for the efficient execution of monotypical computations in operations on groups (matrices or vectors) of data raise the computation productivity of small computers to that of the most power general-purpose ones for the realization of algorithms of the same kind[1].

Below we discuss the "Lens" system, which was designed for operation with two-dimensional holographic arrays containing up to 256 x 256 elements. The system records information from an array with 64 x 64 elements in 4 ms, while the image reproduction time by a Kirchhoff transformation on an array of 64 x 64 elements is 200 ms, and by a Fresnel transformation -- 100 ms (for arrays of 128 x 128 elements these times increase by a factor of 4, and by a factor of 16 for an array of 256 x 256 elements).

The basis of the system's design is a small "Elektronika-100" computer, which was developed in the direction of input and output devices with the help of a set of program-controlled modules, with the modules themselves and the programmed structure of the system being carried out in the CAMAC standard[2] /20,21/. Figure 9 is a functional diagram of the system. Below follows a brief description of the individual subsystems.

The input's processor contains a matching module to drive the recording device and the ATsP, as well as the working memory (OZU) where the hologram and the interference background are stored. The background is automatically subtracted from the hologram during readout.

The matrix processor includes a vector processor (VP -- see below), an OZU and an indexing unit. The OZU is capable of accommodating a working array of 256 x 256 28-bit words and can also be separated into 4 working zones, each containing 128 x 128 words of analogous length for simultaneous reproduction of 2 holograms and the storage of two-dimensional filtering functions.

The output processor contains a television set control circuit, a high-speed buffer memory and facilities for interpolation of a two-dimensional mass, as well as elements for controlling the quality of the image (clipping according to a given level, elimination of computer noises).

In addition to a set of standard computer peripheral gear, the operator's position has a television set for the reproduction of recovered images and a specially developed digital focusing modulus that generates a linearly frequency-modulated sequence of exponential coefficients in accordance with the integral Fresnel and Kirchhoff transformations. On the modulus's face there are discrete switches that assign the linear modulation rate in accordance with the distance z to the object (parameters λ, Δ_x, Δ_y, L_x and L_y are assigned in the modulus equipmentwise)[3]. This tuning is analogous to the adjustment of an optical system for definition of image.

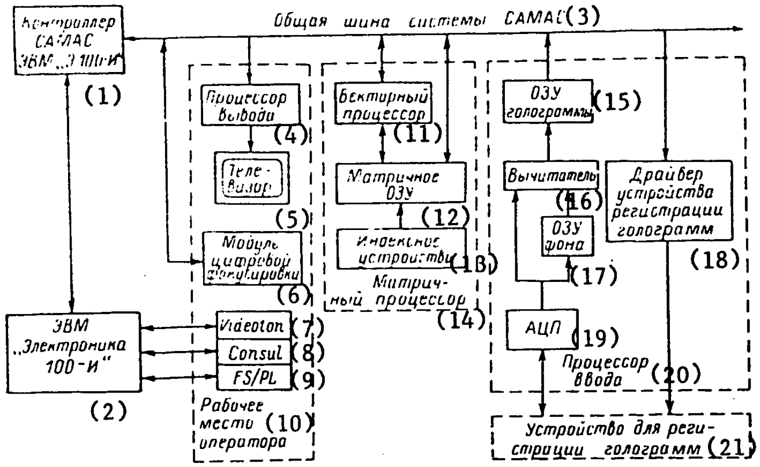

Figure 9. Structural diagram of "Lens" system for reproducing digital holograms in real experiment time.

Key:

1. CAMAC controller for "E 100-I" computer
2. "Elektronika 100-I" computer
3. CAMAC system common bus
4. Output processor
5. Television set
6. Digital focusing modulus
7. Videoton
8. Consul
9. FS/PL
10. Operator's position
11. Vector processor
12. Matrix OZU
13. Indexing unit
14. Matrix processor
15. Hologram OZU
16. Subtractor
17. Background OZU
18. Hologram recording device driver
19. Analog-to-digital converter
20. Input processor
21. Hologram recording device

The vector processor is essentially a specialized computer that was designed in such a fashion as to realize some of the functions most frequently used in integral transformation with maximum efficiency. It is convenient to write in matrix form those algorithms that are realized with the help of the VP and transform the discrete mass of a hologram, given on a grid with dimensions M x N ($0 \leq \xi < M$, $0 \leq \eta < N$), into an image mass. Kirchhoff's integral transformation /4/ takes on the following form:

$$U^1 = \| U^1_{\xi\eta} \| = \Phi^-_M \cdot W \cdot \Phi^-_N,$$

where

$$\Phi^-_M = \left\| \exp\left(\frac{2\pi}{M} i\xi k_\xi\right) \right\|, \quad \Phi^-_N = \left\| \exp\left(\frac{2\pi}{N} i\eta k_\eta\right) \right\|$$

are matrices of Fourier coefficients measuring M x M and N x N, respectively, that realize a two-dimensional inverse DPF[4];

$$W = \| W_{k_\xi k_\eta} \| = \| e_{k_\xi k_\eta} U^f_{k_\xi k_\eta} \| \text{ and } E = \| e_{k_\xi k_\eta} \|$$

is a matrix of exponential coefficients that, for the Kirchhoff transformation, have the form

$$c_{k_\xi k_\eta} = \left\| \exp \left[2\pi i z \sqrt{\left(\frac{1}{\lambda}\right)^2 - \left(\frac{k_\xi}{L_x}\right)^2 - \left(\frac{k_\eta}{L_y}\right)^2} \right] \right\|,$$

where L_x and L_y are the dimensions of the hologram,

$$U' = \| U'_{k_\xi k_\eta} \| = \Phi_M \cdot U^0 \cdot \Phi_N$$

is a matrix of spectral components of the same size ($0 < k_\xi < M$, $0 \leq k_\eta < N$),

$$\Phi_M = \left\| \exp \left(-\frac{2\pi}{M} i k_\xi \xi_0 \right) \right\|, \quad \Phi_N = \left\| \exp \left(-\frac{2\pi}{N} i \eta_0 k_\eta \right) \right\|$$

are matrices realizing the direct Fourier transformation,

$$U^0 = \| U^0_{\xi_0 \eta_0} \|$$

is a matrix of recorded signals measuring M x N.

The integral Kirchhoff transformation is realized with the help of "fast convolution" /22/, which is accomplished by remultiplying the Fourier transformations of the convoluted functions with subsequent inverse Fourier transformation of the product that is obtained. In Fresnel's approximation, the algorithm appears to be quite simple:

$$U' = \Phi_M \cdot D_{\xi_0} \cdot U^0 \cdot D_{\eta_0} \cdot \Phi_N,$$

where

$$D_{\xi_0} = \left\| \exp \left[\frac{\pi i}{\lambda z} (\Delta_x \xi_0)^2 \right] \right\|, \quad D_{\eta_0} = \left\| \exp \left[\frac{\pi i}{\lambda z} (\Delta_y \eta_0)^2 \right] \right\|$$

are diagonal matrices.

The VP's software is formulated in such a fashion that the separate functions realized in it on a microprogramming basis[5] can be combined, with the help of higher level commands -- machine commands from the computer -- into quite complex programs and, in particular, into programs that realize the algorithms presented above, as well as the operations recommended in Section 1. These functions include:
1) data mass copying functions: from the VP into the CAMAC main line and in the opposite direction, as well as from zone to zone in the VP's superoperational memory;
2) functions of a single complex operand[6]: obtaining the square of the modulus of elements in an array; transforming array elements from algebraic form into exponential and vice versa; logarithmation of elements; obtaining elements that are the inverse of the original elements;
3) functions of two complex operands: addition, subtraction, multiplication and division of array elements;
4) several minimax[7] operations on array elements;
5) conversion of array elements from normalized form into one with a fixed decimal and vice versa;
6) direct, inverse and accelerated[8] fast Fourier transformation (BPF) for arrays with real elements, as well as fast convolution[9].

The processor contains all the elements that are traditional for a normal computer: a memory, an arithmetic unit and a control unit with the special feature that in it the basic principles of parallel processing -- separate processing of several data flows and temporal overlapping of operations -- are used on an elementary level.

The measures that have been enumerated made it possible to obtain an operating speed of 2 μs for any of the point operations listed above. For the BPF algorithm this time also applies to the special elementary operation on a pair of complex operands ("butterfly")[10] /22/, so that (for example) a Fourier transformation from an original array into 1,024 complex numbers can be realized in 10 ms.

Matched functioning of the system elements that have been described is carried out with the help of the computer, which realizes the program for controlling these elements. On the lower software level, standard CAMAC system module-access commands /21/ are used. The upper level software is a sequence of computer-generated machine commands that address the required modules or elements of them or the actual subprograms (written in higher level languages) that the VP is not capable of handling. Recently the time spent on processing has, naturally, increased.

This type of control proves to be very flexible with respect to the experimental conditions or to changing software. At the same time it can also be used as the basis for solving production problems where the achievable operating speed (10 frames per second for reproducing an image with 64 x 64 elements) proves to be adequate, while the hologram recording unit and the software remain unchanged. In this case, the computer in the CAMAC controller is replaced by a permanent memory that realizes the program previously contained in the computer (a so-called autonomous controller); only the equipment for adjusting the image remains at the operator's position.

A further increase in the requirements for processing equipment productivity entails an increase in the size of the network. The basic prospective path for the solution of this problem is an increase in the number of simultaneously operating processors.

The implementation of the special measures means that the digital configuration -- the length of the arithmetic register -- can be reduced without any substantial loss of computation accuracy. For the case of the direct reproduction of images, the limitation on the arithmetic register's length and the initial information's word length was discussed in /23/. For the convolution algorithm, the same authors studied the possibility of reducing the length of the trigonometric constants when computing exponential multipliers. They showed that although assigning the trigonometric functions the values +1, 0 and -1 leads to some deterioration in image quality and an increase in the level of digital noise, for certain practical applications it gives satisfactory results.

The use of these results makes it possible to achieve a sharp reduction in the amount of equipment needed for a single VP, which makes a multiprocessor setup achievable even at the present time.

Conclusion

The results of our research and the development of laboratory equipment for the rapid recording of holograms and reproduction of images gives us a basis for creating visual radio and acoustic instruments that operate at a speed of about 10 frames per second. This speed is adequate for most practical uses of long-wave holography.

Increases in operating speed can be expected in the case of parallel operation of all channels in the receiving arrays with a structurally integrated image reproduction unit constructed on the basis of analog elements of the PAV and PZS /expansions unknown/ types. However, in order to create such instruments it is necessary to solve a number of scientific and technical problems, while the proposed variant can be built at the present level of technology, using an industrially produced element base.

It is necessary to mention here that the computing system developed in the course of our research can be used not only in acoustic and SVCh holography, but also in seismic holography, image processing units and a number of other situations where a two-dimensional Fourier transformation apparatus is needed.

FOOTNOTES

1. Algorithms of the same kind are those according to which computations are carried out by the repeated use of monotypical operations.

2. CAMAC (Computer Application for Measuring and Control) is a standard for design, electrical parameters and software for units for connecting peripheral equipment to a computer.

3. Δ_x, Δ_y = hologram quantification steps along the x and y axes.

4. DPF = discrete Fourier transformation.

5. Microprogrammed organization of control is equipment control with the help of a unit that generates a sequence of programmed words at the computer's command. In the control hierarchy, this is low-level software.

6. An operand is a variable that is subject to change as the result of any computational operation.

7. Minimax operations are searching operations for the minimum or maximum values in a sequence of operands.

8. Accelerated BPF on a sequence of real numbers is a modification of the BPF algorithm developed for a sequence of complex numbers that makes it possible to halve the memory volume and calculation time in the case of a sequence of real numbers.

9. Fast convolution is a convolution of two sequences that is realized by multiplying the Fourier transformations of the sequences with subsequent inverse Fourier transformation of the product.

10. "Butterfly" is the basic (base) operation of the BPF algorithm, and contains two addition operations and one multiplication operation for complex numbers.

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ELECTRONIC APPARATUS FOR RECORDING THE AMPLITUDE-PHASE DISTRIBUTIONS OF ACOUSTIC FIELDS

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/Text/ The practical utilization of holographic methods in acoustics and hydroacoustics is attracting the attention of many researchers at the present time /1-3/.

In order to model and transform wave fields it is necessary to be able to record and reproduce a field's phase and amplitude. In connection with this, the bases are the principles of designing the structure of measurement complexes, methods of recording an acoustic field with the help of electronic devices, and automation of the measurement process.

The special feature of the registration of the amplitude-phase distributions (AFR) of acoustic fields is that the volume of information that must be recorded is very large, so that in order to obtain it in a comparatively short time, it is necessary to have a measurement setup with a high operating speed.

Many works are devoted to the problems involved in the construction of measurement complexes, but they are basically concerned with the field of SVCh /superhigh frequency/ holography, although the conclusions /4-6/ concerning the common requirements for measuring devices used to record a field's AFR are also correct for low-frequency recorders. The realization of electronic channels and the conditions for their functioning during the processing of low-frequency acoustic fields have their own special features, so in this article we discuss ways of constructing measuring devices operating in the near field of acoustic antennas, as well as question related to improving their accuracy. The basic focus is on equipment that makes it possible to realize machine processing of an acoustic field's AFR.

1. General Structure of the Electronic Measuring Complex. Special Features of the Complex's Operation in an Antenna's Near Field

The use of holographic methods in antenna technology makes it possible to measure such antenna parameters as the three-dimensional radiation pattern, the front-to-rear factor (KND) and the aperture scattering factor /2/. When normal measurement methods are used, the error in determining the parameters that interest us is up to 20 percent, whereas holographic methods make it possible to reduce it to 5-10 percent, it being the case that this does not impose any rigid requirements on the accuracy of the measurement of the AFR of the acoustic field in an antenna's near zone, which serves as the basis for finding all the necessary parameters. This 5-percent error in determining an antenna's KND can be achieved if the dispersion of the phase and amplitude errors does not exceed 8^o and 1 dB, respectively /6/.

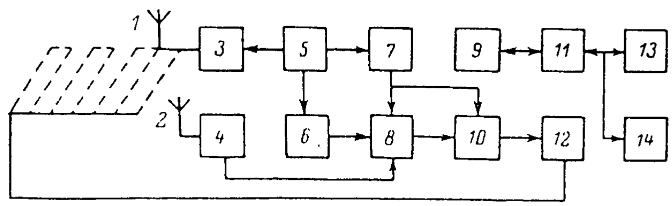

Figure 1. Block diagram of electronic measuring complex for investigating the amplitude-phase distribution of the near field of antennas: 1. scanning device; 2. receiving antenna; 3. radio pulse former; 4. preamplifier; 5. driving oscillator; 6. standard voltage shaper; 7. synchronous pulse shaper; 8. measuring device; 9. identification unit; 10. analog-to-digital converter; 11. keyboard computer (EKVM); 12. matching unit; 13. digital printer; 14. puncher.

The development of the fast Fourier transform (BPF) method, which makes it possible to use machine methods to reproduce acoustic holograms /7,8/, requires the creation of electronic measuring equipment with presentation of the measurement results in a form that is convenient for input into a computer. The general structure of the electronic measuring complex is shown in Figure 1.

In experimental investigations of an acoustic field, in most cases the measurement complex and the computer do not form a unified system. In connection with this, there arises the necessity of using intermediate carriers for the results of the measurement of the near field's parameters, such as a table, punched tape, punched cards or magnetic tape. The production of general-purpose matching devices that are capable of working with different information carriers requires considerable time and material expenditures. Therefore, it is advisable to use in the measurement complex an EKVM with the standard input-output units that are used in computer technology. The computer will also receive and do the preliminary processing of information from the measuring sensors, control the measurement process and, in a number of cases, reproduce an image from unidimensional holograms.

When conducting an experiment to measure the parameters of the near field of an antenna in the pulse mode, the following basic signals can be distinguished at the processing unit's input:

1) a ghost emission pulse that appears at the receiver's input simultaneously with the emitted pulse;

2) a direct acoustic signal that arrives at the receiver's input with a lag determined by the distance between the emission and reception points;

3) a signal reflected from the water-air interface;

4) signals from rereflections between the emitter and the receiver;
5) noncoherent pulse signals of a different nature.

Operation of the emitter in the pulse mode insures temporal separation of the direct acoustic signal from the other signals. Under experimental conditions, noncoherent acoustic signals can be eliminated. The direct acoustic signal should be found between the ghost emission pulse and the return signals. Which of the return signals arrives at the receiver first will be determined by the relative positions of the receiver, the emitter and the water-air boundary. If L is the shortest return signal propagation path ($L = 2L_1$, where L_1 is the distance between the emitter and the receiver, or $L = L_1 + L_2$, where L_2 is the distance between the emitter and the interface of the mediums), the maximum possible signal duration for which it is possible to avoid overlapping of the direct signal with interference is $t_i = LT_0/2\lambda_0$, where T_0 is the carrier's period and λ_0 is the wavelength.

When conducting an experiment, attention should be given to the time of oscillation establishment in the receiver. It is determined by the investigated object's resonance properties (its quality factor) and configuration. Therefore, the minimum time interval between the onset of the direct signal and the beginning of processing is defined as $T_{no} = t_Q + t_{vr}$, where t_Q is the delay determined by the object's quality factor and t_{vr} is the delay caused by the difference in the path of the signals between the closest and most remote points of the receiving antenna.

When measuring the near field's parameters by the synthesized aperture method, it is necessary to allow for the change in the distance from the emitter to the nearest point of the receiver that occurs when the skanator /translation unknown/ moves. This distance can change considerably when $L_1 = (10\text{-}20)\lambda_0$, as well as when the aperture's dimensions exceed those of the antenna being investigated, and it must be taken into consideration when operating a system with rigorous temporal gating. If the time delay in the arrival of the direct signals from different points on the antenna is τ, then the beginning of processing is shifted accordingly by this amount. Thus:
1) the maximum possible duration of an emitted radio pulse is $t_{i\ max} = LT_0/2\ _0$;
2) the beginning of the processing cycle relative to the beginning of radio pulse emission is $t'_{no} = (LT_0/?\lambda_0) + \tau + t_Q + t_{vr}$;
3) the maximum processing time is $t_0 = (LT_0/2\lambda_0) - t_Q + t_{vr}$.

Consequently, when functioning under different conditions and with different antennas, the processing unit must insure an automatic change in the measuring unit's operating mode.

2. Variants in the Structure of a Measuring Device for Recording an Antenna's Near Field

Considering that the change in the signal amplitudes for some types of emitters is 30-40 dB, while a phase-measuring channel can register a phase shift with a dynamic range of the same order, there are grounds for stating that the creatior of a device capable of depicting the entire range of signal ampliphases /sic/ (´0-80 dB) by a single output parameter is a difficult assignment.

The phase shift can be measured by the summed difference method or the multiplication method, the essence of both of which is the conversion of the difference in phases into voltage. In the low- and medium-frequency areas the conversion can be carried out simply and accurately with the help of a temporal sign, by comparing the moments of time corresponding to the points of intersection of the instantaneous values of compared signals on the same level. The time interval is then converted into voltage. In the high-frequency area, it is more feasible to use the multiplication method. A linear multiplier or a nonlinear element with subsequent filtration can be used to multiply the investigated and reference signals. However, the existing multipliers, which are based on integrated circuits, have a limited dynamic input signal range (no more than 16 dB), so it is desirable to have separate measurements of the amplitude and the phase with subsequent multiplication of the results in order to obtain orthogonal projections of the input signal ($A_{ij} \cdot \cos \varphi_{ij}$ and $A_{ij} \cdot \sin \varphi_{ij}$).

Depending on the requirements for phase-measuring devices working with linear or binary output signals, as well as the hologram reproduction method, various ways of realizing a two-channel measuring device are possible. For instance, when recording the ampliphases of an acoustic field on photographic film, it is advisable to modulate the light flux's energy with respect to two parameters: intensity I and pulse duration τ_0. During machine processing of the measurement results, each of the measurement components is converted into digital form and multiplied by the computer. In addition to increasing measurement accuracy, such a setup makes it possible to obtain separate amplitude and phase holograms.

Figure 2a is a block diagram of a measuring device (IU) intended for the parallel measurement of the amplitude A_{ij} and phase φ_{ij} of an investigated signal. Input signal U_{in} is a sequence of radio pulses arriving with a high on-off time ratio ($Q \geq 10$), and can be recorded in the form $U_{in} = A_{ij} \cdot \sin (\omega_0 t + \varphi_{ij})$, while the reference signal is $U_{ref} = A_0 \cdot \sin \omega_0 t$. The IU's output signals are amplitude A_{if} and orthogonal components $U_0 \cdot \sin \varphi_{if}$ and $U_0 \cdot \cos \varphi_{ij}$, which enter an analog-to-digital converter when machine processing is used. In addition, signal $A_{ij} \cdot U_o \cdot \sin \varphi_{ij}$ is formed in output unit 10. This signal modulates the light flux of the emitter that is used to obtain optical holograms. After preliminary amplification in scale amplifier 1, the input signal enters the amplitude and phase measurement channels. The amplitude measurement channel includes precision amplitude detector 4 and memory unit 6. The phase shift measurement channel consists of gated limiter 2, reference voltage former 3, phase detector 5, analog key 7, integrator 9 and memory unit 6. As reference signals, phase detectors 5 use two orthogonal pulsed sequences formed by reference voltage former 3.

The output signals of phase detectors 5 are pulsed sequences with on-off time ratios proportional to φ_{ij}. These signals control the operation of keys 7, into the analog inputs of which amplitude-stabilized signals $A_0 \cdot \sin \omega_0 t$ and $A_0 \cdot \cos \omega_0 t$ are sent from reference voltage former 3. In order to reduce integration errors, in integrators 9 there is a system for periodic compensation for the error caused by integration of the operational amplifier's zero bias voltage and the residual voltage of key 7. Memory units 6 have a voltage transmission factor that equals unity.

Since obtaining an ampliphase signal by direct multiplication of signals A_{ij} and $U_0 \cdot \sin \varphi_{ij}$ is difficult and leads to a large dynamic range D of signal $A_{ij} \cdot U_0 \cdot \sin \varphi_{ij}$, preliminary conversion of the amplitude into a pulse duration is used in the IU. This conversion is performed in pulse-width modulator 8, after which multiplication of signal $U_0 \cdot \sin \varphi_{ij}$ and the output signal of modulator 8 takes place

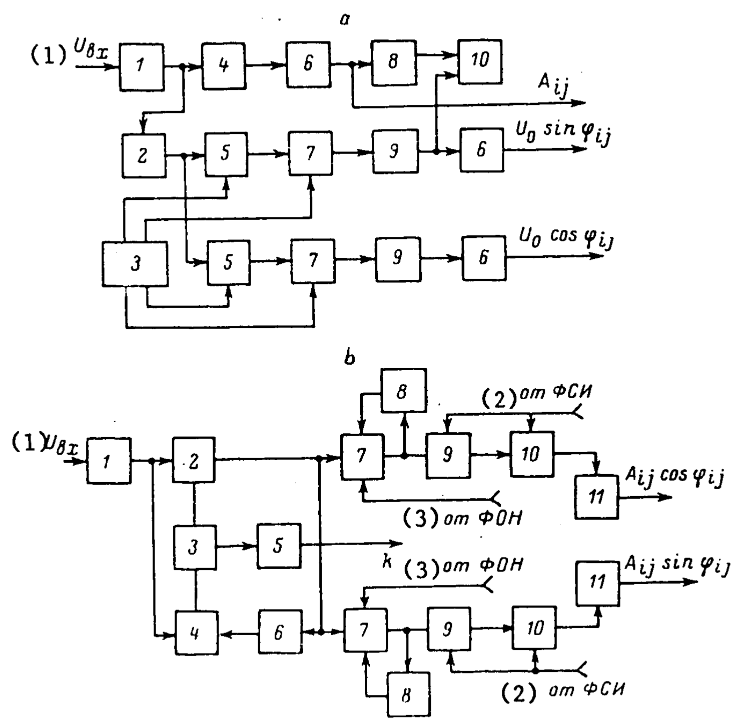

Figure 2. Block diagram of measuring device with parallel (a) and sequential (b) measurement of signal amplitude and phase: 1. preamplifier; 2. controllable splitter; 3. reversible shift register; 4. shift register control unit; 5. controllable frequency splitter; 6. two-stage threshold unit; 7. multiplier; 8. zero level stabilization unit; 9. integrator; 10. memory unit; 11. direct voltage amplifier.

Key:

1. U_{in}
2. From synchronous pulse former
3. From reference voltage former

in the output unit. As a result, the ampliphase signal's dynamic range does not exceed that of signal $U_0 \cdot \sin \varphi_{ij}$ and its duration is proportional to amplitude A_{ij}. Operation of the IU is controlled by signals arriving from the synchronous pulse former (FSI).

A second version of the measuring device, based on sequential measurement of a signal's phase and amplitude, is depicted in Figure 2b.

As has already been mentioned, the existing integrated circuits of analog signal multipliers can operate only in a narrow dynamic range of input signals. The introduction of digital automatic amplification regulation (TsARU) makes it possible to limit all input signal changes to a level providing the given operational accuracy of signal multiplier 7. The basis of an IU with TsARU is controllable splitter 2, the transmission factor of which is changed discretely by a code. An input signal arriving in threshold unit 6 is the decisive factor for the beginning of operation of the IU's amplitude channel. When the threshold level is exceeded there is a multistage change in the state of shift register 3 and, consequently, the transmission factor of controllable splitter 2 until a voltage lower than U_{thr} is received at the input of threshold unit 6. The number of pulses entered in shift register 3 is then converted into a time interval or a code. In this version of the IU there is no measurement of amplitude, while the measuring channel's transmission factor is reduced by a factor of k (k is the coefficient of compression of the dynamic range). Since the control is discrete, signal multiplier 7 will receive a voltage, the level of which changes within the limits of a single quantization step. In the general case, the size of the quantization step can be made as small as is desired, and the IU will then become an analog-to-digital converter operating on the principle of tracking balancing. On the one hand, the choice of the quantization step's size is determined by the preferable change in the amount of voltage in the phase detector and, on the other, by the permissible phase errors contributed by controllable splitter 2, as well as the system's required operating speed. The use in the unit of a quantization step with an amplitude difference of 6 dB (in connection with this, information about the amplitude is entered in register 3 in a binary code) makes it possible to simplify the code-interval converter and increase its accuracy. In the case of operation with a computer, this makes it possible to multiply the results of the two channels' measurements before the computer is reached, by shifting the phase channel's binary code by ℓ positions that correspond to the control register's position ($k = 2^{\ell}$).

3. Matching the Measuring Device With an EKVM. Software for Measurement Complex Operation

Preliminary machine processing of the measurement results can be done with the help of a 15VSM-5 control computer, which has the following parameters: maximum number of program steps -- 960; number of memory registers -- 120; external storage unit (VZU) capacity -- 4 Kbytes with the capability of adding monotypical memory units through the main expander; the number system is binary-decimal with a floating decimal; the perforator and TsPU /digital printer/ coupling equipment is in the form of structurally independent units. A further development of this EKVM is the "Elektronika DZ-28" microcomputer, with built-in coupling devices and a 16-Kbyte memory that can be expanded.

The matching unit (SU) is used to connect an analog-to-digital converter (ATsP) to the EKVM (see Figure 1). Among the operations performed by the SU we can mention conversion of a parallel 1-2-4-8 binary-decimal code into a sequential code; normalization of the information leaving the ATsP; suppression of the information transmitted to the EKVM when the scanning unit switches from one line to another; starting of the ATsP for processing of the next radio pulse.

For the purpose of simplifying the setup, normalization of the information arriving from the ATsP can be accomplished by entering a unit in the high-order digit of the number being transmitted. During normalization this unit is eliminated. The beginning and end of each line of the synthesized aperture is determined by the position of the skanator's final switch, which acts on the SU when it is closed, thereby blocking information transmission. The appearance of zeros in all bit positions in an information transmission can act as a signal to change over to a new work cycle.

During the development of the 15VSM-5 EKVM program, the special features of the IU's operation, the entry of the measured information in the EKVM, and the method of obtaining the synthesized aperture were taken into consideration. In addition, it was also considered that the preliminary processing of the information in the EKVM must provide an algorithm that is acceptable for the investigations; that is, the result must be a unidimensional distribution of the near field being studied, frame by frame, with line-by-line averaging of the measured information. The processed information must be represented in complex form, with the possibility of further processing according to the BPF algorithm.

The special features of the IU's operation mean the two-channel principle upon which it is organized and the resultant necessity of the entry of three values in the EKVM (A_{ij}, $U_0 \cdot \cos \varphi_{ij}$, $U_0 \cdot \sin \varphi_{ij}$ for an IU with parallel measurement of amplitude and phase; $A_{ij} \cdot \cos \varphi_{ij}/k$, $A_{ij} \cdot \sin \varphi_{ij}/k$, k when they are measured sequentially). Since the EKVM can provide simultaneous reception of only two informational messages, all the information is transmitted in two stages. There then follows alternate multiplication of the amplitude and phase messages for the purpose of obtaining the $A_{ij} \cdot \cos \varphi_{ij}$ and $A_{ij} \cdot \sin \varphi_{ij}$ components.

The method of aperture synthesis by scanning with a single emitter requires the introduction into the program of cycles for determining the beginning and end of a line, calculation of the number of measurements per line, and calculation of the number of lines that have been processed. The line-by-line measurement process must be accompanied by information storage in registers, with subsequent averaging according to the number of measurements made per line. As a result, at the end of the line-by-line measurement cycle we have

$$\overline{A_j \cos \varphi_j} = \frac{1}{A^2 N} \sum_{i=0}^{N} A_{ij} \cos \varphi_{ij}, \quad \overline{A_j \sin \varphi_j} = \frac{1}{A^2 N} \sum_{i=0}^{N} A_{ij} \sin \varphi_{ij}, \tag{1}$$

where N = number of measurements in a line; A = a number corresponding to the maximum possible ATsP code.

The next stage of EKVM operation consists of preparing the information for further processing with the BPF algorithm. In connection with this, it is necessary to compute

$$\bar{A}_j = \frac{1}{A^2} \sqrt{(\overline{A_j \cos \varphi_j})^2 + (\overline{A_j \sin \varphi_j})^2},$$
$$\varphi_j = \operatorname{arc\,tg} \left(\sum_{i=1}^{N} A_{ij} \sin \varphi_{ij} \middle/ \sum_{i=1}^{N} A_{ij} \cos \varphi_{ij} \right). \tag{2}$$

The auxiliary stage of EKVM operation consists of representing the measured and processed information in a form that is suitable for preliminary analysis. This is accomplished by printing, for each scanning line, the four parameters described by expressions (1) and (2), as well as a graph of the normalized near field parameters.

The consolidated EKVM operation algorithm, which reflects the points that have been discussed, is depicted in Figure 3. The program's basic characteristics are: number of steps -- 660; number of registers constantly used during computations -- 16; time required for the preliminary processing of the measurement results for an aperture of 128 x 128 points -- 20 min.

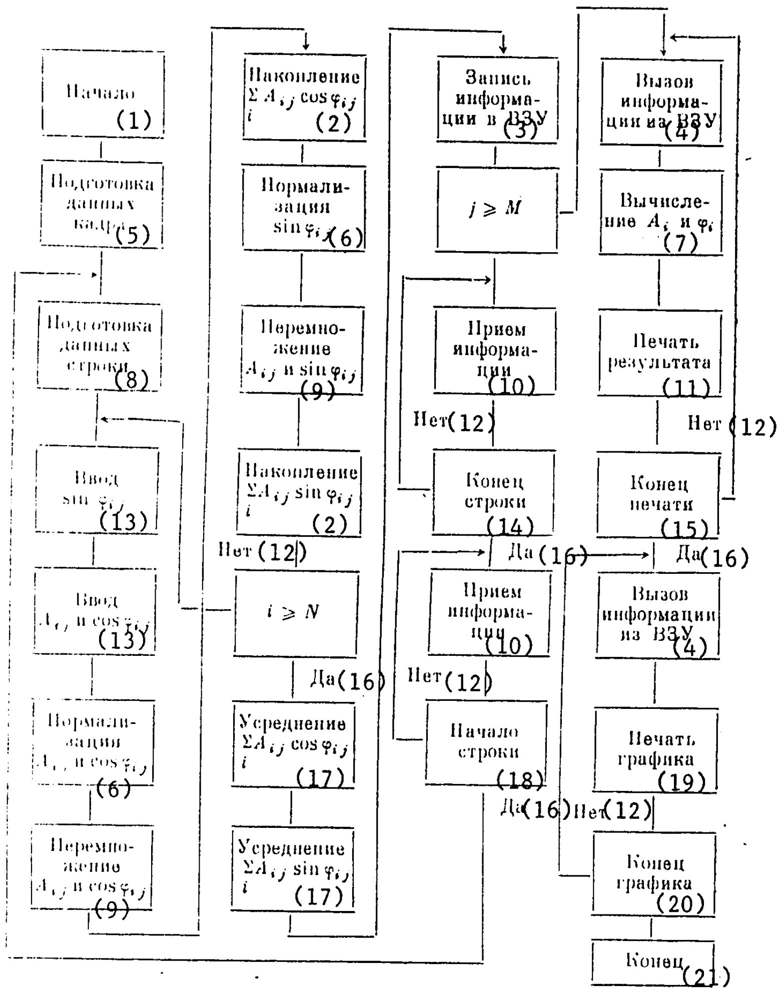

Figure 3. EKVM operation algorithm for reception and processing of measured information.

Key:

1. Begin
2. Store ...
3. Enter information in VZU
4. Call-up information from VZU
5. Prepare frame data
6. Normalize ...
7. Compute A_i and $_i$
8. Prepare line data
9. Multiply ...
10. Receive information
11. Print result
12. No
13. Enter ...
14. End line
15. End printing
16. Yes
17. Average ...
18. Begin line
19. Print graph
20. End graph
21. End

4. Errors in Measurement of Signal Ampliphases

An analysis of the IU structure shown in Figure 2 made it possible to determine the basic sources of error in the measurement of signal ampliphases, which sources are the result of nonidealness of the elements making up the IU. They include: δ_1 -- relative error of nonidentity of the integrators' time constants; δ_2 -- relative error of nonidentity of the amplitudes of the reference voltage former's (FON) signals; δ_3 -- phase error of nonorthogonality of the FON's signals; δ_4 -- phase error of bias of FON's harmonic and pulse voltages; δ_5 -- relative error of bias of the IU's cosine channel's zero level; δ_6 -- relative error of bias of the IU's sine channel's zero level; δ_7 -- relative error in the analog-to-digital conversion.

Allowing for δ_3 and δ_4, the output voltages of the IU's analog part are determined by the expressions

$$U'_{A\,cr\ \cos} = U_0\,[\sin(\delta_4 - \delta_3) + \cos\varphi_{ij}],$$
$$U'_{A\,cr\ \sin} = U_0\,[\sin(\varphi_{ij} - \delta_3) + \sin(\delta_3 + \delta_4)]. \qquad (3)$$

The subscripts "cos" and "sin" indicate applicability to the corresponding IU channels. Keeping the other measurement errors in mind, we derive the final expression for the IU's output voltages:

$$U_{\cos} = U_{A\,cr\ \cos}\cdot K_{cr} \pm \delta_7,\quad U_{\sin} = U_{A\,cr\ \sin}\cdot K_{cr} \pm \delta_7, \qquad (4)$$

where K_{cr} = conversion ratio of the measurer's digital part. Finally, we then have

$$U_{\cos} = U_0 K_{cr}\,[\cos\varphi_{ij} + \sin(\delta_3 - \delta_4) + \delta_5] + \delta_7,$$
$$U_{\sin} = U_0\cdot K_{cr}\,(1+\delta_1)\,\{(1+\delta_2)\,[\sin(\varphi_{ij} - \delta_3) + \sin(\delta_3 + \delta_4)] + \delta_6\} + \delta_7. \qquad (5)$$

From the expressions that have been obtained it follows that the effect of all the errors that have been discussed on the output signals can be compensated for, with the exception of errors δ_3 and δ_7. Using these expressions to obtain a quantitative estimate of the error, its value was calculated as a function of the argument φ_{ij} ($0 \leqslant \varphi_{ij} \leqslant 360°$). A program was compiled to obtain the relationships

$$\varphi = \operatorname{arc\,tg}\frac{U_{out\,1}(\varphi_{ij})}{U_{out\,2}(\varphi_{ij})},\quad A = \sqrt{U_{out\,1}(\varphi_{ij})^2 + U_{out\,2}(\varphi_{ij})^2}.$$

The results of the computations are presented in Figure 4a. The amplitude (1) and phase (1') error curves illustrate the case of the minimum possible error. The values of the parameters δ_i are chosen so as to compensate for the term $\sin(\delta_3 - \delta_4)$ in the expression for $U_{\cos}$, and $\sin(\delta_3 + \delta_4)$ in the one for $U_{\sin}$. The values of the other errors are as follows: $\delta_1 = 0$, $\delta_2 = 0$, $\delta_3 = 1°$, $\delta_4 = 2°$, $\delta_5 = 0.017$, $\delta_6 = -0.052$, $\delta_7 = 0$. Curves 2 and 2' correspond to the case where the integrators' bias voltages are not compensated for, have the maximum possible value (according to the certification data for the operational amplifier), and have opposite signs. The errors are: $\delta_1 = 0.087$, $\delta_2 = 0$, $\delta_3 = 1°$, $\delta_4 = 2°$, $\delta_7 = 0.01$; for curve 1, $\delta_5 = 0.012$ and $\delta_6 = -0.012$, while for curve 2, $\delta_5 = -0.012$ and $\delta_6 = 0.012$.

For a structure with sequential measurement of amplitude and phase (Figure 2b), in addition to the error sources that were also present in the structure just discussed (δ_3, δ_5, δ_6, δ_7), there are errors inherent to this structure alone. Among them we can distinguish: $\delta_A(A_{ij})$ -- dynamic amplitudinal error in the compression of the dynamic range, which error is a function of the measured signal's amplitude; $\delta_\varphi(A_{ij})$ -- dynamic phase error in the compression of the dynamic range, caused by an additional phase incursion that depends on the measured signal's amplitude;

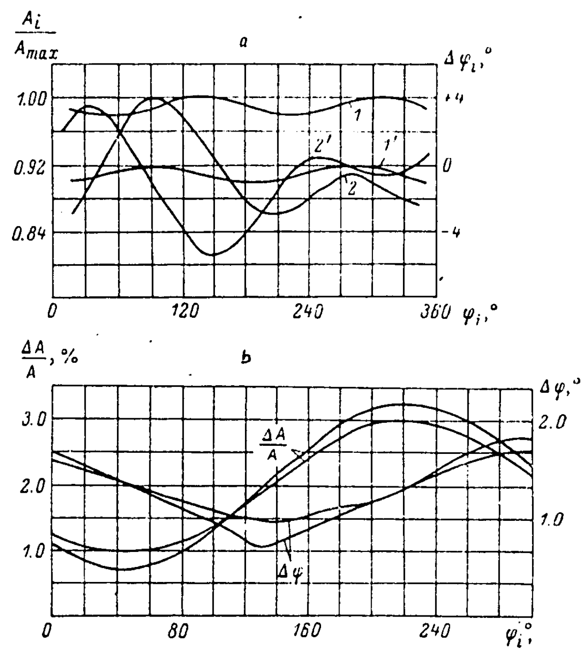

Figure 4. Errors of measuring device with parallel (a) and sequential (b) measurements of signal phase and amplitude.

δ_{PD} -- systematic error of the conversion ratio K_{cr} of the phase detectors in the sine and cosine channels. The voltages at the outlets of these channels are

$$\delta_{\cos} = \frac{A_0 A_{ij} \cos\varphi_{ij}}{K_{cr} k}(1 - \delta'_{\cos}), \quad \delta_{\sin} = \frac{A_0 A_{ij} \sin\varphi_{ij}}{K_{cr} k}(1 - \delta'_{\sin}), \tag{6}$$

where A_0 = amplitude of the reference signal; $\delta'_{\sin}$ and $\delta'_{\cos}$ = analog conversion errors, as determined by the following expressions:

$$\delta'_{\cos} = 1 - \frac{\cos\delta_3 - \operatorname{tg}\varphi_{ij}\sin\delta_3}{[1 - \delta_A(A_{ij})](1 - \delta_{\Phi Д})} - \frac{\delta_5}{\cos\varphi_{ij}},$$
$$\delta'_{\sin} = 1 - \frac{\cos\delta_3 + \operatorname{ctg}\varphi_{ij}\sin\delta_3}{[1 - \delta_A(A_{ij})](1 - \delta_{\Phi Д})} - \frac{\delta_6}{\sin\varphi_{ij}}. \tag{7}$$

From this it follows that the analog conversion error is a function of the measured angles and depends heavily on the instability of the zero level (δ_5 and δ_6). The error caused by zero level instability, which equals 0.1 percent, can be eliminated only by introducing a system for the stabilization of this level.

The total error in the measurement of the argument and the modulus is determined by the expressions

$$A = \frac{A_0 A_{ij} K_d}{K_{cr} k}, \quad \frac{\Delta A_{ij}}{A_{ij}} = \cos^2\varphi_{ij}\cdot\delta'_{\cos} + \sin^2\varphi_{ij}\cdot\delta'_{\sin} + \frac{\delta_7}{A}\times[\cos\varphi_{ij}(1 - \delta'_{\cos}) + \sin\varphi_{ij}(1 - \delta'_{\sin})],$$
$$\Delta\varphi_{ij} = \varphi_{ij} - \operatorname{arc\,tg}\left[\operatorname{tg}\varphi_{ij}\frac{(1 - \delta'_{\sin}) + \left(\frac{\delta_7}{A_{ij}\sin\varphi_{ij}}\right)}{(1 - \delta'_{\cos}) + \left(\frac{\delta_7}{A_{ij}\cos\varphi_{ij}}\right)}\right], \tag{8}$$

where K_d - conversion ratio of the digital part of the measurer. From the curves presented in Figure 4b, which were determined for $\delta_A(A_{ij}) = 0.015$, $\delta_\varphi(A_{ij}) = 15°$, $\delta_7 = \pm 0.001$ and an FD /phase detector/ signal amplitude corresponding to the lower boundary of its dynamic range, it follows that in the entire range of measured angles, $\Delta A_{ij}/A_{ij} \leq 3$ percent and $\Delta\varphi_{ij} \leq 2°$.

3. Experimental Results

The measuring devices developed on the basis of the structures shown in Figures 2 and 3 are characterized by the following parameters: radio pulse duration -- $40T_0$ (where T_0 is the carrier frequency's period); radio pulse processing time -- $20T_0$; radio pulse repetition period -- $8,000T_0$; dynamic range of the change in the input signals' amplitude -- 50 dB.

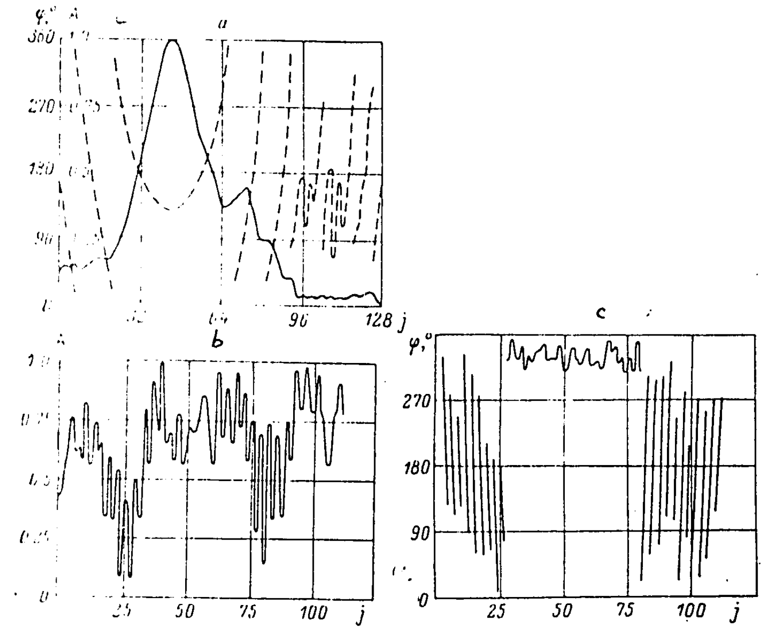

Figure 5. AFR of near field of round (a) and rectangular (b,c) pistons.

The measuring complex was tested during the investigation of antennas of different types, with repeated measurement of the parameters of the near field of monotypical antennas. In connection with this, the total average error in the measurement of the modulus at a level 3 dB from the maximum level was ±3 percent, while at the 30-dB level it was ±8 percent. The total phase error was no more than ±5° at all measurement points. It should be mentioned here that the scanning unit can make a substantial contribution to this error if it does not have a rigid coordinate tie-in. During the experiment, we investigated the amplitude-phase distribution of the near field of a round piston (Figure 5a) with a diameter $d = 16\lambda_0$, a rectangular piston (Figure 5b) with a side $24\lambda_0$ in length and equidistant location of the receiving elements $1.5\lambda_0$ apart, and a cylindrical antenna (Figure 6) with $d = 40\lambda_0$ and height $h = 50\lambda_0$.

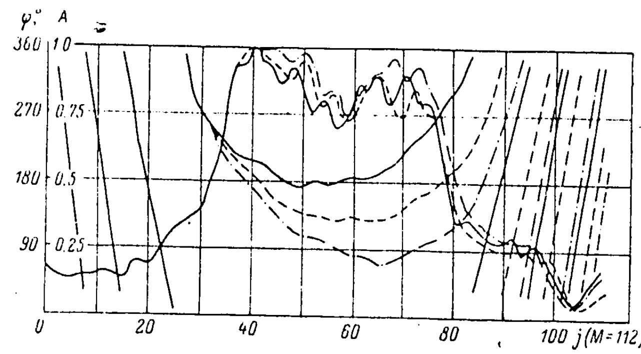

Figure 6. AFR of near field of cylindrical antenna.

During the process of line-by-line measurement of the near field, 128 measurements were averaged, there were also 128 lines, and the scanning rate was 8 cm/s.

The experiments showed that the phase distribution of the field can be used to detect anomalies in an antenna's operation. In Figure 5a there is a phase anomaly at j = 90-120. The phase distribution can also be used to eliminate nonparallelness of the scanning and antenna planes in order to obtain an unshifted main maximum of the radiation pattern's cross-section when reproducing a unidimensional hologram. Figure 6 depicts three unidimensional AFR's that correspond to displacement of one edge of the plane of the investigated antenna's aperture through steps of $0.25\lambda_0$. During reproduction, the phase distribution curve for which the minimum value of the phase in the active area coincides with the center of the amplitude distribution's maximum (the solid line in Figure 6) gives an undisplaced maximum of the antenna's radiation pattern.

Conclusion

The development and testing of the described measuring device structures showed that they can be used to determine the AFR of a field with a dynamic signal range of up to 60 dB. A closer approach of the scanning plane to the antenna entails a need for taking measures to reduce the effect of both the ghost emission signal and return signals of a different nature. This can also be achieved by reducing the pulse message processing time to $(1-3)T_0$.

The use of control EKVM's for preliminary processing of the measurement results and reproduction of unidimensional holograms justified itself completely and makes it possible to create economical and mobile measurement complexes.

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NETWORKS

PROJECT FOR A NETWORK AMONG THE COUNTRIES PARTICIPATING IN THE INTERNATIONAL INSTITUTE OF APPLIED SYSTEMS ANALYSIS

Moscow UPRAVLENIYE I NAUCHNO-TEKHNICHESKIY PROGRESS: DOSTIZHENIYA I PERSPEKTIVY in Russian No 9, 1980 pp 68-83

[Article by S. V. Golovanov and candidates of technical sciences O. L. Smirnov and O. A. Shmykov, USSR]

[Text] The Purpose of the Project

The development of programs of cooperation among scientists of different countries which are carried on at the International Institute of Applied Systems Analysis (IIASA) in Vienna is accompanied by steady growth in the information ties of this institute with the national scientific collectives of the countries participating in its work. Fast, simple, and convenient means of information interaction for scientists working in this area are, of course, an essential condition for efficient scientific research. This is particularly true for such complex interdisciplinary investigations carried on at the IIASA as "energy systems," "resources and the environment," "food and agriculture," and "integrated regional development." The excellent results of these studies, which are of interest to most countries of the world, come in large part from the efficient use of resources invested in these studies in the various countries.

Among these resources can be included: highly qualified scientific-technical personnel; financing, and so on, also including an acceptable data base and computers, that is, information-computing resources. Mutual coordination of research, operational working interaction, and exchange of intermediate and final results permit full use of all the advantages of a rapid determination of the most productive areas of research, division of labor, and specialization of scientific collectives. Operational delivery of results and recommendations obtained to those on whom management of the corresponding processes depends is an important and essential condition for highly efficient research.

This last factor is especially important for the USSR. The high rate of development of the Nonchernozem zone of the RSFSR, Siberia, and the northern oblasts and the implementation of major programs in the fields of energy, agriculture, and the like lead to a definite information "famine" in those places where the programs are being carried out.

Data on the latest results of scientific research on a particular problem, data on similar situations in the experience of other countries, operational communications and consultation with leading scientific collectives using sophisticated information-computing mean, are often critically necessary for decision-making bodies.

The vast territory of the USSR, however, and the time delays associated with traditional forms of moving information (scientific reports, publications, sending material by mail, and so on) lead to significant limitations on the accessibility of essential information at a certain point when it is needed. In a number of cases this isolates investigations and practical projects being carried out in different places from one another with respect to information. The existence of sophisticated means of information interaction would make it possible to eliminate these limitations.

At the same time IIASA and the work there by representatives of leading Soviet scientific collectives present good opportunities for comparing the results of domestic scientific investigations and experience with similar foreign results. The efficiency of using these opportunities in the interests of the users, the scientific collectives who are studying the particular problem and the bodies responsible for concrete practical activities, is directly dependent on the operationality (speed and flexibility) of information interaction.

One more important feature of systems research conducted at the IIASA should be noted. This relates to the necessity of regularly receiving and analyzing data (climate, energy, and the like) that goes beyond the national boundaries of particular countries.

It is also true that such investigations typically use intricate mathematical models that, in turn, require significant computing resources. But the resources involved in these studies are territorially distributed, both within particular countries and among different countries. As a result raising the efficiency of such research is directly linked to the need to integrate the information-computing resources of all interested parties.

The appearance of new means of information interaction, computer networks which integrate in themselves all the potential of traditional means of data transmission (mail, telegraph, telephone, and the like) as well as a number of new functions, for example using remote information-computing resources, fully satisfy the needs considered above.

Thus, we may formulate the following basic purposes of the international network of IIASA countries [1, 4]:

1. insuring access to remote information-computing resources for the topics of studies conducted at IIASA;

2. development of efficient means of communication, data exchange, and interaction among scientific organizations and scientists conducting studies in the general subject area;

3. more rational use of the information-computing resources available in the member countries of the IIASA in the interests of projects being developed jointly at IIASA;

4. increasing the efficiency and accelerating the process of introducing the results of scientific research in practice in the countries that are carrying out the corresponding programs in the fields of energy, the environment, agriculture, and the like;

5. creation of conditions for the conclusion of political and economic agreements that support effective cooperation between the countries of the socialist community and Western Europe and America in the field of computer networks;

6. the creation of means of communication between the networks of Western Europe and America, on the one hand, and the networks of the socialist countries, on the other, in those cases where there are no other opportunities for such connections;

7. the formation of an information consulting body on the use of computer networks and specialized data bases functioning in the interests of the scientific research organizations of the socialist countries.

History of Development of the Project

These objectives were the reason that work was begun to build the computer network to join the information-computing resources of the IIASA member countries. Experiments to study the possibility of creating such a network were begun in late 1974. Short-term connections were established between the computing means of the IIASA and different scientific organizations in the participating countries (see table below). From the theoretical point of view these experiments made it possible to evaluate the problems of remote terminal access to the information-computing resources and communications of various types of computer systems and to analyze the possibilities of using international switchable and separate telephone communications lines to support permanent connections. The questions of using other communications lines — radio communications in the ultrashort-wave part of the spectrum and data transmission through communications satellites — were also studied.

For example, the experiments on use of ultrashort-wave radio channels for communication between computer systems located fairly close to one another such as IIASA and the Vienna Technical University or IAASA and the Bratislava Research Computer Center in Czechoslovakia made it possible to conclude that these communications channels had high economic efficiency and reliability compared to telephone lines [1].

To conduct such experiments it was necessary to do the corresponding work to supply remote users with essential equipment and programs. Studies

Table. Experimental Connections between IIASA and European Scientific Organizations

Connection	Date	Computer	Equipment Terminal	Modems	Communications Channel	Remarks
IIASA - Moscow Institute of Control Problems	Apr, 74 1975 1977	PDP II/45+ DLII/E+ ICL4/70	Tektronix 4012 AVDU 7153	ITT-GH 2052	600/1200 bits/sec, semiduplex, switchable and separate, synchronous	Problems with separation of communications lines. Interference by telephone station operators at the beginning of transmission of a discrete signal
IIASA - Budapest Institute of Automation and Computer Technology	1975	PDP II/45 TPA-70+ CDC 3300	CDC 732/12 CTD 71	Racal-Milgo 2200/24 SZAM-32	1200/1600/2400 bits/sec, semiduplex, switchable, synchronous	Problem of evaluating the hardware of one producer working in the network
Bratislava-Moscow	Oct, 1975	NORD 20+ CDC 3300	Display AVDU 7153	ITTGH 2002 GH 2056	600/1200 bits/sec, asynchronous	Remote feeding of jobs
IIASA - Edinburgh University Computer Center	Oct, 1975	PDP II/45+ DM II	Tektronix 4012 + teletype	ITT 2052 Phillips D200 E, English Modem 1, 2	1200 bits/sec, semi-duplex, asynchronous; 110 bits/sec, duplex, switchable	" " "
IIASA - Pisa (CNUCE)	Dec, 1975	IBM 370/168+ IBM 3804	Terminet 300	Racal-Milgo 2200/24	2400 bits/sec, duplex, synchronous, separate; 200 bits/sec, semiduplex, asynchronous, switchable	" " "

[Table continued next page]

Table Continued

Connection	Date	Computer	Equipment Terminal	Modems	Communications Channel	Remarks
IIASA - Warsaw Institute of Communications	May, 1976	PDP II/45+ DPII Singer 10+ Singer 1500	Teletype Display Singer 7012	Racal-Milgo 2200/24 " "	1200/2400 bits/sec, switchable, semi-duplex, synchronous	Remote feeding of jobs
IIASA - CYCLADES	Feb, 1976	Network	Terminet 300	Phillips D200E	200 bits/sec/asynchronous, duplex, switchable	Entry to the network accomplished through concentrators plugged in at Grenoble and Paris
IIASA - Vienna Technical University	1976-1977	PDP II/45 Cyber 74		FRTX-5 "	2400 bits/sec, duplex	Ultrashort-wave radio network
Bratislava Research Computer Center	1977-1978	PDP II/45 CDC 3300			2400/4800 bits/sec, duplex	" "

led to the formation of special working groups of IIASA and several interested countries for the purpose of conducting joint coordinated activities to set up an international network of the IIASA member countries. There were several meetings of the representatives of these groups. At the first meeting in December 1975 in Bratislava, the fundamental principles of joint activity in this area were formulated. Specifically, it was decided not to develop new, original standards for the protocols of connections, but rather as much as possible to use existing international standards. Establishment of the IIASA network was to be done on the basis of the subnetworks of the national organizations of participating countries and the existing computer and communications equipment with close interaction among all working groups, avoiding technical concepts involving large expenditures for equipment purchase.

As the result of significant difficulties identified during the experiments with reference to modifying existing operating systems on the existing computers of the participating countries, the meeting adopted a recommendation to use functionally specialized processors (front end processors), which could also perform the functions of communications centers in those cases.

At later meetings it was decided that the IIASA network would use the HDLC protocol, orient itself to batch switching, and conduct further studies of the needs of potential users.

The Condition of the Network in 1979-1980

At the present time the network of IIASA member countries has the configuration shown in Figure 1 below. A permanent link between IIASA and the IBM 370/168 computer of the Italian National Research Institute (CNUCE) in Pisa has been functioning since August 1977.

At first the communications lines from Pisa was used for interactive work with the IIASA terminal and remote feeding of jobs. As use of the line by IIASA scientists grew, it was connected directly to the PDP 11/70 computer at IIASA, which emulates the corresponding terminals. The load on the line is more than 5 million characters for a working day of 5-6 hours [3].

Another permanently functioning line connects the IIASA computer with the Cyber 74 computer of the Vienna Technical University, which works primarily in the batch processing mode.

In 1979, following an agreement concluded by IIASA, the International Atomic Energy Agency in Vienna, the Information Service of the European Space Agency (ESRIN) in Frascati, Italy, and CNUCE in Pisa, a common communications line was set up. The line, which is a multiplex telephone communications channel, has provided these organizations with shared use of information-computing resources since 1980 while at the same time reducing the operating costs of all participants.

The IIASA also has entry to the TELENET and TYMNET networks through the Radio Austria organization in Vienna. Entry to the networks CYCLADES, MARK III, and CYBERNET is also possible through switchable telephone communications lines.

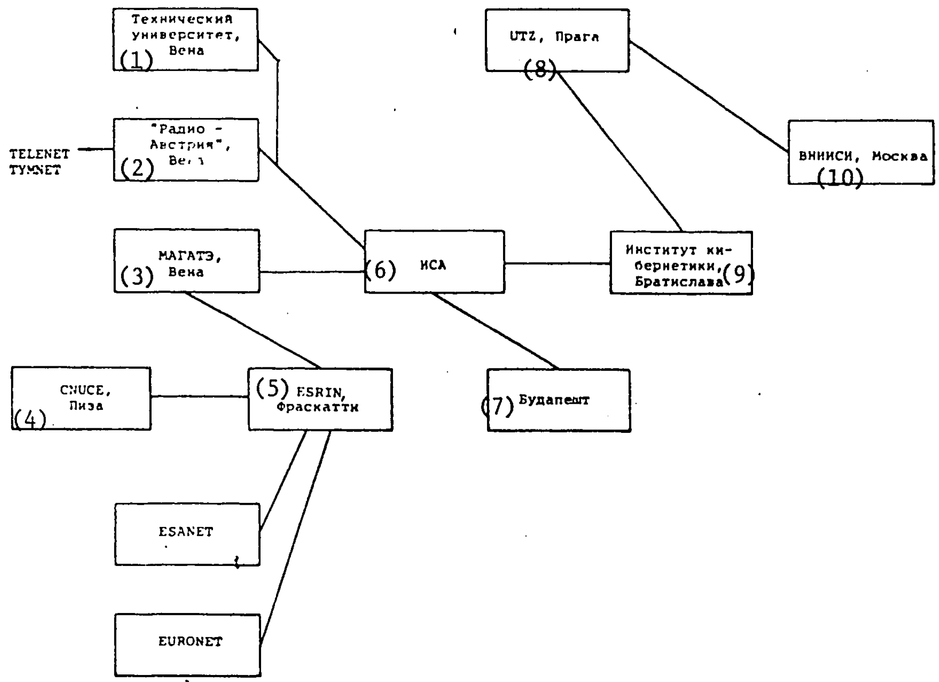

Figure 1. Configuration of the Network in 1980

Key:
(1) Vienna Technical University;
(2) Radio Austria, Vienna;
(3) International Atomic Energy Agency, Vienna;
(4) CNUCE, Pisa;
(5) ESRIN, Frascati;
(6) IIASA;
(7) Budapest;
(8) UTZ, Prague;
(9) Institute of Cybernetics, Bratsilava;
(10) VNIISI [All-Union Scientific Research Institute of Systems Research], Moscow;

A direct connection has been established between IIASA and Budapest since April 1979, and in 1980 the Moscow — Prague — Bratislava line was connected to IIASA. These lines give the scientific research organizations of Hungary the Soviet Union, and Czechoslovakia access to the information-computing resources of IIASA.

Problems of Development of the Network

Although the issue of setting up the network was raised several times after the first scientific experiment on communication among remote computer systems and the advisability of solving the problem as quickly as possible was recognized by most of the representatives of the national organizations, no significant progress has taken place in this direction in the last four years. But the hard work of the appropriate group at IIASA and interested representatives of national organizations made it possible to identify the broad range of problems involved with setting up such a network (see Figure 2 below).

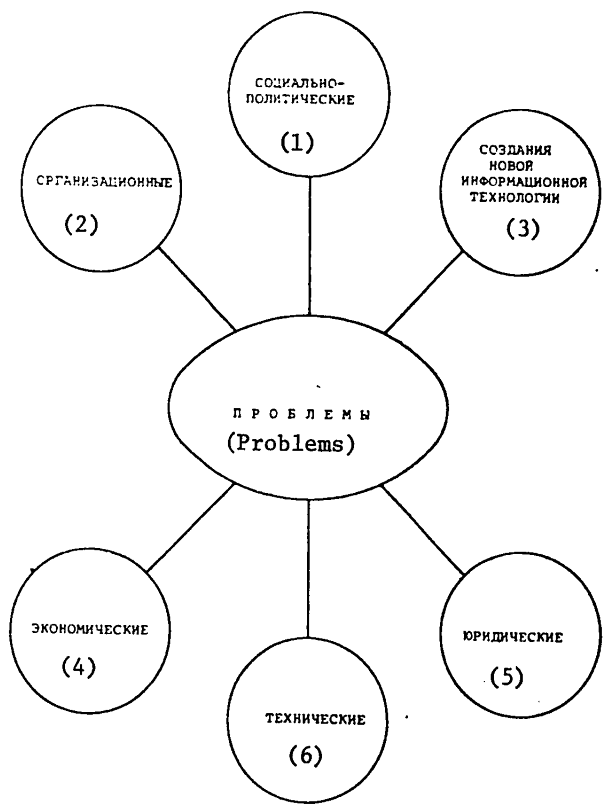

Figure 2. Problems Related to Setting up International Computer Networks

Key:
(1) Sociopolitical;
(2) Organizational;
(3) Building New Information Technology;
(4) Economic;
(5) Legal;
(6) Technical.

Above all it became clear that, from a theoretical point of view, realization of the network is possible at the present time and does not present serious problems.

Existing telecommunications equipment and data processing means have begun to be produced in series both in the socialist countries and in Western Europe. It was recognized that the primary factor preventing rapid practical realization of this project were organizational, economic, legal, and sociopolitical problems. Some of these problems relate to the appearance, for the first time in human history, of such a universal and powerful means of information interaction as the computer network. Other problems are related to the fact that the network of IIASA member countries is a functionally oriented international network set up in conditions of the centralized responsibility of participants and joining together specialized information-computer resources of countries with different sociopolitical, economic, and legal systems.

History affords no precedent of solving such problems, which is what necessitates the systems approach to working out the conception of this network. A detailed analysis of all aspects of this project and formulation of a conception that brings together the interests and potential of all the participants in a single integrated whole will make it possible to define a way to realize a network that is feasible and can develop over time.

Before presenting a possible approach to formulation of such a conception, it is useful to analyze the above-mentioned problems in greater detail.

Organizational Problems

The postulate of decentralized responsibility for the establishment and operation of the network of IIASA countries may potentially lead to a certain conflict among technical, economic, legal, and other concepts on the basis of which the national parts of the network are built.

Minimizing the negative consequences of such an organizational concept is possible with precise development of a system of goals and identification of those advantages which all participants in the network can receive from making efficient and coordinated decisions. Definite ideas on what work in the network will provide for each scientific research organization and how much it will raise the organization's scientific-technical potential, in other words the clarity, attractiveness, and promise of the network for all national organizations, can greatly strengthen the desire to work out various practical solutions and speed up the building of an operating system. In connection with this, the organizational mechanism of the network should envision the following these procedures (see Figure 3 below):

1. coordination of the activities of national organizations participating in the network;

2. identification of the responsible representatives of the national network;

3. identification of the needs of the national organizations that are forming the national networks;

4. making technical, economic, and other decisions to satisfy these needs;

5. carrying out these decisions in a planning period;

6. distributing responsibility for declaration of the information-computer resources of the national network, its functioning, and providing adequate information representation for other users of the network.

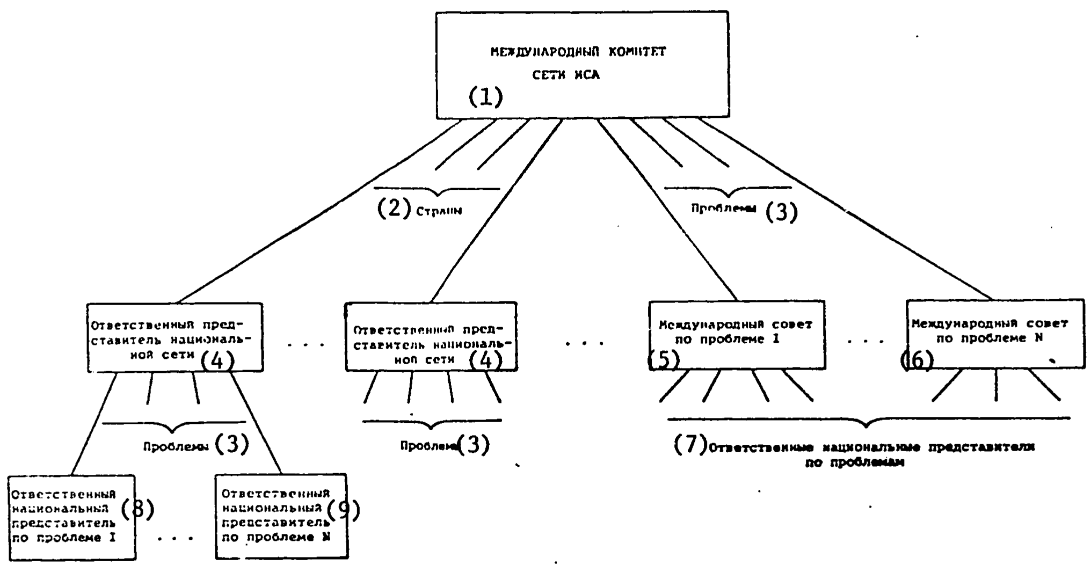

Figure 3. Variation of the Organizational Structure of a Problem-Oriented International Network of IIASA Member Countries

Key:
(1) International Committee of the IIASA Network;
(2) Countries;
(3) Problems;
(4) Responsible Representative of a National Network;
(5) International Council on Problem I;
(6) International Council on Problem N;
(7) Responsible National Representative on Problems;
(8) Responsible National Representative on Problem I;
(9) Responsible National Representative on Problem N.

The above-listed procedures should provide a fast and effective organizational mechanism, for example for reconciling the standards of the network for such primary services as the interactive work mode, remote job feeding and batch processing, communication between users and programs, transmission of data files, and the like.

Subsequent standardization of general services based on the primary services, for example, systems to control data bases and parallel computations, are an equally necessary condition.

Differentiation of the functional orientation of the information-computer resources of the national networks is an important organizational factor. It is made necessary by the limited character of resources allocated to form and operate the network.

Numerous issues relate to organizational interaction with already existing computer networks and data bases and those being put into operation, for example EIN, EURONET, and RPCNET (Italy).

Economic Problems

The limited resources of the scientific research organizations on whose basis the international network of IIASA member countries is being constructed makes it necessary to minimize overall expenditures for the network. In the most general form, the expenditures of national organizations participating in the network are related to setting up the system, its functioning, and development of the system. Expenditures for setting up the network include the purchase and installation of communications equipment, allocation of computer resources for use in the network, development of specialized software that includes systems for control of data bases, and so on.

Expenditures for functioning include maintaining the system in working condition, filling and expanding data bases, modernizing and improving information-computer resources, and leasing communications channels. All these expenditure subheadings except the last occur in stages and are spread over time. The leasing of communications channels (separate telephone lines are most acceptable at the present time) is a permanent expenditure heading and an issue that requires special analysis.

As the corresponding studies show [1-3], the basic economic problems of international computer networks are linked to the relatively high cost of leased telephone communications channels for transmission of discrete messages. This is generally a purpose for which they were not designed. As a rule, the cost of leasing international communications lines is several times higher than leasing costs for equivalent distances of lines within a country. In some countries the additional expenditures are a result of national rules established by ministries of communications.

These rules require that users lease telecommunications equipment in addition to the communications channel, and the cost of leasing in some cases is as much as the cost of the equipment itself. In other cases a practice is employed that is difficult for users to understand: the charge for communications channels is increased when the speed of data transmission increases, despite the fact that the very same channel is being used. An international network such as the network of IIASA countries should permit users in one country to work with the computers of another country and the communications channels to pass through several other countries with different systems of charges and serve several users in different countries at the same time. The question of the principles of regulating financial relations among participants in such a network has not been resolved at the present time. Only recently has work been begun to develop recommendations on a system of charges for international data transmission networks after 1980. This is being done by the International Telegraph and Telephone Consultative Committee, which is a member of the International Union of Electrical Communications, a U. N. body. As we know [2], these recommendations envision that charges for data transmission in networks with batch switching will be independent of distance. The analysis of existing international networks in Western Europe given by work [3] made it possible to estimate the range of costs for transmitting 1,000 characters of information. This range today is between 1 and 10 cents for different specialized networks (with which the IIASA network — 4 cents — can be classified) and from 0.7 to 3.5 cents for general-purpose networks (EPSS — Great Britain, NORDIC — Scandinavia, TRANSPAC — France, and EURONET — European Economic Community).

It is interesting to note that the cost of transmitting data through the international Telex network exceeds the similar cost of computer networks by more than 20 times, chiefly because of the low traffic capacity of Telex lines.

Thus, one of the serious economic problems for international computer networks is leasing communications channels. But even the brief experience with operating a few international networks shows that a network can function with high economic efficiency [3].

Differentiation and specialization of the information-computer resources of the network are an important principle that makes it possible to achieve this efficiency. This approach is a natural consequence of the fact that the use of software-hardware complexes and data bases that are specialized in a definite topic area to obtain final results and information is more profitable than establishing similar potential at each individual organization. The term "profitable" here means not only economic efficiency, but also "reaction time," the time between the occurrence of the need and its satisfaction. This plays an important part in all scientific research and development.

Sociopolitical Problems

Setting up an elaborate system of information links among systems with different social orders is certainly a complex problem. Such a system can only function efficiently if it helps solve problems that interest all the countries participating in the work of the IIASA. The IIASA's activity which resulted in the draft plan for the international network is a successful example of this approach. Problems such as the earth's climate and atmosphere, the limited nature of energy resources, agricultural systems, water resources, and the like are common concerns of all the IIASA members and are curcially important for the future of the entire human race.

There are, however, many factors that make it difficult to solve this problem quickly. Among them, for example, are the following:

1. different levels of resources which may be allocated for such research in different countries;

2. different levels of preparedness and potential of the scientific collectives that carry out such projects;

3. significant differences in domestic policy, legislation, and governmental practices in different countries, as well as procedures for regulating information flows to the country and out of it;

4. language, cultural, organizational, and other differences.

These factors were the reason that the development of technology for computer networks in the capitalist countries was accompanied right from the start by steadily growing government control and regulation, even where these networks were developed by independent private companies. A careful analysis of these factors and finding solutions acceptable to all parties is an essential condition for the feasibility and effectiveness of an international network such as the network of IIASA countries.

Legal Problems

The international computer network is only a new means of information exchange, a powerful new information technology appearing for the first time in the course of scientific-technical progress. It is natural that the use of this means must be put on a mutually-agreed and mutually acceptable legal foundation, which has not yet been worked out at the present time. An example of the consequences of this situation is the difficulties experienced while setting up such international networks as EIN, EURONET, NORDIC, and several others as well as the periodically occurring complications in the development of private (that is, belonging to one company) networks such as the MARK-III, CYBERNET, and TELENET in the territory of other countries.

The issues of mutual transfers from one network to another, work by governmental and private organizations in the same network, and others still have not found proper solutions. Soviet users are particularly interested in the question of how work can be carried on with the information-computer resources of a third network, a fourth, and so on, for example entry to the Arpanet network through EIN, EURONET, or the private commercial network MARK-III. In such cases, what should be the formal procedure for writing up the document and how should financial relations be regulated?

Another problem that has appeared in connection with the establishment of computer networks is the problem of authors' rights. Of course, information producers try to give the largest possible number of users access to this information through the computer network, and demand a certain compensation for this. This principle, which has existed since before the appearance of networks, was based on the total number of items published or copied.

But the realization of this principle becomes unclear when electronic data bases included in computer networks appear. Among the capabilities of these data bases are retrieving bigliographic and factographic information in the interactive mode, using automated means to retrieve information by key words, indexes, and the like, and receiving full or partial copies of the material on paper at the user's work place. The development of new information technology is also clearly influenced by the reduced efficiency of information systems based on paper media compared to electronic data bases. This makes the cost of publishing printed materials higher and steadily decreases the cost of storing, processing, and transmitting information by computer. These contradictions and existing trends should be taken into account when working out agreed-upon legal norms and procedures for resolving the broad range of similar issues related to the process of setting up and operating the international network of IIASA members. Beginning practical work in this direction and putting the appropriate norms in fixed legal form are important conditions for fast development of the plans for the IIASA network.

Technical Problems

Despite the fact that the technical problems of setting up the network of IIASA members are not as complex as the others, there are a number of questions on which the efficient operation of the system as a whole depends. As an example we might point out the problem of estimating traffic, which is the basis for organization and topology of the network and for selecting particular technical concepts.

Any concrete estimates of traffic in the network made at the present time will be too unreliable owing to the absence of information on the potential number of network participants, the problems it solves, alternatives for organization of the national subnetworks, and so on. In addition, as work [5] correctly observes, such estimates are inevitably mistaken because the very existence of the network by itself changes the capabilities of the users and, as a consequence, their desire to use these capabilities. These things make it essential to take the uncertainty of our knowledge of the future into account and adopt those technical decisions which will provide greater system adaptivity and flexibility.

Another complex problem is selecting hardware and a rational network structure to meet the contradictory demands of high system efficiency and minimum cost. Preliminary work in this direction done by the IIASA working group on computer networks and certain national organizations of the IIASA countries made it possible to determine certain characteristics of the network. Thus, at the present time a network with batch switching on the basis of recommendations X.25 with synchronous four-line separate communications channels and data exchange speeds of more than 2,400 bits per second.

The advantages of setting up a network on a uniform basis are widely known. Favorable conditions for solving this problem are being created with the beginning of production of SM-3 and SM-4 minicomputers, which have analogous structure of the "common line" type, as well as microprocessor sets in the CEMA countries.

Setting up an operating system does not solve all the technical problems of the network. In addition to questions of technical improvement of the system and increasing its functional capabilities, there will be questions of evaluating network efficiency which require special theoretical and practical studies.

Formulating the Conception

Analysis of existing information flows, which form the information networks, the organizational structures of contemporary society, allows us to identify three basic classes of such networks according to the principle of organization.

The first class may include centralized hierarchical structures (see Figure 4 below) in which interaction among levels involves exchange of control and coordinating data. Each level of such a hierarchical network has a definite degree of processing of the information received from lower levels.

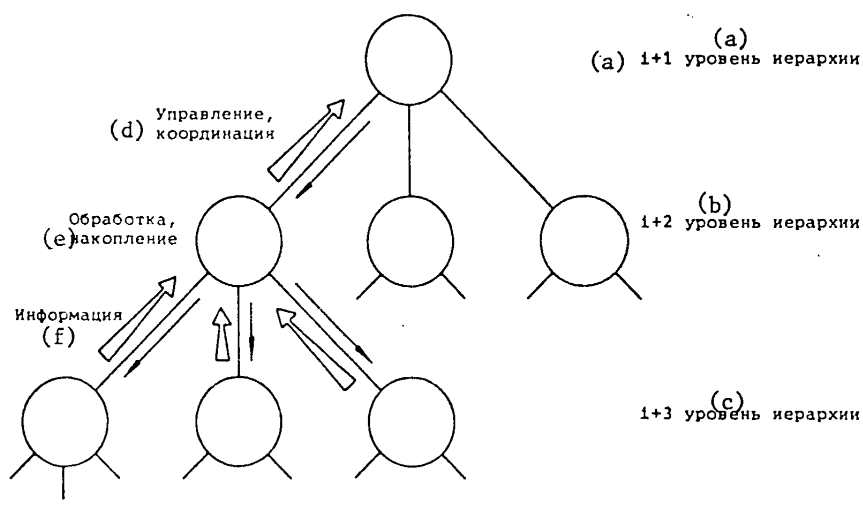

Figure 4. Information Network with Hierarchical Structure

Key: (a) Hierarchical Level i + 1; (d) Control, coordination;
(b) Hierarchical Level i + 2; (e) Processing storage;
(c) Hierarchical Level i + 3; (f) Information.

The second class can comprise problem-oriented networks based on the principle of integrating the problem-differentiated labor of its individual participants into a single system (see Figure 5 below). In such networks information flows move from the bodies that generate and collect information to the organizations that accumulate and store it, then through information retrieval systems to the users.

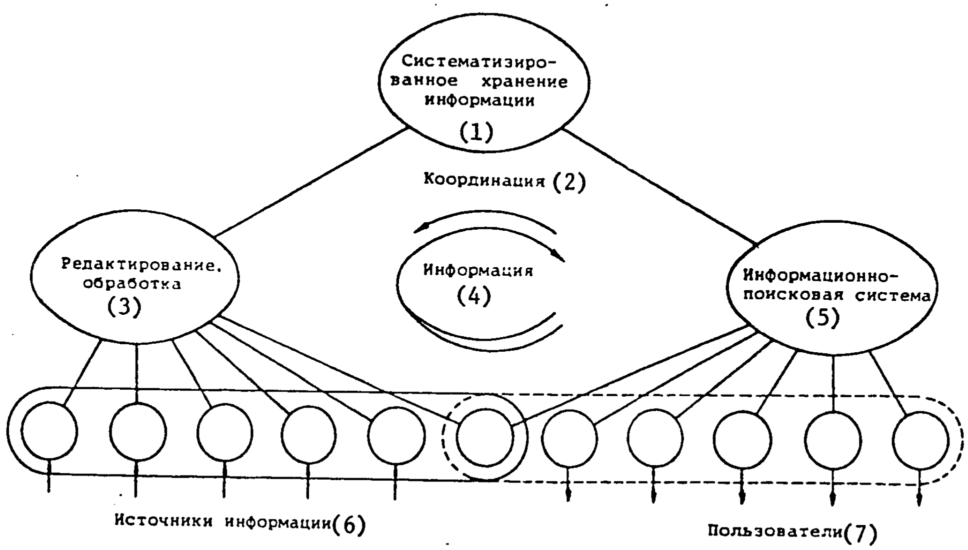

Figure 5. Problem-Oriented Information Network

Key:
(1) Systematic Data Storage;
(2) Coordination;
(3) Editing, Processing;
(4) Information;
(5) Information Retrieval System;
(6) Sources of Information;
(7) Users.

The third class of information networks can include homogeneous networks of "equal partners" who periodically exchange information on different questions (see Figure 6 below).

For obvious reasons, networks of the first type cannot be used to set up international computer networks. Networks of the second and third type come closest to meeting the requirements for international networks. Information networks of these two types can be realized in a single computer network and represent a means of information interaction for territorially remote, problem-oriented information-computer resources.

It must be observed that while networks of the third type are unstable and have a weak economic basis, networks of the second type are stable and may serve as

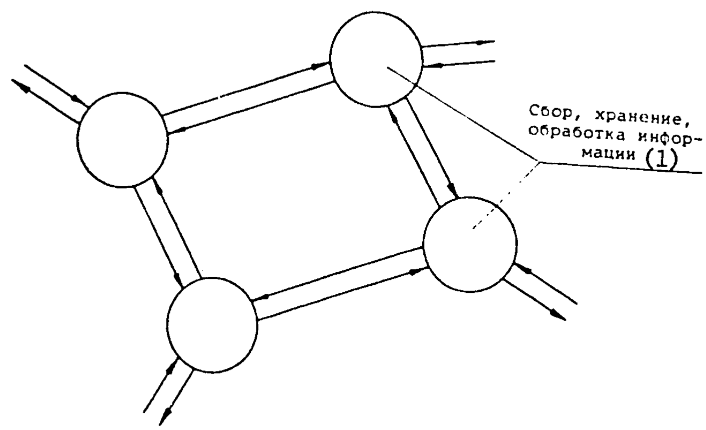

Figure 6. Homogeneous Distributed Information Network

Key: (1) Collection, Storage, and Processing of Information.

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the foundation for setting up the IIASA network. To substantiate this thesis it is useful to review the following premises.

A well-known condition for high efficiency and return from scientific research at the present time is for the organizations and scientific collectives doing this work to have sophisticated information-computer potential. Increasing this potential leads to even greater capacities and rates of development. Where these resources are developed independently each of the scientific organizations tries to attain the maximum level of its own information-computer potential in a relatively broad problem area covering all the possible needs of the scientific collective.

The limited resources available for the particular organization (qualifications of personnel, financing, hardware and software, and the like) naturally lead to differences in the level of potential achieved in fact. This process, analyzed from the standpoint of the efficiency of studies that are important for many countries of the world, leads to unproductive expenditures of aggregate resources allocated in different countries for similar research. It leads to duplication of labor.

When such problem-oriented organizations specializing in a definite subject area are included in a well-developed system of information interaction, a computer network, a trend begins to develop for many participants in the network to use the information-computer resources with maximum potential. This is more profitable from the standpoint of time and money than achieving the same potential through the efforts of the organizations themselves. At the same time available resources may be used fully for research on problems in which the particular scientific collective is most efficient. The results of this research in this case may be a direct contribution to development of the information-computer potential of the particular collective on a definite problem and, in turn, may be used by other participants of the network. This kind of narrow problem specialization is a natural consequence of the limited nature of resources allocated for scientific research and has become widespread in different fields of science and technology. The use of an analogous principle to set up an international computer network that joins together the collectives of different countries would lead to more efficient use of aggregate resources at the disposal of the scientific collectives of different countries, greater cooperation on the basis of division of labor, and more incentive to develop the aggregate information-computer potential of the network.

Realization of this conception of an international network of the IIASA member countries would make it possible to establish a solid economic and organizational base for setting up a feasible, efficient, and developing system that functions in the interests of all participants in scientific studies being carried on in the IIASA.

Setting Up a Computer Network in the USSR Connected with the IIASA and Other Foreign Computer Networks and Data Bases

A number of steps taken by the USSR State Committee for Science and Technology and the USSR Academy of Sciences brought us very close to a practical solution to the question of setting up a network with entry to the IIASA and other computer networks. Many Soviet scientific research organizations have spoken in favor of finding a practical and permanent solution to this problem as quickly as possible.

The VNIISI [All-Union Scientific Research Institute of Systems Research] has been named the base organization for this work. Since the second half of 1979 it has been putting together an information-computer system for communication with the IIASA to allow representatives of various Soviet scientific research organizations who are cooperating with the IIASA to work with foreign computers and data banks. Work to solve the theoretical and practical problems of setting up this system is going forward within the framework of the Scientific Council on the Problem "Computer Technology and Systems" of the Committee for Systems Analysis of the Presidium of the USSR Academy of Sciences, where a large number of scientific research organizations interested in the establishment of a network are represented. The objectives of the council include coordinating the activities of Soviet organizations on formation of such a network, working out the principles and practical steps to allocate problem-oriented resources, formulating the position of the responsible representatives of the Committee for Systems Analysis at IIASA on network problems, and so on.

As a practical solution is found to the problem of allocating problem-oriented information-computer resources plans envision including the scientific organizations of the Siberian Department of the USSR Academy of Sciences, the Ukrainian SSR Academy of Sciences, the Latvian SSR Academy of

Sciences, the Ukrainian SSR Academy of Sciences, the Latvian SSR Academy of Sciences, and various others in the network. It is contemplated that the network will also include some international organizations located in the USSR, in particular the International Center of Scientific and Technical Information (MTsNTI), which already has prepared information resources in the form of data bases on scientific-technical topics.

The draft plan for development of the eastern part of the computer network of IIASA member countries is represented in Figure 7 below.

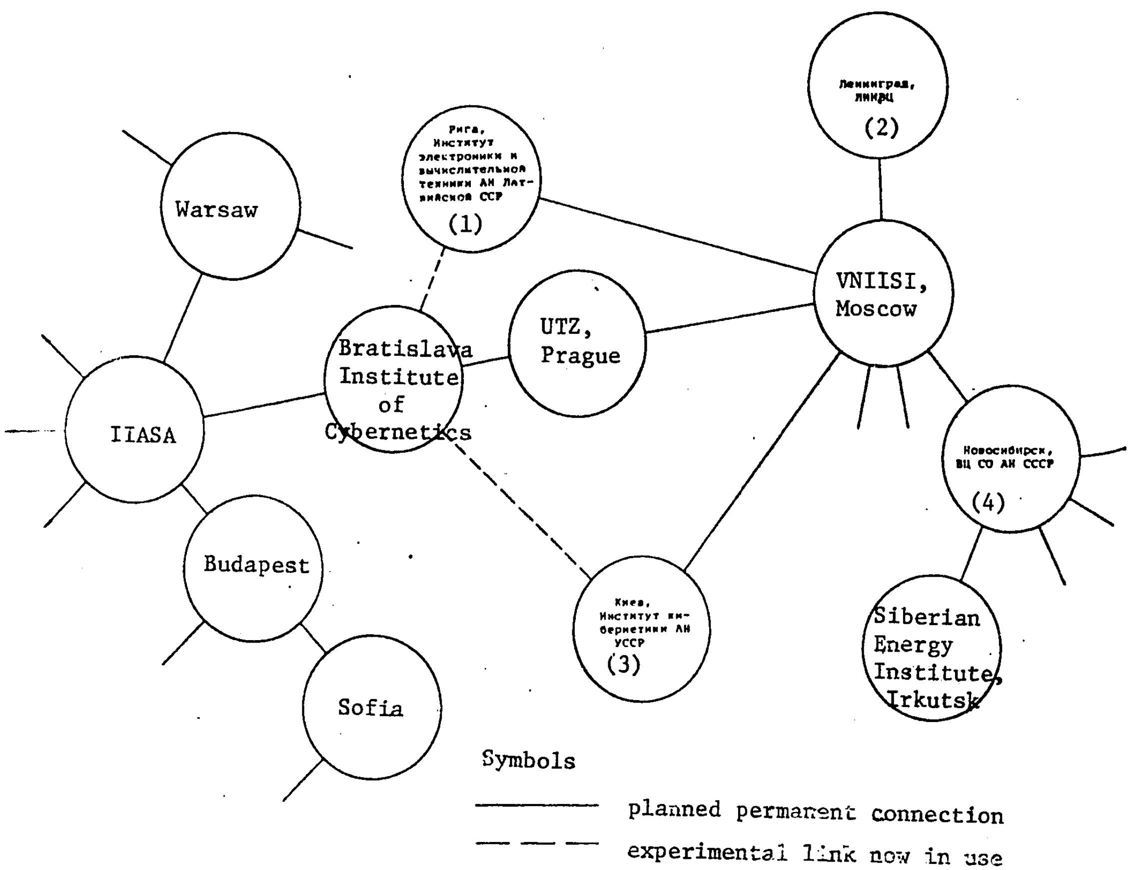

Figure 7. Draft Plan for Development of the Eastern Part of the IIASA Network

Key:
(1) Institute of Electronics and Computer Technology of the Latvian SSR Academy of Sciences, Riga;
(2) LNIVTs [possibly Leningrad Scientific Research Institute of Computer Centers];
(3) Computer Center of the Siberian Department of the USSR Academy of Sciences, Novosibirsk;
(4) Institute of Cybernetics of the Ukrainian SSR Academy of Sciences, Kiev.

Conclusion

The efficient functioning and development of a project such as the international network of IIASA members requires careful analysis and identification of all aspects that can either retard or accelerate progress in this direction. The novelty of this work and the lack of ready prototypes must presuppose, in addition to the need for an interdisciplinary systems approach to the problem, creative and coordinated work by all interested participants in the project. The plan for such a network can and must serve as a vivid example of cooperation among scientists in all countries working on problems that are of global significance to the entire human race.

FOOTNOTES

1. "Feasibility Study of Austrian Participation in International Computer Networks," IIASA Report, 1977, vol 1, 2, March.

2. "Study of the Potential Use of Informatics Technology for Problems in Scientific and Technological Cooperation," IIASA Report, 1978, July.

3. "The Usage of International Data Networks in Europe," Logica Ltd., Report 2424/13033 for OECE, 1978.

4. "Objectives and Tasks for IIASA Networking Activity," prepared by the Advisory Committee on IIASA Networking Activity, 1978, 7 June.

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SOFTWARE

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INCREASING THE DEGREE OF NONPROCEDURALNESS OF ARITHMETIC EXPRESSIONS IN PROGRAMMING LANGUAGES

Moscow PROGRAMMIROVANIYE in Russian No 2, Mar-Apr 81 (signed to press 10 Mar 81, manuscript received 4 Jul 80) pp 15-27

[Article by M. R. Shura-Bura, Moscow, and G. Sh. Vol'dman, Riga]

[Excerpts] Methods are discussed that permit considering some semantic properties of chains in programming languages by using refinement of syntax at the price of giving up its uniqueness. A new type of grammar is suggested.

It is well known that arithmetic expressions are components of the majority of programming languages. For obvious reasons, arithmetic expressions in programming languages appear very similar to mathematical expressions and in essence are intended for these very purposes. At the same time, the orientation of programming languages to translation and the following execution of the translated program by a computer introduces a certain specific nature to the permitted forms of arithmetic expressions and to the rules for computing the values defined by them. The usual mathematical interpretation of an expression as a function does not prescribe a specific algorithm to compute the value, which under the conditions of limited accuracy of representation of values and the presence of side effects may be the source of troublesome and unpredictable ambiguity. Computation rules for arithmetic expressions have now been defined in ALGOL-60 [1], where the corresponding formal description is given, apparently for the first time, together with the design rules prescribed by the Backus-(Naur) formulas. In the process, the computation rules rest directly on the design rules. This method of semantic specification, used for other concepts in ALGOL-60 too, has proved very convenient and has been evolved and formalized in many later programming languages. This method has proved useful not only for studying the respective language, but also for creating common methods of translation and even of automatic construction of translators. However, this method is inadequate when an optimizing translator is desired. Usually, in the latter case, there are additionally specified some kinds of equivalence relations that open the possibility of choice. In the case of arithmetic expressions, these relations could be under certain conditions, for example, associativity, commutativity and distributivity of the corresponding operations. There has been substantial study of the possibilities of specifying some additional relations in the form of traditional specification of syntax and semantics, i.e. the possibilities of considering these relations by the general method.

It should be understood that with this method, uniqueness of syntactic analysis will have to be given up and ambiguous grammars allowed for programming languages. However, there is no need to give up semantic uniqueness and we shall propose it in what follows.

Obviously, the suggested changes in grammar may be used not only to extend the degree of nonproceduralness of arithmetic expressions, but also, for example, Boolean. Such constructions are also suited to realization of alpha-expressions [6], where execution time and storage used depend on the order of computation of parts of the expression.

In the general case, introducing ambiguity into grammar while maintaining functional uniqueness divides the set of language chains into classes. One class must contain chains equivalent in a functional sense. Apparently, the reverse problem is of interest: by specified breakdown of chains into classes, finding that grammar for which the chains derived after computation of symbolic functions yield the remaining chains from that same class, i.e. produce the same breakdown.

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AUTOMATION OF PRODUCTION OF APPLICATION PROGRAM PACKAGES (AUTOMATION OF PRODUCTION OF TRANSLATORS)

Moscow PROGRAMMIROVANIYE in Russian No 2, Mar-Apr 81 (signed to press 10 Mar 81) pp 90-92

[Report on symposium by Vooglayd, A. O., and Tepandi, Ya. Ya., Tallinn]

[Text] The All-Union Symposium, "Automation of Production of Application Program Packages (Automation of Production of Translators)," was held in Tallinn from 8 through 10 September 1980. The symposium was sponsored jointly by the Computer Center of the USSR Academy of Sciences, the Computer Center of the Siberian Branch of the USSR Academy of Sciences, the Institute of Cybernetics of the Estonian SSR Academy of Sciences and the Tallinn Polytechnical Institute.

Taking part in the work of the symposium were 122 specialists from 8 union republics and 21 cities in the Soviet Union. Two corresponding members of the USSR Academy of Sciences and one academician of the republic academy of sciences took part as authors of papers and delegates. There were 5 plenary and 57 sectional papers; 3 panel discussions were held.

Review of the Papers

The symposium opened with the paper by A. P. Yershov (Novosibirsk), "Fundamental Processes of Translation," who discussed the problems of syntactically controllable decomposition, language-independent optimization and semantically controllable generation. The characteristics of theoretical models applicable in each of these areas and the links between them were given. Much attention was paid to the problems of mixed computations in translation. Functional and operational interpretations of mixed computations were described.

Discussed in the paper by S. S. Lavrov (Leningrad), "Dekart Language," were the features of the language, among which were singled out: introduction of abstract types and abstract relations as the basic means of raising the language level, extensive use of axioms (prompts) for synthesis of programs, separation of language of the user and language of the administrator, incorporated means of accessing a data base. Examples of programs in the Dekart language were given.

In the paper by A. O. Vooglayd (Tallinn) and M. V. Meriste (Tartu), "Survey of Systems for Constructing Translators," the major technologies for implementing languages in a translator design system (SPT) were described, as well as the problems of designing, implementing and applying the SPT in practice.

M. M. Bezhanova (Novosibirsk) and E. Kh. Tyugu (Tallinn)presented the paper, "Methods of Constructing Program Packages," in which the field of characteristics of PPP [application program packages] was described, and classification and a modern technique for creating them were presented. The paper by V. M. Kurochkin, V. A. Serebryakov and A. N. Biryukov (Moscow), "Modern Methods for Description of Languages," was devoted to the main approaches to describing syntax, interpretation semantics, translation semantics and the pragmatics of programming languages.

Sectional papers were distributed over five sections: technology (12 papers), methods of translation in a translator design system (14), theory (13), construction of program packages (6) and implemented translator design systems (12). The order of presentation in this review basically corresponds to the listed topic of the sections.

The paper by S. P. Prokhorov (Moscow) was devoted to the technology of creating minicomputer software. A meta-language for external documentation of language processors was presented by V. Sh. Kaufman and V. A. Levin (Moscow). In the paper by V. N. Red'ko (Kiev), a new level for describing program structures was presented, in which the bases are semantic structures. Methods of determining programming languages for systems of the interpreting type were discussed in the paper by V. V. Bublik, S. S. Gorokhovskiy and V. S. Chuykevich (Kiev). The paper by N. M. Mishchenko (Kiev) dealt with expansion of semantics of the input language of the TEREM expansion system of programming. The paper by N. N. Shegoleva (Kiev) was devoted to questions of embedding languages for programming and design in the computational environment of the PROYeKT system. The report by V. P. Bolotov, A. V. Grokh and A. G. Krasovskiy (Moscow) dealt with some aspects of creating an integrated system for design of PO [software]. The work by A. O. Vooglayd and D. B. Liyb (Tallinn)was devoted to realization for description of structure facilities for data processing. An error message generation system was described in the paper by M. Matskin (Tallinn). In the paper by L. V. Vasil'yeva (Khar'kov), questions of compilation of modules with a variable structure were discussed. The report by V. V. Fedyurko and O. D. Felizhanko (Kiev) dealt with methods of realization of specialized languages to manage the processes of the functioning of systems of programs. The paper by I. F. Lesova, V. N. Polivanov, N. A. Shishova and others (Novosibirsk) dealt with models and realization of a translator from autocode of the MVK [expansion unknown] "El'brus-1."

The work by S. M. Abramovich and Kh. D. Dzhenibalayev (Rostov on the Don) dealt with design of syntactically controllable translators in an interactive translator design system. The paper by V. V. Grushetskiy (Novosibirsk) was devoted to construction of efficient translators in a translator design system. A technique for description of translation through an attributed, thinned-out tree was covered in the paper by M. Lenn (Tallinn). The problems of using a data base management system in a translator design system were covered in the paper by Ya. Ya. Tepandi (Tallinn).

The realization aspects of parametrization of abstract types of data were covered in the report by R. A. Markyavichyus (Vilnius). A self-improving method for correcting syntactic errors was presented in the paper by Kh. Kh. Rokhtla and L. K. Vykhandu (Tallinn). An approach to neutralization of syntactic errors was given i.. the work by Z. A. Balashvili and V. M. Kurochkin (Moscow). Pseudoexecution as a method of compilation was discussed in the work by V. V. Chernyugov (Leningrad). Ya. S. Kogan (Izhevsk) discussed translation with a logic approach to programming. A technique for integrating processing of descriptions and syntactic analysis was presented in the paper by I. V. Kyutt, M. O. Tombak and A. I. Niguli (Tartu).

Use of the attribute technique to optimize programs was discussed in the report by G. M. Solov'yeva (Moscow). In his paper, A. N. Biryukov (Moscow) discussed the stacking organization of storage when computing semantic attributes. Discussed in the paper by K. S. Chebotar' (Kishinev) was the development of means of automation of constructing translation systems based on attribute grammars. The paper by M. V. Meriste (Tartu) covered the attribute technique based on abstract syntax. An algorithm for computing semantic attributes, suitable for any correct attribute grammars, was suggested by V. M. Kurochkin (Moscow). Realization of semantics of programming languages in the PRIZ [expansion unknown] system based on a method of attributes was discussed in the paper by Ya. E. Pen'yam (Tallinn).

In his paper, M. G. Gonets (Kishinev) discussed the compositional-structural languages and processors. A model of asynchronous computations in structures to determine operating semantics and realization of context analysis using computain structures were discussed in the papers by S. P. Kritskiy (Rostov on Don).

Techniques of formalization of application program packages and use of the logic approach to programming were discussed by N. N. Nepeyvod (Izhevsk). The paper by L. I. Nagorna, G. B. Tseytlin and Ye. L. Yushchenko (Kiev) covered structural programming and problems of parallel translation. A method of designing systems of parallel translation of the parametric type based on the strategy of an asynchronous conveyor with multilayer multiphase processing of information was discussed. A method of realization of mixed calculations was covered in the paper by M. S. Margolin (Minsk). Compositional semnatics of algol-like languages and the technology of designing programs were discussed in the paper by V. V. Byts' (Kiev).

Selecting a general-purpose intermediate language in the programming complex of the NI [expansion unknown] of the Computing Center of Moscow State University for computer networks was covered in the paper by O. I. Rau (Moscow). The problem of a deterministic explanation of an indeterminate automaton was discussed by Ya. A. Khenno (Tallinn).

In his paper, S. S. Shkil'nyak (Kiev) discussed the syntactic problematics of programming languages. The principles of the parametric approach to describing programming languages were covered in the paper by S. N. Berestova (Kiev). A mathematical model of language was offered by V. A. Tuzov (Leningrad). S. Yu. Solov'yev (Moscow) proposed a certain approach to restoration of context free languages by a specified finite subset of the language.

I. N. Parasyuk and I. V. Sergiyenko (Kiev) discussed the modular approach to automating construction of families of PPP [application program packages]. In their paper, V. A. Serebryakov and A. F. Urakhchin (Moscow) described the organization of dialog control of PPP [application program packages] using the LORD [expansion unknown] system. An instrumental system for design of route systems, intended to combine specialized PPP [application program packages] to expand and consolidate a class of problems to be solved, was discussed in the paper by O. L. Perevozchikova (Kiev). Automation of synthesis of computational procedures in modular models was covered in the paper by Yu. I. Drushlyakov and S. N. Padalko (Moscow). V. A. Matulis and A. A. Chaplinskas (Vilnius) described a system for designing the "Vilnius" PPP [application program package]. Features of architecture and language support for systems to generate interactive PPP [application program packages] for the YeS EVM [unified system of computers] were discussed in the report by D. I. Batishchev and Yu. L. Ketkov (Gor'kiy).

I. R. Aksel'rod, L. F. Belous and V. I. Shleynikov (Khar'kov) described the technology of constructing translators based on the SPUTNIK SPT [system for design of translators]. The SAGET system for construction of translators was covered in the paper by V. P. Makarov and S. G. Peshkov (Gomel'). The problem of automatic construction of language-oriented analyzers by the method of mixed computations was investigated in the work by B. N. Ostrovskiy (Novosibirsk). A generator of interpreters of problem-oriented languages of a SAPR [automated design system] was discussed by B. R. Andriyevskiy, A. A. Spiridonov, V. N. Utkin and A. L. Fradkov (Leningrad). A system for automation of design of syntactic analyzers was discussed in the paper by P. V. Gamin, V. V. Kulikov and M. A. Shamashov (Kuybyshev). Implementation on the BESM-6 of the first version of the KROSS SPT [translator design system] was discussed by V. I. Gololobov and V. A. Isayev (Novosibirsk). In their paper, A. Lomp, M. Kharf and A. Shmundak (Tallinn) described the MIS system which is a further development of the PRIZ YeS programming system. Questions of implementation and concomitance of DEFIPS--a system for construction of language processors were discussed in the paper by V. N. Volokhov, N. A. Gasanenko, I. V. Karpenko and others (Kiev). In their paper, I. L. Artem'yeva, S. B. Gorbachev, A. S. Kleshchev and others (Vladivostok) described an instrumental complex for realization of languages for representation of knowledge. The main features of realization of the SUPER SPT [translator design system] were discussed by V. A. Serebryakov (Moscow). In their paper, S. V. Koryagin, V. I. Kryachko and K. K. Chernyshev (Moscow) presented the experience of using the projection approach and the MASON instrumental system for development of a translator.

During the symposium there were discussions by sections and three panel discussions which were very lively with the active participation of those present. In his summary report, A. N. Yershov (Novosibirsk) stressed the purposeful and lively nature of the symposium. Problems requiring resolution in the near future were named. A Working Group for Implementation of Programming Languages was formed and held its first meeting during the symposium.

The symposium took place at a high scientific level. It offered the participants the opportunity to get acquainted with the latest work in the field of automation of creating translators and PPP [application program packages], to discuss the status and prospects for research in this field, to exchange expertise, to establish contacts and to improve mutual understanding of specialists-theoreticians and specialists-developers. The necessity of continuing and intensifying work in these areas was stressed.

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SCIENTIFIC RESEARCH SEMINAR ON AUTOMATION OF PROGRAMMING

Moscow PROGRAMMIROVANIYE in Russian No 2, Mar-Apr 81 (signed to press 10 Mar 81) pp 92-93

[Report on seminar by Ye. A. Zhogolev]

[Text] In the 1979/80 school year, the scientific research seminar on automation of programming continued working under the direction of Professor M. R. Shura-Bura, Docent Ye. A. Zhogolev and Docent N. P. Trifonov with the School of Computational Mathematics and Cybernetics, Moscow State University imeni M. V. Lomonosov [MSU]. This seminar was begun at MSU back in 1956 and converted, essentially, into a city seminar on systems programming. Many leading USSR specialists on systems programming have appeared at this seminar over the years.

From September 1979 through April 1980, 21 papers were read and discussed in the seminar.

In his paper, "Questions of Formalization and Realization of Semantics of Programming Languages within the Scope of a Multilanguage Translating System," M. G. Gonets (Kiev) discussed the basic aspects of using the compositional approach for formalization of programming language semantics. The basic questions of the technology of using this approach for specifying and realizing language semantics were presented within the scope of designing multilanguage translating systems.

In his paper, "Theoretical Model of Data Structures and Computations with Them," Yu. G. Gostev presented an interpretation of data structures as a set of directed graphs with marks at the vertices and arcs.

The papers by G. A. Bosman (Kishinev), "KU-Technology of Multilanguage Interactive Systems," and G. A. Magariu (Kishinev), "Realization of Programming Language Semantics in Interactive Systems," elaborated the main theses of the paper by M. G. Gonets.

Yezhi Zagrevski, in his paper, "A Method of Neutralization of Syntactic Errors in Languages Describable by KS [Context-Free] Grammars," discussed a method for neutralizing syntactic errors based on the function of the distance between the trees for the inference of chains containing the syntactic errors and the trees for inference of the correct chains.

In his paper, V. N. Glushkov (Rostov on Don) presented a classification of syntactic analyzers.

L. V. Surkova, in her paper, "A Class of Grammars of Antecedence," defined a class of unambiguous grammars permitting determinate right parsing. The conditions defining the class make it possible to ease the requirement of reversibility of grammars of antecedence and to substantially reduce the sizes of control matrices.

In his paper, "Designing a Systems Programming Language for a Computer with a High Level Microprogram Control," S. A. Tadevosyan (Yerevan) discussed the problems of creating an instrumental system for development of software for a computer with high-level microprogram control.

Yu. A. Shebeko, in his paper, "A Machine-Oriented High-Level Language for the Central Processor of the AS-6 Multimachine Computing Complex," discussed the principles of constructing a programming language that in addition to its machine orientation reflects the most common concepts of the popular high-level programming languages.

The paper by L. F. Shternberg (Kuybyshev), "Efficiency of Mobile Software in the Almo Language," covered the features of the Almo language that reduce the efficiency of machine-independent and machine-adjustable programs.

In his paper, "Use of the Macfor-IV Macrolanguage in Planning Computations," S. M. Yudin discussed the language to describe computations in models based on Fortran-IV and which uses methods of macrogeneration and planning of computations in a model organized in the form of a graph. The organization of the software of this language was presented.

In a continuation of his earlier paper, Yu. G. Gostev discussed questions of maintaining integrity in data base management systems.

In his paper, "Task Management Dispatcher for Real Time Operating Systems," V. I. Golovach presented the main features of the dispatcher for UZOR [task management in real-time operating systems] being developed with the SM-3 minicomputer. The language facilities of the dispatcher are based on the facilities of the Modul multiprogramming language.

In his paper, "Hyperprogramming and Bases of Application Programs," Ye. A. Zhogolev presented a certain model of a programming language and a new technique, based on it, for constructing programs using metasyntactic notation.

In his paper, "Technological Complex for Design of Application Software," V. I. Yalovetskiy presented a method of constructing a unified technological complex of the interpreting type, based on the principle of generation of technological schemes.

In his paper, "Formal Check of Program Protection from Malfunctions and Saving Storage in the Control Program," A. L. Beskin presented an algorithm for checking the correctness of construction of the protection blocks in control programs based on the suggested algorithm.

In his paper, "Information Support for an Automated Design System," L. N. Chernyshov discussed an information model for an object to be designed and formulated the requirements for its software, for development of which some procedural expansion of Fortran is assumed.

At one of the sessions, a discussion was held on the structure of the questionnaire on problems of automation of programming circulated to computer users to determine the status of automation of programming for computers of various classes and the trends in development of language facilities. A. N. Maslov described this questionnaire.

In his paper, "Automatic Genetic Generation of Syntactic Analyzers," T. V. Rudenko discussed the main features of an optimizing translator from a metasyntactic language to provide automatic conversion of KS [context free] grammars to a partitioned form with formation of syntactic tables for the corresponding syntactic analyzers.

In their paper, "Interactive System for Automation of Scientific and Technical Calculations," S. S. Gaysaryan and V. Ye. Zaytsev discussed the system developed at MAI [expansion unknown]. The system has several input languages, one of which is a language for description of problems. The system is based on the concept of generation of calculation programs with computer models.

In the report by Laslo Gerevich (VNR [Hungarian People's Republic]), "Analyzer of W-Grammars," a modification to the grammars of (Van Weingarden) and an analyzer to handle them were proposed.

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ABSTRACTS FROM THE JOURNAL 'PROGRAMMING', MARCH-APRIL 1981

Moscow PROGRAMMIROVANIYE in Russian No 2, Mar-Apr 81 (signed to press 10 Mar 81) pp 94-95

UDC 519.1

HEIRARCHY OF MODELS OF PROGRAMS

[Abstract of article by R. I. Podlovchenko, Yerevan]

[Text] The problem of program modeling is discussed and two types of program models--the semantic and the formal--are introduced. The quasiorder is determined in a set of models, and the necessary and sufficient conditions for the order of a pair of models are found. Fig. 5, bibl. 4 titles.

UDC 681.3:519

INCREASING THE DEGREE OF NONPROCEDURALNESS OF ARITHMETIC EXPRESSIONS IN PROGRAMMING LANGUAGES

[Abstract of article by M. R. Shura-Bura, Moscow, and G. Sh. Vol'dman, Riga]

[Text] Methods are discussed that permit considering some semantic properties of chains in programming languages by using refinement of syntax at the price of giving up its uniqueness. A new type of grammars is suggested. Bibl. 6 titles.

UDC 681.142.2

SOME CLASS OF GRAMMARS ALLOWING IRREVERSIBLE ANALYSIS BY THE UNGER METHOD

[Abstract of article by N. G. Grafeyev, Leningrad]

[Text] Conditions sufficient for efficient irreversible analysis of context-free grammars by the Unger method using a system of tests are discussed. A method to formalize the system of tests and construct regular sets by it is given. Fig. 1, bibl. 6 titles.

UDC 681.142.2:518.5

VERIFICATION OF FILE PROCESSING PROGRAMS IN PASCAL

[Abstract of article by V. A. Nepomnyashchiy, Novosibirsk]

[Text] A technique for proving the partial correctness of sequential file processing programs in the Pascal language is given. Presented is a system of rules for derivation of the conditions of correctness, as well as a system of concepts and axioms for annotating programs and proving the conditions of correctness. Bibl. 8 titles.

UDC 51:681.3.01.007

DATA STRUCTURE DESCRIPTION USING GRAPH-PRODUCING GRAMMARS

[Abstract of article by Yu. G. Gostev]

[Text] Data structures are considered as graphs of a specific type. Grammars are suggested to produce these graphs. Fig. 10, bibl. 6 titles.

UDC 518.5

STRUCTURAL ATTRIBUTES AND THEIR REALIZATION IN THE 'SUPER' TRANSLATOR CONSTRUCTION SYSTEM

[Abstract of article by A. N. Biryukov, V. M. Kurochkin and V. A. Serebryakov]

[Text] Generalization of the Knuth attribute grammars, intended for natural description of objects arising during translation, is discussed. The necessary and sufficient conditions are given that the generalized attribute grammar must meet for an algorithm to exist to check its correctness. Fig. 1, bibl. 5 titles.

UDC 681.3.068

A METHOD OF REPRESENTING SURFACES IN COMPUTER GRAPHICS

[Abstract of article by S. V. Klimenko and V. N. Kochin, Serpukhov]

[Text] A method of representing surfaces specified by a unique continuous function of two variables in an arbitrary system of coordinates is described. Effective determination of the visibility function is suggested. Examples of the work of the programs that realize the described method of representation are shown. Fig. 6, bibl. 7 titles.

UDC 681.3.06

STACK-TYPE SYNTACTIC ANALYZERS

[Abstract of article by M. V. Dmitriyev and S. S. Lavrov, Leningrad]

[Text] A class of analyzers with rigid limitations on allowable actions and values of parameters is defined in the work. A set of languages recognized by the analyzers is discussed. These languages allow efficient practical realization. Bibl. 1 title.

UDC 681.326:51

MEANS OF AUTOMATING COMPUTER PROGRAM DEBUGGING USING A CROSS-MODELING PROGRAM

[Abstract of article by I. V. Gerasimov and S. V. Rodionov, Leningrad]

[Text] Means of automating debugging using the MOSK-580 cross-modeling program are discussed. Fig. 1, bibl. 2 titles.

UDC 681.3.06

MACHINE GRAPHICS IN BANKS OF PROGRAMS

[Abstract of article by V. P. Shampal] [This article is not listed in the table of contents and is not in this issue]

[Text] An approach to providing banks of programs (BP) with machine graphics facilities (SMG) is discussed. The SMG BP have been realized using the instrumental system of programming PRIZ YeS. Bibl. 12 titles.

UDC 681.3.06

FUNCTIONAL CLASSIFICATION OF INFORMATION SYSTEMS

[Abstract of article by N. A. Krinitskiy]

[Text] An information system is mathematically defined in terms of the theory of algorithms. Semantic schemes of the basic types of automated information systems are given and classified by functional principle. Fig. 1, bibl. 4 titles.

UDC 681.323

METHOD OF ADDRESSING IN A SEARCH ALGORITHM IN A MULTIPROCESSOR COMPUTER

[Abstract of article by L. I. Baranov]

[Text] A parallel algorithm for search in a sorted file, the addressing in which is done using numbers similar to the numbers of (Fibonachchi), is discussed. An estimate of the response speed of the algorithm is given, and a problem of optimization is solved by the criterion of the minimum of the maximal number of compare cycles. Fig. 1, bibl. 2 titles.

UDC 681.3.015

AUTOMATED SYSTEM FOR DEVELOPMENT OF INTERACTIVE PROGRAMS

[Abstract of article by A. V. Rybakov]

[Text] Defined is the elementary step of dialog and the typical operating route of the developer of interactive programs, which served as the methodological basis for creating an instrumental system for automation of development of these programs. Fig. 4, bibl. 1 title.

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CSO: 1863/187-A

MAIN ELEMENTS OF THE R-TECHNIQUE OF PROGRAM PRODUCTION

Moscow TEKHNOLOGICHESKIY KOMPLEKS PROIZVODSTVA PROGRAMM NA MASHINAKH YES EVM I BESM-6 in Russian 1980 (signed to press 16 Jan 80) pp 30-52

[Chapter 2 from the book "Program Production Complex Based on YeS EVM and BESM-6 Computers", by Igor' Vyacheslavovich Vel'bitskiy, Vasiliy Nikolayevich Khodakovskiy and Leonid Ivanovich Sholmov, Izdatel'stvo "Statistika", 30,000 copies, 264 pages. Additional sections of this publication appeared in the USSR REPORT: CYBERNETICS, COMPUTERS AND AUTOMATION TECHNOLOGY, JPRS L/9540, 10 Feb 81 pp 27-45]

[Text] 2.1. The Concept of the R-Computer

It is clear from the previous description that the basis of the R-technique is some arbitary R-computer designed especially for the programmer. Several structures of the R-computer may correspond to the organization of information processing described above. Let us consider an R-computer structure oriented toward a class of textual (symbolic) information processing problems (Figure 2.1). A computer structure oriented toward the same class of problems is shown in Figure 2.2 for comparison.

A R-computer consists of a control device (processor P), computer (processor F) and memory. Four types of memory: input tape for storage of information to be processed, a memory for storage of R-programs, a memory for storage of the internal alphabet of the R-computer and a general-purpose memory called the functional memory of the R-computer, are distinguished in Figure 2.1.

In the first approximation the processor F and the R-computer input tape do not differ from similar devices for the computers in Figure 2.2. The R-computer has three new components: a control device, R-computer functional memory and the concept of internal alphabet, in the block diagram.

The R-computer control device, unlike a computer, operates as a function of four independent variables: the program, the current symbol on the input tape, the internal alphabet of the R-computer and the integral state of the computer (signals of type ϕ and ω are a result greater than, equal to or less than zero and so on). The computer control device operates as a function of only two independent variables--the first and last, i.e., to determine the type of operations and for processing R-computer symbolic information more powerfully and more flexibly than an ordinary computer. Since the R-computer is the basis of the machine

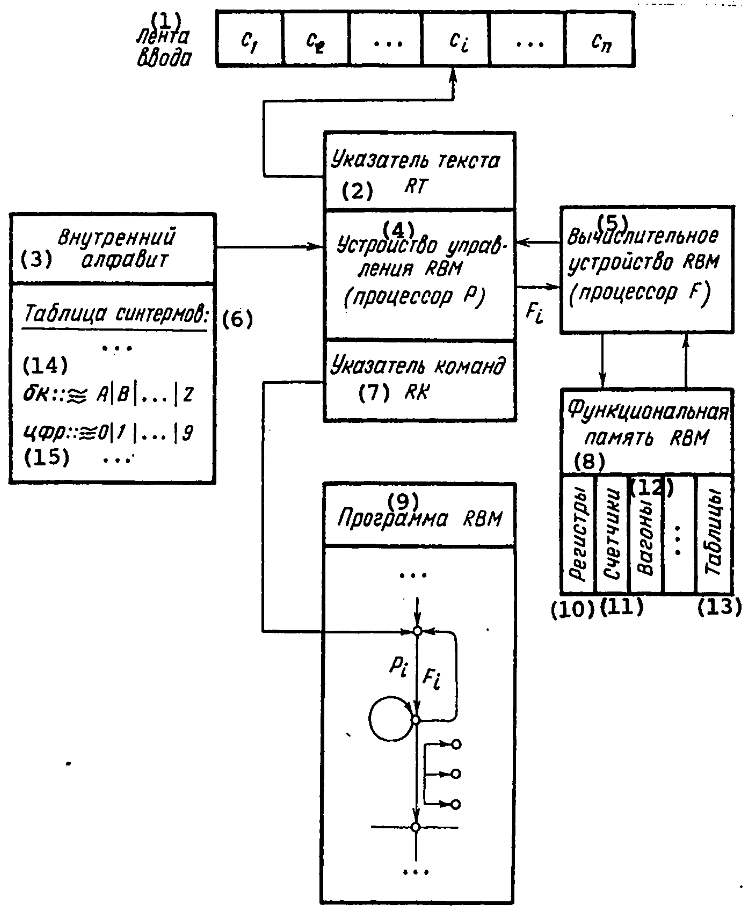


Figure 2.1. R-Computer Structure Oriented Toward Symbolic Information Processing Problem

Key:

1. Input tape
2. Text designator
3. Internal alphabet
4. R-computer control device (processor P)
5. R-computer (processor F)
6. Synterm table
7. Instruction display
8. R-computer functional memory
9. R-computer program
10. Registers
11. Counters
12. Carriages
13. Tables
14. Letters
15. Numbers

structure and requires no actions of any kind from the programmer (for example, selection of the current symbol on the input tape, comparison of it with a set of syntactically different symbols and so on), a special program should be carried out on an ordinary computer and should be determined by the programmer. Many functions of the R-computer, which are carried out automatically in it and which are typical and used frequently in information processing, are simulated in an ordinary computer by special systems programs or by user programs. This complicates to a significant degree the programming techniques for electronic computers.

The memory of a R-computer, unlike that of an electronic computer with arbitrary address access, consists of individual functional types: for data storage on which arithmetic operations (the counter type of memory) are performed, for gathering of symbolic information into larger units for processing (the register type of memory), for associative processing of information (tabular memory) and so on. The sense of this division includes the fact that the user carries out some classification of his own variables at the beginning of writing his own program. This provides him with a number of advantages.

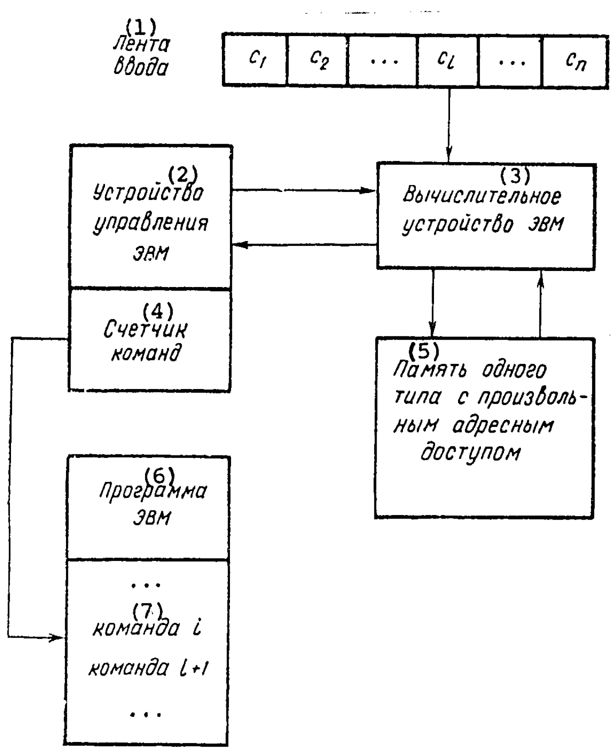


Figure 2.2. Electronic Computer Structure Shown for Comparison in R-Computer Style in Figure 2.1

Key:
1. Input tape
2. Electronic computer control device
3. Electronic computer
4. Instructions counter
5. Memory of single type with arbitrary address access
6. Computer program
7. Instruction

First, having described the variable as a counter or table, the programmer thus determined the corresponding mechanism of access to these variables. He does not have to write any actions (instructions or operators) to utilize this mechanism. Everything is determined by the name of the variable itself and is realized structurally in the R-computer.

Second, it becomes possible to get by with a smaller number of characters for writing R-programs. For example, the symbol for recording in the memory "→" will induce different actions of the R-computer depending on the memory from which and to which the recording is made. A number of natural information conversions can still be accomplished along with this recording, for example, information is converted from binary to decimal form symbol by symbol upon rerecording from the counter memory to the register memory. This would require an entire program of operations for an electronic computer. This is accomplished structurally and automatically for the R-computer. On the whole, this minimization of the operational alphabet of R-programs makes them more readable and technologically efficient for production.

Third, the role of the declaration section is enhanced when recording R-programs compared to recording programs in existing programming languages (Algol and Fortran). The declaration section was transformed from an auxiliary section serving mainly to monitor the use of variables by the program to the active part of the R-program. Because of this section, the actuating part of the R-program is reduced significantly and consequently the actions of the programmer in recording corresponding algorithms are simplified.

Fourth, the nature of the programmer's thinking in creating a corresponding algorithm is changed. Whereas the programmer usually arranges an abstract model of his algorithm for the corresponding rigid and fixed structure of an electronic computer, in the R-technique the programmer selects the corresponding configuration of the R-machine (with the corresponding set of functional memories) for the most natural recording of the corresponding algorithm. This makes the step of algorithm design more technologically efficient compared to the traditional approach.

Four main types of functional memory of R-computers have now been distinguished from the experience of symbolic information processing: counter, register, carriage and tabular. These memories are described in detail in section 2.2. The ideology of a R-computer is such that the user can determine and introduce his own new types of functional memory of R-computers for work which best correspond to the method of data storage and processing. This is done in the descriptive part of the user's R-program. He himself determines in it how many and which types (standard or unique) of memory he needs and what the characteristics should be (capacity, operating speed of each memory, number, type and mechanism of access to the data), i.e., the user himself determines the configuration of the R-computer which is most efficient for his problem.

The concept of an internal alphabet of a R-computer is introduced to increase the compactness of R-programs (or to reduce the number of instructions in the R-program). If some symbols on the input tape cause identical processing of them in the R-program, then these symbols are called syntactically equivalent and are denoted in the R-computer instruction by a single symbol of the internal alphabet, which is called a synterm. Examples of synterms may be the following generally known symbols of the internal alphabet of a R-computer: numbers (tsfr), letters (bk), letters and numbers (bts), all symbols (vse) and so on. If a syntem is recorded in the R-computer instruction, then this instruction operates identically with any syntactically equivalent symbol corresponding to it. For example, by the R-computer instruction

tsfr C = C + 1 COUNT

a one will be added to the counter C if the current symbol on the input tape is either a 0, 1, 2, ..., or 9, where tsfr is a synterm given by the following formula of syntactically equivalent symbols:

$$\text{tsfr} ::\tilde{=} 0|1|\ldots|9.$$

The correspondence between synterms and syntactically equivalent symbols is given by the synterm table which determines the internal alphabet of a specific R-computer (see Figure 2.1). This alphabet is some integral characteristic of the information to be processed and usually remains unchanged (or rather little and rarely changed) for each specific R-computer. When determining the R-computer configuration in the descriptive part of his own R-program, the user can determine any synterm of the internal alphabet of the R-computer. This considerably reduces the number of symbols which the programmer uses to write the R-program.

Operation of the R-computer is accomplished by the R-program. The R-program consists of the named instruction complexes. Each instruction is written with a separate line and consists of four fields: the field of the name of the complex, the field of the condition (or predicate) of fulfilling the instruction, the field of instruction operators and the hopper field. The fields are separated from each other by blanks.

The RT designator is initially (see Figure 2.1) set on the first c_i ($i = 1$) symbol of the input tape and the RK designator is set in the first instruction complex of the R-computer (unlike an electronic computer that begins operation with the first instruction and (any) nonspecific symbol on the input tape. Processor P selects from the instruction complex one for execution from a previously given algorithm determined by the function of four independent variables of its operation. The selection is usually accomplished by sequential sorting (review) of the instructions of the complex from first to last. The first instruction, as a result of this inspection in which the condition of feasibility written in the second instruction field is correct, is declared as the current one for execution (unlike an electronic computer in which any instruction is carried out and is not omitted without some conditions). Review of the remaining instructions stops with this.

Execution of the instruction includes performing all the operators written in the third instruction field. The operators are performed sequentially in the order of their writing. Since only linear operators among which there are no branching operators (of the go to, if and for type) are written in the third instruction field, then all operators of the R-computer instruction to be executed are fulfilled. The next symbol is then declared as the current symbol on the input tape (the RT designator is modified in an appropriate manner) and the complex whose name is written in the last (fourth) instruction field is declared as the current instruction complex of the R-computer. This name is given to the RK designator of the R-computer control device. The operating cycle of processor P is then repeated. The processor completes its work upon transition to the instruction complex with fixed name output.

If all the predicates of the current instruction complex are false, that is, not one instruction of the R-program can be fulfilled, then further operation of the R-computer is not specified. This situation corresponds either to errors in the information on the input tape or to errors in the R-program. The response of the R-computer to this situation is determined by its specific realization. This is usually a program stop with transition either to the user's special R-program which he determined earlier in the text of the R-program prior to the occurrence of the indicated situation or to a special systems R-program for automatic neutralization of the erroneous situation. The indicated conditions are an essential feature of the R-computer compared to an electronic computer. These conditions permit one to construct those redundant program systems which will be uncritical of their own errors not determined during debugging and which will be capable of automatically neutralizing these errors. R-programs for processing incorrect (error-containing) data may also be constructed by using these conditions.

2.2. Abstract Memories of the R-Computer

The variables in the user program can be classified differently. The most widespread method of classifying the variables in modern programming languages is based on determination of the nature and type of the variable to be processed: real, integer, boolean and so on. The type may be changed and determined by the user himself. A somewhat different method of classifying the variables in the user's program is adopted in the R-computer. This method is based on determining the mechanism of access to an processing of the corresonding variables. With this method variables of the real, integer and boolean type are not distinguished and these are variables with identical (address) method of access and with identical method of processing (computer method using conferring operators).

The variables in the R-program are classified by the memory of the R-computer in which they are stored. The memories of the R-computer in which the corresponding variables will be recorded rather than the variables for processing and their name and type are written in the R-program. Which variables is unimportant. The name of the variables is also unimportant. All variables have one name--variables recorded in P, P1 and P2 memory. The variables are distinguished not by what they themselves represent as how they are processed and what names they have, but by where they are recorded (in the memory of which type), while the memory determines the method of access to the variables and the permissible method of processing them.

Four standard types of memory of the R-computer: counter, register, carriage and tabular are used in the R-program. The standard operations: write, read, search and empty, are also determined above these memories. The user can determine any type of his own memory of the R-computer distinct from the standard set and any of his own operations over standard operations and his own sets of memory of the R-computer.

The standard memories of the R-computer and the permissible operations of them are described in this section. In order that this description not be linked to a specific realization, it is presented in general form.

Register memory. This type of memory can be represented in the form of a tape infinite in one direction (usually to the right) (Figure 2.3) and consisting of cells. Any one symbol can be written in each cell. Writing is accomplished beginning from the first cell to the last. After writing, the index of the accessible cell (the arrow from above) is shifted accordingly to the right, noting the first free cell. Writing is accomplished with preliminary clearing of the entire memory (by the operation "/<-") and without preliminary clearing by prewriting (by the operation "<-") to the contents of the memory, beginning with the first accessible cell, for example,

P/←'B'--memory P is cleared and the symbol "B" is then written in it;

P←'E'--the symbol "E" is prewritten in memory P. As a result the chain "BE" will be written in the memory;

P←'GIN'--the chain of symbols "GIN" is prewritten in memory P. As a result the word "BEGIN" will be written in the memory.

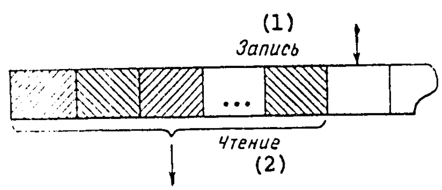


Figure 2.3. Register Memory of R-computer

Key:
1. Write
2. Read

The entire contents are read from the register memory as one indivisible word. If reading is accomplished by the operation "/→", then the contents of the memory are renewed after reading (the memory is cleared. If reading is accomplished by the operation "→", then the contents of the memory remains unchanged after reading, for example,

P1/←P--the contents of memory P are written in the previously cleared memory P1. The contents of both memories becomes identical: "BEGIN";

P1←(P1,P)--the contents of memory P1 becomes "BEGINBEGINBEGIN" after completion of this operation and memory P remains unchanged: "BEGIN";

P1/←/P--the contents of P1 are "BEGIN" after this operation is completed and memory P contains nothing (it is cleared).

The read memory. This type of memory is represented (Figure 2.4) by an endless tape to the left on which any number can be written from right to left: the highest orders of the number are written from the left and the lowest orders are written from the right. Recording in a read memory is accomplished by the arithmetic conferring operator. Reading is accomplished as from the register memory (see Figures 2.3 and 2.4) of the entire contents as one indivisible word (number), for example

C = 0 --the contents of memory C are renewed;

C = C + 1 --a one is added to the contents of memory C;

C = C + C ↑ 2--the result of executing the arithmetic expression "C + C ↑ 2" is conferred to the contents of memory C.

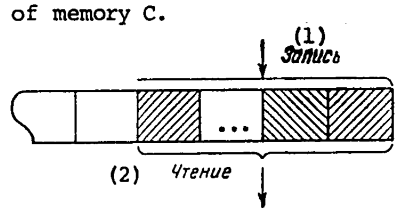


Figure 2.4. Read Memory of R-Computer

Key:
1. Write
2. Read

Carriage Memory. The carriage memory* can be represented (Figure 2.5) by an endless tape in both directions on which some ordered writing (not containing gaps) is made at any point. The accessible or active cells of the carriage memory are delineated on the edges of this recording, noted by the arros in Figure 2.5. The remaining cells are regarded as inaccessible and access to them is impossible. The accessible cells are clearly identified by name when describing a carriage memory. A carriage memory is described by the name of its own accessible cells, for example,

carriage LC*PC, FLOW*INFLUX

where LC, FLOW are the notations of the left accessible cells of two different carriage memories and PC, INFLUX are the names of the right accessible cells of the corresponding memories.

Unlike register and counter memories, each cell of the carriage memory has a structure: it consists of n elements (recordings), n ≥ 1. A word of any length can be located in each element of the occupied cell. Each element is designated by a number in order from left to right in the accessible cell of the carriage memory, for example, LC.1, INFLUX.5, PC.2049. In the general case the number of elements in each occupied cell of the carriage memory is different. If a carriage memory has

*In [52], D. Knut described a similar memory and called it a queue with two ends or a deq (double-ended-que). Unlike the memory described by Knut, the cell of a carriage memory can be a complex structure and can contain recordings of any length.

a fixed structure for all its cells, then the name during description of the memory can be conferred to each element of this structure, for example,

carriage MAG*QUEUE.IDER.PRIZN.ADDRESS

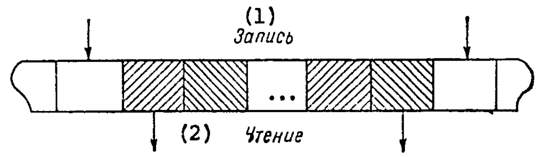


Figure 2.5. Carriage Memory of R-Computer

Key:
1. Write
2. Read

Each cell of carriage memory MAG*QUEUE consists of three elements with the names IDER, PRIZN and ADDRESS in which the identifiers, attributes and addresses, respectively, are written.

Three operations: write, read and search, are determined above the accessible cells of the carriage memory.

Information of any structure consisting of a word, two words and so on can be written in any accessible cell of the carriage memory, denoted by the top arrows in Figure 2.5. In this case the corresponding arrow of the carriage memory is automatically shifted to the next free cell (as in Figure 2.5), which is declared accessible for the next recording. The bottom arrow is also shifted accordingly, noting the last filled cell accessible for the read and search operation, for example

LC*PC/←'ABC'--the chain of symbols "ABC" is written in the pre-cleared carriage memory from the left and right accessible ends;

PC←(P1,'ABC',1)--a word consisting of three elements: the contents of register memory P1--"BEGIN", the chain of symbols "ABC" and the notation "1", is written in accessible cell PC from the right end of the same memory.

The status of a carriage memory, after the indicated writing operations have been carried out, has the following form:

LC:ABC
ABC
PC:BEGIN .ABC.1

Writing in the element of the accessible cell of the carriage memory is accomplished in the cell noted by the bottom arrow in Figure 2.5. Automatic shifting of the arrows of accessible cells of the carriage memory described above is blocked upon recording to the element of the accessible cell of the carriage memory, for example, PC.2←'CAB5'--recording of a chain of four symbols "CAB5" in the second element of the accessible cell PC of the carriage memory instead of the chain of three symbols "ABC" stored in the second element;

LC.3←'1'--recording the notation 1 in the third element of accessible cell LC of the carriage memory.

The state of the carriage memory after the indicated right operations in the elements of accessible cells have been carried out has the following form:

LC:ABC. .1
ABC
PC:BEGIN.CAB5.1

Reading from the carriage memory can be accomplished only from accessible cells (noted by the bottom arrows in Figure 2.5) and is accompanied by automatic reciprocal shifting of the bottom and top arrows compared to that described above for writing. Reading the element of the accessible cell of a carriage memory, as for writing, is not accompanied by automatic shifting of the arrows of accessible cells, for example,

PC.1→LC.3--reading of the contents of the first element "BEGIN" of accessible cell PC of the carriage memory and writing of it in the third element of accessible cell LV of the same memory to the point of notation "1";

LC→PC.2--reading of the contents of accessible cell LC of the carriage memory and writing of it in the second element of accessible cell PC of the same memory.

As a result of completing the indicated operations, the latter state of the carriage memory is changed and assumes the following form:

LC:ABC
PC:BEGIN.ABC. .BEGIN.1

The read operation from the nonexistent element of accessible cell of the carriage memory is not determined. Examples of these operations are the following notations:

LC.2→
PC.6→ and so on.

The order of performing these operations is determined upon realization of the carriage memory. A program stop of the R-computer with the user being informed of an incorrectly written operation is usually realized in this case.

One of the states is taken as the beginning for correct functioning of the carriage memory. This state corresponds to combined top and bottom arrows of the accessible cells of the carriage memory in Figure 2.5, i.e., the carriage memory is empty in this state. The read operation from an empty carriage memory is not determined. In this case a program stop of the R-computer and transfer of control to a program previously determined by the user is usually realized.

The search operation is carried out only on accessible cells of the carriage memory or on their elements. The accessible cells of the carriage memory do not change by this operation (the arrows in Figure 2.5 are not shifted and the contents of the cells remain unchanged). The search operation is some logical predicate over the accessible cells of the carriage memory. The result of fulfilling this predicate and the search operation are two logic values: "true" or "false." For example, the following search operations have the "true" value for the latter state of the carriage memory achieved above:

LC = 'ABC
LC = PC.2
PC.8 = #
PC.3 = *
PC.5 = '1' and so on,

where * and # are metasymbols that denote the feature of empty recording and the feature of the absence of recording, respectively. The corresponding predicates check that the accessible cell PC of the carriage memory does not contain an eighth element and that nothing is written in the third element.

Accordingly, the following search operations have a "false" value:

LC ≠ 'ABC'
LC = PC.1
PC.2 = *
PC.3 = # and so on.

The following search operations are regarded as undetermined for the state of carriage memory presented above:

LC.2 = *
LC = PC.6
PC.1 = PC.8 and so on.

The R-computer stops upon completion of them and the user will be given information about an incorrectly written search operation.

Thus, the write, read and search operations described above for the carriage memory are carried out only on accessible cells. The other cells of the carriage memory are inaccessible for the operations described above. No restrictions are placed on the order of writing (reading) of the search from any accessible cell of the carriage memory, as on the number of accesses to it. This means that the user can work only on one (any) end of the carriage memory which corresponds in this case to the cartridge memory thoroughly studied in the literature. The user can accomplish all recordings in the carriage memory from only one (any) end and all readings from the other opposite end. In this case this carriage memory corresponds to that known in the literature under the names bobsled, queue and so on. Any other mixed strategies of access to accessible cells of the carriage memory are possible. The user can determine other operations on the carriage memory different from those described.

The tabular memory. This type of memory is represented by an endless tape in both directions divided into cells (Figure 2.6). The cells of the tabular memory have a structure similar to that of the cells of the carriage memory. Unlike the carriage memory, the recordings in the cells of the tabular memory are not ordered (they may contain gaps) and there is no previously fixed accessible cells in the tabular memory. The only accessible cell of the tabular memory is determined by the special search operation which will be described below. The structure of the tabular memory is given by the corresponding description of type

table T, TAB,TB.ID.PR1.PR2.ADR,T1

Four tabular memories: T, TAB, TB and T1, are given in the description. The first two and the last tabular memories have arbitrary structure of the cells and the third has fixed structure. All the cells of this tabular memory consist of four elements which have the names ID, PR1, PR2 and ADR, respectively.

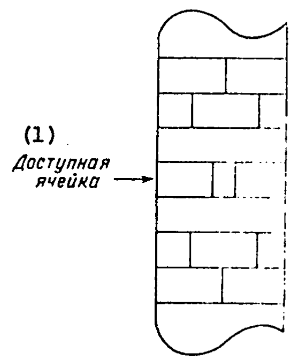


Figure 2.6. Tabular Memory of R-Computer

Key:
1. Accessible cell

Write and read operations are determined on the accessible cell of the tabular memory. The remaining cells are inaccessible for the indicated operations. The accessibility of the cell does not change after the read or write operation has been completed (the corresponding arrow of the accessible cell in Figure 2.6 remains unchanged). This means that as many read and write operations as desired and in any sequence can be carried out on the accessible cell of the tabular memory. The search operation is determined over the contents of all the filled cells of the tabular memory, including the accessible cell.

The write operation is accomplished in the tabular memory similar to the write operation in the carriage memory but without variation of cell accessibility, for example,

T←(R1,PC)--write operation in the accessible cell of the tabular memory T of structure of six elements: the contents of register memory R1--"BEGIN" and five elements of accessible memory PC of the carriage memory--"BEGIN.ABC..BEGIN.1." The following notation will be made as a result of completing this operation in the accessible cell of the tabular memory T: "BEGIN.BEGIN.ABC..BEGIN.1."

Other examples of write operations in tabular memories are : T.3 T.4, T.2 LC, TB.ID T.2, TB (T.6,'23',T1.1) and so on.

The read operation from the tabular memory is also accomplished similar to the read operation from the carriage memory, but without a change of cell accessibility, for example,

TB.PR1 T.6--code "23" is read from element of PR1 of the accessible cell of the tabular memory TB (according to the latter write operation in the previous paragraph) and is written instead of "1" in the sixth element of the accessible cell of tabular memory T.

The search operation in the tabular memory serves to determine the accessible cell. The operation is written in the form of a logic predicate of type T.3 = R1, TB.PR2 ≠ '1', T.1.3 = TB.PR1.'1' and so on, where the name of the element (or elements of the tabular memory for which the search operation of the accessible memory is made is written from the left of the symbol "=" or "≠." The logical expression is used on all the filled cells of the tabular memory. The order of review of filled cells of the tabular memory when performing the search operation is not determined and can be any order (this order is given upon specific realization of the search operation). The search operation in the tabular memory has two modifications: search by coincidence (=) and search by noncoincidence (≠).

The indicated logic predicate is carried out by the search by coincidence operation over all elements of the filled cells of the tabular memory, the name of which is indicated from the left of the character "=," for example,

T.3 = R1--all three elements of the filled cells of the tabular memory T are compared for coincidence with the contents of register memory R1;

T.1.3 = TB.PR1.'1'--all the first and third elements of the tabular memory T are compared for coincidence with the contents of element PR1 from the accessible cell of tabular memory TB and code "1," respectively.

Upon coincidence, the corresponding cell of the tabular memory is declared accessible while the logical predicate is declared "true." The tabular memory is filled such that the indicated cell will always be single; therefore, the search by coincidence operation is always uniquely fulfilled.

Upon noncoincidence, the accessible cell is not changed--it remains as previously declared and the logic predicate is declared "false."

The indicated logic predicate is carried out by the search by noncoincidence operation (≠) over all elements of the filled cells of the tabular memory, the name of which is indicated from the left of the character "≠," for example, TB.PR2 ≠ '1'--elements with the name PR2 from the filled cells of tabular memory TB are compared to code "1."

If the accessible cell of a tabular memory TB is not coincident, any free (not previously filled) cell is declared and the logic predicate is declared "true."

Upon coincidence, the accessible cell does not change--it remains as previously declared and the logical predicate is declared "false."

2.3. The Language of the R-Computer

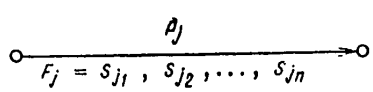
The purpose of this section is not to describe a specific language of the R-computer, but to describe the rather general ideology of constructing this language. This description may be regarded as some language diagram which can be used rather effectively during programming by the top-down R-technique. Since this description is based on abstract data structures (on abstract memories of the R-computer) and does not contain many technical parts of realizing the R-computer on an electronic computer, the given description of the R-language is some theoretical idealization of it which one may have prior to study of specific realizations of the R-language for YeS EVM [Unified computer system] (Chapter 5) and BESM-6 (Chapter 10) computers.

The R-computer is oriented toward the programmer, therefore, its language should be on the one hand an adequate process of his thinking and on the other it should be convenient and technologically efficient for recording the logic data structures and the processing algorithm for entry into the electronic computer on which the program model of the R-computer is manufactured.

Solution of any problem by man is construction of some mapping R from the initial subject area E1 into the resulting subject area E2:

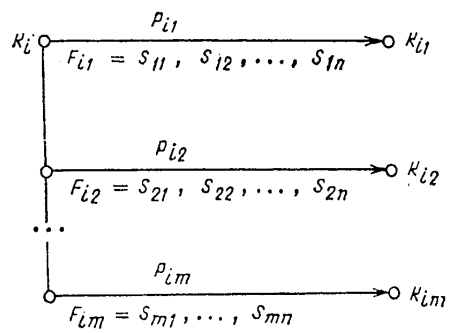
$$R{:}E1 \rightarrow E2$$

To solve the problem on an electronic computer means to construct a program that realizes mapping R. One must have the initial problem to construct this program in practice and accordingly the subject areas must be divided into a number of simple subareas. In the general case individual mappings do not give clear conformity of the subareas and should be clearly identified by means of certain conditions that take into account the relationship between individual subareas. When converting from postulation of the problem to realization of it, one may observe a further division of mappings that reach the limit to the operators of the language in which the corresponding algorithm is encoded. To realize mapping R, let us consider the programming technique that fixes the level of detail based on the use of the apparatus of loaded oriented columns. This apparatus gives mapping R as a composite of certain elementary mappings F. In the general case elementary mapping F_j is written in the following manner on the arc of column R:



where P_j is the condition (predicate) of fulfilling mapping F_j given by the sequence of operators $S_{j1}, S_{j2}, \ldots, S_{jn}$ of some language. Both P_j and F_j may be absent on the arc of column R. In the first case operators $S_{j1}, S_{j2}, \ldots, S_{jn}$ are fulfilled unconditionally and in the second case transition along the arc of the column is accomplished without fulfillment of any operations. The arc of column R given above with all the commas on it is called the elementary instruction of the R-computer.

Unlike an electronic computer, the instructions in a R-computer are combined into complexes. The arcs emerging from one apex of column R correspond to the instruction complex of the R-computer:



If it not specially stipulated, all the instructions (arcs) in the complex have a fixed order of review and analysis: top-down, left to right and the instruction in which predicate P is absent is analyzed last. The current complex at each moment of time in a R-computer is a single complex K_i from which one instruction, the first by order of review, is fulfilled in which the condition of fulfillment $P_{ij} (1 \leq j \leq m)$ is "true." Mappings F_{ij} are executed as a result of completing this instruction and transition to the corresponding new current instruction complex K_{ij} is then accomplished. Thus, the sequence of completing the elementary mappings F_{ij} obtained as a result of detouring the oriented column R by accessible routes determined by the true values of predicates P is set into agreement to the process of solving some problem on the R-computer.

Let us now consider the characteristics (syntax) of writing each of the instruction fields of the R-computer in linear form.

Field of the name of the instruction complex. This field may contain any identifier. This identifier usually carries some significant load, being the name of the corresponding subroutine, the name of its executor and so on (for example, NAChUST, ARIFMVYR, ShOLMOV5).

Field of condition of executing the R-instruction. This field contains some predicate P_j whose value is "true" or "false." In the first case the instruction of the R-computer is carried out and in the second it is omitted. The predicate P_j in R-language can be written in any most natural manner. Seven main methods of writing predicate P_j can be distinguished from the existing experience of R-computer operation.

1. The predicate term is denoted by any symbol not coinciding with the notation of metasymbols "␣" and "*" in R-language. The predicate term controls completion of the R-instruction if the symbol (term) in its condition field coincides with the current symbol on the input tape (see Figure 2.1). If it does not coincide the predicate term is "false" and the corresponding instruction is not carried out.

2. The predicate chain of terms is denoted by a sequence of any symbols included in single primes: 'CHAIN OF SYMBOLS','A X (B + C) 2' and so on. The primes themselves in the sequence of any symbols are given as double, for example, 'ERROR SIGNAL IS DENOTED BY "SOSh'." An empty sequence of symbols is denoted by the metasymbol * without primes. The sequence of any symbols may consist of a single symbol and metasymbol, for example, 'A', '␣', '*' and so on.

The predicate chain gives the group fulfillment of the predicate term.

3. The predicate indirect is denoted by "=P" and corresponds to the predicate chain of terms, which are written in memory : (indirect assignment of the chain of terms in the conditional field of the R-instruction).

4. The predicate synterm is denoted by any symbol of the internal alphabet of the R-computer and controls the execution of the R-instruction if the current symbol on the input tape corresponds with any symbol corresponding to the synterms. Synterms in R-language are determined by boldfaced script, for example, bk, bts, tsfr and so on, in the book.

5. The predicate pattern has the symbol "!" (repeat of pattern) and "?" (search of pattern). Any of the predicates named above can be placed after the indicated metasymbols.

Repetition of the predicate indicated after metasymbol "!" on the input tape (beginning from the current symbol) is given by the predicate repeat of pattern. Repetition is carried out until the predicate written after metasymbol "!" becomes false. For example "!tsfr" denotes omission of all numbers on the input tape, beginning from the current number, to the first symbol distinct from the number. The predicate "!'␣ if ␣'" gives the order of the proceeding symbols on the input tape "␣ if ␣" to the next sequence of symbols distinct from "␣ if ␣".

Sequential search on the input tape (beginning from the current symbol) of the predicate indicated after the metasymbol "?" is given by the predicate search of pattern. The search is continued until the predicate after metasymbol "?" becomes true. For example, the predicate "?," denotes an omission on the input tape, beginning from the current symbol, of all symbols to the next comma ",". The predicate "?'␣ END ␣;'" denotes an omission of all symbols on the input tape to the next symbol "␣ END ␣", after which a point with comma ";" proceeds.

The predicates described above are related to analysis of information on the input tape; therefore, the corresponding modification of the RT display in the R-computer is accomplished after they are completed (see Figure 2.1): RT = RT + L, where L = = 0 for an empty chain "*" in the conditional field of the R-instructic , L = 1 for predicates term and synterm (Figure 2.7), L assumes a fixed value equal to the length of the corresponding sequence of symbols given by the predicate chain and indirect (Figure 2.8) and L assumes the corresponding variable value for the predicate pattern (Figure 2.9). For example, L = 7 for predicate '␣ BEGIN ␣', L = 1 for -figure, L = 2 for -': = ' and L = n for = REGISTER, where n is the number of symbols written in the REGISTER memory; L = 10 for ?',␣' if a given sentence is written on the input tape and the display RT is set at the beginning of it on letter "H."

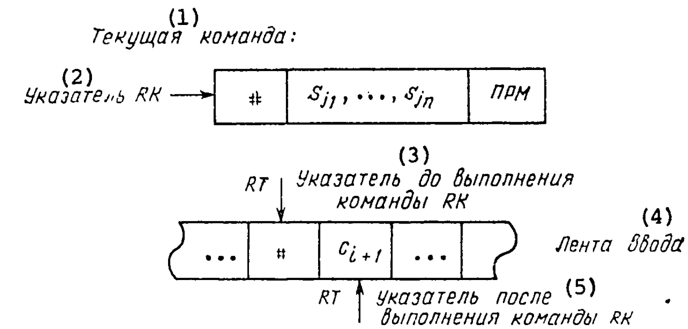
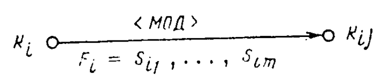


Figure 2.7. Diagram of Executing Instruction of R-Computer With Predicate Term in Conditional Field

Key:
1. Current instruction
2. RK designator
3. Designator to execution of RK instruction
4. Input tape
5. Designator after execution of RK instruction

6. The predicate module is given by the name of the R-module included in brackets:



The significance of this predicate is always "true." The RT designator does not change after completion of this predicate and operators F_i are carried out after emerging from the R-module <MOD>. Writi. g of a cha:n of R-modules is permissible: <MOD_1, MOD_2, ..., MOD_n> executed sequentially in the order of writing (N $\geq$ 1). Operators F_i are executed in this case after access to all R-modules.

The R-module is the part of the R-program having a single input and one or several outputs denoted by fixed name RM (output from the R-module). The R-module can be determined by other modules and recursively. For example, the R-program PO that recursively gives the list of lists of integers of type

LIST (1, 2, 3)
LIST (1, ((2, 3), 4), (2, 456), 1); and so on

is written in the following manner with the predicate module.

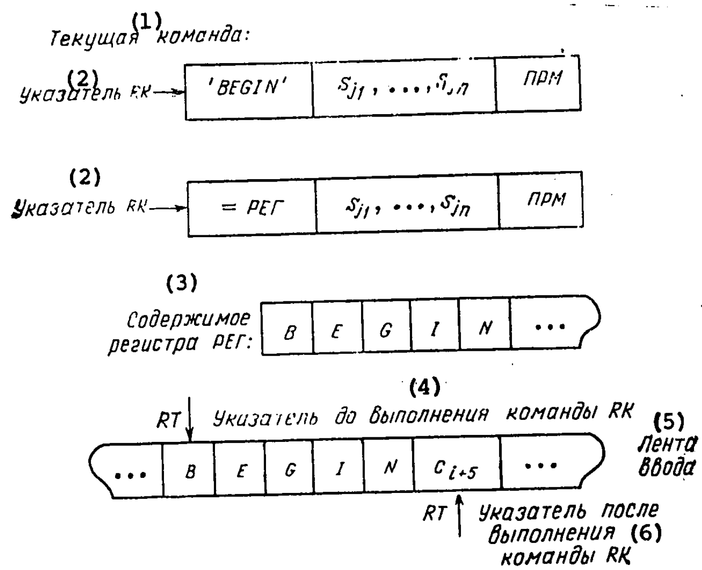
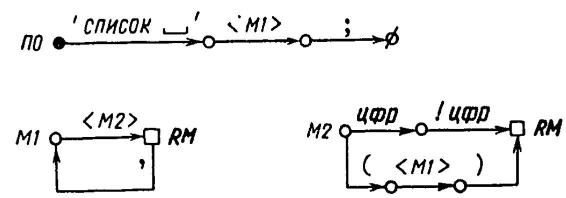


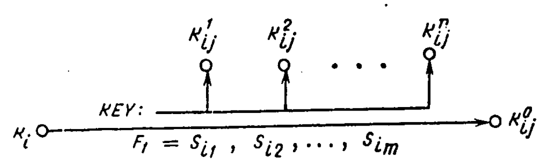
Figure 2.8. Diagram of Executing Instruction of R-Computer With Predicate Chain and Indirect in Conditional Field

Key:

1. Current instruction
2. RK designator
3. Contents of register REG
4. Designator to execution of RK instruc instruction
5. Input tape
6. Designator after execution of RK instruction



7. The predicate key:



in linear notation

$$K_i \quad KEY: K^1_{ij}, K^2_{ij}, \ldots, K^n_{ij} \quad F_i = S_{i1}, S_{i2}, \ldots, S_{im} \quad K^0_{ij}$$

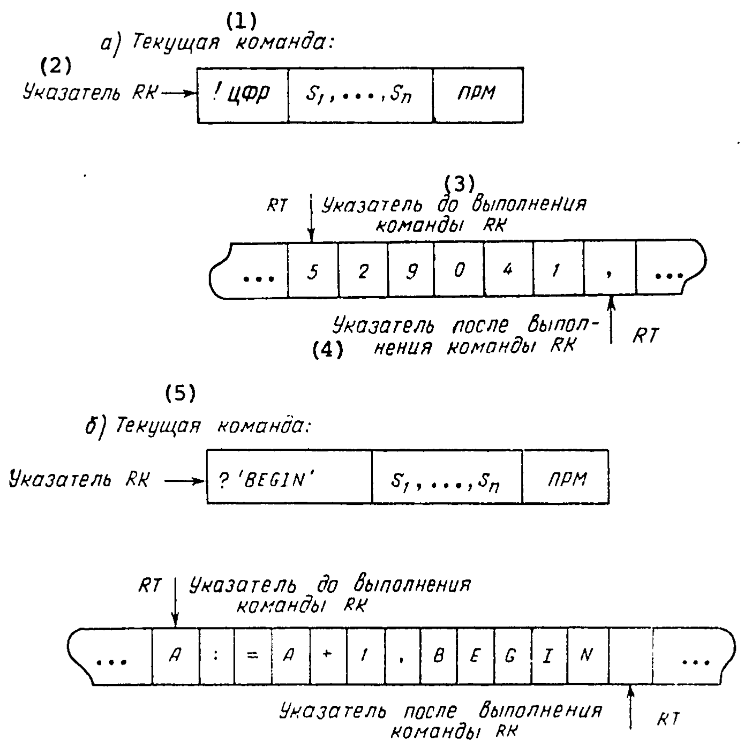


Figure 2.9. Diagram of Executing Instruction of R-Computer With Predicate Pattern in Conditional Field: a--predicate repetition of pattern; b--predicate search of pattern

Key:

1. a) Current instruction
2. RK designator
3. Designator to execution of RK instruction
4. Designator after execution of RK instruction
5. b) Current instruction

where KEY is a logic or arithmetic expression whose value is rounded off to the nearest whole number. The values of the arithmetic expression in the range 0 > > KEY > n are assumed false, while those in the range $0 \leq KEY \leq n$ are considered true. $F_i = S_{i1}, S_{i2}, \ldots, S_{im}$ is fulfilled at KEY = 0 and transition along the arc on K^0_{ij} is made as usual. Transition to complexes with the names $K^1_{ij}, K^2_{ij}, \ldots, \ldots, K^n_{ij}$, respectively, is made at KEY = 1, 2, ..., n and F_i is not fulfilled. Let us note that KEY may be a simple variable and a function of $F(X_1, \ldots, X_k)$ that assumes values from 1 to n. For example, according to the R-instruction

SEMAFOR:L1, L2, L3 C = C + 1 L0

if the contents of the cell SEMAFOR is equal to zero, the contents of counter C are increased by one and transition to the instruction complex L0 is made. If the contents of cell SEMAFOR is equal to 1, 2 or 3, control is transferred to L1, L2 or L3, respectively, and counter C remains unchanged. The indicated instruction is not fulfilled at any other values of cell SEMAFOR.

If n = 0 or KEY is a logic expression, then the predicate key has the following simple form: "KEY". For example, "TRIGGER;", "3 $\geq$ A $\geq$ 1:", "T.2 $\neq$ R1:" and so on.

Seven standard predicates which can be written in the conditional field of the instruction of the R-computer were considered above. However, the user may introduce any of his own predicates into circulation. This is done most simply and conveniently by using the predicate key. To do this, it is sufficient to introduce any logic function or function assuming a whole value into the R-computer. To enter such a function $F(X_1, \ldots, X_m)$ into a R-computer means to write it in any language of an instrument electronic computer and to translate and write it in the corresponding library. This function may then be used in the predicate key in the standard manner--"$F(X_1, \ldots, X_m)$: K^1_{ij} ..., K^n_{ij}".

If writing function $F(X_1, \ldots, X_m)$ in general form is inconvenient (unclear), then it can be standardized and entered in the language of the R-computer with any syntax. In this sense the language of the R-computer is open to modification by the user.

The field of operators of the R-instruction. This field serves to record the elementary mapping $F_i = S_{i1}, \ldots, S_{im}$ ($m \geq 0$). Several operators S_{ij} separated by commas may be located in a single instruction in the operator field. If the instruction contains no operators (m = 0), the metasymbol "*" is placed in the operator field. The metasymbol "*" may be omitted (assumed) during graphical writing of the R-instruction. The operators of the R-computer can be divided into several types by the form of writing them:

1) operators or operations of transmissions between memories P1 and P2 of the R-computer, for example, P1 $\rightarrow$ P2;

2) confer operators of arithmetic or logic expressions, for example, a = = a + b X c, a = (a X (b - c) $\uparrow$ 2) + d and so on;

3) systems operators;

4) operators in functional write formate of type $F(X_1, \ldots, X_k)$.

Systems operators switch on and switch off the action of information transmission operators from the input tape. The corresponding operators may not be written (may be assumed) in the mapping field after inclusion and will be executed by any instruction of the R-computer which has access to the input tape. For example, the systems operator "SISTVKL(BF,PECh)" includes duplication of all the symbols in registers BF (buffer) and PECh (print) reviewed on the input tape.

Operators of type $F(X_1, \ldots, X_k)$ permit the user himself to expand the capabilities of the R-computer simply and without limit. The programs corresponding to these operators should be pre-written in any programming language accessible to the user, translated and included in the libraries of the R-computer in the standard manner. If writing of operator $F(X_1, \ldots, X_k)$ in general form is not clear, it can be standardized and entered in the language of the R-computer with any syntax.

The hopper field. The name (any identifier) of the instruction complex executed after a given R-instruction and the service words: RM--standard output from the R-module and output--standard completion of the R-program and the instruction of stopping the R-computer are written in the hopper field.

The structure of the program in R-language. The program in R-language is structurally divided into two parts. The descriptive part is written initially and then the executive part is written. The program begins with the word of the R-program after which follows the name of the program and ends with the work end:

```
R-program  <name of program>
<descriptive part>
<executive part>
end
```

The programmer determines the configuration of the R-computer which is required to solve theproblem in the descriptive part. He assigns the names and types of the abstract memories in it, the name of the abstract memory which will be used as the input tape, determines the internal alphabet of the R-computer and so on. The descriptive part of the R-program consists of statements. Each statement is begun with a service word: register, table, synterm and so on. Each statement of the descriptive part is begun with a new line. Examples of correct statements of the descriptive part of the R-program are the following notations obvious in light of the previously given definitions of abstract memories (see 2.2) and synterms (see 2.1):

```
counter  C1, COUNTER
register BUFFER, BF1, R3
carriage LC*PC, MAG*QUEUE.IDER.PR.ADR
table    T, TAB.ID.PR1.PR2.ADR, TB5
synterm  tsfr: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
octal synterm: vtsfr:  0, 1, 2, 3, 4, 5, 6, 7
synterm vowels:  gls:  A, Ye, I, O, U, Yu, Ya and so on,
```

where the equivalent notations are written between the colons upon definition of the synterms.

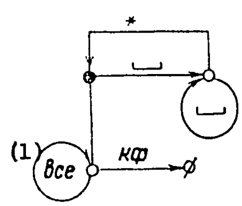
All memories of the R-computer which are used in the user program should be described without fail. The description of the synterms in the program may be assumed if the programmer uses the generally known synterms from the internal alphabet of the R-computer. Each new description of a synterm in any user program expands the alphabet of the R-computer, i.e., it is stored in the system for subsequent use by all users.

The executive part of the R-program is begun with the name of the first instruction complex. The work of the R-program is always begun with the first complex;

therefore, its arrangement in the user program is always fixed at the beginning of the executive part of the R-program. The arrangement of the remaining complexes is not fixed and may be arbitrary. It is recommended that the entire program be divided into R-modules so that each occupies no more than one sheet of the ATsPU [Alphanumeric printer] and is always begun from the beginning of the sheet, to enhance the clarity of the R-programs and also for the technological efficiency of debugging and operating them.

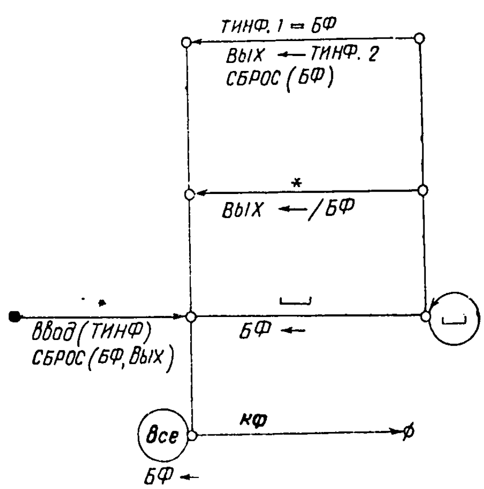
Let us consider notation of a text file compression algorithm to illustrate writing of a program in R-language. For simplicity let us consider only two file compression procedures. First, each sequence of spaces following each other is replaced by a single space. Second, any word (a sequence of symbols between spaces) in the text may be replaced by a shorter corresponding equivalent. These words and their equivalents are previously given in the table TINF. The table has two columns: the word is written in the first and its equivalent is written in the second.

According to the given postulation of the problem, the structure (LSD) of the text to be processed can be defined by the following R-program:



Key:
1. All

where kf is a synterm which denotes the end of writing on the input tape. The unique, so-called internal symbol of the R-computer which is written (or which is generated schematically) at the end of all notations on the input tape corresponds to this synterm. Having predetermined the LSD of the text to be processed to the required algorithm, we find the next R-program



Notation of this program in linear form for entry into the R-computer has the following form:

```
                                   R-program COMPRESSION
                                   register BF, VYKh
                                   table TINF
BEGINNING       *                  ENTRY (TINF),
                                   RESET (BF, VYKh)          WORD
WORD            '␣'                BF←                       COMPRESSION
                all                BF←                       WORD
                kf                 *                         output
COMPRESSION     '␣'                *                         COMPRESSION
                TINF.1 = BF:       VYKh←TINF.2,
                                   RESET (BF)                WORD
                *                  VYKh←/BF                  WORD
                                   end
```

VF in this program is the register in which each word is gathered in the input tape and VYKh is the register in which the result of compression of the initial information on the input tape is gathered. The program works in the following manner. Table TINF is initially entered and the working registers BF and VYKh are reset (cleared). The current word on the input tape is then formed in the register BF in the instruction complex WORD. As soon as the word is formed (the attribute will be a space on the input tape), control is transferred to the instruction complex COMPRESSIONS in which the formed word in the memory BF is compared to the words in the first column of memory TINF. If a similar word is found, a shorter equivalent of the word in register BF will be written in register VYKh. This equivalent will be taken from the second column of the accessible cell of Table TINF. If the word is not in the first column of memory TINF in register BF, then the original of the word is written from register BF to register VYKh. Register BF is erased in both cases after recording in register VYKh. The work of the program is completed after reading the last symbol on the input tape (reading the attribute kf end of file).

To strengthen techniques of working with the R-language, we recommend that the reader himself: 1) change the algorithm so that the last word of the text file ending in synterm kf be compressed; 2) construct an algorithm by which the compression coefficient of the processed text is read and printed at the end of work; and 3) construct an algorithm by which table TINF is not entered but is formed operationally during review of the initial text. Those words in which the length is greater than n symbols, where n = 3, 4, ..., are entered in this table; and 4) construct a word-combination compression algorithm.

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CSO: 1863/208

UDC 531:62-5

PRINCIPLE OF NONDETERMINISTIC CONTROL OF A WALKING ROBOT

Moscow IZVESTIYA AKADEMII NAUK SSSR: TEKHNICHESKAYA KIBERNETIKA in Russian No 2, Mar-Apr 81 pp 100-108

[Article by V. P. Pyatkin]

[Text] A walking automaton has a number of advantages over wheeled or track automata, mainly on account of the high degree of adaptation to distinctive features of the relief of the locality. A number of problems which still do not have final solutions arise in the realization of a system to control the motion of a walking robot, which must assure stable motion of the robot and coordination of its legs and rid it of dragging of its feet, etc, which is an especially difficult task when a robot moves over a locality with a complex relief [1-8].

The first work in that direction in our country was done in the Institute of Applied Mathematics of the USSR Academy of Sciences [2,3]. In the present work an original approach to solving the problem of control is proposed, a nondeterministic model of control of a walking robot, a model which assures breadth of tactics in the selection of an approach within the framework of limitations natural for the given design.

The term "nondeterministic algorithm" was first proposed by Floyd [9], who allowed in such algorithms functions of selection to simplify the description of strategies of complete analysis. Earlier, Manna [10] described a class of programs which allow both nondeterministic appropriation operators similar to selection functions and nondeterministic branching operators. He proposed a procedure for demonstrating the correctness of programs containing those new elements. Finally, Fikes [11] described a problem-solving system in which the problems are set in some procedural language which permits use of nondeterministic functions of selection.

Figure 1 presents a block diagram of a simulating complex of programs. Control of the motion of a walking robot is regarded as a system of interaction of three main levels: generators (lower level), strategy (medium level) and path (upper level). Let us consider in greater detail each of the blocks of the modelling complex of programs.

1. Models. Investigations were conducted on a fairly wide spectrum of models. The first two models are plane (two-dimensional); their legs have two degrees of freedom each and move in parallel planes arranged so near one another that we can consider them coinciding, that is, the legs move in practically a single plane without

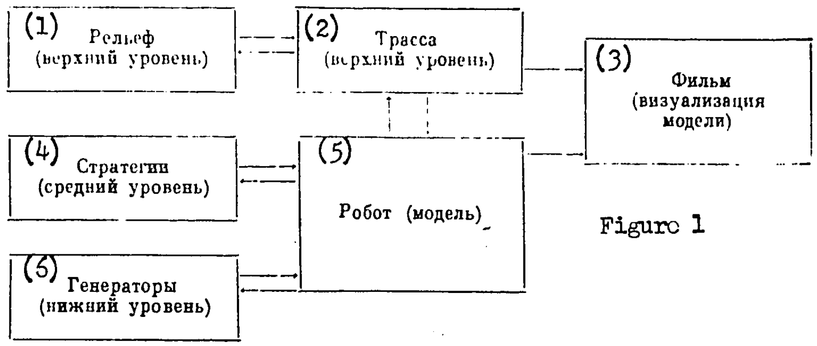

Figure 1

1. Relief (upper level)
2. Route (upper level)
3. Film (visualization of model)
4. Strategy (medium level)
5. Generators (lower level)
6. Robot (model)

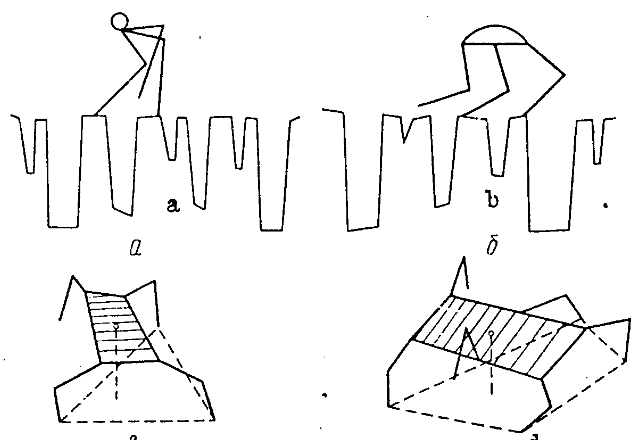

Figure 2

affecting one another, but they can intersect (Fig 2a, b). The other two models are three-dimensional; each of their legs has three degrees of freedom (Fig 2c, d). All four variants have no mass, but each of them has a center of gravity and the legs are weightless. The following main limitations are imposed on the models.

1. The center of gravity moves along a straight line with a certain constant velocity v.

2. A vertical projection of the center of gravity always must intersect the reference segment for two-dimensional models and a reference polygon for three-dimensional models (the requirement of static stability).

3. The fulcrum of the supporting leg cannot move in relation to the relief (that is, a robot is not permitted to "drag" a leg).

4. Each step, that is, the operations of separation, displacement and placement of the legs together, requires the time $\tau_0 + t$, where τ_0 is a constant and t is selected arbitrarily within limits assuring fulfilment of conditions 1-3.

The further development of models is unconditionally connected with consideration of the dynamics of the displacement of ponderable legs and the platform. It is quite likely that the process of control in that case can prove to be simpler. It is convenient to cite an analogy here. The first work in the area of modelling systems for the perception of visual information of integral robots in the problem of analysis of three-dimensional visual scenes were directed mainly toward improvement of algorithms for the analysis of plane images (the type of algorithms for the recognition of letters, numbers, etc). However, it soon became clear that the investigation of abstract two-dimensional forms rather takes away from the development of technology for the recognition of three-dimensional objects than approaches that goal. The perception of solid bodies is a process which can be constructed on the properties of three-dimensional transformations and laws of nature. It is precisely that idea which led to impressive results in the simulation of systems for the perception and analysis of three-dimensional scenes by integral robots.

The idea of a telescopic leg, that is, a leg the length of the articulations of which can be varied within certain limits, seems very attractive. This undoubtedly will enhance the possibilities of a walking automaton in overcoming a complex relief and complex obstacles.

2. Generators. The lower level of control represents a nondeterministic automaton (generator of behavior) which accomplished the planning of a specific sequence of elementary acts of motion: in which sequence legs move, at what points of the relief they are set, at what moment of time it rises and each leg is placed, etc.

For each model a set of variables is distinguished which completely describe the internal state. For example, for a symmetric three-legged model (Fig 2a) their variables are:

1) the coordinates of the points of reference of legs in relation to the center of gravity x_i;

2) the time elapsed from the moment of opening for non-supporting legs τ, and

3) the velocity of the center of gravity v.

The symbol $\emptyset$ is used for the coordinate of a raised leg. The state of that straight line of the model is described by the cortege $< x_1, x_2, x_3 >$, where $x_i \in \{ -\alpha-\alpha, \emptyset \}$ ($\alpha\sqrt{\ell^2 - h^2}$, where ℓ is the length of the extended leg and h is the height of the center of gravity in relation to the relief).

Statically unstable states are excluded from the set of all possible values of the variables describing the internal state of the model. Each model is assigned a pair $<Q, A>$, where Q is the set of all statically stable (allowable states and A is the set of operators realized by the model. For each model an approximate graph G can be compiles, the apices of which are elements of the set Q, and the corresponding operators from A are the arcs. The set Q in that case naturally decomposes into the three intersecting subsets:

1) cyclic states belonging to G, even if a single cycle;

2) input states, from which in G there is even one path into the cyclic;

3) dead-end states.

Let us explain the meaning of the dead-end state. The operator $a \in A$ is applicable to the state $q \in Q$ if and only if $q' = a(q) \in Q$, that is, the newly obtained state remains statically stable. The state $q \in Q$ of the model is called dead-end if there is not one applicable operator for it.

It is easy to cite examples of statically stable states which are dead-end states. The separation of such dead-end states from the accessible also is a task of the behavior generator.

The subgraph obtained from G by exclusion of the dead-end apices is called a behavior generator. In a behavior generator, in turn, it is possible to distinguish subgenerators satisfying definite limitations on the selection of states from Q. The process of walking within the introduced formalism is the process of constructing a chain of allowable states, each subsequent one of which is obtained by applying one of the allowable operators to the preceding one. The set of all cycles in the behavior generator represents the set of all possible gaits of a walking robot.

Various approaches to the construction and representation of behavior generators can be proposed. Two of them have been the subject of our constant attention.

The predicative approach to the construction of behavior generators is an attempt to express allowable states through geometric and kinematic correlations of elements of the model, starting from analysis of the physical process of walking and the physical essence of falling into dead-end states. The system of predicates determining the generator of behavior of a symmetric model with three legs is fairly simple (Fig 2a); it is presented in [5]. The problem of predicative representation of the behavior generator is the same as for the system of axioms of any non-trivial theory and consists in proof of the completeness and non-contradictoriness of the system of predicates describing the behavior generator. The complexity of that problem emphasizes one fact: we have succeeded completely in doing this only for the generator of behavior of a symmetric model of an automaton with three legs, using graphic interpretation of predicates, so-called τ-representation. Its essence consists in the fact that it is not the state of the generator but its temporary projection on the phase plane which is examined, where the axis of abscissas corresponds to the amount of time before loss of stability, and the axis of ordinates to the amount of time before dragging of the leg. (The τ-representation and corresponding proof were presented by P. A. Kim, associate worker of the Siberian Department Computer Center, USSR Academy of Sciences). Incidentally, this is a typical example of problems of artificial intelligence, when the successful selection of representation of a task in the space of states substantially reduces expenditures of efforts on the search for its solution.

For an asymmetric plane model (Fig 2b), proof was successfully presented of the completeness and non-contradictoriness of the system of predicates describing the generator of behavior only for some classes of an asymmetric three-legged model automaton for the case of so-called predicate-balance representation, based on distinguishing a certain class of main gait readily described by means of predicates, such that all the remaining gaits could be obtained as a certain filling of the "corridor" formed by the framework of the main gait.

Attempts to construct a predicate representation of the generators of behavior for three-dimensional models (Fig 2c,d) were unsuccessful.

The physical model for representation of the behavior generator is based on representation of the automaton in the form of a discrete space of states where the generator, in essence, represents a marking off of states into allowable and dead-end. It is assumed that the discretization of space and the control parameters (v, t_0, etc) are such that closure of all the operators on that space is assured. One of the possible algorithms for construction of a physical model of a behavior generator is the sorting algorithm. The states for which no operator is unacceptable (the dead-end states) can be readily determined by direct sorting of all the states. On the following step the states from which it is possible to fall into those distinguished dead-end states, etc, are distinguished. It is obvious that after the final number of steps, possibly very large, necessary marking of all states or a physical model of representation of the behavior generator will be obtained. This process is readily automated. The distinguishing of some heuristics which use the structure of the transitions graph G, the probable distribution of the allowable apices, etc, has permitted considerably reducing the machine time in obtaining physical models of generators of behavior of symmetric and asymmetric plane three-legged automaton models (Fig 2a, b).

The main problem in the physical representation of the behavior generator involves a phenomenon which Bellman called "the curse of dimensionality." Needed to obtain a meaningful model is a more detailed breakdown of the space of possible states, but in that case the memory resources are rapidly exhausted. Even all-possible contrivances (use of the symmetry of models, the introduction of representative segments, etc) does not change the essence of the matter in the general case. We did not succeed, for example, in obtaining sufficiently meaningful physical generators of behavior for three-dimensional models of a walking robot (Fig 2c,d). It has become obvious that the deductive approach, used to synthesize generators of behavior of plane models of a walking automaton, is completely unsuitable in the synthesis of generators of behavior of three-dimensional models. The inductive approach appears to be more promising here; in it several supporting cycles (gaits) and states are distinguished first, and then in the process of experience accumulation by the walking robot the generator is supplemented with new cycles (gaits) and states (a growing generator of behavior). In the inductive approach to synthesis of a behavior generator a walking robot can move while being guided by information obtained from the available subgenerator. In the process of motion it obtains information which permits it to both supplement and modify the subgenerator. This is very important from the point of view of economy of memory. In the inductive approach to construction of a behavior generator the problem of reduction arises in accordance with growth of the behavior generator and the reduction, unavoidable in that case, of the effectiveness of its use even in that case, if the memory resource will not be exhausted. This is a fairly general problem for tasks of artificial intelligence; the well-known frame problem [12] represents a task of such a type. Two approaches to the solution of this problem can be proposed.

1. Dynamic increase of the effectiveness of deduction. This can be done by structuring (segmenting) of the behavior generator, that is, subdividing it into simply described regions. For example, the use of physical subdivision of the τ-representation, since for asymmetric models (Fig 2b, d) the transitions into τ-representations become more complex and therefore cannot be described by simple predicates. The procedure of combining states close in a certain sense into certain consolidated states, and those in turn into larger states, etc, permits substantially reducing the number of states under consideration.

2. Dynamic economy of memory to store the behavior generator. This is the freedom of the memory from excessive specific information not algorithmically necessary. The use of various strategies of "forgetting" (from statistical to semantic).

The transition to the inductive construction of behavior generators does not at all mean rejection of the nondeterministic principle of control of a walking robot. We simply change to the region of potential feasibility of complete nondeterminism. The growth of the behavior generator can proceed to completeness, until the time and memory resources are exhausted.

3. Strategies. The presence of the behavior generator provides a walking robot with the possibility of moving only over a definite "smooth" relief. The lower level of control is insufficient for movement of a walking robot over a real, complex relief. A complex relief imposes dynamic limitations on the behavior generator and makes it necessary to plan walking robot motion several steps in advance.

The medium level of control (strategies) also assures the planning of motion several steps in advance in the direction of the path designated by the upper level. Starting with full information about robot possibilities, the medium level takes into consideration the assigned values of the external parameters of the motion mode (the rate, the reserve of stability, the height of the platform above the relief, etc), and also local features of the relief in the direction of motion. The assigned values of the control parameters determine the corresponding "corridor," formed by the aggregate of paths allowable under the given combination of external and internal conditions. Interesting theoretical results have not been obtained for the formal description of strategies for planning the motion of a walking robot by several steps in advance. Only in some cases, when the structure of the behavior generator is simple, for example, for some subgenerators of the behavior of a symmetric three-legged automaton, is analytical computation of dynamic limitations on a behavior generator possible. The computation of limitations generally requires a large volume of computational work. Therefore two heuristic approaches were proposed for construction of a "corridor" of walking robot motion. One of them is the "frame" strategy, the essence of which is as follows. During movement, N processes which imitate the motion of an automaton along a given relief are organized. Those processes can develop independently of one another, constructing some specific paths allowed by the relief. Having fallen in a dynamic dead-end, the process ends and information about it enters the generator. In that case cleavage of one of the still existing processes occurs in such a way that the presence of N existing processes is maintained. The paths realized by those processes form the "frame" of the corridor within which the walking automaton also moves. The "corridor" of motion thus constructed does not always assure passability of a relief passable in principle, but creates the prerequisites for effective work of direct algorithms for sorting.

Another heuristic approach to construction of a "corridor" of motion of a walking robot is the "stack" strategy. In the automaton memory a certain region is distinguished, a "stack," in which is recorded a chain of allowable states q_i, q_{i+1}, ..., q_{k-1} of some gait of a walking robot from the given state q_i. The walking automaton as it were "plays through" in advance several states in the depth of the "stack." If the next state q_h is inaccessible, the automaton returns to the preceding state q_{h-1} and tries to find a continuation of the chain of allowable states from if it is again unsuccessful, then in the preceding q_{h-2}, etc until the entire stack is exhausted. Just as that occurs the walking robot gives information about the fact that the path is impassable. If the next q_2 is allowable, the automaton completes the chain of allowable states in the depth of the stack. If the state q_k is allowable, we have a new state of the stack for analysis in the following steps: q_{i+1}, q_{i+2}, ..., q_k. There is no sort of apriori information about the selection of the stack depth and its volume is selected experimentally. In the simulation of a plane asymmetric three-legged walking automaton (Fig 2b) a stack depth of 7 was selected ($k = 7$).

Below, two approaches which we consider promising are described, approaches which could be used for the realization of that level of control. One of them is connected with the formulation of that task as a game with the world. The game approach to the planning task has been very little investigated, whereas extensive class of algorithms for searching for solutions on a game tree has been thoroughly worked out and carefully verified in practice (in chess programs, for example). The use of game algorithms for the effective search for a solution in non-game spaces, which is properly a generator of the behavior of a walking automaton, appears promising. Another approach is connected with the use of various strategies of teaching, for example, the type of procedure for generalization of plans in the planning system STRIPS of the Standord Research Institute robot [13].

4. Routes. The upper level of control is planning the route of movement with consideration of general characteristics reflecting the ability of a walking automaton to overcome given features of the relief, and also its orientation on the locality. The task of planning the route in the static variant, when the robot has at his disposal a detailed plan of the locality, knows its own coordinates and those of the target, is reduced to one of the extreme tasks on the graph, to solve which the method of dynamic programming is used [4].

In dynamic route programming the robot knows about the locality only, what it "sees" or has already "seen" from the moment of start of motion, and also his own coordinates and those of the target. The functions of vision are not simulated and it is considered that the robot has "ideal" vision. For each given position of the robot on the locality the zone of direct visibility is determined and the corresponding part of the plan is considered to be known to the robot. Since the relief is three-dimensional, shadow (invisible) sections of localities form for the robots. The main problem in dynamic route planning is the prediction of shadow sections, marking and evaluating them from the point of view of passability. In simulation, prediction of the relief in invisible zones by the spline-interpretatic method has been used [14,15].

The system of static and dynamic route planning realized in the model works only on "clean" relief without dangerous zones of the type of rock waste, swamp, rivers, etc. In that case the robot naturally will be equipped with some tactile system for gathering information about the environment, besides a visual system. In route planning on a real relief the robot in practice deals with a multi-colored map of the locality. The transition from a three-colored to a multi-colored map seems to be very complex.

To create a system capable of laying out a route on a real relief it is necessary to include in the upper level of control algorithms for the identification of obstacles and characteristic signs of the locality.

5. Relief. Let us examine a complex of auxiliary programs which serves for the synthesis of a complex three-dimensional relief. The synthesized relief is simulated by a single-valued two-dimensional function represented in the machine by a uniform grid (matrix) of its values. The relief is three-dimensional, and so the accomplishing function is the sum of three functions, each of which represents its own level.

In relief synthesis the operator (man) assigns some of the parameters determining it. On the basis of that information the system generates the relief, selecting the remaining parameters randomly. In principle the process of relief generation on all three levels differs little and the simply linear dimensions of a section of the microrelief are smaller than the linear dimensions of a section of the macrorelief by a factor of hundreds.

After introduction of the determining elements of the relief a macrorelief is constructed with the use of a combined method of relief generation which consists of a piecewise method (for counting on a preliminary grid) and the spline-interpretation method (for counting on a complete grid). There is a program for the distribution of random elements on the relief (pits, gullies, rocks, etc). Further, on the basis of a macrorelief section a mean relief is generated either by the combined method or by the spline-interpretation method. For the mean relief, as for the macrorelief, the random elements are distributed.

The microrelief is synthesized similarly to the construction of the mean relief; in that case a section of the mean relief is taken as a basis.

Included in the same program complex are subroutines which permit obtaining on a traph construction lines of the level and isometric projections of the generated relief.

The further development of that program complex involves the use of a graphic display and interactive mode in the process of relief formation.

6. Film. It is advisable to process algorithms for control of a walking automaton by simulation on a computer with visualization on the display screen of the process of movement of the automaton over the locality.

With the introduction of the "KARAT" BESM-6 computer system into operation at the USSR Academy of Sciences Siberian Department Computer Center ("KARAT" is a microfilm device developed at the Institute of Automation and Electrometry, USSR Academy of Sciences, Siberian Department) and the SMOG software system [16] (SMOG is a system of graph constructor software developed in the USSR Academy of Sciences, Siberian Depertment Computer Center) an effective instrument was obtained for investigating the processes of control of complex systems, which undoubtedly include a walking automaton [8].

With the BESM-6 computer "KARAT" system photographs were taken which illustrate the process of static and dynamic route planning, and also the process of control of the motion of plane models of a three-legged automaton, which in principle can be regarded as three-dimensional if the operation of parallel transfor is performed. In that case we have movement of the model of a walking automaton over a cylindrical three-dimensional relief with a fixed gait of the gallop type.

That film is the first scientific machine film of the USSR Academy of Sciences Siberian Department Computer Center and, as far as we know, the first machine film in the USSR taken in on an on-line mode (w9thout an intermediate carrier).

The results of computer simulation of a walking automaton in the BESM-6 computer "KARAT" system have enabled the designation of some new approaches to solution of the problem of control of a walking robot which were examined above.

In conclusion, I would like to note that the principle of nondeterministic control has a clearly expressed methodological character. It is possible to distinctly outline the class of control problems to which the ideology of nondeterministic control can be applied. They are problems which allow representation in the system state-operator and which have many states (cycles are possible) and few operators. There have been possitive results in use of the principle of nondeterministic control in computer simulation of the process of control of a manipulator.

The author thanks V. N. Dement'yev and P. A. Kim for useful discussion of the results of this work.

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CSO: 1863/186

SIGNAL PROCESSING

UDC 621.391

ABSTRACTS FROM COLLECTION 'DIGITAL SIGNAL PROCESSING AND ITS APPLICATION'

Moscow TSIFROVAYA OBRABOTKA SIGNALOV I YEYE PRIMENENIYE in Russian 1981 (signed to press 28 Jan 81) pp 219-222

UDC 621.391.2

CONVOLUTION OF MULTIVALENT DISCRETE SIGNALS IN A RANDOM BASE

[Abstract of article by Ayzenberg, N. N., and Semirot, M. S.]

[Text] This article considers multidimensional signals and spectral conversions of multidimensional discrete signals. The authors attempt to prove the theorem of the convolution of multidimensional signals. It is demonstrated that the convolutions given in the article exhaust all convolutions of multivalent discrete signals for each of which the spectrum of convolution is equal to the product of the spectra. The article has five bibliographic entries.

UDC 621.391.141

GENERALIZED FOURIER-HAAR CONVERSION ON A FINITE ABELIAN GROUP

[Abstract of article by Boyko, L. L.]

[Text] This article considers algorithms for fast or orthogonal conversions of the fast Fourier and Haar types from the group theory point of view. The author demonstrates that the existence of fast algorithms is based on the availability of an extended composite series in a finite abelian group of a non-prime order. A broad class of orthogonal nonsymmetrical conversions, a generalized Fourier-Haar conversion, is defined. Each of this class of conversions has a fast computational algorithm, and the number of essential operations depends significantly on the length of the composite series of the group for the particular conversion. Particular cases of the given class are the conventional discrete Fourier conversion, Walsh, Walsh-Adamar, and Walsh-Pailey conversions, number theory conversions, the traditional Haar conversion, and the conversion by Haar k-functions. The article has 20 bibliographic entries.

UDC 621.391.141

NUMBER THEORY FRENEL CONVERSION AND ITS APPLICATION IN DIGITAL PROCESSING OF MULTIDIMENTIONAL DATA ARRAYS

[Abstract of article by Givental', A. B., and Krenkel', T. E.]

[Text] This article is devoted to a multidimensional generalization of the Blyusteyn algorithm, construction of number theory Frenel functions on a finite commutative group above a commutative ring with a one, and to a description of possible applications of such functions in digital processing of multidimensional data arrays. The article has 18 bibliographic entries.

UDC 535.317

SOME QUESTIONS OF THE THEORY OF DISCRETE ORTHOGONAL SIGNAL CONVERSIONS

[Abstract of article by Yaroslavskiy, L. P.]

[Text] This article reviews questions of discrete representation of integral Fourier and Frenel conversions and the theory of fast algorithms of orthogonal conversions. The author introduces shifted discrete Fourier conversions and discrete Frenel conversions and analyzes their properties. On the basis of the concept of staged Kronecker matrices, it is demonstrated how to construct a single notation of orthogonal matrices that allow factorization to produce weakly filled matrices. The author formulates factorization theorems, shows the possibilities of their application with examples, and gives factored representations of matrices of orthogonal conversions known from the literature. The article has four tables and 26 bibliographic entries.

UDC 519.240

SELECTING THE PARAMETRIC REPRESENTATION OF CURVES IN DIGITAL DESCRIPTION AND PROCESSING OF FLAT FIGURES

[Abstract of article by Nagornov, V. S., and Polyakov, V. G.]

[Text] The article raises the question of seeking for a smoother, in a certain sense, parametric description (whose spectrum has minimum width) relative to a closed curve assigned on a surface. It is demonstrated that the criteria of spectrum width are related to its fourth-order moment and lead to the problems of seeking the lowest proper value (minimum spectrum width) and corresponding function proper (optimal speed of movement along the curve) of the Shturm-Liuvill operator with a periodic coefficient, which is the square of the curve as a function of arc length. Examples are given of optimizing the parametric representation and the authors briefly describe the possibilities of using this procedure. The article has three illustrations and four bibliographic entries.

UDC 621.391.172:621.397

COMPARISON OF LINEAR METHOD OF RESTORING DISTORTED IMAGES

[Abstract of article by Lebedev, D. S., and Milyukova, O. P.]

[Text] The authors consider the problem of linear reconstruction of distorted images in the absence of random noise, where the reconstruction algorithms are defined by various optimality criteria of the generalized Euclidian distance type. The article compares restored images for certain distances: the minimum norm image, the smoothest image, and the image that deviates least on the average from the original. The article has three illustrations and three bibliographic entries.

UDC 621.391.172:621.397.681.518.2

SOME METHODS OF DIGITAL PREPARATION OF IMAGES

[Abstract of article by Belikova, T. P.]

[Text] The article presents data from an experimental test using computers of these methods of preparing images: (a) the method of adaptive amplitude conversions (exponential intensification and hyperbolization of the histogram); (b) the method of optimal linear filtration and localization of objects in images. A mammogram of the mammary gland and an aerial photograph of a segment of the earth's surface were used as objects of study. The author describes the work of the corresponding algorithms for preparing images. The article considers the possibilities of generalization and further elaboration of the methods of adaptive amplitude conversions. The article has six illustrations, two tables, and 13 bibliographic entries.

UDC 681.325+621.379

AUTOMATIC PROCESSING OF INTERFEROGRAMS ON A DIGITAL COMPUTER

[Abstract of article by Ushakov, A. N.]

[Text] This article considers the question of restoring the phase of an interferogram recorded on photographic film. The problem was solved by stages: (1) correction of nonlinear distortions of the photographic film; (2) filtration of register noise; (3) filtration of low-frequency noise; (4) restoration of the relative phase value; (5) reconstruction of the absolute phase value. The article reviews the questions of automatic filtration of register noise for narrow-band and broad-band interferograms and automatic filtration of low-frequency noise. The author presents the results of experiments with formulation of interferograms. There is an evaluation of the precision of restoration. The article has 15 illustrations and 36 bibliographic entries.

UDC 681.3.01:687.051.21

AUTOMATIC MEASUREMENT OF HUMAN SUBJECTS FOR MACHINE CUTTING OF CLOTHING — PRINCIPLES OF OBTAINING AND PROCESSING DATA

[Abstract of article by Aydu, E. A., Nagornov, V. S., and Polyakov, V. G.]

[Text] This article gives a schematic description of the tangential tape method of measuring the human being. This method solves the technical-economic, esthetic, and psychological problems that have hindered widespread automation of the process of measuring the human figure for the needs of machine clothing design and anthropometric studies. The experimental device that accomplishes this method is then viewed as a specific discrete source of two-dimensional signals whose computer processing for the purpose of spatial reconstruction of the human figure necessarily requires two-dimensional procedures of filtration and interpolation as well as many other special operations. The article has 12 illustrations and two bibliographic entries.

UDC 535.317.1+681.141+772.99

MOVIE-TYPE DIGITAL HOLOGRAPHIC FILM

[Abstract of article by Karnaukhov, V. N., and Merzlyakov, N. S.]

[Text] The article presents experimental results of a computer synthesis of movie-type holographic film. The object, two evenly colored spheres rotating at a variable speed aroused an immobile third sphere, was modeled on the computer. For visualization of the full cycle of the spheres 48 movie-type projections of the object were synthesized on a surface, corresponding to 48 successive positions of the object in space. Both the horizontal and the vertical parallaxes were taken into account in transmitting the volume. The frequency of tracking the angles of approach was variable. The film, which was a composite macro-cine-form containing 1,152 elementary cine-forms, was secured to a circular metal frame and illuminated with a laser light with a spherical wave front. With an immobile observer and rotating film the illusion arises of smooth rotation by the spheres, and the direction of rotation can be clearly tracked. The article has two illustrations and eight bibliographic entries.

UDC 535.2:317.1

SYNTHESIS OF COLORED HOLOGRAMS OF THE DIGITAL COMPUTER

[Abstract of article by Merzlyakov, N. S.]

[Text] The author proposes a method of synthesizing colored macroholograms on the digital computer. By contact copying three color-divided synthesized Fourier holograms recorded on black-white photographic film are transferred in sequence behind red, green, and blue light filters to the corresponding layers of reversed color film. A three-color laser is used to restore the image. The proposed technique makes it possible to obtain colored macroholograms that contain up to $16 \cdot 10^6$ elements. They are also suitable for direct visual observation. The article has eight bibliographic entries.

UDC 535.317

DIGITAL MODEL OF RECORDING AND RECONSTRUCTING HOLOGRAMS

[Abstract of article by Popova, N. R.]

[Text] The article describes a digital model for recording and reconstructing Fourier and Frenel holograms. The author considers the effect of distortion in the hologram on the quality of reconstruction of diffuse objects. She derives the characteristics of speckle contrast depending on the limitation of dimensions, the superimposing of random noise, the limitation of the dynamic range, and quantization of the hologram, as well as for the case of an unfocused image. The results obtained may be used in radio, acoustic, and seismic holography. The article has 16 illustrations and seven bibliographic entries.

UDC 621.395.44

DIGITAL MODEL OF A COMMUNICATIONS CHANNEL BASED ON A POWER TRANSMISSION LINE

[Abstract of article by Andronov, A. A.]

[Text] This article considers the set of questions involved in the work of a high-frequency communications channel for a power transmission line, especially the basic type of interference in the channel — interference of the corona discharge of the wires. The author constructs a digital model of a high-frequency communications channel for a power transmission line on the basis of the physical mechanism of formation of interference from the corona and experimental data on its statistical characteristics. The article analyzes the question of the adequacy of a digital model and a high-frequency channel. It is shown that results obtained on the digital model correspond to experimental data. The digital model is used to obtain and analyze various statistical characteristics of the channel. The article gives results from investigations which permit a deeper study of the processes taking place in a high-frequency communications channel. The article has five illustrations and 10 bibliographic entries.

UDC 528.9:681.362-506

INVESTIGATION OF THE MUTUAL DEPENDENCE OF MICROPARAMETERS OF THE RELIEF BY THE STATISTICAL MODELING METHOD

[Abstract of article by Lotov, V. N.]

[Text] This article considers the problem of determining the interrelationship of the macroparameters of a surface by statistical modeling. These parameters are the mean local number of horizontals per unit of area, the correlation interval, and the mean quadratic elevation. A normal statistically homogeneous isotropic random surface with a gaussian correlation function of elevations was selected as the mathematical model. The statistical digital model was obtained on the digital computer by two-dimensional sliding summation on a set of normally distributed pseudorandom numbers. The functional relationship between the parameters of the reliefs that were studied was found by multifactor regression analysis. The results can be used to form digital models of real surfaces for topographical maps. The article has one illustration and eight bibliographic entries.

UDC 681.142.6:621.397.2

DISPLAY PROCESSOR FOR DIALOG PROCESSING OF SEMITONE IMAGES

[Abstract of article by Bokshteyn, I. M.]

[Text] The article gives an analysis of the possibilities of constructing a display processor and the general requirements for its structure. The author reviews in detail the primary block of the display processor, the arithmetic unit. The article enumerates the basic operations which must be performed by the "fast" and "slow" parts of this unit and discusses the possibilities of building these blocks. A convenient method of building the device which insures high speed and provides communication between the display processor and the central computer is described. The author considers a device designed to control the work of the display processor and presents certain possibilities for organizing dialog (interaction) between the operator and the processor. The article has 10 illustrations and nine bibliographic entries.

UDC 621.391.24:681.325.650.21:621.391.25

SPECIALIZED MICROPROCESSORS THAT PERFORM FAST CONVERSIONS

[Abstract of article by Rakoshits, V. S., Kozlov, A. V., Mozhayev, I. A., and Belyayev, A. A.]

[Text] This article analyzes diagrams of fast conversions and the architecture for constructing specialized microprocessors that perform fast conversions. It is shown that where the fast conversion is accomplished on a general-purpose microprocessor there is a scheme of fast conversion that makes it possible to reduce the necessary main memory volume in half. During development of the specialized microprocessor the choice of its architecture depends significantly on the problem to be solved by the microprocessor, especially where it is necessary to search for one or several maximum values of spectrum coefficients. When microprocessors are developed in the form of large integrated circuits, a circular structure is preferable for the microprocessor. The article has seven illustrations and 10 bibliographic entries.

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UDC 681.142.6:621.397.2

DISPLAY PROCESSOR FOR DIALOG PROCESSING OF SEMITONE IMAGES

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[Article by I. M. Bokshteyn from book "Digital Signal Processing and Its Application," edited by L. P. Yaroslavskiy, candidate of technical sciences, USSR Academy of Sciences, Izdatel'stvo "Nauka", 3,850 copies, 223 pages]

[Text] More and more information about the external world is being represented to people today in the form of various types of semitone images. The imperfections of systems for obtaining the images and the desire to extract as much significant information as possible from the image make it necessary to construct systems that provide better visual image quality and better preparation for the purposes of identifying distinctive characteristics and classification. Because the corresponding image processing is most conveniently done by digital methods, most current processing systems are digital systems which contain a central computer and a number of units for input-output and storage of images [1-3].

The ultimate goal of processing semitone images is to represent them in the most convenient form for human study. For this reason any image processing system must include a device that insures high-quality, operational reproduction of results during processing. This device is called the semitone display.

To build a semitone display it is essential to insure storage of the image for the purpose of reproduction. Storage may be done at the analog level (using memory CRT's) or at the digital level (using special digital magnetic disks, LIS [large integrated circuit] digital memory with random access, or LIS shift registers). The storage of images in a digital memory unit permits much better quality in the reproduced image (lower interference levels and greater number of gradations of brightness) than units with CRT memory. Moreover, when the digital memory is correctly organized it is possible to read the image at the speed of television scanning and form a television videosignal by means of a code-analog convertor. In this case a standard television monitor can be used to present the visual image. Therefore, a large majority of the devices for operational reproduction of images are units with digital memory that scan at the speed of television scanning. These are called raster displays. Because of the low reliability and intricacy of digital memory on magnetic disks, the memory units of raster displays are usually based on large integrated circuits.

The necessity of visual evaluation of the results of processing semitone images makes processing in principle a dialog process; the type and parameters of processing must be determined by the operator during the work process itself, as the results of the particular stage of processing (images or their characteristics) are reproduced on the display screen. For this reason, a digital image processing system must include a number of means to insure dialog (operator-machine interaction) oriented to working directly with the image that is reproduced.

Various standard processing algorithms are often used for "serial" homogeneous processing of one type of images (for example aerial photographs); the operator determines the specific algorithms, order of their use, and parameters of their work. Their working time proves quite substantial (tens of minutes) in digital image processing systems built on the basis of general-purpose computers that are not oriented to handling such algorithms. Therefore, it is desirable to design a specialized unit oriented to dialog processing of semitone images. This device, which we call the display processor, should contain a digital memory unit as a basic element; the images stored in memory should be reproduced on the screen of a television monitor. It is essential to insure broad opportunities for operator interaction with the display processor using both conventional and specialized means of interaction and to insure that standard image processing algorithms are run at high speed (from fractions of a second to a few dozen seconds). The flexibility typical of digital image processing systems with a central computer can be maintained by establishing a two-way communications channel between the display processor and the powerful central computer. A communications channel with the computer is also necessary to feed the raw images to the memory of the display processor and output results of processing for the purpose of long-term storage.

The present article is devoted to a description of the structure of a display processor with shift register memory and its individual units.

1. The Structure of the Display Processor

The structural diagram of the display processor (see Figure 1 below) meets the requirements given above for the functions it performs.

A semitone display memory unit on shift registers was selected as the memory device during development of the display processor. This memory unit provides direct storage and reproduction on the television monitoring screen of 256 lines with 512 six-bit readings of image brightness apiece. A two-bit display superposition memory unit was also used. A code coming from this memory unit is logically added to the brightness code, which makes it possible to display service information on the screen in the form of bright white points and lines.

Information was written into memory by line. The buffer memory was used to coordinate the low speed of the central computer that controls the input of raw data with the high speed of the memory unit. The allocation of a line of the

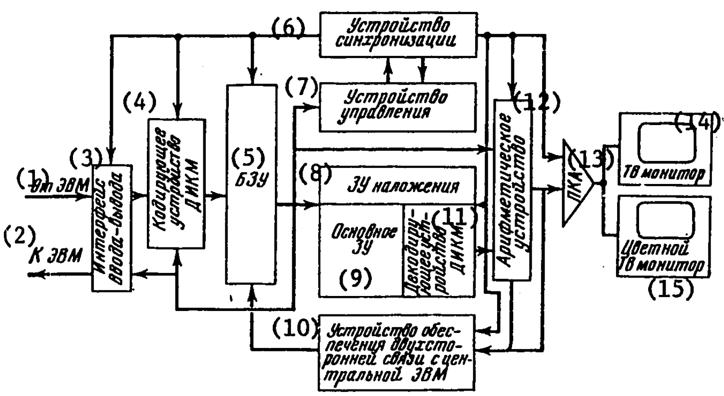

Figure 1. Structural Diagram of the Display Processor

Key:
- (1) From the Computer;
- (2) To the Computer;
- (3) Input-Output Interface;
- (4) DIKM [differential pulse-coded modulation] Encoder;
- (5) Buffer Memory;
- (6) Synchronization Unit;
- (7) Control Unit;
- (8) Superposition Unit;
- (9) Main Memory;
- (10) Unit for Two-Way Communication with Central Computer;
- (11) DIKM Decoder;
- (12) Arithmetic Unit;
- (13) Code-Analog Convertor;
- (14) TV Monitor;
- (15) Color TV Monitor.

image in the memory unit was determined by the coordinates of its initial element received from the computer.

Because of the inadequate speed of existing LIS shift registers built on the basis of MOS technology (up to 10^6 write/read cycles per second), the memory unit used was designed for parallel work by a large number of large integrated circuits. It consists of six independent plates, each of which stores one bit of the code of image brightness. Each plate has the structure shown in Figure 2 below. It contains eight groups of registers working in parallel. They are called sectors and each is designed to store 32 lines of the image. The 16 cyclical shift registers that make up the sectors are connected in parallel to reduce the writing and reading frequency. Breaking the memory unit into sectors makes it possible to write the lines of an image immediately in the necessary sector and to reduce eight-fold (to an average of 1/800 of a second) the waiting time for shifting the necessary cell of the register to the place where writing is possible. To insure that writing is done only in the necessary memory cells, so-called write authorizations are fed to the inputs of the memory together with the data. After 16 sequential values of the data and write authorizations are accumulated, they are fed in parallel to 16 shift registers of all the memory sectors; the choice of a sector is done by a special circuit.

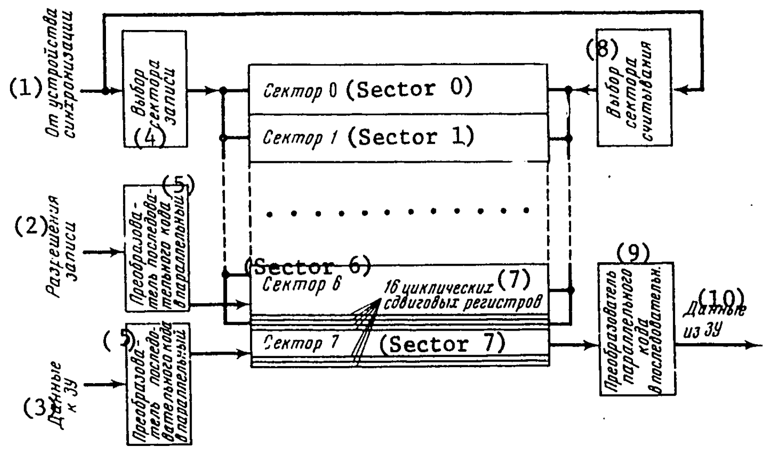

Figure 2. Structure of a Memory Unit Plate

Key:
(1) From Synchronization Unit;
(2) Write Authorization;
(3) Data to Memory Unit;
(4) Selection of Write Sector;
(5) Convertor of Sequential Code to Parallel Code;
(7) 16 Cyclical Shift Registers;
(8) Selection of Read Sector;
(9) Convertor of Parallel Code to Sequential Code;
(10) Data from Memory Unit.

During the process of reading data to reproduce an image on the screen, the memory sectors are chosen in sequence and the brightness values of the 16 elements of the image are read from the shift registers and then reproduced in turn on the screen.

The available volume of the memory unit is inadequate to support efficient work by the display processor with direct storage of brightness readings. For this reason, a system [4, 5] was devised that consists of a coding unit that codes data by line before writing in memory and a decoding unit that restores the values of the videosignal during the process of writing the coding results. The so-called differential pulse-coded modulation (DIKM) technique was used in designing encoding and decoding units; the values of the codes of the error of predicting the value of the video signal by the preceding element of the line, quantized on seven levels, is written into memory. This makes it possible to reduce the memory volume needed to store one image from eight to three bits per reading while maintaining reproduction quality corresponding to 256 gradations of brightness. With the existing six-bit memory unit this makes it possible to store information on two images at the same time, so that they can be processed together. An analog coding system [6] was used to reproduce a color image corresponding to an image with 2^{24} colors (24 bits per reading) in the display processor (with a six-bit memory unit).

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As noted above, the device to insure two-way communication with the central computer is needed to feed the raw image to the display processor and output the results of processing it. Section 2 below describes the realization of this device, which makes effective use of the characteristics of memory structure.

The arithmetic unit of the display processor is designed to perform the basic operations of image processing in real time. Section 3 below gives a possible structure for it.

The control device (see Section 4 below), based on a microprocessor, should serve to coordinate the work of all the units of the display processor and to control the various means of interaction.

2. Realization of Interaction Between the Display Processor and the Central Computer

During development of the display processor it is essential to insure that it has two-way communication with the central computer. Because the speed of the display processor is very great, the time of data exchange with the computer may be a considerable part of total processing time. Therefore, it is desirable to maximize exchange speed.

Intelligent organization of the memory unit being used and the availability of buffer memory (see Section 1 above) produced a situation where the time required to feed a line of the image to the display processor was determined entirely by the speed of the computer, while waiting time for the initiation of feeding a line did not exceed the time required for a complete shift of one sector, that is 1/400 of a second. Unfortunately, reading data from memory during reproduction is done from all sectors in order. For this reason, when the existing read circuit is used directly to output processing results from the display processor the maximum waiting time for initiation of output is 1/50 of a second, that is, equal to the scanning time for all sectors of memory. An attempt to construct a special read circuit oriented to data output significantly increases the volume and complicates the structure of the device to provide communication with the computer.

The use of simulation of writing during reading for outputting data from the memory of the displaced processor makes it possible to greatly simplify the diagram of this device. In fact, if the computer simulates the write regime when it is necessary to read data (of course, blocking off the actual process of writing data), then it will take no more than 1/400 of a second for the write authorization signals corresponding to the possibilities of writing data in the necessary places of the necessary sector of memory and the signal for selection of the necessary write sector to appear at the output of the write circuit. If the signal for selection of the write sector is used as a signal for selection of the read sector and the write authorizations are delayed for the necessary number of cycles, the moments of arrival of the latter will correspond to the moments of appearance of the necessary data at the output of the arithmetic unit and it will be possible to strobe these data.

Figure 3 below shows the simplified structural diagram of the device to output data to the computer with simulation of writing during reading. Data is read in two passages with the help of the buffer memory. At the moment that the process of data output begins the read control circuit is triggered and simulates the write regime for that part of the line that corresponds to the length of the part of the line being read. This circuit blocks the arrival of write authorizations to the input of the memory unit (that is, actual writing) and connects the circuit for selection of the read sector. After a certain time, not greater than 1/400 of a second, the write circuit generates write authorization signals. After delay for a certain number of cycles the signals are used to write the data arriving from the output of the arithmetic unit to the code-analog convertor through an intermediate register in the buffer memory. The writing process continues until the necessary part of the line has been read because the number of pulses of the write authorization corresponds to the length of this part of the line.

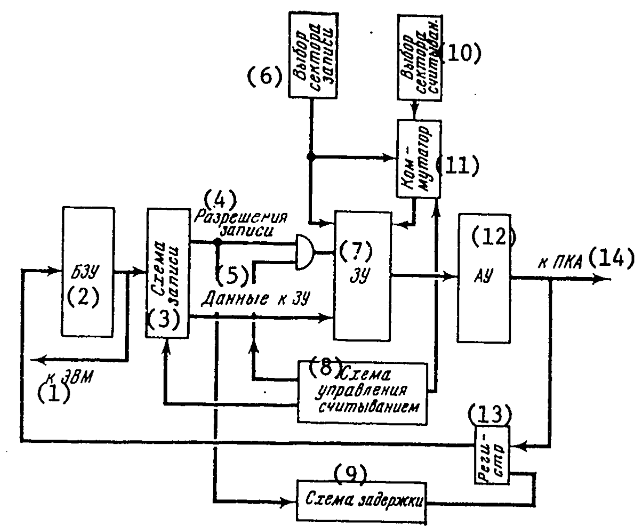

Figure 3. Simplified Structural Diagram of the Unit for Output of Data to the Computer with Simulation of Writing During Reading.

Key:
(1) To Computer;
(2) Buffer Memory;
(3) Write Circuit;
(4) Write Authorizations;
(5) Data to Memory;
(6) Write Sector Selection;
(7) Memory Unit;
(8) Read Control Circuit;
(9) Delay Circuit;
(10) Read Sector Selection;
(11) Commutator;
(12) Arithmetic Unit;
(13) Register;
(14) To Code-Analog Convertor.

After the data is read into buffer memory its output is connected to the input of the central computer, and during the second passage the contents of the buffer memory unit are transmitted asynchronously to the computer. The time of this transmission is determined entirely by the speed of the computer. When outputting of the necessary volume of data is completed, the read regime is cleared and the normal structure of the write circuit is restored.

Realization of this scheme in the delay processor made it possible to insure rapid (0.5 seconds per image) output to the computer of an image obtained by processing or a random segment of it with a very slight (about 20 microcircuits) increase in the volume of available write and read circuits.

3. The Arithmetic Unit of the Display Processor

The operations of image processing which it is wise to accomplish in the display processor can be broken into two groups:

1. Operations that do not require complex or cumbersome computations and the use of memory (point and certain local conversions of one or several images). In order to be able to perform these operations a number of times to select the parameters of conversion and for maximizing the speed of the display processor as a whole, it is natural to perform these operations directly during the process of making the image visible (that is, at the speed of television scanning), writing only the final result of processing in the main memory unit;

2. Operations involving significant computation volume with simultaneous use of information on the brightness of many elements of the image or multiple data shifts (geometric conversion, convolution type conversion, operations of computing the statistical parameters of the image, and the like). The result of the performance of these operations must be written in main memory, superposition memory, or buffer memory. In this case the speed of processor work is less (image processing may take from fractions of a second to several dozen seconds depending on the complexity of the algorithm), but still it is adequate for convenient work.

The processing of images in the display processor should be done in conformity with the breakdown of operations in these two groups by two arithmetic units (see Figure 4 below): a "fast" arithmetic unit that includes a DIKM decoder between the output and the code-analog convertor, and a "slow" arithmetic unit whose input is connected with the fast arithmetic unit through the buffer memory and whose output are connected to the DIKM encoder of the memory unit, the buffer memory, and the superposition memory. Both units can be controlled partially by commands from the control unit and partially by means of special switches, buttons, and keys on the control panel.

The fast arithmetic unit of the display processor is designed to perform the following point and local operations of processing one or two semiton images in the dialog regime:

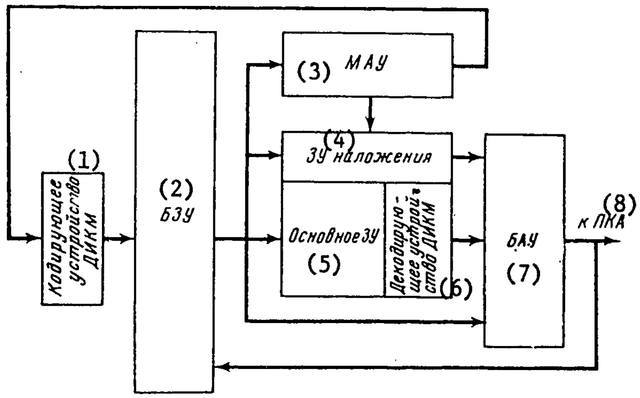

Figure 4. Structure of the Arithmetic Unit and Its Interrelationships with the Memory Units of the Display Processes.

Key: (1) DIKM Encoder;
(2) Buffer Memory;
(3) Slow Arithmetic Unit;
(4) Superposition Memory;
(5) Main Memory;
(6) DIKM Decoder;
(7) Fast Arithmetic Unit;
(8) To Code-Analog Convertor.

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1. Operations of Processing and Individual Image:
   a. Identity conversion
   b. Line-segment conversion of the amplitude of the videosignal, which serves to increase the contrast in different brightness ranges;
   c. Obtaining a negative image;
   d. Identifying levels and zones of a given brightness;
   e. Quantization of the image;
   f. Random-type point conversion;
   g. One-dimensional identification of contours in the image (determination of the estimation of the brightness gradient);
   h. Evaluation of the modulus of the brightness gradient;
   i. Increasing the sharpness of the image by superposing identified contours;

2. Operations of Combined Processing of Two Images:
   a. Addition and subtraction of images;
   b. Logical operations with images;

3. Operations of Processing an Image Obtained as the Result of Joint Processing of Two Images:

   a. Modification of brightness (adding a constant to brightness values);
   b. Masking the image;
   c. Superposing graphic and symbolic information;
   d. "Zeroing" ["obnuleniye"] the bits of the brightness code;
   e. Pseudocoloring of the image;
   f. Increasing the sector of the image for easier review of the image.

Figure 5 below gives a structural diagram of the arithmetic unit. The primary block for processing a single image, whose structural diagram is shown in Figure 6 below, is a memory with variable-length field random access which performs point conversion of the original signal. The number of cells of the variable-length field is equal to the number of possible code combinations (256), while the size of a cell is the length of a code combination (eight bit positions). The video

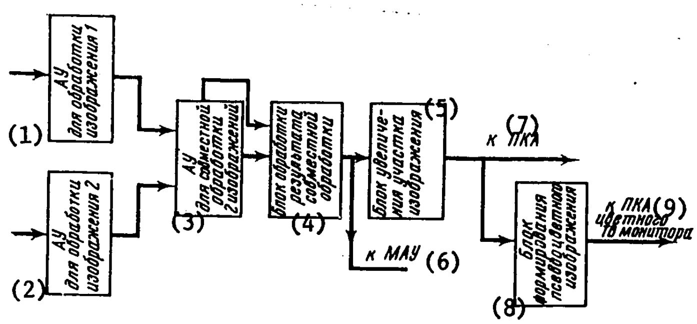

Figure 5. Structure of the Fast Arithmetic Unit

Key:
(1) Arithmetic Unit for Processing Image 1;
(2) Arithmetic Unit for Processing Image 2;
(3) Arithmetic Unit for Joint Processing of Two Images;
(4) Block for Processing the Results of Joint Processing;
(5) Block for Enlarging a Sector of the Image;
(6) To Slow Arithmetic Unit;
(7) To Code-Analog Convertor;
(8) Block for Shaping Pseudocolor Image;
(9) To Code-Analog Convertor of Color TV Monitor.

signal code arriving from the decoder is used as the address of the variable-length field, and the contents of the corresponding cell of the field goes to the output. In this case the form of the conversion characteristic (the dependence of the output code on the input code) is determined entirely by the contents of the cells of the variable-length field, and performance of the necessary operation involves filling the field with definite numbers.

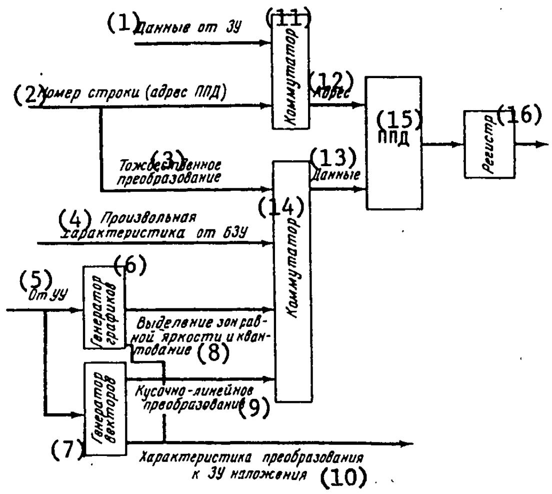

Figure 6. Block for Processing a Single Image

Key:
- (1) Data from Memory;
- (2) Number of Line (Address of Variable-Length Field);
- (3) Identity Conversion;
- (4) Random Characteristics from Buffer Memory;
- (5) From Control Unit;
- (6) Graphics Generator;
- (7) Vector Generator;
- (8) Identification of Zones of Equal Brightness and Quantization;
- (9) Line-Segment Conversion;
- (10) Characteristic of Conversion to Superposition Memory;
- (11) Commutator;
- (12) Address;
- (13) Data;
- (14) Commutator;
- (15) Variable-Length Field;
- (16) Register.

In the digital image processing systems that exist today [7], the process of filling the variable-length field of the display processor usually amounts to writing information in each cell in turn using a control program. This makes it necessary to construct a special program to fill the variable-length field for each operation and causes considerable computational hardships. It is much more convenient to use "standard" conversion characteristics, which correspond to operations "la— le" and special characteristic generators for recording.

To record data in a variable-length field it is convenient to use the numbers of the current scanning line which change in order from 0 to 255 as addresses. In this case the characteristic generators should be synchronized with the scanning generator. It will take 1/50 of a second to fill the variable-length field by this procedure. Construction of the characteristic of identity conversion involves using the line numbers both as addresses of the variable-length field and as stored codes.

The line segment conversion generator has the most complex structure. It constructs the conversion characteristic by the coordinates of its breaking-off points. It is convenient to use a vector generator to build this generator. The vector generator, which uses the given coordinates of the beginning and end of the vector to determine the values of the coordinates of the points of its intersection with each of the intermediate lines, is necessary to reproduce graphic information in any case. When the coordinates of two neighboring breaking-off points are given and the line numbers are used as variable-length field addresses, the numbers produced by the vector generator are the coordinates of the points of the corresponding segment of the conversion characteristic. At the same time as it records the characteristic in the variable-length field it can be reproduced on the screen, which makes visual monitoring of the process easier.

Obtaining a negative image, identifying levels and zones of a given brightness, and quantization of the image can be done in principle by the line-segment characteristic generator; but it is wiser to use the graphics generator included in the display processor set in the last two cases.

To give the fast arithmetic unit working flexibility it is essential to provide for the possibility of recording a random conversion characteristic from the buffer memory in the variable-length field. This possibility is essential, for example, for gamma-correction or equalization [8] of the image (in the latter case buffer memory should contain quantities proportional to the values of the stored histogram of brightness distribution).

The type of point conversion is selected by switching the appropriate conversion characteristic generator or buffer memory to the input of the variable-length field.

Because the display processor's memory unit stores the quantized values of errors of prediction based on the preceding element, that is, the differences of adjacent elements of the reproduced image, it is easy to perform local by-line image conversions. Thus, for one-dimensional identification of contours it is sufficient to feed to the output of the fast arithmetic unit the values of prediction errors reconstructed in the decoding process, and not the signal from the output of the decoding unit. The use of a variable-field length field makes it possible to determine, and when necessary quantize, the value of the modulus of prediction error (estimation of the modulus of the brightness gradient). The gradient image can be superposed on the initial image by feeding the signal from the output of the memory unit simultaneously to the inputs of both decoding units, determining the gradient values, multiplying the gradient by the desired coefficient in the block for processing the corresponding image of the fast arithmetic unit, and adding the result to the initial image by means of the joint image processing block.

The primary block for joint processing of images is an arithmetic-logical unit that performs a number of arithmetic and logical operations such as addition, subtraction, logical addition, and multiplication of images (see Figure 7 below).

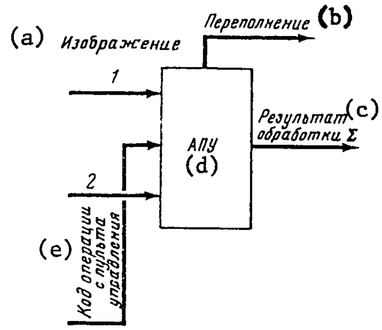

Figure 7. Block for Joint Processing of Images

Key: (a) Image;
(b) Overflow;
(c) Result of Processing Σ;
(d) Arithmetic-Logical Unit;
(e) Op Code from Control Console.

The operation is selected by a four-bit code coming from the control console of the display processor. Signals from the output of the block goes to the input of the block for processing the result of joint processing; information on the occurrence of an overflow during addition or subtraction of the successive elements of the image in the arithmetic-logical unit is also sent to this input.

The blocks for processing images obtained as the result of joint processing must provide for modification of the brightness of the image, that is, adding a constant to its value, masking the image, superposing alphabetic-symbolic and graphic information on it, and zeroing the bits of the image code. Figure 8 below shows a structural diagram of the block. The basic element of the block is the arithmetic-logical unit, which is analogous to the arithmetic-logical unit of the block for joint image processing. A signal from the output of the joint processing block goes to one group of inputs of the arithmetic-logical units, while the code of the constant, modified from the control console, or one of the signals of the superposition memory unit goes to the other group of inputs. After the work of the arithmetic-logical unit an algebraic or logical sum of the image and constant or the logical function of the image and signal of the superposition memory occurs at its output; in other words, the brightness is modified or the image is masked. The result of the work of the arithmetic-logical unit goes to the "truncation" circuit, which is essential to eliminate

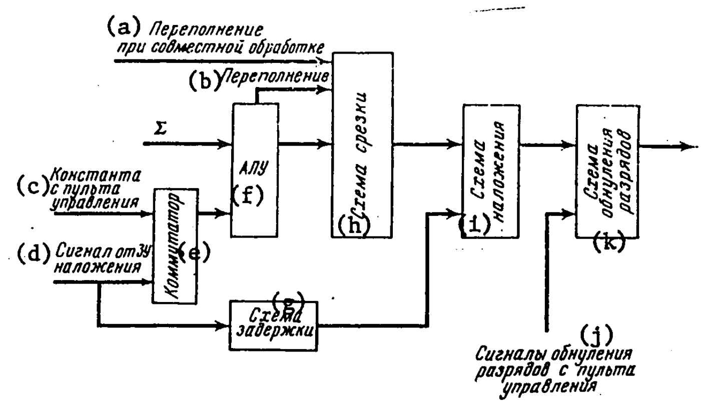

Figure 8. Block for Processing Images Obtained as the Result of Joint Processing

Key:
(a) Overflow During Joint Processing;
(b) Overflow;
(c) Constant from Control Console;
(d) Signal from Superposition Memory;
(e) Commutator;
(f) Arithmetic-Logical Unit;
(g) Delay Circuit;
(h) Truncation Circuit;
(i) Superposition Circuit;
(j) Signals for Zeroing Bits from Control Console;
(k) Bit Zeroing Circuit.

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overflows. Where there is no overflow this circuit leaves the code of the video signal unchanged, but when an overflow occurs above or below it replaces this code with code 255 (which corresponds to maximum brightness) or code 0. The truncation circuit is controlled by overflow signals that come from both arithmetic-logical units. If logical operations are being performed in the arithmetic-logical unit, the truncation circuit is locked out.

The signal from the output of the truncation circuit is logically added to the signal from the superposition memory which is delayed for several cycles to compensate for delay in the fast arithmetic unit. This allows superimposing graphic or symbolic information on the image. The result of logical addition is fed to the bit zeroing circuit and logically multiplied by the masking code, which is determined by the state of the keys on the control console. This makes it possible to perform the operation known as "slicing," a conversion of the image that involves zeroing the bits of the video signal code, and also, when necessary, permits suppression of reproduction of the contents of the superposition memory.

The code of the video signal corresponding to the image processed goes from the bit zeroing circuit through the block to enlarge the image sector to the code-analog convertor and then through the integrated emitter follower to the input of the television monitor for reproduction of the image on the screen. The five higher-order bits of the code of the video signal are also fed to the input of the block for forming a pseudocolor image.

The block for forming a pseudocolor image is a code convertor which juxtaposes three eight-bit codes that determine the appropriate pseudocolor to each of the 32 possible brightness values. In all the systems existing today reproduction of the pseudocolors is accomplished either by directly forming two-level color signals depending on the state of three higher-order bits of the brightness code or by using a memory unit with random access to a large memory volume, in which the user is allowed to enter the codes of the pseudocolors [7]. The first method allows only eight fixed pseudocolors, which is often not enough; the second method involve some uncertainty in the selection of pseudocolors. Therefore, it is desirable to optimize the set of pseudocolors used by their mutual arrangement in color space (maximize the distances between pseudocolors) and use a diode logical matrix to form the corresponding code.

Realization of a real-time block to enlarge the image sector requires a fairly large additional memory unit, because only sequential access is possible to the data coming from the main memory built on shift registers (random access to the memory is also impossible because it stores the codes of prediction errors, not brightness codes). It is usually desirable to use a considerable enlargement of the sectors of the image for studying its details, and enlargement of a part of the image by factors of 9, 17, and 33 can be accomplished with a supplementary unit with a volume of 256 eight-bit cells. For 33-fold enlargement the first line of the fragment (15 elements) is first written into supplementary memory, and then each of its elements is reproduced 33 times during the scanning of one line and this process is repeated for 33 lines. Access to the second line of the fragment becomes possible during this time (Section 1 above); it is written into supplementary memory and reproduced like the previous one. The elements of the third and subsequent lines of the fragment are reproduced in a similar fashion. For 17-fold enlargement it is necessary to store two lines of the fragment of 31 elements apiece in the supplementary memory units and reproduce them in order, while for nine-fold enlargement four lines of 63 elements apiece must be stored (which requires the use of 252 memory cells).

The "slow" arithmetic unit. The set of operations performed by the slow arithmetic unit may be very broad in conformity with the multiplicity of concrete requirements for image processing jobs. The availability of communication between the display processor and the powerful central computer makes it possible to limit this set to the most frequently used operations, which are the following:

1. line processing operations (reading a line of the image, processing it, and writing the results);

2. fragment processing operations (when they are performed the fragment of the image is read, processed, and the results obtained are recorded);

3. operations of shifting the image or part of it from one place in memory to another;

4. geometric conversions of the image:

   a. shifting the image upward, downward, or to the left or right;
   b. compensation for "cutting off" the image in the line direction;
   c. transposition of the image;
   d. turning the image to an assigned angle;
   e. arbitrary alteration of the scale of the image;

5. calculation of the statistical parameters of the image:

   a. determination of the average brightness of a sector of the image;
   b. constructing a histogram of the distribution of brightness;
   c. constructing a stored histogram;
   d. calculating local average values and the local dispersion of brightness for each fragment of the image;

6. constructing a profile of the brightness of the image:

   a. along the line;
   b. along a random line;

7. calculating the number of elements of a random sector of the image;

8. determining and individualizing the local brightness value;

9. shaping standard images;

10. synthesizing graphs, vectors, and symbols.

Figure 9 below shows a structural diagram of the slow arithmetic unit. The basic element of the unit is the microprocessor. It must be fast enough to provide acceptable image processing time, for example a unit such as the INTEL-3000, whose cycle time is 100 nanoseconds. The slow arithmetic unit must be connected to a large buffer memory; the slow arithmetic unit must also include a number of devices to perform concrete processing operations.

The two principal working modes of the slow arithmetic unit are the line and fragment processing modes. With these two types of processing it is easily possible to perform fairly complex nonlocal image conversions, various fragment conversions, computation of local image parameters, and certain geometric conversions. In the line processing mode the next line of the image is read into buffer memory on a command from the control unit and processed there by means of the microprocessor. When necessary the result of processing is written into main memory through the DIKM encoder. If the result of processing is a set of image characteristics, when necessary they are written into superposition memory by graphics, vector, or symbol generators and reproduced on the screen.

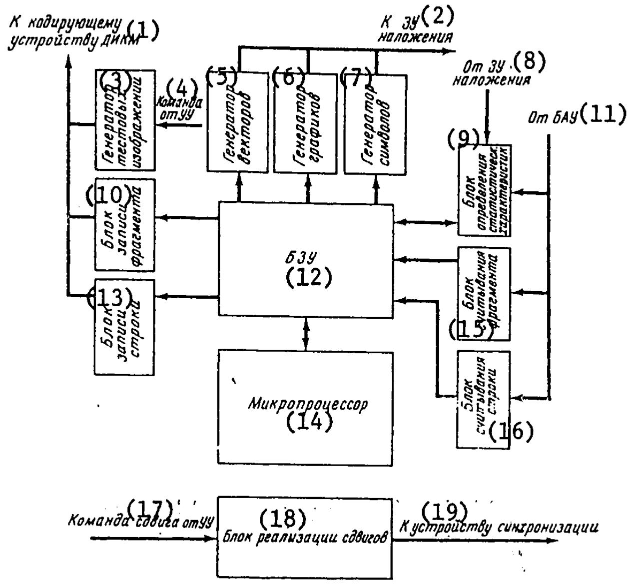

Figure 9. Structure of the Slow Arithmetic Unit

Key:
(1) To DIKM Encoder;
(2) To Superposition Memory;
(3) Test Image Generator;
(4) Command from Memory;
(5) Vector Generator;
(6) Graphics Generator;
(7) Symbol Generator;
(8) From Superposition Memory;
(9) Block for Determining Statistical Characteristics;
(10) Block for Writing Fragments;
(11) From Fast Arithmetic Unit;
(12) Buffer Memory;
(13) Block for Writing a Line;
(14) Microprocessor;
(15) Block for Reading a Fragment;
(16) Block for Reading a Line;
(17) Shift Command from Control Unit;
(18) Block to Realize Shift;
(19) To Synchronization Unit.

Fragment processing is done in a similar manner. Several sectors of the lines that make up the fragment are read into buffer memory in order. The sequential nature of the process of reading line sectors causes only a slight decrease in speed compared to the line processing mode because in both cases one need not wait for a read opportunity more than once for processing the next line or fragment.

Because main memory contains the codes of prediction errors for the image, not brightness value, the processing and recopying of the entire fragment with changed brightness values for its points may lead to sharp distortion of the fragments adjacent to it on the right because the codes of predicted errors for them remain unchanged and decoding is done in sequence for all the points of the line of the image. Therefore, images should be processed by fragments that have a common domain, which somewhat increases processing time.

Lines and fragments are read from main memory by the line and fragment read blocks, while the results are written by the corresponding write blocks. Line reading is done by the same circuit that realizes the first stage of the process of outputting data to the central computer (see Section 2 above). In connection with the need to encode processing results located in the buffer memory, they are written into main memory in two passes of buffer memory. First the output of the buffer memory is connected to the input of the DIKM encoder and the output of this device is connected to the input of buffer memory; then data writing is simulated. The work of the encoder causes the code of the prediction errors corresponding to the brightness values of line elements located in it earlier to be recopied into buffer memory. During the second pass of buffer memory the codes contained in it are recopied into the necessary places in main memory.

Fragments are read and written by similar circuits that read or write the necessary number of line sectors in sequence. The necessity of two passes of buffer memory when writing each line of the fragment has no effect on writing time because there is always a sufficient time interval between completion of writing the present line sector in memory and receiving the opportunity to write a sector of the next line.

It is easy to shift an image from one part of main memory to another or to move any fragment of the image by using line and fragment processing operations. Access to either of the two images stored in memory is provided by introduction of a special command to switch the blocks of the memory unit.

Processing operations can be used for geometric conversions of images. Thus, line processing can be used to compensate for "cutting off" an image, and fragment processing can be used to transpose the image, that is, to turn it on the diagonal. By combining compensation for "cutting off" with transposition, it is possible to turn the image to any angle [9].

The use of processing operations makes it possible to enlarge an arbitrary sector of the image by the necessary factor and to shift the image in any direction. In a display processor with shift register memory, however, it is much more natural to do shifts using a special block. To shift the image to the right, for example, it is sufficient to allow several pulses that trigger the shift registers to pass, and to shift to the left one need only form a few additional pulses. The image can be shifted up or down in a similar fashion. Some problems with shifts occur because the main memory is not one, but eight independent shift registers; these difficulties can be overcome by using a circuit that determines which register corresponds to the present element after performing the shift. Because the data from the registers are read in groups of 16 numbers, it is essential to perform a shift along the line within a group by delaying the synchronized pulses that control reading elements of the group from an auxiliary memory register.

The shift block affects only the synchronization unit of the display processor; therefore, it is a separate block which has no connection with the other blocks of the slow arithmetic unit. The work of the block is controlled by commands from the control unit. It is possible to shift either of the two images independently of the other.

The slow arithmetic unit should provide for performing a series of statistical analysis operations on images. Because some of these operations such as construction of a histogram of brightness distribution and determination of the average brightness value for the given sector of the image, are very commonly used in image processing, it makes sense to do these operations by a special block that works at maximum speed.

The sector of the image that is used to calculate statistical parameters may be of fairly random form. For this reason, the only realistic way to assign such a sector is to construct its contour directly in the superposition memory by means of a light pen, courser, or other means of interaction (dialog). Because the memory unit of the display processor has fairly high reliability, it is possible to use the intersection of the contour constructed during the process of scanning the superposition memory as a sign that subsequent elements of the image (until the next intersection of the contour) belong to the sector under study.

Figure 10 gives the structural diagrams of the sub-blocks for computing average brightness value and calculating the histogram of brightness distribution. Simultaneously with computation of the average brightness value, in the time between intersections of the left and right boundaries of the image sector the brightnesses are added and the number of elements of the image is counted. When scanning of the sector is complete, the ratio of the quantities obtained is computed by the microprocessor of the slow arithmetic unit; in other words, the average brightness value is determined. When necessary it is possible to use the number of elements of the sector as a measure of its area.

To construct a histogram of brightness distribution the 512 cells of the buffer memory are combined by pairs and set at zero; data from the output of the buffer memory is fed to its input through the summator, which adds one to the stored values. In the process of scanning the sector the brightness value of the next element serves as the address for a pair of buffer memory cells and its content is increased by one. Upon completion of the scanning, cells 2i and 2i+1 of buffer memory contain a number equal to the number of elements with a brightness of i. The quantities obtained are then used further by the microprocessor of the slow arithmetic unit.

The calculation of local average values and dispersion, and calculations of local brightness values for quadratic fragments of the image, may be done in the processing mode for fragments of the necessary size.

It is desirable to use the slow arithmetic unit also for determining the brightness characteristics of the image, above all the distribution of brightness along a line or random curve. In the first case the line processing mode can be used; in the second it is possible to assign an appropriate curve in the superposition memory by means of, for example, light pen and to read the brightness values of the elements of the image into buffer memory when one appears at the output of the superposition memory.

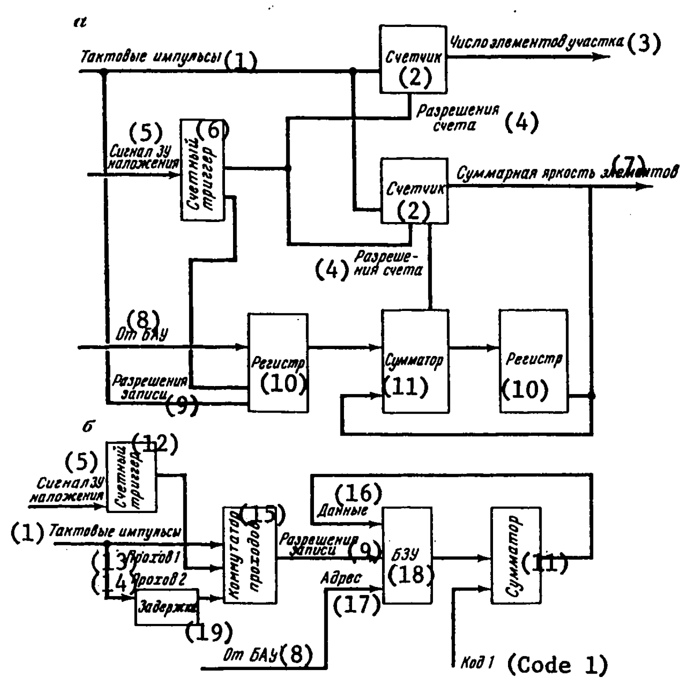

Figure 10. Block for Determining the Statistical Characteristics of the Image: (a) Computation of the Average Brightness Value; (b) Calculation of the Histogram of Distribution of Brightness.

Key:
(1) Cycle Pulses;
(2) Counter;
(3) Number of Elements of the Sector;
(4) Read Authorization;
(5) Signal of Superposition Memory;
(6) Calculator Trigger;
(7) Total Brightness of Elements;
(8) From Fast Arithmetic Unit;
(9) Write Authorization;
(10) Register;
(11) Summator;
(12) Calculator Trigger;
(13) Task 1;
(14) Task 2;
(15) Task Commutator;
(16) Data;
(17) Address;
(18) Fast Arithmetic Unit;
(19) Delay.

To insure effective display of the results of the work of the slow arithmetic unit, it should include devices to present graphic and symbolic information in visual form: vector, graphics, and symbol generators. It is possibl to obtain additional possibilities of work with images in the display proce sor by envisioning the possibility of setting up test images using the slow arithmetic unit, for example an even background, an optical wedge, and the like.

4. Device To Control the Display Processor and Means of Interaction

Because the display processor is an autonomous unit, it should include a control unit that provides coordination and selection of the work regime of the arithmetic units, control of data exchange with the central computer, and efficient work by available means of interaction.

Since the arithmetic unit of the display processor includes two blocks with significant functional differences, the fast and slow arithmetic units, the control unit should also consist of two blocks. The first, which controls the work of most of the elements of the fast arithmetic unit, is a control panel with keys and buttons that directly affect the circuit of the fast arithmetic unit (for example, pressing the key to set a bit position at zero triggers the corresponding element of the bit zeroing circuit). The nature of the operation being performed is displayed on a light diode panel and changes when the next button or key is pressed. The presence of the control panel makes it possible to change operations quickly, lessens requirements for special operator training, and increases the speed of interaction.

The second block of the control unit controls the work of several elements of the fast arithmetic unit (for example, filling the variable-length field) and the work of the slow arithmetic unit. It is also used to organize interaction with the central computer. This block is based on a microprocessor (the same one used in the work of the slow arithmetic unit). A number of devices designed for control and support of interaction must be connected to the input of the microprocessor. The image processing operation may be selected by briefly typing the name of the appropriate operation on the alphanumeric keyboard. The most frequently used processing program can be called up by pressing a certain button on the functional keyboard.

The display processor should have several specialized devices to support the interactive mode of work by the slow arithmetic unit. Specifically, these are a set of buttons queried by the microprocessor, a lever (joystick), and a light pen. The set of buttons, whose state is known to the microprocessor at every moment, and the joystick may be used to shift various specialized markers on the screen: a courser, a horizontal line, a figure of a certain shape, and so on. The light pen, which generates the coordinates of the point on the image close to it when it is held up to the screen, may be used to identify the sector of the image being processed and to construct the graphics necessary for further processing.

When constructing the display processor, an effort should be made to maximize the use of special means of interaction because this makes the work more convenient and reduces time expenditures for interaction, which are a significant part of total time expenditures for image processing because of the high speed of the processor.

FOOTNOTES

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11,176
CSO: 1863/189

UDC 621.391.23:681.325.650.21:621.391.25

SPECIALIZED MICROPROCESSORS THAT PERFORM FAST CONVERSIONS

Moscow TSIFROVAYA OBRABOTKA SIGNALOV I YEYE PRIMENENIYE in Russian 1981 (signed to press 28 Jan 81) pp 206-217

[Article by V. S. Rakoshits, A. V. Kozlov, I. A. Mozhayev, and A. A. Belyayev from the book "Digital Signal Processing and Its Application," USSR Academy of Sciences, Izdatel'stvo "Nauka", 3,850 copies, 223 pages]

[Excerpts] The possible range of applications of orthogonal systems of discrete functions is steadily broadening [1-6]. The Walsh functions [7, 8], which have found greatest application in recent times, play a special role among them. The Walsh functions stand out among other orthogonal discrete systems of functions by their simplicity of generation [9, 10] and the simplicity of practical realization of spectrum analysis in them. It is very important that conversions in the Walsh base can be done on the basis of fast algorithms [1, 5, 6, 8, 10] that permit a significant reduction in the number of operations necessary to compute expansion coefficients.

There are many possible diagrams of fast conversions and, therefore, many possible alternatives for constructing specialized microprocessors that realize these conversions in a Walsh base. This article analyzes the sequential, parallel, and sequential-parallel versions of constructing such microprocessors. This makes it possible, within the framework of existing constraints on the complexity and speed of hardware, to select the necessary structure for designing microprocessors. Because the applications (noise-resistant encoding, digital filtration, synchronization, and the like) quite often require a search for one or several maximum coefficients upon completion of spectrum analysis in the base selected, the article also analyzes devices that seek the maximum. The hardware that realizes this device is usually dependent on the diagram of conversion chosen and the structure of the microprocessor that carries out this diagram.

Comparative analysis of the algorithms of the microprocessors and devices that seek the maximum. As can be seen from the above analysis, selection of the type of diagram for fast conversion significantly influences the structure and principle of design of the specialized microprocessor. In general, the convenience of using the particular schemes differs for a general-purpose microprocessor with address-type main memory. In this case it is obviously preferable to select schemes that correspond to factorization of types (5) and (8). This conclusion follows from the fact that the results of processing at each step (outputs of the summators) can be written in the same addresses of main memory from which data were sent to the summators, and in this case main memory needs to be only half as large.

In Figure 7 below for cases where V_1 = 10 gates, V_2 = 16 gates, and V_3 = 2 gates, fine lines show the dependences of V(N) (the dotted lines show k = 3 and the solid lines k = 4) of the logical complexity of the device to search for the maximum coefficient at the output of the microprocessor on the length of the vector N which is being processed. As the graphs show, to process information by blocks

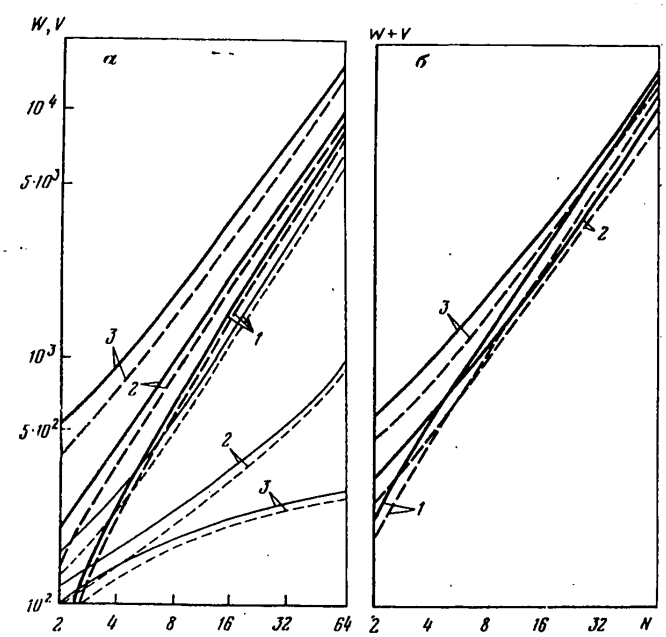

Figure 7

(dependences 2 and 3), the device to seek the maximum coefficient is much simpler than for the case of seeking the maximum when processing in real time (dependence 1). But expenditures for block data processing (computation of spectrum coefficients) are larger in this case.

Figure 7 shows the dependences W(N) + V(N) of the logical complexity of micro-processors together with the devices to seek maximum coefficients. As the graphs show, where N is equal to or greater than eight, the microprocessor that performs parallel crossing of information blocks (dependents 2) has the smallest number of gates. However, this alternative does not allow building up the capacity of the device to process large N by interconnecting identical microprocessors. For this purpose the sequential processing version is more convenient. This convenience is especially notable when developing the base large integrated circuit for microprocessors with a broad range of N and k. Such a large integrated circuit must contain a register main memory and two summators. In this case constructing a specialized microprocessor of any capacity that performs the fast Walsh conversion is possible in the form of a set of uniform base large integrated circuits with fairly simple control.

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PUBLICATIONS

ABSTRACTS FROM THE JOURNAL 'TECHNICAL CYBERNETICS' MARCH-APRIL 1981

Moscow IZVESTIYA AKADEMII NAUK SSSR: TEKHNICHESKAYA KIBERNETIKA in Russian No 2, Mar-Apr 81 pp 233-239

UDC 62-506:548-5

SOME STOCHASTIC TASKS OF OPTIMUM CONTROL WITH LIMITED PHASE COORDINATES

[Abstract of article by Kolosov, G. Ye.]

[Text] Examples are presented for solving some model tasks in the synthesis of stochastic optimum systems while taking into consideration limitations on control and phase coordinates. In cases where an exact solution cannot be obtained, an approximate method is used.

UDC 681.322.06:51

ASYMPTOTICALLY OPTIMUM ALGORITHM FOR SOLVING A GENERALIZED PROBLEM IN THE CONNECTION OF CITIES

[Abstract of article by Yudin, A. D.]

[Text] The article examines a multi-index model of the transport type, of interest in planning various communication networks. An approximate method of solution is presented for that model, which is an extremal combinatory problem, and it is demonstrated that the method works better, on the average, the higher the dimensionality of the problem. Examined as an example is the problem of approximate construction of a combined distribution function of a multi-dimensional random value on limited statistical material.

UDC 62-50

INTERACTIVE SEARCH FOR THE EXTREMUM OF A FUNCTION WITH AN UNDETERMINED GRADIENT

[Abstract of article by Rabinovich, Ya. I.]

[Text] Within the framework of a guaranteed approach the task of optimizing a function, the gradient of which is imprecisely calculated, is examined; this is especially characteristic of procedures of extremum search in a man-machine interaction mode. Determination of the best possible direction, guaranteeing a maximum increment of the function, is reduced to search for a minimum of convex quadratic form at the intersection of the positive ortant with the hyperplane. For the particular case of practical interest the best guaranteeing direction was found analytically.

UDC 62-50

TASKS IN RESOURCE DISTRIBUTION ON MIXED SCALES

[Abstract of article by Larin, V. Ya.]

[Text] The article examines tasks in resource distribution in the case where a portion of the information used for selection of the best plan is quantitative an a portion is given on ordinal scales. Under certain assumptions such resource distribution tasks are reduced to a certain class of tasks of mathematical programming. An algorithm for solving the latter for the linear case is given.

UDC 62-50

SOME QUESTIONS OF THE THEORY OF THE L-PROBLEM OF MOMENTS

[Abstract of article by Ringo, N. I.]

[Text] The article examines some questions regarding the theory of the L-problem of moments for asymmetric limitations and limitations of the simplex type. A theorem of the number of switchings of solution of the problem of moments with complex limitation is demonstrated which permits analyzing the solution of a certain class of problems of control and in a number of cases reduces the task of search for optimum ordering to the task on the conditional extremum of a function of many variables. An epsilon-solution of the task of moments is constructed which guarantees as small an error as desired.

UDC 549.283

OPTIMUM INTERACTION OF TWO PURSUERS IN A GAME PROBLEM

[Abstract of article by Milikyan, A. A.]

[Text] The article examines the task of simple pursuit by two points with equal velocities of a third point with a lower velocity. A game price is constructed in the task of pursuit from a nominal point and the region in which the presence of two pursuers is essential is designated. On the assumption that the pursuing points can move only during one time interval of a given length (for example, as a result of resource limitedness), an investigation was made of the possibility of the evading point to intersect the segment connecting the pursuers at the initial moment and evading capture.

UDC 62-50:531.3

PLANNING THE OPERATIONS OF AN INTEGRATED ROBOT

[Abstract of article by Yerokhin, Ye. A., and Sudeykin, M. I.]

[Text] In the control system of an integrated robot an important place is occupied by the decision-making system, which provides planning of its activity. The developed system for planning operations of an integrated robot (SPRINT) represents a symbiosis of three models of search, memory and training, the interaction of which assures the accumulation and use of knowledge in decision-making. The formal description of SPRINT is based on complex use of methods of semiotic simulation and methods of heuristic search. The representation of information in SPRINT is based on a developed pseudo-physical language of a relational type. SPRINT has been realized in the form of a package of programs and has been experimentally used in a number of tasks of the robot "world."

UDC 62-50

THE TASK OF EVADING MANY PURSUERS WITH CONTROLLED VELOCITY

[Abstract of article by Zak, V. L.]

[Text] Control is constructed which assures evasion of an arbitrary number of pursuers. The evading object remains in the close vicinity of the assigned trajectory. An estimate of the distance between the evaders and pursuers, calculated from the initial data, was obtained.

UDC 62.51:612.014.42:331.015.1

EXPERIMENTAL DATA ON USE OF A PEDAL ANALYZER IN BIOTECHNICAL CONTROL SYSTEMS

[Abstract of article by Yaroshenko, A. A.]

[Text] The article examines a space-time method of forming input sensory signals which permits causing a tactile sensation of motion in an operator. The article presents results of investigations of boundary conditions of the caused rate of motion, the resolution of the sensory system and also the operator's performance of the control task of return of the system to a prescribed state, determined by the range of the reference velocity. It is concluded that it is advisable to use the investigated method to solve control tasks where it is necessary to simultaneously transmit to the operator information about two variables of the state of the system.

UDC 531:62-5

PRINCIPLE OF NONDETERMINISTIC CONTROL OF A WALKING ROBOT

[Abstract of article by Pyatkin, V. P.]

[Text] The article examines the states and problems of an original approach to the process of control of a walking automaton, the principle of nondeterministic control, which provides a walking robot with a breadth of tactics in the selection of a gait within the framework of the limitations natural for the given design.

UDC 519.283

OPTIMUM CONTROL OF A MULTI-STORY QUEUEING SYSTEM

[Abstract of article by Dubin, A. N.]

[Text] The article examines the task of selecting the optimum strategy for designating the rate of servicing requirements in a multi-velocity unilinear queueing system. For the class of multi-threshold strategies, recurrent formulas are presented for determining the stationary probabilities of the number of requirements in the queue and the type of generating function of those probabilities and the queue length is indicated. A numerical example is presented.

UDC 62-50:519.95

TWO-STAGE SUCCESSIVE SELECTION IN A SYSTEM OF RELATIONS. I. POLYNOMIAL COMPLETENESS OF THE TASK

[Abstract of an article by Sholomov, L. A.]

[Text] The article examines a method of multi-stage successive selection in which each stage is realized on the basis of some relation reflecting a certain group of preferences. The task consists in constructing in accordance with a given (observed) set a system of relations realizing it or establishing that it cannot be done. It is demonstrated that even during two-stage selection the task of synthesis belongs in the class of very complex combinatory problems.

UDC 519.2

RELIABILITY OF A PERIODICALLY CONTROLLED SYSTEM WITH PREVENTIVE MAINTENANCE

[Abstract of article by Titenko, I. M.]

[Text] The author solves the problem of constructing a reliability model used in the continuous regime of a system, failures of which can be detected only during monitoring or preventive maintenance. The model is constructed without any substantial limitation on the properties of control or on the characteristics of no-failure operation and maintainability of the system. The use in the work of the concept of a monitoring error of the third kind made possible use of the constructed model also under other possible assumptions.

UDC 519.2

SELECTION OF OPTIMUM SWITCHING MOMENTS IN QUEUEING SYSTEMS

[Abstract of article by Pechinkin, V. V.]

[Text] The author examines the task of selecting the switching moments of the working conditions of Markov queueing systems in the presence of limitations on the total number of switchings. An example is presented.

UDC 62-50

METHODS OF APPROXIMATELY SOLVING TASKS OF DYNAMIC REDUNDANCY

[Abstract of article by Ushakin, I. A.]

[Text] The author gives a classification of very simple tasks of dynamic redundancy. Approximate solution algorithms are proposed. In some particular cases a solution is successfully obtained in simple form.

UDC 519.2

INCREASE OF THE EFFECTIVENESS OF CONFIDENCE ESTIMATION OF SYSTEM RELIABILITY

[Abstract of article by Groysbert, L. B.]

[Text] The author compares the efficiency of the heuristic method and the plane and substitution methods for confidence estimation of the indicator of system reliability from data obtained in tests of its elements. The advantage of the heuristic method for structural reliability circuits of the series type is shown. The conditions were formulated, by types of structural reliability circuits and the results of tests of elements, for preferential application of the plane and substitution methods. To enhance the efficiency of the interval reliability estimation of redundant systems a combined method of confidence estimation is proposed, one constructed on joint use of the procedures of the heuristic and substitution methods. Recommendations are given on selection of the most effective method of estimating as a function of the results of tests of elements and the type of structural reliability circuit system.

UDC 681.142.2

PLANNING PARALLEL COMPUTATIONS IN A REAL-TIME MULTIPROCESSOR SYSTEM

[Abstract of article by Vayradyan, A. S., Korovin, A. V., and Udalov, V. N.]

[Text] The article proposes a complex of algorithms of various comple ity, intended for organization of the processing of information-dependent ta ks in multiprocessor control computer systems of different capacity. Estimates of the quality of the obtained decisions, the labor-intensiveness and the efficiency of the algorithms are presented. The article contains the results of experimental investigations, obtained for arbitrary sets of graph-diagrams.

UDC 007.52

CHARACTERIZATION OF LOGICAL CIRCUITS IN UNCONNECTED BASES

[Abstract of article by Gorbatov, V. A., and Fedorov, N. V.]

[Text] The article examines the task of realizing Boolean functions in specific (unconnected) bases such as Webb, Scheffer and implicative bases, etc. The conditions are formulated for realization of a homogeneous Boolean function of a nonrepetitive dendritic logical circuit. An example is presented.

UDC 62-50

METHOD OF INVESTIGATING COMPLEX LINEAR SYSTEMS

[Abstract of article by Starikov, V. F.]

[Text] The author examines the case of arbitrary disposition in space of external effects of regions of values of an unexcited operator and an operator of excitation which participate in the description of a complex linear system. Necessary and sufficient conditions of existence and unity of the response of the complex linear system to external effect are presented and in the case of existence it was constructed. The article describes "free movements" of complex linear systems--responses during zero external effect, notes the inadequate efficiency of the proposed method for investigation of a single class of distributed systems and presents an example.

UDC 62-50

INDUCED MOTION IN AUTOMATED CONTROL SYSTEMS WITH A VARIABLE STRUCTURE AND MAJORITY COMPONENTS

[Abstract of article by Zhil'tsov, K. K., and Rabinovich, I. I.]

[Text] The article examines the induced motion of automated control systems with majority devices. An analysis is made of some methods of stabilizing systems on the basis of the principle of combined control during simultaneous variation of the parameters of equations of switching hypersurfaces. The use of majority devices assures qualitative work of systems in the absence of discharges of the first kind in the control signal.

UDC 629.13

CONSTRUCTION OF FLIGHT CONTROL ALGORITHMS BASED ON SOLUTION OF INVERSE PROBLEMS OF DYNAMICS. PITCHING

[Abstract of article by Petrov, B. N. (deceased), and Krut'ko, P. D.]

[Text] The article presents a procedure for the construction of flight control algorithms based on the solution of inverse problems of dynamics. Nonlinear equations of motion are used without linearization to synthesize the algorithms. The authors examine the main tasks in the automated control of pitching: the equation of the angular rotational velocity, stabilization of pitching components and of the slope of trajectory, and also the equation of the height of flight. Structural diagrams are presented for the synthesized control circuits.

UDC 62-50:519.24

ESTIMATING THE PROBABILISTIC CHARACTERISTICS OF SYSTEMS FROM THE RESULTS OF TESTS AND SIMULATION

[Abstract of article by Barlashov, N. I., and Gal'chenko, M. V.]

[Text] The authors examine combined estimates of the characteristics of systems from results of tests and simulation. It is shown that the application of parametric methods of mathematical statistics permits increasing the precision of estimation in comparison with existing combined methods. The case of polynomial output distributions of the system and model is analyzed in detail.

UDC 62-505

THEORY AND APPLICATION OF GAUSS-REYDER TRANSFORMS

[Abstract of article by Beloglazova, O. V., and Labunets, V. G.]

[Text] For spectral analysis and filtration of complex signals the theoretical-numerical Gauss-Reyder transform is introduced, generated as the basis of orthogonal functions given on a cyclic broup (or on a whole-number segment [0. T-1]) and assuming the value in the ring Z_m [i] of classes of remainders of whole complex numbers with respect to the whole complex number m = p + iq, where p and q are mutually simple whole numbers. The given transform has a simple matrix connection (a not well filled matrix) or with a Fourier and also with a Reyder transform, which permits substantially increasing the speed of digital algorithms for filtration, spectral analysis and correlation analysis of signals.

UDC 62-505

SUCCESSIVE METHOD OF CHECKING MULTIALTERNATIVE COMPLEX HYPOTHESES

[Abstract of article by Tonomarenko, V. Yu.]

[Text] In tasks of image recognition in tracking systems, etc, the situation is typical in which information arrives from an observed object in portions in proportion to the observations. In that case one of several possible solutions must be selected and the observations cease during decision making. The successive method of selection from several complex hypotheses for multidimensional random normally distributed values is presented. The efficiency of the method is computed and it is compared with the optimal Val'dovskiy method in the particular case of two hypotheses. Substantiation of the method flows from two statements made in the article which permit substantially computing the probability of an erroneous decision and the mean number of observations required for decision making.

UDC 62-60:007.65

FORMATION OF A PREFERENCE RATIO BASED ON DIFFUSE DESCRIPTIONS

[Abstract of article by Blishun, A. F.]

[Text] The author presents an algorithm for determining the preference ratio for a set of alternatives according to information obtained in comparing a certain accessible subset. The alternatives are characterized by diffuse estimates formed by means of indistinct sets.

UDC 681.532

EXPERIMENTAL INVESTIGATIONS OF THE PRECISION OF POSITIONING OF A MANIPULATOR ROBOT

[Abstract of article by Kuzetenko, A. S., Lomaka, M. V., and Fedorov, V. P.]

[Text] The article describes a procedure for conducting an automated experiment to investigate the precision of positioning of a manipulation robot. Possible ways to increase the precision of work of the manipulation robot are discussed, ways based on use of information feedback on the position of the robot drives in the computer when control signals form on the drives.

UDC 519.152

CONDITION OF ERGODICITY OF A SYSTEM WITH DEPENDENCE BETWEEN THE SERVICING TIME AND THE WAITING TIME FOR A REQUIREMENT IN A QUEUE

[Abstract of article by Morozov, Ye. V.]

[Text] The author examines a single-channel queueing system in which the requirement servicing time is determined by the time of waiting for it in a queue. The sufficient condition of ergodicity of such a system is found with use of methods of the theory.

UDC 519.283

CARRYING CAPACITY OF A QUEUEING SYSTEM WITH PERIODIC WORK INTERRUPTIONS

[Abstract of article by Voroshilov, V. A., and Shishov, Yu. A.]

[Text] The article presents an analysis of the quality characteristics of a queueing system with periodic work interuptions, intolerable claims and erors in servicing. Analytical expressions are obtained for the relative carrying capacity and the maximum and minimum queue lengths for stationary working conditions of the queueing system.

UDC 519.2

APPLICATION OF THE TEST FUNCTIONS METHOD IN THE TASK OF SELECTING THE OPTIMUM SERVICING DISCIPLINE

[Abstract of article by Perlov, Yu. M.]

[Text] The author discusses a system consisting of two elements with exponential distributions of time of failure-free work with the parameters λ_1 and λ_2 and a single repair device. The repair time distributions of element 1 are 2 $A_1(t)$ and $A_2(t)$ respectively. The criteria for selection of optimum repair discipline are determined for various reliability indicators.

UDC 62-50

ANALYSIS OF A PHASE AUTOMATED n-TH ORDER SYSTEM WITH DISCONTINUOUS DISCRIMINATOR CHARACTERISTICS

[Abstract of article by Belousova, T. S., and Shakhtarin, B. I.]

[Text] The article examines a phase automated n-th order system with rectangular and saw-tooth discriminator characteristics. The transition from an equation in operator form to a system of differential equations not containing derivatives of discontinuous functions is completed in advance. The frequency characteristic of the phase automated system in the form of a system of transcendental equations is found in the case of a rectangular characteristic, and an explicit dependence in the case of a saw-tooth dependence.

2174
CSO: 1863/186

UDC 629.127.066

ANNOTATION, ABSTRACTS FROM BOOK 'BASIC ELEMENTS OF UNDERWATER APPARATUS AND ROBOTS'

Moscow ELEMENTNAYA BAZA PODVODNYKH APPARATOV I ROBOTOV in Russian 1980 (signed to press 31 Oct 80) pp 2, 141-144

[Annotation of book "Basic Elements of Underwater Apparatus and Robots" edited by Professor V. S. Yastrebov, doctor of technical sciences, Izdatel'stvo "Nauka", 1,000 copies, 144 pages]

[Text] The present collection contains reports given at the second Plenum of the section on "Underwater Apparatus and Robots" of the Oceanographic Commission of the USSR Academy of Sciences. The plenum was devoted to the problems and challenges of developing the basic elements of these new technical means of ocean research. The concept of basic elements [literally "element base"] includes not only the actual elements and systems of underwater apparatus and robots, but also the elements of their theory. It should be noted that the theory of underwater robots is in the very initial stage of development. Many of the fundamental issues are being decided at the present time on the basis of theoretical principles that relate to manned underwater vehicles.

The articles in this collection consider the state of the basic elements for these devices and propose some successful solutions. The book is intended for scientific workers and engineers engaged in designing technical means of developing the world ocean.

The book was ratified for printing by the Scientific Council on the Theory and Principles of the Design of Robots and Manipulators of the USSR Academy of Sciences and the Institute of Oceanology imeni P. P. Shirshov

UDC 629.127.065

INTERACTIVE SYSTEMS FOR CONTROLLING UNDERWATER ROBOTS

[Abstract of article by Popov, Ye. P., and Kuleshov, V. S.]

[Text] This article considers the basic principles of building interactive systems to control the movements of underwater manipulating robots which function purposefully in the ocean environment under conditions of high hydrostatic pressure. The article has one illustration and three bibliographic entries.

UDC 629.127.066

PURPOSEFUL MECHANICS AS A STANDARDIZED APPARATUS FOR THEORETICAL SUBSTANTIATION OF MANIPULATOR DESIGNS

[Abstract of article by Korenev, G. V.]

[Text] This article reviews the basic principles of purposeful [tselenapravlennaya] mechanics for manipulators and techniques of using this knowledge for effective design of systems to control the movement of manipulators operating in an extreme ocean environment. The article has one illustration for bibliographic entries.

UDC 629.127.066

BASIC ELEMENTS OF THE SOFTWARE OF AN ALGORITHM TO CONTROL THE MOVEMENTS OF AN UNDERWATER CARRYING ROBOT IN A MARINE ENVIRONMENT STRATIFIED BY DENSITY

[Abstract of article by Chirskov, S. N.]

[Text] This article reviews the principles of formation of the file structure of an algorithm to control the movements of underwater robots. It discusses the elementary command of the file to accomplish vertical movements by an underwater robot in a stratified environment. The article has four bibliographic entries.

UDC 629.127.066

EQUATIONS OF THE MOVEMENT OF A SOLID BODY IN A MARINE ENVIRONMENT STRATIFIED BY DENSITY

[Abstract of article by Chirskov, S. N.]

[Text] This article reviews the principles of the dynamics of motion by a solid body in a stratified environment. The author investigates the characteristic phenomena that occur when a solid body moves in a stratified liquid. The article has two bibliographic entries.

UDC 629.127.066

A LINEAR MODEL OF A RESTRICTED UNDERWATER APPARATUS-MANIPULATOR SYSTEM

[Abstract of article by Krylov, G. K.]

[Text] This article considers an underwater apparatus, secured in a current by a line and receiving disturbances from the work of a manipulator. By analysis of the dynamics of the apparatus a system of three scalar differential equations was derived for planar disturbed motion. By excluding the binding reactio , a linear system of two heterogeneous differential equations is shown, and then they are represented in generalized form. The system of equations permits study of the motion of a restricted underwater apparatus. The article has one illustration and three bibliographic entries.

UDC 629.127.066

METHOD OF CONSTRUCTION AND STRUCTURE OF AUTONOMOUS SYSTEMS FOR CONTROL OF THE MOTION OF UNDERWATER APPARATUSES

[Abstract of article by Popov, O. S.]

[Text] Underwater apparatuses can be highly efficient only when control of their movement is automated. The distinctive problems are tracking the bottom and holding the apparatus at an assigned depth. This article proposes a combined method to synthesize autonomous control systems. The method is based on combined use of the techniques of optimal control and autonomous regulation.

UDC 629.127.066

PRINCIPLES OF CONSTRUCTION OF SPECIALIZED COMPUTERS FOR POSITIONAL SUPERVISORY CONTROL OF UNDERWATER MANIPULATORS

[Abstract of article by Vereshchagin, A. F., and Minayev, L. N.]

[Text] Control of contemporary manipulating robots involves the use of new sources of command data: coordinating handles, light pens, and displays. With the computer they convert supervisory information into signals to control the actuating units. This article reviews the theoretical foundation, control algorithms, and principles of construction of specialized computers which perform these conversions for positional (static) control systems. The job of these systems is to switch the gripping device of the manipulator automatically. The article has two illustrations and five bibliographic entries.

UDC 629.127.066

COMBINED CONTROL OF REMOTE-CONTROLLED UNDERWATER APPARATUSES IN THE DYNAMIC POSITIONING REGIME

[Abstract of article by Lomonosov, Yu. I.]

[Text] This article is devoted to the questions of automatic stabilization of an underwater apparatus near the work site in the presence of disturbances by the manipulator that affect the apparatus. The author considers the possibility of building devices to measure the disturbances created by the working manipulator. He demonstrates the possibility of devising a combined system to stabilize the position of the apparatus relative to the work site when the apparatus has a device to analyze disturbing forces and moments created by the working manipulator. The article has one illustration and two bibliographic entries.

UDC 629.127.066

SOME QUESTIONS OF STUDYING SYSTEMS TO CONTROL SECOND-GENERATION APPARATUSES AND ROBOTS

[Abstract of article by Vasil'yev, V. A.]

[Text] This article considers characteristics of the process of solving problems related to devising systems to control underwater apparatuses and robots. The author gives a block diagram of their hierarchy and analyzes the constituent elements. This analysis makes it possible to propose regimes and methods of examining an assigned region using underwater robots. The article has one illustration and five bibliographic entries.

UDC 629.127.066

DETERMINATION OF THE DYNAMIC CHARACTERISTICS OF A REMOTE-CONTROLLED APPARATUS IN THE STAGE OF ROUGH DESIGN

[Abstract of article by Stefanov, G. A.]

[Text] This article reviews the possibility of determining the dynamic characteristics of a remote-controlled apparatus based on the characteristics of the actuating, receiving, and transmitting devices of a television system, the persistence of the operator's visual analyzer, and the rate of updating of the information content of the television image. Based on the persistence of the transmitting tubes, the author derives equations for maximum rates of the most typical movement of remote-controlled underwater apparatuses (forward and rotating) around the axis of symmetry. These equations are recommended for rough calculations when determining the maximum tolerable speeds of movement of remote-controlled underwater apparatuses and, therefore, for determining the parameters of the propelling unit and selecting the electrical drive of the propeller aggregates when studying the work regimes of remote-controlled underwater apparatuses near the bottom, when the operator is making observations or searching for an object using a television communications channel. The article has three illustrations and four bibliographic entries.

UDC 629.127.066

HYDROACOUSTIC SYSTEMS OF A DEEP-WATER COMPLEX

[Abstract of article by Lomonosov, Yu. I., and Sychev, V. A.]

[Text] This article presents a classification of the problems solved by the hydroacoustic systems of a deep-water complex. The authors review the systems used to solve these problems and give their basic parameters. The article has four bibliographic entries.

UDC 629.127.066

SECTOR SURVEILLANCE SONAR FOR REMOTE-CONTROLLED UNDERWATER APPARATUSES

[Abstract of article by Zhavoronkov, S. V., Lomonosov, Yu. I., Rimskiy-Korsakov, M. A., Stefanov, G. A., and Sychev, V. A.]

[Text] This article gives a description of a sector surveillance sonar unit designed for use in remote controlled underwater apparatuses. The authors set forth its operating principles and describe the interaction of the primary assemblies of the unit. The article has one illustration and two bibliographic entries.

UDC 629.127.066

THE POSSIBILITY OF USING THE STEREO METHOD FOR SURVEYING THE BOTTOM WITH A SIDE-LOOKING SONAR

[Abstract of article by Lomonosov, Yu. I., and Sychev, V. A.]

[Text] This article considers the possibilities of using the stereo method to obtain an image of the sector of the bottom being investigated with a side-looking sonar unit. Expressions are given for determining the magnitude of displacement beyond the topography owing to the conditions of surveying. The authors consider two alternatives for obtaining a stereo image and analyze the images obtained using them. The article has five illustrations and four bibliographic entries.

UDC 62.52

SOME CHARACTERISTICS OF CONSTRUCTING CONTROL SYSTEMS FOR REMOTE-CONTROLLED UNDERWATER APPARATUSES

[Abstract of article by Stefanov, G. A.]

[Text] This article reviews the functions of the human operator as an element of the control system for remote-controlled underwater apparatuses, characteristics of the operator, and the working conditions. Recommendations are given for reducing the operator's workload and fatigue by means of automatic elements and computers that make it possible to use internal potential operator reserves to solve more complex problems that require fast, operational action. The article has one illustration and 14 bibliographic entries.

UDC 62.514.5

COMMAND AND ACTUATING ELEMENTS OF SYSTEMS TO CONTROL THE MOVEMENT OF REMOTE-CONTROLLED UNDERWATER APPARATUSES AND SOFTWARE FOR OPERATORS

[Abstract of article by Stafanov, G. A.]

[Text] This article reviews the development of control systems depending on the complexity of the problems which the particular remote-controlled underwater apparatus is to solve. The broadening range of jobs done by such apparatuses, the increasing complexity of their design and equipment, and the growing number of degrees of freedom of the apparatus and its manipulating devices have made it much more difficult to control them. It is suggested that ways to increase the efficiency of the operator's multifunctional activity should be sought not so much in improvements of data display equipment as in identifying new principles of control which also contain new forms of information. The article considers a fundamentally new information-controlling biotechnical system that has been developed. This system involves creating a multistep suspension system for the operator's console which simulates the spatial movement of the apparatus and also has a television image. The article has 19 bibliographic entries.

UDC 629.127.066

PRINCIPLES OF CONSTRUCTION OF PASSIVE DIVING SYSTEMS FOR UNDERWATER APPARATUSES

[Abstract of article by Smirnov, A. V., and Yastrebov, V. S.]

[Text] Passive diving systems include oil-filled electrical drive systems, control systems, and systems for electrical power supply. This article presents the results of the study of their characteristics under conditions of high hydrostatic pressure and reviews the interrelationship and mutual dependence of these systems and of their individual elements within a diving complex. The authors formulate 10 principles for the construction of passive diving systems. The article has three illustrations and one bibliographic entry.

UDC 629.127.066

PRINCIPLES OF CONSTRUCTING HYDRAULIC DIVING SYSTEMS FOR UNDERWATER APPARATUSES

[Abstract of article by Smirnov, A. V., and Yastrebov, V. S.]

[Text] This article presents the results of studies of all the basic elements of a hydraulic diving system under conditions of high hydrostatic pressure. The mutual influence of particular elements is also investigated. As a result, the authors propose basic principles for designing a deep-water hydraulic drive system. The "Skat" robot, which was designed on the basis of a hydraulic diving system, is given as an example. The article has three illustrations and two bibliographic entries.

UDC 629.127.066

PHOTOGRAPHIC COMPLEXES OF UNDERWATER ROBOT-APPARATUSES AND THEIR BASIC ELEMENTS

[Abstract of article by Kalinin, Yu. S.]

[Text] This article considers the working conditions and requirements of photographic complexes in underwater apparatuses. The author gives different alternatives of optical systems and also a number of types of light sources and their characteristics in a marine environment with different optical properties.

UDC 629.127.066

ANALYSIS OF THE CHARACTERISTICS OF THE POWER PLANTS OF UNDERWATER APPARATUSES

[Abstract of article by Gorlov, A. A., and Siminskiy, V. V.]

[Text] This article reviews the structural elements of the energy complex of an underwater apparatus: the engine installation, the onboard energy unit, the power supply installation, and the ship support system. The authors give a system of equations that determine the weight and dimension characteristics of the sources of various types of energy for the general case where they are arranged in the solid, spherical body of an underwater apparatus. The article has two bibliographic entries.

UDC 629.129:620.91

SOURCES OF ENERGY FOR DEEP-WATER APPARATUSES

[Abstract of article by Brilliantov, A. N.]

[Text] This article considers storage batteries, fuel cells, thermal energy systems, and atomic and radioisotope energy sources. Their energy and weight-dimension characteristics, strong and weak points, feasibility, and promise for use as energy sources for deep-water apparatuses are compared. The article has two illustrations and five bibliographic entries.

UDC 629.1.075

SOME CHARACTERISTICS OF THE MOVEMENT OF A TOWED BODY

[Abstract of article by Yagodzinskiy, V. A.]

[Text] This article investigates change in the resulting hydrodynamic force of interaction between liquid and a body traveling close to the bottom. The author establishes the relationship between the magnitude of the Kelvin force that arises and the dimensions of the dome and distance from the ocean floor when a carrier of scientific-technical apparatus is towed in the vertical plane. The article has two illustrations and two bibliographic entries.

11,176
CSO: 1863/181

UDC 629.127.066

PRINCIPLES OF CONSTRUCTION OF SPECIALIZED COMPUTERS FOR POSITIONAL SUPERVISORY CONTROL OF UNDERWATER MANIPULATORS

Moscow ELEMENTNAYA BAZA PODVODNYKH APPARATOV I ROBOTOV in Russian 1980 (signed to press 21 Oct 80) pp 42-49

[Article by A. F. Vereshchagin and L. N. Minayev from book "Basic Elements of Underwater Apparatus and Robots", edited by Professor V. S. Yastrebov, doctor of technical sciences, Izdatel'stvo "Nauka", 1000 copies, 144 pages]

[Excerpts] The developers of equipment for science and industry face important challenges: build machines designed for full automation of production and for work in extreme environments during the conquest of space and the ocean depths. One of the most important of these machines is the manipulating robot, which reproduces and amplifies the movement capabilities of human hands and is able to replace people in many sectors of contemporary production and to perform mechanical work in environments which are inaccessible to human beings.

At the present time control systems for manipulating robots are developing on the basis of using new sources of command information: coordinating handles, light pens, displays, and other means of diaglog between the human being and the robot, in addition to specialized computers, microcomputers, and minicomputers that convert supervisory information into actuating control signals.

This article reviews the theoretical principles and algorithms of control, as well as the principles of constructing specialized computers to perform this conversion for positional control systems whose job is to automatically switch the gripping unit of the manipulator from any current position to an assigned target position taking account of basic constraints.

To obtain automatic systems that work in the supervisory mode, the practical precision of computation does not have to be greater than 1-2 percent. Based on these considerations, we investigated supervisory control of a manipulating robot with a computing unit based on the MN-14 analog computer.

11,176
CSO: 1863/181

AUTOMATION OF SCIENTIFIC RESEARCH

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 146-147

[Table of contents from book "Automation of Scientific Research: Materials of the 13th School on Automation of Scientific Research, USSR Academy of Sciences", edited by S. S. Kuznetskiy, candidate of engineering science, Institute of Physics, Siberian Department, USSR Academy of Sciences, 500 copies, 156 pages]

[Text] Contents Page

8545
CSO: 1863/183

UDC 681.326

USE OF SOME ADDITIONAL OS CAPABILITIES AND ORGANIZATION OF THE COMPUTING PROCESS

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 3-9

[Article by V. V. Ivanov, V. V. Zel'nik, Yu. N. Barchenko and S. V. Sokolov, from book "Automation of Scientific Research: Materials of the 13th School on Automation of Scientific Research, USSR Academy of Sciences", edited by S. S. Kuznetskiy, candidate of engineering science, Institute of Physics, Siberian Department, USSR Academy of Sciences, 500 copies, 156 pages]

[Text] This report is aimed at describing usable additional components of an operating system [OS] and some aspects of organization of the computing process that we believe are of interest to other YeS computer users too.

We have the medium YeS computer model, the YeS-1030, with a small amount of main storage (256K bytes), but are rather well equipped with disk storage (four 7.25M-byte disk storage units and six 29M-byte units). We have a YeS-7906 unit with five YeS-7066 terminals and the standard set of the other devices. The computer operates under the control of OS version 4.1, generated by us, in the MFT mode. Batch processing is actively used, but the computer is also used in the interactive mode for a considerable portion of the time (YeS-7066's are used as terminals). About 60 to 80 jobs with an average length of 7 to 10 minutes each are processed daily through the computer.

General Organization and File Management

We believe computer efficiency should be increased through maximum utilization of batched processing along with interactive facilities. The presence of several OS versions and the difficulties in managing user disk files are the main organizational barriers to introducing both efficient batched processing and the interactive mode. The situation of having several incompatible versions of operating systems, both OS and DOS, is very widespread in the computing centers. In such cases, usually almost every user has his own resident volumes mounted before starting his work. And actually, operation with a third-generation computer differs little from operating behind the console of a second-generation computer of the M-20 type with the corresponding level of efficiency.

In our computing center, all user programs operate under the control of just OS version 4.1. The exception is a small group of users who operate with DOS for about one hour a day.

The availability of one main OS version is a necessary, but sufficient condition when organizing batched processing or combining it with interactive systems in the time-sharing mode. Just as important, though as a rule an aspect getting less attention, is the method of managing user data sets on disks (jobs using tape storage are usually encountered more rarely).

Similar to the situation with OS versions, the two extreme strategies for operating with files, being used in practice when the system is organized, are:
a -- the user has one or more personal volumes mounted before starting his work; or
b -- all user files are located on permanently mounted general-purpose volumes, and in some systems, the user as a matter of principle may not even know which volume holds his information.

Strategy "a" in essence has one positive aspect--a minimum of organizational efforts. A consequence of implementing it is the necessity of breakdown in batched processing, to say nothing of more complicated modes. And it is understandable why this is so: only several disk volumes may be mounted simultaneously, and therefore the job for each successive user leads to the need of mounting a new volume.

Using for all (or almost all) jobs fixed, mounted general-purpose disk volumes allows a large number of jobs to be processed with no conflict between them due to external storage. In the process, both for the programmer and the nonprogrammer-user, the system appears simpler, since it is easier for them to manage their files and the system is always ready for expeditious maintenance, etc.

From the viewpoint of the system, this approach simplifies the process of storing information, eases the work of operators be keeping volume mounting and dismounting to a minimum, and simplifies organization of the computing process; but the main thing is that throughput is increased.

In organizing operations in our computer center, we tried to follow strategy "b." Almost all volumes needed to operate the computing system are permanently mounted. External storage is distributed the following way: two resident volumes (25M bytes) and one volume for storage of about 10 application program packages (PNP PL/1, OKA, SSN etc.), and some PNP's are located on resident volumes. Remaining storage is allocated for common disk volumes and when required--for personal. To prevent overflow, unneeded data sets are systematically removed. Every week the general-purpose volume is dumped to magnetic tape, which is used to restore the contents of the erased pack when required.

Components of the Operating System and Distribution of Main Storage

Since spring of 1978, the computer has been operating under OS version 4.1 with a fixed range of 86K. A number of additional capabilities have been realized, in particular a composite console that allows initiating OS now within 1.5 to 2 minutes with p/k [punched cards]. Included in OS are the subsystem for planning, KROS, the SUBD [data base management system = DBMS] "OKA" and a number of other components which we will cover later.

A substantial part of the job stream in our computer center consists of debugging problems and problems involving little calculating time. To select the most efficient operating mode, we made a number of tests with the same batch of short jobs. It turned out that shifting from operating in one partition to simultaneous computing in two partitions increased throughput 20 percent. And using KROS leads to a 30 to 40 percent increase in throughput.

We use mainly PL/1 and Fortran which also determines the size of the partitions for computing. The standard Fortran compiler needs 80K, and the PL/1 at least 44K. Several test jobs showed that when the partition size was increased from 50-60 to 80K, compilation time for a 200-card PL/1 program was cut in half. But further increase of the partition produced no noticeable speedup in compilation. Usually, at least 60-80K of main storage is needed in the execution step with PL/1. For these reasons, we use at least 80K partitions for compilation and execution. An additional 50K partition is needed for KROS. For these reasons, in the batch processing mode, using KROS and one 120K partition is preferable to operating with two 80-90K partitions without the KROS subsystem.

In addition to raising throughput, KROS considerably simplifies management of the system through automation of some operator functions. In particular, KROS plans and starts system input programs, system output programs and initiators. KROS provides the convenience of system restart in event of failure. The functional checkpoint program periodically stores all the information needed for restart in KROS internal storage and the input job batch is preserved and does not require reinput.

There are additional operator commands in KROS facilities to control devices; he has the capability to reset, to duplicate, to cancel and delay printing and to control the number of skips between pages.

KROS allows the programmer to determine the number of printout copies needed.

Software for Interactive Modes

The YeS-7066 displays are used actively in the computer center. To operate them, we use a substantial complex of both standard YeS OS software and that which we developed in-house.

The five YeS-7066 displays are positioned as follows. One sits next to the computer control console and is used as a console display. The other four have been installed in the work areas in three different offices about 50 to 100 meters away from the computer.

When we generated OS 4.1, we included in the operating system the mode that supports operation of the YeS-7906 complex and the conversational remote job entry (DUVZ) system [CRJE]. To operate the CRJE system with the YeS-7096 complex, the modules supporting the AP-70 were replaced by those that support the YeS-7096 operation. Including CRJE in the OS gave the users a convenient means of preparing, editing and inputting jobs from a terminal for computer execution. Results may be output directly to the terminal or on the ATsPU [printer].

When the CRJE system is used, main storage is allocated as follows: 86K for the fixed region, 80K to partition 1 for operation of CRJE proper, and 90K to partition 2 for job starting.

The CRJE partition size is the minimum for realization of the main CRJE capabilities and supporting the operation of three displays. Unfortunatelt, as we mentioned earlier, we need at least an 80K partition for job starting. Therefore, we had to forego a very useful CRJE capability--the facilities for line-by-line operator control of PL/1 and Fortran syntax in the interactive mode. (Syntax control facilities require at least another 20K of storage for partition 1 with CRJE.)

Partition 2 is used mainly for starting jobs initiated by using the CRJE system. As a rule, the programmers editing and starting programs from the three terminals do not fully load partition 2. In principle, it could be used for running through jobs from p/k [punchcards] and terminal jobs, but this would require more operator intervention to:

-- query the status of partition 2;
-- if this partition is free, then start the system p/k [card] input program in this partition; and
-- upon completion of the job input, cancel the system input program to free the partition for CRJE system jobs.

To raise overall system efficiency, only two hours are allotted daily now for CRJE operation.

Despite the shortcomings and operating difficulties caused by insufficient OP [main storage], the CRJE system is very popular with our computer center users.

For handling jobs that do not involve editing and job input, for example, development of application interactive systems, CRJE is not very advantageous. Very useful in this case are the facilities that expand the programming languages through inclusion of statements supporting message exchange with terminals. For this purpose, we have modules, developed in-house, written in Assembler that support communication from PL/1 with the YeS-7906 displays. The modules are called in as subroutines by using the standard CALL statement. These facilities have proved very convenient because of their extreme simplicity and compactness. They have been used to write several interactive subsystems of an ASU [automated management system], in particular a small information retrieval system to manage office paperwork. The system is designed to operate exclusively in the interactive mode. All input of information, editing and removal of data is handled only from the display. Retrieval and processing of information is handled from the same display using the commands of the special language. Retrieval or processing results are output to the display or printer. An 86K partition is required to operate the system.

The system is now in use on a trial basis. An 86K partition and four hours of machine time are allocated daily for operation of this system. Parallel with operation of this system, jobs are processed in the batch mode in the second partition with a size of 84K.

Collection of Statistics

Collection of statistics has been organized to obtain a precise description of the computing process and status of the hardware. Included in OS during generation for this purpose is the mode for recording machine errors and collection of statistics by the system monitor program (SMP).

Analysis of the statistics obtained on device malfunctions permits anticipating equipment failures and maintaining more stable hardware operation.

The automated statistic collection system for jobs processed with YeS OS on the YeS computer was developed in-house and had been operating since the second half of 1978. System programs were written in PL/1 and allow processing files obtained by using the SMP. The system operates like this. The names of all jobs put through the system must be recorded in a special index-sequential file-directory, where for each job, the programmer, subject, office, etc. are indicated. In a second file, a summary file also organized index-sequentially for each name of a job passing through the system, the following information is gathered: how many times the job has been run, total central processor time used by the job, number of abnormal job ends, number of cards put in by the job, etc. The summary file is supplemented with processing of records formed by the SMP. The summary file is processed monthly and summary data is output by each programmer, office, subject, etc.

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INTERMACHINE DATA EXCHANGE SOFTWARE IN COMPUTER COMPLEXES

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 9-12

[Article by G. A. Baranova and Yu. Ya. Ivanov, from book "Automation of Scientific Research: Materials of the 13th School on Automation of Scientific Research, USSR Academy of Sciences", edited by S. S. Kuznetskiy, candidate of engineering science, Institute of Physics, Siberian Department, USSR Academy of Sciences, 500 copies, 156 pages]

[Text] For exchange of data between computers making up a complex, hardware that differs from the nomenclature of devices supported by the YeS OS operating system (OS) is often used. In the experimental computer system (EVS) of the Latvian SSR Academy of Sciences, this device is a channel-to-channel adapter (AKK). To support the capability of data exchange through the channel-to-channel adapter at the level of user programs executing in the YeS OS environment, the systems method of access (SMD) [SMA] was developed at the IEVT [Institute of Electronics and Computer Technology] of the Latvian SSR Academy of Sciences.

The SMA is a basic method of access permitting the user to operate with an input-output device (channel-to-channel adapter) at a logical level, which does not require knowledge of the physical features of the device and details of programming on the physical level. But, as required by a basic access method, the functions of record blocking, bufferization of data and synchronization of events are the user's responsibility. At the same time, the SMA realizes certain functions of a higher level, which is determined by the assignment of the adapter as a computer complexing device. Thus, for example, the SMA effects time monitoring of input-output operations so that they do not get "hung up" in the device.

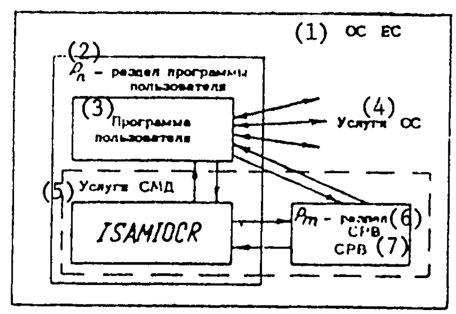
The physical level of operation with the device is handled by the real-time supervisor (SRV) [RTS], which is used as a means of complexing during operation with the adapter. The SMA includes a set of macroinstructions, the macro definitions of which are stored in one of the system libraries, an access method module, loadable into the user's main storage, and the real-time supervisor as the basic means of complexing. Thus, the YeS OS version, the problems of which use the SMA, must include in one of the libraries the generated version of the RTS loadable into main storage as a user program and taking up from 16 to 30K.

The real-time supervisor is a package of application programs offering the user the following services for operation with nonstandard input-output devices:
-- a means of expeditious operation with the input-output [IO] devices at the level of execution of channel programs written by the user;
-- a means of assigning user programs for expeditious processing of IO device interrupts;
-- a means of assigning user programs for expeditious processing of interrupts occurring upon expiration of specified time intervals;
-- a means of multiprogram data processing with use of the most efficient disciplines for program dispatching for real-time (RV) systems;
-- presentation to user programs in the real-time mode of a higher, relative to the YeS OS, priority for use of the central processor and IO channels;
-- providing a high degree of interruptibility of the YeS OS operating system with regard to IO devices and external interrupts serviced in the real-time mode; and
-- a means of user program communication, executing in the real-time mode, with the computer operator.

The SMA macro definition library contains a group of macroinstructions for opening and closing data sets, initiating IO definitions and the basic method of processing "attention" signals.

The access method module is located in the system link library and takes up to 4K of storage. When the appropriate macroinstruction is issued by the SMA for opening a data set, the module is loaded into the user partition, receives control and initializes itself in RTS, thereby forming an interface between the user and RTS and obtaing the right to burst mode operation with the IO device. From this time on, the user may use all SMA services, but the user program is actually broken into two independent parts, one of which uses the services of YeS OS, and the other--SMA. This situation is illustrated by the figure.

Key:
1. YeS OS
2. R_p - user program partition
3. user program
4. OS services
5. services of systems method of access
6. R_t - real-time supervisor partition
7. real-time supervisor



The access method module has several entry points to which control is passed when IO macroinstructions are executed, when adapter interrupts occur and when interrupts occur from the timer monitoring execution of IO operations.

The universality of the SMA and the efficiency of the facilities provided by it are achieved thanks to the availability of means of generation. The generation facilities allow obtaining specific versions of the SMA taking into account the hardware configuration used. The SMA generation facilities permit adjusting the SMA for operation in the system of the corresponding configuration.

The systems method of access is basic, meets the principle of modularity and allows expansion of capabilities. The available versions of the SMA allow processing of attention signals both in the real-time mode and with use of the asynchronous planning facilities in YeS OS.

Compared to the existing software for complexing facilities in YeS OS, SMA provides greater flexibility and adaptation to the various protocols for computer interaction. The value of SMA is the realization of it as a package of application programs, which allows use of it in any version of YeS OS without regeneration. The relatively small size and capability for release of storage taken up by the SMA when the computer system operation ends give the SMA an advantage over standard complexing facilities and permit switching from one operating mode to another without overloading the system.

The SMA is a convenient means for realization on its basis of programs to control a network and of transport stations.

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STRUCTURAL ALGORITHMIC MODEL OF THE RATAN-600 COLLECTIVE-USE SYSTEM

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 37-38

[Article by V. V. Vitkovskiy and V. N. Mansurov, from book "Automation of Scientific Research: Materials of the 13th School on Automation of Scientific Research, USSR Academy of Sciences", edited by S. S. Kuznetskiy, candidate of engineering science, Institute of Physics, Siberian Department, USSR Academy of Sciences, 500 copies 156 pages]

[Excerpt] In developing large systems for automation of scientific research at major experimental complexes, and especially systems for collective use of these complexes, the structure and functions of the future system are as a rule not described in detail or exhaustively in the technical specifications and draft plan. These systems are generally built by the evolutionary model method [1], wherein the latest model takes into account not only the internal deficiencies of the previous one, but also the change in the experimental situation (statements of the problems, methods, apparatus, etc.). To avoid radical alteration of the entire system at each stage, the systems are built by the building block principle; however, reprogramming of individual blocks or developing new ones remains an extremely labor-intensive task requiring the enlistment of a collective of professional programmers.

The method used in developing the system for collective use (SKP) of the RATAN-600 complex consists in creating an initial model capable of learning and evolution (including self-change and adaptation to external conditions). In doing so, only some base of the system is programmed; all remaining work on reprogramming and programming is performed by the system itself in the process of learning and functioning. The system "teachers" are the users who must gain a good understanding of the statement of their problems and may not have any idea of programming in general and the system structure in particular. In other words, system programming is done in the "language of the problem." The most important feature here is discarding a rigid algorithmic description of the system and shifting from algorithms of functioning to the processes of functioning and development.

Realization of the method is based on a number of theoretical studies: introduction and study of "self-changing" algorithms, consideration of the process as the generalization of the algorithm, development of methods of metalinguistic programming (MLP), development of structures and methods for constructing linguistic models (LM) and formalization of the concepts of learning and development.

The model for the RATAN-600 collective-use system consists of quasi-autonomous subsystems constructed according to the overall initial algorithmic scheme. For each subsystem, an initial model of the world (MM) is built which is supplemented and changed in the process of learning and operation. Each subsystem may be considered a system of artificial intelligence (II) oriented to operation with its own world model. Intercourse between the subsystems is carried out in the form of question-answer or assignment-report in a "quasi-natural" language that the operator and systems engineer can understand without directories and dictionaries. In the process, any subsystem may be the initiator of the intercourse. The prototype of the internal system dialog may be the dialog in the DILOS system [2]. A special role in the model is played by the "Coordinator" subsystem that organizes joint operation of all subsystems and maintains a dialog with the system operator, users and service personnel in a natural language with a restricted subject field (multilanguage dialog is possible).

The RATAN-600 collective-use system is based on a multimachine complex with a tri-level hierarchical structure. The subsystems are realized either with individual computers or as programs executing in their own program partitions in the time slicing mode.

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'ELEKTRONIKA K-200' PROCESS CONTROL COMPUTER AS A DISPATCHER FOR A UNIFIED BUS EXCHANGE SYSTEM TO AUTOMATE EXPERIMENTS ON EMISSION ELECTRONICS

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 75-76, 81-82

[Article by T. A. Zakirov and A. Nazirov, from book "Automation of Scientific Research: Materials of the 13th School on Automation of Scientific Research, USSR Academy of Sciences", edited by S. S. Kuznetskiy, candidate of engineering science, Institute of Physics, Siberian Department, USSR Academy of Sciences, 500 copies, 156 pages]

[Excerpts] In conducting experiments on emission electronics, the values of the factors of secondary emission are usually determined, as well as their dependencies on mass, energy, ionization potential, angle of incidence of primary particles, on the nature and state of the surface, and on the temperature of the target. The composition, charge state, and angular and energy distribution of the stream of secondary particles are studied as well. In estimating the number of measurements for the study of just the basic parameters of secondary emission at about 10^{20} and the number of operations that a researcher may perform "manually" as about 10^{10}, one can see that there are just not enough people. This inconsistency is now resolved by limiting the number of objects subjected to research, the number of parameters studied and by speeding up the operation of the experiment. Automation is one way to intensify the research.

A considerable part of the early work, in which secondary emission with a target was studied, was done on targets not pure, but covered with adsorbed films of varying nature, composition and thickness and accordingly of varying properties. Therefore, it is very important to bring out the nature of the effect of the films themselves on the secondary emission properties of solids and the conditions under which this effect may be disregarded. Experiments [1] show that for the study of pure surfaces, the experiemnt has to be performed in a time less than the time of emergence of the adsorbed films from the atoms of the residual gas and the primary beam proper of the bombarding particles.

To solve this problem and many others, an oscillographic method of measurements that is an important step in automating the experiment was developed at the Institute of Electronics of the UzSSR Academy of Sciences. The method of double modulation was proposed to develop the oscillographic method [1]. But this method too is incapable in the complex of resolving questions such as precision, rate, reliability and the capability of expeditiously intervening in the course of the experiment which may be solved by introducing a computer into the experiment.

Since all experimental facilities for studying emission phenomena have the vacuum instrument as the basis, the preparatory part of the experiment takes up considerably more time than the measurements proper. Therefore, to raise the efficiency of computer operation, it has to be used in the time sharing mode, i.e. used by many users. Statistical analysis of a number of experimental facilities has shown that the law of distribution of time of readiness of the facility for the experiment is most accurately approximated by the normal law. Based on a given probability of failure satisfying the experimenters and considering the capabilities of the "Elektronika K-200" UVM [process control computer], we developed a structural scheme for the system of automation that combines 15 facilities.

In connection with the need for larger main storage for mathematical processing, including interpretation of results, at the UzSSR Academy of Sciences' Institute of Electronics imeni U. A. Afimov, which has the YeS-1022 computer in addition to the "Elektronika K-200" process control computer, the problem arose of effecting communication between these machines.

Key:
1. YeS-1022
2. Elektronika K-200
3. Adapter
4. AK [channel adapter]
5. Controller
6. Storage

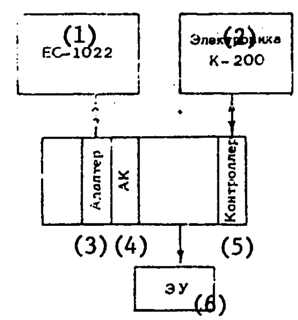

Fig. 2.

Figure 2 shows the structural diagram of the system. In this system, the YeS-1022 acts as a subscriber to the unified bus exchange system, while the "Elektronika K-200" process control computer is the dispatcher, indicating the direction of the exchange of information between the two computers. Information from the experimental facilities goes into the process control computer, undergoes primary processing and then, when necessary, is sent to the YeS-1022 computer.

Facilities needing access to one or the other computer may be equipped with the appropriate adapters and subscriber controllers. Then these facilities will be subscribers to the UMSO [unified bus exchange system] which will allow them to exchange data with each other.

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USE OF 'ELEKTRONIKA S5-11' MICROCOMPUTER IN CAMAC SYSTEMS

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[Text] In developing systems to automate physical experiments, the following problems have to be solved:
acquisition of information;
monitoring the functioning of the various systems;
control of the systems participating in the experiment;
expeditious display of results of observations;
real-time information processing; and
information transmission over communication lines.
As a rule, the complex for automation must provide simultaneous solution of the problems posed. These and many other reasons have led to the development of multimachine measuring computer systems using the program-controlled structure of KAMAK [computer automated measurement and control systems = CAMAC] [1].

With the emergence of microcomputers built with LSI circuits, possibilities have been opened for successful use of them in various complexes to automate scientific research. The "Elektronika S5-11" belongs to this class of computers [2]. This microcomputer has the microprogram principle of control. Main storage size is 128 16-bit words with the capability of expanding to 32K words. Access time from main storage is no more than 2.5 microseconds. The processor performs operations on bytes and 16-bit words, and the time for a short operation is on the order of 150 microseconds. For microcomputer communication with external devices, there are:
four 8-bit digital inputs; and
four 8-bit digital outputs.

Relatively low speed limits the possibility of using the microcomputer to control CAMAC crates. However, the "Elektronika S5-11" may be successfully used as a controller of "slow" peripherals. In doing so, main storage size has to be increased. The microcomputer main storage may be expanded by adding a standard CAMAC module, access to which is available from both the microcomputer side and the dataway side. Thus, the microcomputer communicates with the crate dataway through its main storage.

Key:
1. address counter
2. main storage of 4096 x 18 with refresh circuit
3. data register
4. from the CAMAC dataway
5. command decoder
6. control unit
7. control signals
8. to the dataway
9. service register
10. interrupt request
11. main storage request
12. exchange register
13. from the S5-11 computer
14. address bus
15. address register
16. bus shapers
17. data bus
18. interrupt
19. to computer

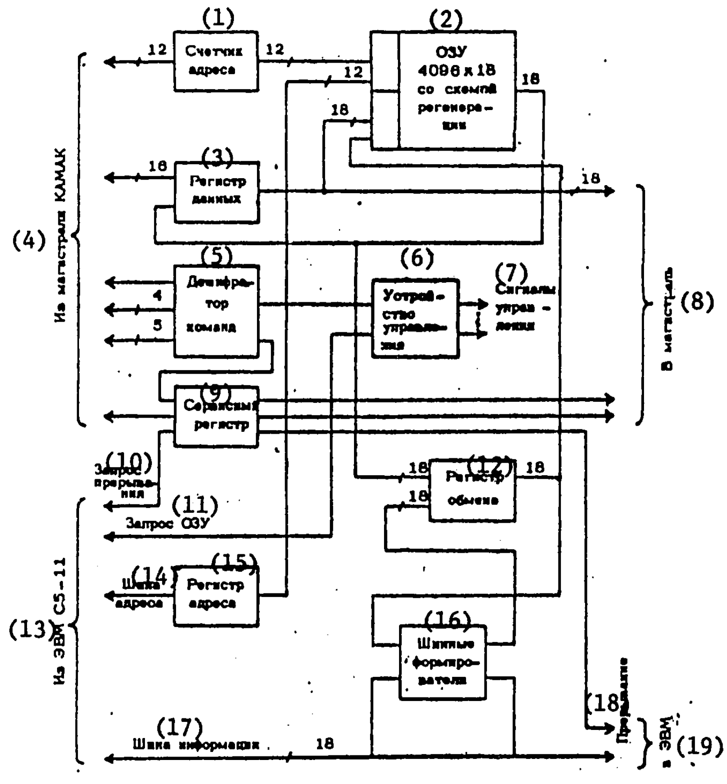

Fig. 1. Structural diagram of main storage expansion module

The main storage expansion module consists of (fig. 1.):
main storage with 4K 18-bit words with refresh circuit;
address counter and data register for access to main storage from dataway;
address register and exchange register (with bus shapers) for access to main storage through the two-way bus from the microcomputer;
command decoder and service register for communication with crate dataway; and control unit for synchronization of main storage during access from both the microcomputer and the dataway.

The module has the following list of commands:
A(1) F (16) - write storage cell addresses;
A(0) F (16) - write data in storage cell at specified address;
A(0) F (0) - read data from storage;
A(9) F (19) - selective setting of bits of service register;
A(9) F (23) - selective clearing of service register bits;
A(9) F (1) - read service register
A(0) F (8) - check request; and
A(0) F (25) - start microcomputer.

Key:
1. computer
2. controller
3. CAMAC dataway
4. microcomputer main storage expansion module
5. "Elektronika S5-11" microcomputer
6. peripheral
7. peripheral interface module

Assignment of service register bits:
2 - exchange of files (mode of scanning of addresses);
9 - request from microcomputer;
13 - permission to issue request; and
17 - masked request.

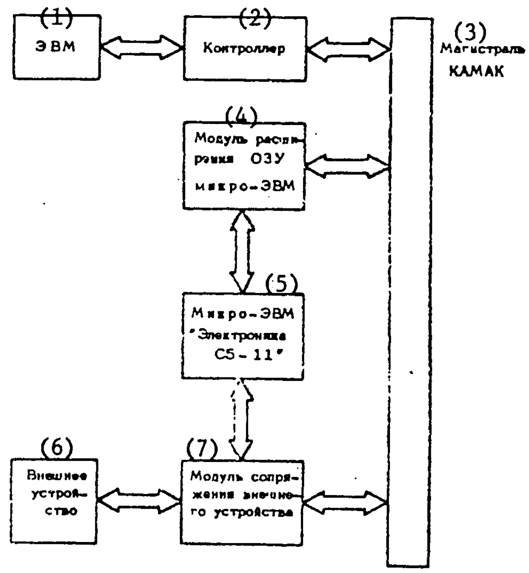

Fig. 2. Use of the "Elektronika S5-11" microcomputer as a peripheral controller

With the main storage expansion module, the "Elektronika S5-11" may be used to control low-grade computer peripherals or to organize data transmission between remote machines over communication lines. The version of using the microcomputer in CAMAC systems is shown in fig. 2. A simple interface module that is connected to the digital inputs and outputs of the microcomputer is required for peripheral control. The peripheral control program is entered into main storage through the crate dataway from the central machine. A peripheral controller using the "Elektronika S5-11" microcomputer provides flexibility of control: changing the interface module and control program suffices for connection of any device.

Using the microcomputer main storage expansion module with program access from the central computer is a universal solution and allows satisfying various requirements that arise in the process of building systems to automate scientific research.

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CAMAC MODULE FOR CONTROL OF STEP MOTORS

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 87-91

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[Text] A module has been developed to control the antennas of the Siberian solar radio telescope (SSRT) that is now under construction [1]. The radio telescope is intended for study of solar radio images in the centimeter band and is a 256-antenna interferometer. The antennas are controlled with a servo tracking system [2]. System actuating elements are ShDM-7F step motors. The group principle is used to organize tracking: the system contains 16 units of the same type to control groups of 16 antennas. Each unit consists of a module to control (MU) the step motors and power amplifiers loaded directly to the motors of the 16 antennas. The control module is installed in a crate connected through a serial branch to the central computer, and is connected to the 16 power amplifier modules.

The control module maintains independent control in two coordinates (hour angle and declination) of arbitrarily selected antenna groups A and B at four different rates in forward and reverse directions. These capabilities fully meet the requirements laid on the system for tracking in the various modes of antenna movement (regular tracking mode, stop, run, internal group phasing). The control module receives signals from limit switches (KV) installed in each antenna for the two coordinates to fix its boundary (extreme) positions. When the limit switches are tripped, motor operating mode is changed (for example, the corresponding motors are stopped or rotated in the opposite direction).

The module is built on the base of the series K589 microprocessor set using series K155 [3] and is a microprogrammable automaton without OZU [main storage]. All modes are supported by microprograms in the read-only memory. Microprogram calls for the mode needed are made by its initial address (number) that is input through the crate dataway. The algorithm for the microprogram for the general mode is shown in fig. 1 and the module flowchart in fig. 2.

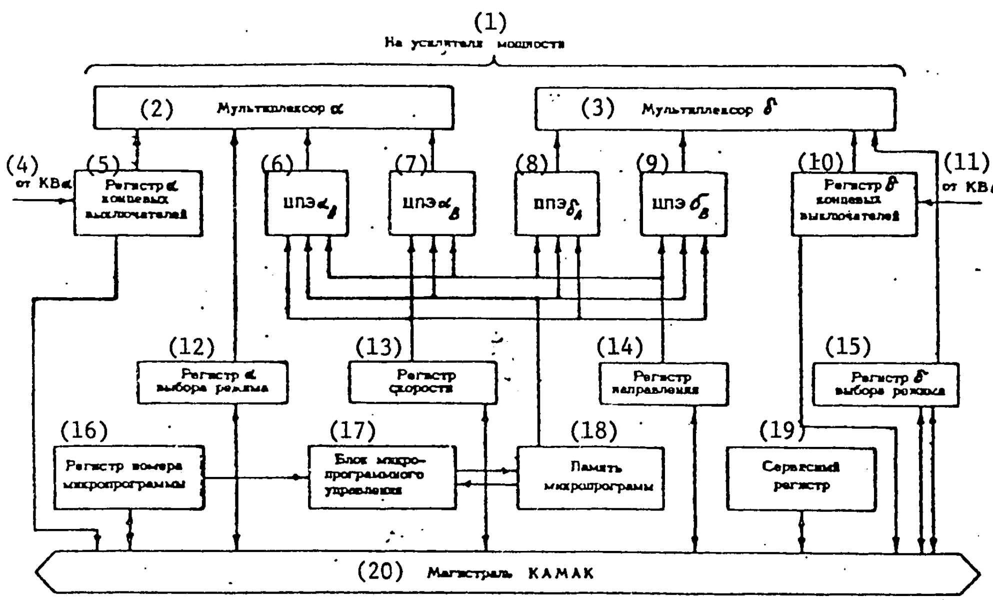

Fig. 1. Structure of the module that controls the step motors

Key:

1. to power amplifier
2. multiplexor α
3. multiplexor δ
4. from KV [limit switches] α
5. register α for limit switches
6. TsPEα_A [processor elements]
7. TsPEα_B [processor elements]
8. TsPE δ_A [processor elements]
9. TsPEδ_B [processor elements]
10. register δ for limit switches
11. from KV [limit switches] δ
12. register α for mode selection
13. register for rate
14. register for direction
15. register δ for mode selection
16. microprogram number register
17. microprogram control unit
18. microprogram memory
19. service register
20. CAMAC dataway

During operation of the microprogram, its initial address (number) is loaded into the microprogram control unit (BMU) with the frequency specified by the highly stable crystal oscillator (64 Hz). The microprogram control unit controls the fetching of microcommands from the PZU [ROM] of the microprograms with a capacity of 256 x 24 bits. The motor control codes are shaped by four processor elements (TsPE), each of which supports one of the modes in one coordinate. The initial data is entered into the processor elements from the 16-bit rate register and the 8-bit direction register, to which access is available from the crate dataway. Modes are specified by the mode selection registers for each coordinate. The contents of these registers are subject to conjunction with the position codes of the status of the limit switches contained in the corresponding 16-bit registers.

Key:
1. start
2. SChT [counter] = 0
3. no
4. yes
5. 12 microinstructions
6. rate code input to counter
7. new control code generation
8. counter = counter - 1
9. control code input to multiplexor
10. stop
11. Total: 48 microinstructions

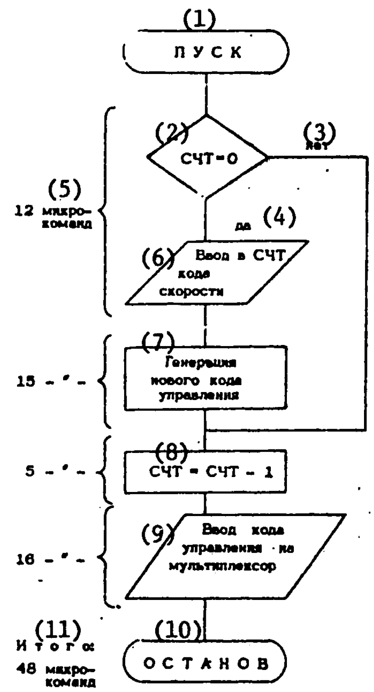

Fig. 2. Structure of algorithm for microprogram for general mode

Using the multiplexor, the motor control codes generated by the processor elements are issued to the corresponding antenna stations. The multiplexor is made up of output registers, a decoder and circuits for mode switching, made as multiphase AND circuits.

The availability of the service register allows modification of the modes without the use of special microprograms. Realized in addition are: transfer of all motors of the selected coordinate to mode A (i.e. masking of the corresponding register for limiting switches); transfer of all motors of the selected coordinate to mode B; and disabling write to the selected register for the limiting switches.

The module includes a generator that specifies the synchroservos needed for operation of the control module and synchronization of antenna movement.

The control module has an internal common bus through which data is exchanged between thk inidivudal elements of the module. This bus has an outlet to the buses for reading the crate.

This structure supports high reliability and flexibility of control. The functional capabilities of the module allow use of it in various control systems that make use of step drive.

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ARCHITECTURE OF HARDWARE AND SOFTWARE OF AN INFORMATION COMPUTING COMPLEX FOR RESEARCH ON LASER SPECTROSCOPY

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[Text] Solving a whole number of national economic problems on environmental protection and the study of natural resources involves the problems of spectroscopy of atmospheric gases [1]. Recently, in spectroscopy of atmospheric gases, methods of laser spectroscopy have made considerable progress. This is due to the fact that many applications of lasers (detection and ranging, distance measurement, transmission of information and atmospheric parameter sounding) involve passing laser radiation through the atmosphere. The main problems of laser spectroscopy of atmospheric gases are:

-- study of the intermolecular interaction of molecules;
-- study of the interaction of laser radiation with the gaseous atmosphere and the effect of gaseous components of the atmosphere on the propagation in it of weak and strong radiation;
-- measuring concentrations of the basic and polluting gaseous components of the atmosphere; and
-- development of methods and means of laser gas analysis.

To solve these problems, optical spectral characteristics of molecular media are being studied and experimental research is being conducted on the spectra of absorption of atmospheric gases and the parameters of individual lines (in the visible and infrared regions of the spectrum as a function of the type of molecules, macroparameters of the medium and parameters of laser radiation.

Obtaining the final results of spectral research (spectral factors of absorption, models of interaction, cross-sections of collision, molecular constants, etc.) entails complicated processing of experimental data and integrations of results, which requires considerable computing resources and a sophisticated system of software with packages of application programs and a data bank.

Key:
1. M-4030 MK [multiplexor channel]
2. BSI [expansion unknown]
3. group adapter
4. SS [expansion unknown]
5. UO [expansion unknown]
6. BVU [expansion unknown]
7. MIR-2
8. EPM SPMK PL [expansion unknown]
9. EPM SP PL [expansion unknown]
10. SARATOV-1
11. D [expansion unknown]
12. T [expansion unknown]
13. K [expansion unknown]
14. ATsP [analog-to-digital converter]
15. D MIR-2
16. BZU [buffer storage]
17. PK [expansion unknown]
18. KS [expansion unknown]
19. KK [expansion unknown]
20. OAP [optoacoustical receiver]
21. DM [expansion unknown]
22. optoacoustical spectrometer
23. television meter of spectrum
24. Intraresonator spectrometer

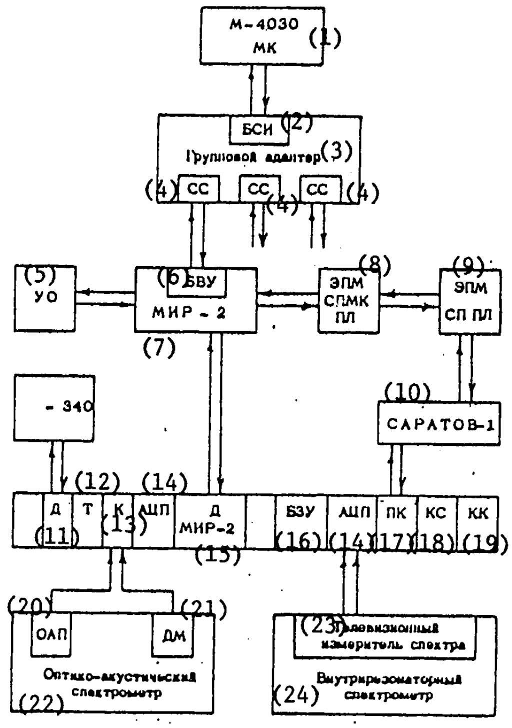

Fig. 1. Structure of information computing complex

The complex of diverse problems on automation of spectrometric research can be expediently solved within the bounds of a multilevel measuring and computing system with appropriate distribution by levels of the functions of control, data processing and storage of results. The system hardware (fig. 1) includes:
-- the M-4030 computer as the basic computer for the collective-use system (SKP) with time sharing;
-- group adapter;
-- the MIR-2 computer, as one of the intelligent terminals for the collective-use system;
-- the SARATOV-1 mini control computer; and
-- a crate with a set of CAMAC system, measuring and interface modules.

The collective-use system terminals are connected to the M-4030 computer channel through the group adapter. One of the collective-use system terminals is the MIR-2 computer located in the laboratory for laser spectroscopy. The MIR-2 computer is connected to the M-4030 computer by cable communication line through the interface unit and the circuits for matching to the bus of the adapter. The system allows the user at the MIR-2 computer console to operate in the interactive mode with both the MIR-2 and the M-4030 computers, to debug programs on the MIR-2 computer devices and to start jobs.

The MIR-2 is linked to the experiment automation system through the interface module for the MIR-2 driver in the standard CAMAC. The module is an interface to the computer program channel and is connected to the system of its internal buses. The main parts of the driver are: the computer control function decoder, the buffered transmission register, the buffered receiving register, the CAMAC command decoder, the status register and the univibrators. Modifications associated with connecting an additional peripheral have been made to the computer.

The lower-level system includes the SARATOV-1 minicomputer with a set of peripherals (EPM, SP, PL), the Videoton-340 display, which is the main terminal for the experimenter and the device for displaying the experiment results, and the crate with the CAMAC apparatus. The CAMAC apparatus includes system modules, interface modules (display driver, MIR-2 driver) and measuring modules that support communication with the experiment. The system services two experiments. Connected to the crate are the optoacoustical sprectrometer and the intraresonator spectrometer.

In experiments on the laser spectrometer with the optoacoustical receiver (OAP), the spectra of absorption of gases and mixtures in the visible range of the spectrum are studied. The spectrometer (fig. 2) includes the laser with a control unit and sweep frequency marker sensor, an optical modulator (M), a container with the substance being studied, apparatus for measuring wavelength (λ) and an optoacoustical receiver with a capacitor microphone.

The main measuring channels of the system are:

- the channel for measuring the spectral factor of absorption of the studied sub-substance, which contains the optoacoustical receiver and selective amplifier (IU);
- the channel for measuring the output power of the laser, consisting of a sensor (calibrated photodiode) and amplifier (U);
- the channel for measuring wavelength based on an interferometer and the DFS8-3 instrument; and
- the channel for measuring macroparameters of the medium under study (pressure, temperature, humidity).

Key:
1. OKG [laser]
2. M [optical modulator]
3. container
4. I [expansion unknown]
5. D [expansion unknown]
6. OAP [optoacoustical receiver]
7. U [amplifier]
8. IU [selective amplifier]
9. to switch

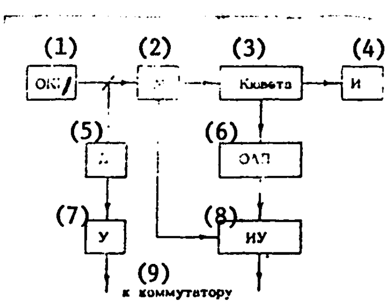

Fig. 2. Block diagram of optoacoustical spectrometer

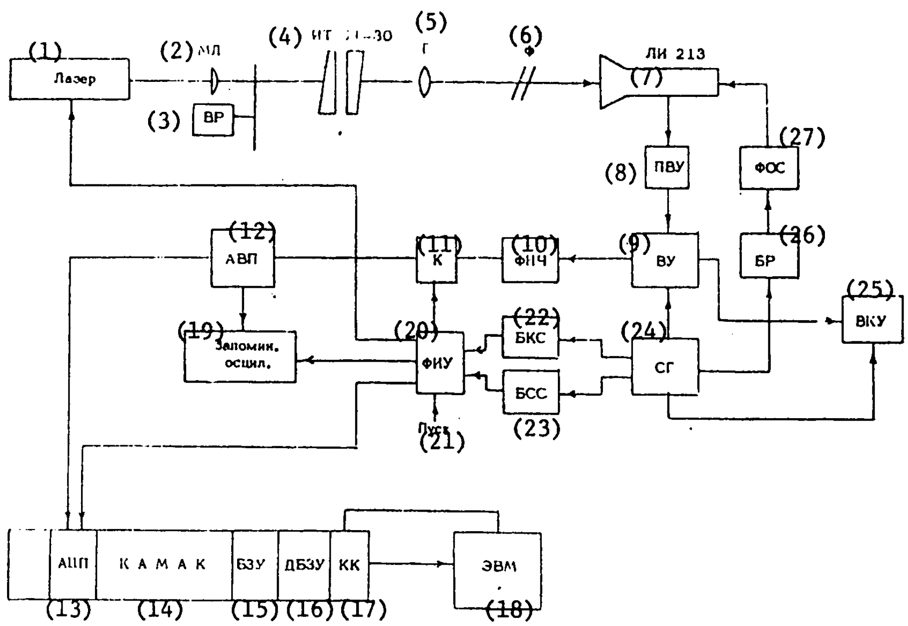

Fig. 3. Structural diagram of television meter of spectrum

Key:

1. laser
2. ML [ground lens]
3. VR [rotating polydispersion diffuser]
4. IT 51-30
5. G [expansion unknown]
6. F [expansion unknown]
7. LI 213
8. PVU [expansion unknown]
9. VU [video amplifier]
10. FNCh [low-pass filter]
11. K [analog switch]
12. AVP [analog time converter]
13. ATsP [analog-to-digital converter]
14. CAMAC
15. BZU [buffer storage]
16. DBZU [expansion unknown]
17. KK [expansion unknown]
18. EVM [computer]
19. storage oscilloscope
20. FIU [control pulse shaper]
21. start
22. BKS [vertical sync unit]
23. BSS [horizontal sync unit]
24. SG [sync generator]
25. VKU [video control unit]
26. BR [sweep circuit]
27. FOS [focusing-deflecting system]

When the modulated radiation passes through the cell of the aptoacoustical receiver, pulsations of pressure of the studied gas occur in it that are sensed by the capacitor microphone diaphragm installed in the side of the cell. The signals received are detected, amplified and sent for recording. The reference signal for the sync detector is fed from the sensor installed in the disk interrupter. The opto-acoustical receiver signal, proportional in the case of poor absorption to the product of the gas absorption factor and its concentration and the power of the laser source, is digitized simultaneously with the signal, proportional to the power of the radiation. The derived arrays go to the computer for processing.

In experiments on the intraresonator laser spectrometer, spectra of absorption of gases and water vapor are studied. The range of application of the intraresonator spectrometers is the analysis of weak lines of absorption of atoms and molecules in the short-wave region of the spectrum and the study of fast-flowing processes. The substance to be studied is placed in the laser resonator. Absorption of radiation in individual lines in the spectrum of generation of the laser results in formation of gaps beraing information on the studied spectrum. The absorption factor is determined as a result of computer scaling of the spectrum of generation according to specific algorithms.

To record the pulsed laser spectrum, the television method of recording the interference pattern is used. Fig. 3 shows the structural diagram of the system. The pulsed laser radiation passes through the ground lens (ML), the rotating polydispersion diffuser (VR), the interferometer and is focused by the objective lens (F) on the target of the television tube (LI-213 image orthicon). When the interference rings are projected on the photocathode of the transmitting tube, a charge pattern is formed on the target that is stored and then serially read and converted. From the video amplifier (VU) output, the video signal goes to the analog switch (K), the operation of which is synchronized by vertical and horizontal pulses. In the process of horizontal scanning, a part of the videosignal is isolated from the line. The gate signal is stored in the analog-to-time converter (AVP) and then converted into digital code. The digital values of the video signal are written into buffer storage (BZU). Control of the main assemblies of the television unit: the scan unit (BR), the horizontal sync unit (BSS), the vertical sync unit (BKS) as well as the units in the measuring and conversion section is provided by the sync generator (SG) and the control pulse shaper (FIU).

The software for the computing complex includes system and problem-oriented facilities in accordance with the function and capabilities of each of its levels (fig. 4).

The software for the lower level subsystem is a complex, united by an interactive monitor, of autonomous programs, each of which realizes one of the standard functions of the system: equipment control, data recording and input, display, documentation, data exchange with the upper level, express processing, etc.

The most common parts of these programs have been separated into individual programs and used jointly by them. All autonomous programs of the lower level system have been given names. Recognition of the names relevant to execution of programs and start of them is handled by the monitor. Starting from a specific address in MOZU EVM [computer magnetic core storage] is possible with programs for debugging and initiating. There are facilities to send to the higher level not only data, but even specific processing programs.

The MIR-2 software includes programs for expeditious statistical and subject processing of experimental data, determination of parameters of lines of absorption, consideration of the effect of parameters of laser radiation on the value of the absorption factor, and graphic display facilities.

Key:
1. M-4030
2. DOS-2 ASVT [modular system of computer equipment
3. exchange facilities
4. SKP [collective-use system]
5. debugging facilities
6. data bank
7. modeling facilities
8. facilities for processing experimental data
9. MIR-2
10. configuration and control facilities
11. control and input facilities
12. statistics package
13. special PO [software]
14. SARATOV-1
15. system interactive monitor
16. initiating program
17. interactive correction and debugging program
18. data display facilities
19. processing facilities
20. output of results
21. nonstandard software

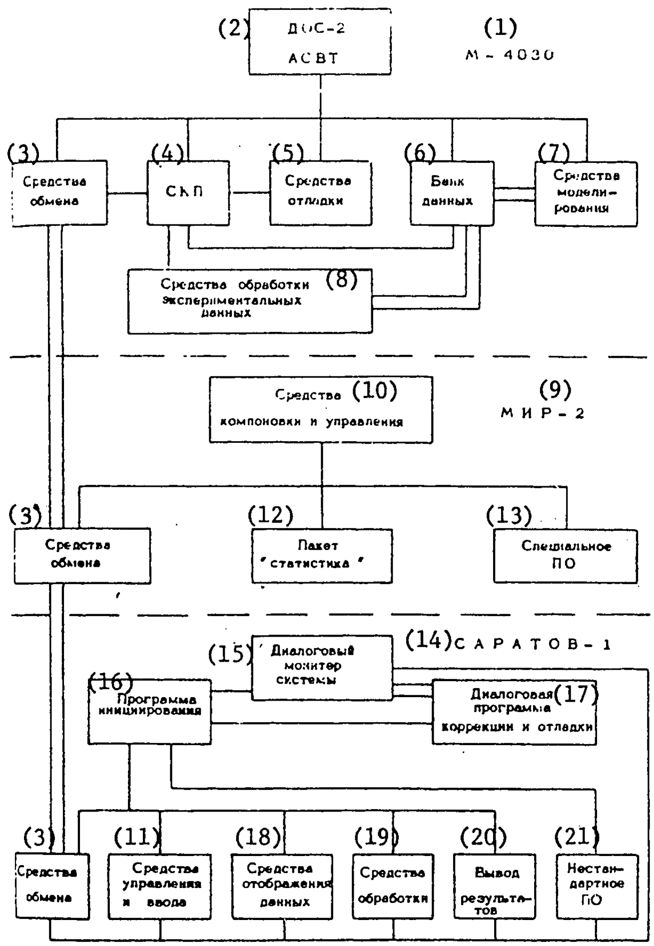

Fig. 4. Software structure

The software for the basic M-4030 computer includes the standard facilities plus specialized packages of programs that operate under control of DOS ASVT:
-- collective-use system program package;
-- package of programs to manage the bank of spectral characteristics of atmospheric molecules; and
-- package of programs for processing spectrometric data.

The collective-use system software is a specialized package of programs operating under control of DOS ASVT. The resident program, an expansion of DOS ASVT for operating with the collective-use system terminals, is loaded into a separate program partition with a higher priority. The program performs the following functions:
-- organizes terminal input of subscriber requests and jobs;
-- maintains subscriber job queue for using main storage;
-- initiates execution of subscriber jobs; and
-- supports data exchange and interaction with subscribers.

The package of processing programs contains:

-- programs for calculation of absorption, width of absorption line, form of contour, determining parameters of overlapping lines of absorption, and programs for eliminating equipment distortion;
-- programs that account for the effect of parameters of laser radiation on the value of the factor of absorption of spectral lines with optoacoustical measurements;
-- programs to determine the parameters of lines of absorption in the intraresonator sprectrometer by the parametric method;
-- programs to approximate the experimental dependencies of the absorption factor line width on the pressure of the absorbing and buffer gases by the theoretical models of (Foygt, Rautian, Galater) ....
-- programs to approximate the contours of lines of absorption by the theoretical models of contours of lines of absorption of: Lorentz, Doppler, (Foygt, Rautian and Sobel'man).

For theoretical calculations and solving the problems of molecular spectroscopy, software is being developed to restore the parameters of spectral lines based on data from experimental measurements, and to determine spectroscopic constants, structural molecular constants, electrical and magentic properties of molecules by spectroscopic data.

A file of spectroscopic data is being created on magnetic tape. A file on spectral factors and a file on absorption line parameters are being maintained. The data for each experiment are given an identifying log of 10 digits (index of the user, date of the experiment, number of the experiment). The parameter file holds information for each line (width, intensiveness, absorption factor at the center of the line, position of the center).

Complexing of the hardware and programs for control, processing and facilities for interaction with the computer will allow making a closed automated cycle of analysis of results. Use of these complexes is expanding the capability of researchers to conduct complicated experiments.

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MULTIPLEXOR DISTRIBUTED SYSTEM OF AUTOMATION (SAMUR) BASED ON DATA TRANSMISSION

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 100-107

[Article by V. M. Zavadskiy, from book "Automation of Scientific Research: Materials of the 13th School on Automation of Scientific Research, USSR Academy of Sciences", edited by S. S. Kuznetskiy, candidate of engineering science, Institute of Physics, Siberian Department, USSR Academy of Sciences, 500 copies, 156 pages]

[Text] Described are the principles of building a data transmission (PD) network for collective use with a cyclical discipline of service that supports simultaneous operation of many computers with a common storage area and peripherals in the multiprocessor mode. The network has a loop structure. Transmission is effected serially over one cable at the rate of 10M baud. The line protocol of the packet switching models referencing storage with direct access. Operations on the network are an extension of operations on a common computer bus.

The need to develop the SAMUR system emerged in the process of automating experiments on controlled thermonuclear synthesis (UTS) at the Leningrad FTI [Physicotechnical Institute] of the USSR Academy of Sciences. In the plasma physics laboratory, there are several major facilities located up to 300 m away from the laboratory VTs [computing center]. There may be several experiments going on simultaneously at each facility. Assessing the information flows shows that with a good level of automation at the facility, about 100 sensors are used. The time for recording the process with an ATsP [analog-to-digital converter] at a rate up to 1 MHz reaches to 10-100 ms, and the volume of information being accumulated per pulse up to 1M byte. This poses the problem of organizing storage of raw data in a central operative buffer with large capacity and of flexibly using the buffer for various experiments. Fast data tranmission networks to deliver the raw data to the buffer and then from the buffer to the processing processors are needed. Among the features of work on the problem of controlled thermonuclear synthesis are continual changes in experiment plans. Automation of control of plasma and the facility is an experiment itself. The problem comes to automating individual processes, the nature, number and importance of which change with time an order faster than the composition and structure of the basic hardware for systems of automation. A series of experiments are conducted with long interruptions associated with adjusting the facilities. The quantity of computer equipment is limited by the shortage of service personnel. Flexibility in accumulating and distributing system resources is needed as is constant readiness for operation. In the foreground are questions of hardware simplicity and ease of system operation.

The basic engineering ideas of the laboratory computing and measuring complex (LVIK) that allows solving the problems posed consists in the following. The LVIK as a whole, like any other computer network, is on the one hand a hardware network of processors and functional peripherals, and on the other, a network of processors. At the lower level are local automated systems (LAS) connected to the facility. A LAS has the minimum required apparatus, for example, the CAMAC crate oriented to a specific experiment, and a display with a console--the work place for the physicist operator. At the upper level in the laboratory computing center (LVTs) are concentrated the resources of the computer hardware operatively connectable to the LAS. These are the compatible processors (SM3, SM4, E60, M400), main storage buffers and the common machine peripherals. Concentration of resources allows simplifying maintenance and increasing system flexibility. The territorially distributed LAS, processors, and hardware in the LVTs are connected by a single general laboratory system of communications through which proceeds bufferization of raw data and input and output of programs and data. The communication system maintains efficiency in disconnecting subscribers by using an automatic and controllable configuration.

When experiments are planned, LAS and other LVTs resources are assigned to processors. A processor, engaged in a specific experimental process, is formed that is distributed through the network. The communication system solves the problem of hardware organization of an arbitrary number of processes. The multiprocessor mode is organized by using collective access to the network with cyclical servicing of requests. A "relay baton" special signal is circulated in the network through loop coupling. A device ready for transmission catches the baton and seizes the network. After executing the operation, it issues a baton, releasing the network. Each master, after seizing the network, may execute a read or write operation at the address or even transmit a data file at the rate of 1 megabyte/second. The entire LVIK functions as a "pure" multiprocessor--the System of Automation, Multiprocessor Distributed (SAMUR).

Logically, the entire data transmission network is a field of storage with direct access. The size of directly addressable storage is 128K words. The storage is broken down into pages of 8K words each. The OSh EVM [computer common bus] is connected to the SAMUR network and the two independent loop systems for data transmission are coupled to each other through two-way symmetrical "window" type adapters. The adapters allow building a heirarchical multilevel structure with a limited size of storage and autonomous simultaneous operation of sections of the network. The adapters translate commands from one bus to the other, replacing the physical page numbers after preliminary adjustment. It can be said that switching of fields of storage occurs in the system. The network with direct access and switching of storage assumes new properties. A computer connected to the loop coupler may perform expeditious processing of data simultaneously with other computers. The usual processor commands operate with the storage, distributed through the network. Organization of transmission of messages through the network requiring special software and additional time outlays is not necessary. Properties of storage protection emerge since the hardware reacts to addresses within the bounds of the windows. An incorrect address from a computer is not sent to the network and is not propagated further. Planning of experiments, distribution of resources and assignment of addresses under the conditions of automation of experiments may be done administratively and manually since the system is still not large and rearrangment is required relatively rarely. After distribution of addresses, each process is programmed as unique, with its own virtual storage. All these properties of the network allow substantial simplification of programming of specific problems in the system for automation of experiments. SAMUR allows operation with any type of computer and the interface to the computer takes on the form of a direct access channel. However, the system is especially suited to a computer with a common bus.

The loop system of communication allows using powerful monitoring of data transmission--information feedback, since the message issued through the loop is returned to the master. To simplify the logic of peripherals, monitoring during reading is done by repetition of the output of data. The master compares the message for coincidence. For technical servicing of the network, we are introducing a system of monitoring, indication and control (KIUS) consisting of a console for manual control, a processor and additional address registers for checkpoints in the network modules. The KIUS uses the network equally with the other modules, organizing yet another independent process. The KIUS allows reading the detailed status of registers and triggers, makes technical diagnostics and issues monitoring signals to the network module.

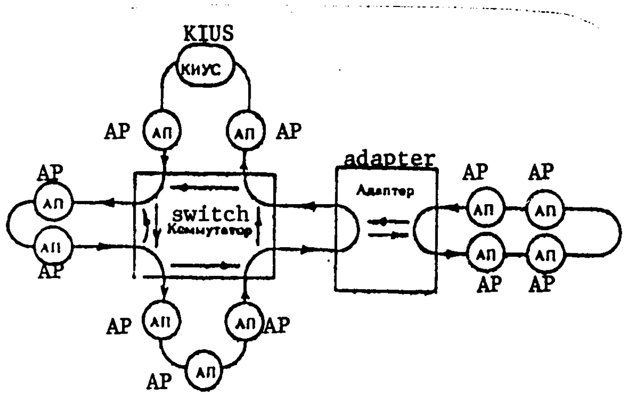
Let us examine in more detail the technical questions of organization of the SAMUR network. Three types of messages are used in the network:

the address 1 0 K (A00 - A16)P,
the data 1 1 0 (D00 - D17), and
the baton 1 1 1 E Z1 Z2 Z3,

where K is the command bit for read (0) or write (1),
P is the confirmation signal set by the receiver upon receiving its command when it can execute it,
E is the signal of the baton designating that the network is free (0) or busy (1), and
Z is the signal of the request from the devices to the processors and their number may be extended.

Simple terminals set requests to the network by which the computer starts a program poll of statuses. In the multiprocessor mode, bits for requests are assigned to their own computers. "Intelligent" terminals can reference the processor, sending a vector of interrupts according to the register address for interrupt of the computer adapter. The packet of messages in the network starts with an address, and then follows one or more data words. In read operations, data is issued by the executor. The packet ends with a baton message sent by the master with a zero in the baton bit. In the closed coupling loop, messages proceed asynchronously and have to be cancelled. This is done by the masters, opening the network for information after seizure of the network which is done by replacing the E bit with a "0" or "1" when the baton passes through the master demodulator. After detecting a baton with a "1", the master remains in the passive state or assumes it after completion of the operation, closing the network. Physically, the loop structure of the communication line is organized in the form of a radial tree cable network (fig. 1) using panels-switches, to which are connected the branches containing a forward or reverse cable. The switches automatically disconnect a branch upon loss of synchropulses from it, restoring the integrity of the rest of the network. A branch may also be disconnected to function separately from the network, establishing communication upon call according to the principle of switching of channels.

Shown in the table are the comparative characteristics of the SAMUR system, the instrument bus of the MEK [International Electrotechnical Commission] emulating the



AP — subscriber station

KIUS — monitoring, indication and control system

Fig. 1. Structure of the SAMUR loop network

operations of the CAMAC system, and of two types of serial CAMAC branches. In the column "signal delay," the time for signal propagation through the cable, the relay time for a system of 10 subscribers and the time for execution of an operation in the crate--1 microsecond--have been taken into account. The "efficiency" column shows the number indicating by how many fold the SAMUR exceeds the given system in throughput. The convenient discipline of operation and high transmission rate allow the SAMUR system to compete successfully with multiwire trunks. Execution time for one operation in the SAMUR ranges from 7 to 12 microseconds with a trunk length up to 1 km. The time for switching the network by baton from one request to another ranges from 1 to 6 microseconds. Replacing masters in the MEK and CAMAC networks is no simple task and cannot be done so quickly. And without this, the multiprocessor mode is inefficient. Processor wait time for a response from the network with cyclical servicing does not exceed the execution time for one operation multiplied by the number of active masters using the network.

Data is transmitted through the RK-50 and RK-75 cables by phase-frequency code (FChK); ones are coded by the entire 10 MHz frequency period, and zeros by the 5 MHz half-period. This code has a number of exceptional features. It contains the edges of the signal in the clock frequency which simplifies the task of synchronization by bits. Clock pulses of one generator are propagated throughout the entire network. There is a common reference frequency in the system. The signal does not contain a direct component; its spectrum lies within the 2 to 20 MHz band, and this allows eliminating low-frequency noise (less than 0.5 MHz) by using a resistor-capacitor filter, restoring the direct component at the level of the operation of the input logic element and partially compensating for phase distortions. All this allows transmitting information with a frequency of 10 MHz at a distance of up to 300 m without refresh through the RK75-4-11 cable. In the network, there is a simple device for phase synchronization that automatically closes the coupling loop when the length of the communication line is changed. Fig. 2 shows the circuit for the modem of the code with the receiving register. The modem circuit takes 6.5 packages of series 131 TTL IC's, and the rest of the circuit is made with 155 series. The input matching filter decouples all network devices by grounds and direct level.

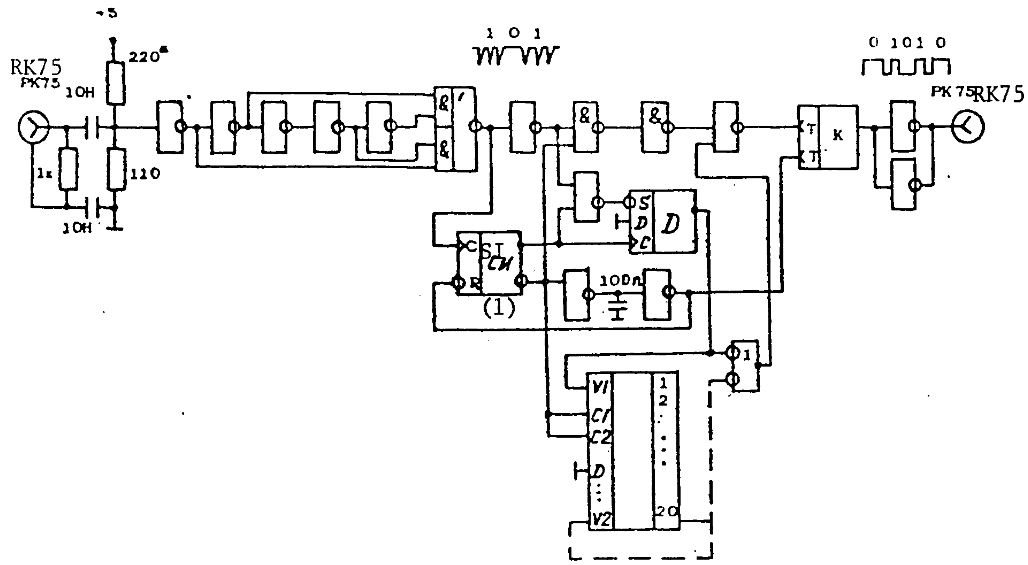


Fig. 2. Phase-frequency code modem circuit

Key:
1. SI [expansion unknown]

The signal passes through the MDM [modem] and the additional delay introduced into the network by the modem is 130 ns. Hardware outlays for network modules are not large. The adapter circuit for the M400 computer that fully implements the algorithm shown takes about 120 IC packages. The simplest stations, for example, the TsAP [digital-to-analog converter] control circuit--about 30 packages. Hardware outlays essentially depend on the discipline of network operation. The serial data transmission method allows building very simple LAS [local automated systems]. For example, the system that just transmits commands from the M400 computer has a transmitter from the computer the size of 16 IC packages and the receiver for the TsAP--20 packages.

In conclusion, a very important problem should be mentioned that occurs when two SM3 type machines are joined through adapters with direct access. This is the occurence of a clinch at the outlet of the computer to the network when a command referencing this computer has started in the network. In the process, the command from the network is waiting for the computer bus to be free, but the bus is busy and is waiting for the network to be free. The situation is resolved the following way. The operation with the common bus is ended fictitiously, and then the common bus, as usual, is released for the request for direct access for the network operation. After this, a special interrupt goes from the adapter to the computer. The simplest reaction, adequate in the majority of cases, will be a repetition of the entire preceding computer command, one of the cycles of which was executed

Table. Comparative characteristics of data transmission networks

Parameter	SAMUR		CAMAC		CAMAC		MEK	
number of signal wires		1		9		2		16
trunk length, km	1	0.02	1	0.02	1	0.02	1	0.02
signal delay, microseconds	7.5	2.7	9	4.2	9	4.2	1	1
byte transmission time, microseconds	0.8	0.8	0.2	0.2	1.6	1.6	12	1
number of bytes for CAMAC operation	6	6	17	17	17	17	8	8
operation execution time, microseconds	12.3	7.5	12.4	7.6	36.2	31.4	97	9
efficiency	1	1	1	1	3	4	8	1.2

incorrectly when the network was referenced. The waiting time for the synchronization signal of the executor to the computer must also be extended since the operation time for reading from the network to the common bus may extend beyond 10 microseconds.

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SYSTEM FOR AUTOMATION OF STRUCTURAL RESEARCH OF CRYSTALS

Krasnoyarsk AVTOMATIZATSIYA NAUCHNYKH ISSLEDOVANIY in Russian 1980 (signed to press 21 Sep 80) pp 137-145

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[Text] Structural crystallography is currently the main method of studying the atomic and molecular of solids of a varying nature. Mineralogy, materials technology, structural chemistry, solid-state physics, electronics, molecular biology and other divisions of science and technology need information on the atomic structure of matter. The problems of isomorphic penetration of rare and trace elements into minerals, and the atomic level of such processes, for example, as hardening of cements, the structural-sensitive properties of semiconductors, ferroelectrics, magnetic materials and materials for quantum electronics, the atomic mechanism of actions of enzymes and, finally, the storage and transmission of hereditary information of living organisms--these are some of the problems for the solution of which information on the atomic structure of objects of research is of paramount importance. Structural definitions are made based on experimental data on the diffraction of X-rays, neutrons or electrons in crystals. As the demand for structural information increases, the question of how long it takes to obtain this information becomes more and more acute. There are special difficulties in analyzing the structure of objects that disintegrate during irradiation. Successful resolution of the problems of structural analysis of crystals is possible only on the basis of creating diffractometers and employing the facilities of computer technology in all stages of research.

The design, plans and specifications for AROKS--automatic X-ray definition of crystal structures--were developed by the Institute of Crystallography of the USSR Academy of Sciences and are being implemented jointly with other scientific and design organizations. This project is aimed at creating a system to automate research of the atomic structure of crystals by diffraction methods [1, 2]. The AROKS project calls for development and manufacture of apparatus to conduct the diffraction experiment, development of new and elaboration of known methods of building and refinement of the atomic model of the crystal studied.

It is natural to single out three stages in the process of structural definition of a crystal:

-- preliminary study of the sample and derivation of the necessary experimental set of integral intensities of diffraction reflections;
-- construction with the experimental set of intensities of an approximate model of the atomic structure of the crystal under analysis; and
-- refinement of the atomic model.
The object of investigation of structural crystallography is the monocrystal which is a three-dimensional periodic structure that can be considered a diffraction grating created by nature itself for radiation with a wavelength on the order of one angstrom. If monochromatic X-ray radiation is directed at such a crystal and the crystal is set at the necessary orientation, a narrow diffraction beam occurs that is intercepted by a detector for measurement of its geometric characteristics and intensity.

Used until recently in the overwhelming majority of cases as the detector of diffraction radiation was X-ray film. X-ray film is an inexpensive two-dimensional detector that allows simultaneous recording of several diffraction beams, which speeds up considerably conducting the experiment. This property of photographic film is also made use of currently when studying protein crystals which are unstable with respect to X-ray radiation and where, forgoing accuracy, it is important to provide for the maximum rate of recording of the diffraction pattern. In the practice of X-ray diffraction analysis in solving problems of solid-state physics and structural chemistry, precision of definition of the structural characteristics of a crystal and the capability of controlling the course of an experiment while it is being conducted are assuming ever greater importance. Such possibilities are opened when the X-ray diffraction experiment is conducted by using automatic diffractometers--instruments for recording the diffraction pattern by using counters of varying design. Replacement of X-ray camera film by counters of quanta in X-ray diffractometers makes it possible to maximally enhance sensitivity and to increase the precision and rate of recording of the diffraction pattern. With diffractometric measurements, there is the capability of following the state of the sample and fixing the changes occurring in it during exposure. A second major feature of the diffractometric experiment is that it allows realizing feedback at the level of measurement of each reflex. This is a prerequisite for full automation of the diffraction experiment.

In 1966, the first domestic X-ray diffractometer, the DAR-M, in which a special automatic machine controlled the course of the experiment, was developed at the Institute of Crystallography of the USSR Academy of Sciences. In 1969, the diffractometer was connected for control to the Dnepr-1 UVM [control computer] which allowed optimization of measurement in the process for a number of parameters. In 1974, the first domestic series diffractometer controlled by the M-6000 ASVT was developed jointly by the SKB IK AN SSSR [Special Design Bureau of the Institute of Crystallography, USSR Academy of Sciences] and the "Burevestnik" NPO [Scientific Production Association]. Over ten of these instruments have now been produced and they have proved themselves in various scientific organizations in the country.

The DAR series diffractometers have allowed automating the process of deriving the three-dimensional sets of diffraction data. Development and implementation of the RED-4 four-disk [4-kruzhnyy] X-ray diffractometers have now been completed. These instruments allow fuller automation of the primary X-ray investigation of the monocrystal. The monocrystal under study is placed in a goniometric head in an arbitrary position. The control computer makes it possible in an automatic mode to investigate the crystal, determine the parameters of its lattice cell, establish and refine the crystal orientation matrix and conduct the entire experiment on measuring diffraction data. To facilitate interaction between the experimenter and the instrument, a chrystallographically oriented language has been developed that allows making a different type of measurement in the diffractometer without pondering over the algorithm for execution of these operations.

The introduction of automatic unichannel diffractometers has substantially raised the rate of conducting the diffractometric experiment on crystals with a small number of atoms in the lattice cell, for which recording of several thousands of reflexes is required. To study the structural mechanism of the functioning of biological objects having a lattice constant greater by one order of magnitude, the number of reflexes that must be measured is greater by two orders than the usual. Due to the low intensity of reflections from imperfect crystals of proteins and the high level of background, and because of the instability of crystals under irradiation, a diffraction experiment may last for months. However, an increase in the lattice constant leads to the simultaneous occurrence of hundreds of diffracted beams with a stationary crystal. Parallel recording of these beams allows speeding up the experiment by two orders and reducing by two orders the dose of irradiation and number of specimens studied. To rapidly derive the full set of integral intensities of diffraction reflexes from crystals with large dimensions of the unit cell, the KARD multichannel diffractometer with a coordinate detector was developed and manufactured and has undergone tests. Diffraction reflection recording is done by 512 proportional detectors with an area of (1.5 x 6.0)mm^2 each, assembled in four arc sections with 128 detectors in each. The productivity of the diffractometer with the coordinate detector is about 20-fold greater than that of the unichannel diffractometer. An M-6000 ASVT controls the KARD diffractometer. To further speed up the experiment, a detector with 256 x 256 elements of spatial resolution and with a time resolution on the order of fractions of a microsecond is under development. At the laboratory of high pressures of the OIYaI [Joint Institute of Nuclear Research] (Dubna), tests have already been run on a breadboard model of such a dual-coordinate position-sensitive detector for soft X-radiation, based on a proportional camera. This detector will be the basis for a diffractometer intended for study of protein crystals. Detector elements will be linked to the control computer by using equipment in the standard CAMAC. The diffraction pattern will be observed on a television screen interfaced with the computer through a (litokhon).

Under intense development in modern structural analysis are techniques to fix the distribution of valence electrons in crystals through precision diffraction data. To solve these problems, experimental data derived at low temperatures is needed. Especially promising for establishing the distribution of valence electrons in crystals is the parallel use of X-ray and neutron diffraction data from the monocrystals studied. Development of the first domestic four-disk diffractometer of the equatorial type for conducting the neutron experiment is now nearing completion.

Very promising are the combined studies of biological objects by the methods of X-ray structural and electron microscopic analysis. Photometrically scanning microphotographs and processing them on a computer, one can obtain a three-dimensional reconstruction of the biological object under investogation. Electron microscopic photos and X-ray photographs are processed by using an automatic microdensitometer controlled by a minicomputer.

Based on the experimental facilities listed above and a different type of computer, a system for automation of scientific research in structural crystallography has been developed and is being used effectively at the Institute of Crystallography. The drawing shows a diagram of this two-stage heirarchical system. The following automatic experimental facilities are at the lower stage of the system.

1. The SAD-2 system which includes two DAR diffractometers controlled by the M-6000 computer in the time sharing mode. Experimental data is grouped as belonging to one or another experiment and accumulated on disk. It is sent to the communications channel for further processing. Up to four instruments may be connected to this system. Operations are currently conducted through connection of the RED-4 four-disk equi-inclined type X-ray diffractometer.

2. The automatic $R2_1$ (USA) four-disk diffractometer controlled by a Nova 1200 minicomputer. The experimental data is accumulated on magnetic tape and sent to the communications channel upon system request.

3. The 512-channel diffractometer for biological objects is controlled by an individual ASVT-M-6000 minicomputer. Data is accumulated on magnetic tape which serves as an intermediate information medium. For input to the system for further processing, this information is read on each of the magnetophones of the HP-2100 computer.

Two different diffractometers are shown in the drawing--one with a coordinate detector and the four-disk neutron diffractometer. These diffractometers are in the development stage and will be connected to the system in the future.

4. Film information is processed on the R1000 drum type microdensitometer controlled by the Alpha-16 (USA) minicomputer. Information is accumulated on magnetic tape and is sent for further processing to the system through the communications channel. After scanning of the microdensitometer reaches 125 x 165 mm^2, raster is 25, 50 and 100 mk [micrometers], number of density levels is 256, and scanning rate is up to 55 kHz. Microdensitometer operation is controlled in the interactive mode from a Videoton-340 display connected to the Alpha-16 computer.

Operation of the experimental facilities in the lower stage of the system results in data files that are transmitted through communication channels to the second stage of the system for interpretation and refinement of the atomic structures of the crystals. The upper level of the system is organized on the base of the M-220M computer, as the main computing capacity, and the HP2100 computer that exercises the role of an exchange computer. Introducing an exchange computer makes it possible for us to combine data flows from different automatic facilities in lines with random loading, to convert the data format, taking the receiver requirement into account, and to build up the system or replace its individual parts without changing the entire system as a whole. In addition to exchange functions, the HP-2100 computer performs a number of functions associated with providing additional conveniences for the researcher, including long-term data storage (organization of a data bank) and operation in the mode of terminal processor (plotter control). The plant version of the M-220M computer did not fully meet the requirements imposed on the central computers for the system. The main deficiencies were the primitive system of interrupts and the lack of communication channels, insufficient direct access storage for organization of the solution of the multiparameter problems of

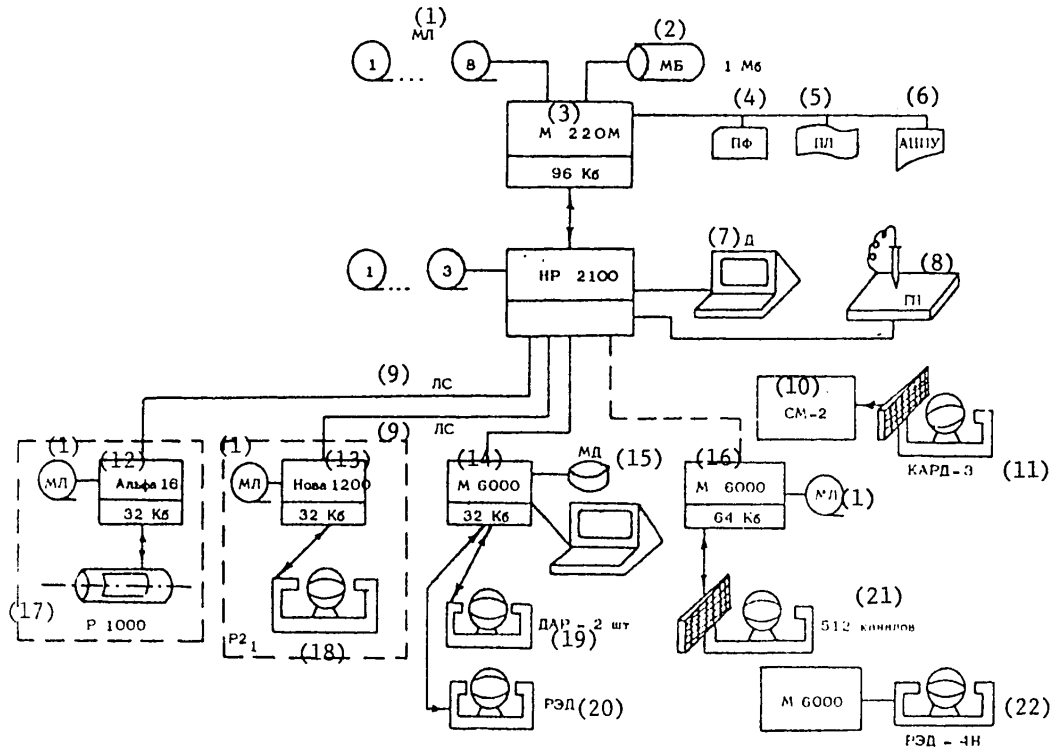

Figure. System for automation of scientific research in structural crystallography

Key:

1. ML [magnetic tape]
2. MB [magnetic drum], 1 Mb
3. M-220M computer, 96 Kb
4. PF [puncher]
5. PL [punched tape]
6. ATsPU [alphameric printer]
7. D [display]
8. GP [plotter]
9. LS [communication line]
10. SM-2 computer
11. KARD-3 diffractometer
12. Alpha-16 computer, 32 Kb
13. Nova 1200 computer, 32 Kb
14. M-6000 computer, 32 Kb
15. MD [magnetic disk]
16. M-6000 computer, 64 Kb
17. R1000 microdensitometer
18. $R2_1$ diffractometer
19. DAR diffractometer, 2 units
20. RED diffractometer
21. 512-channel diffractometer
22. RED-4N diffractometer

structural analysis, and the lack of facilities for intercourse with the operator in the automatic mode. This required considerable hardware changes and development of system software. The main hardware changes were as follows. Storage protection was organized, an operator's console was developed based on the Konsul-254 EPM, the interrupt system was improved, and a communications channel with the HP-2100 computer was developed and implemented. The "Dispatcher" handles job transmission. System status analysis is handled by the "Monitor"--a unit in the "Dispatcher" program. A set of diagnostic programs comments in detail on events occurring in the system, which substantially eases the operator's work.

Data is transmitted from experimental facilities by two methods: transit and with entry into the archive file. The transit method of transmission is used upon request of the central processor, when it is free, and can begin processing data at once. When the central processor is busy and the information storage of the experimental facilities has to be released, the data goes through the communication channel to the HP-2100 computer where it is put into an archive file on magnetic tapes. Upon request of the M-220 computer, the data is extracted from the archive and sent for further processing. Experiment data is blocked into records of up to 2,500 bytes each for transmission through communication channels.

The accumulated data is processed after the complete file of experimental data on the crystal being studied is received.

Crystal atomic structures are determined and refined by the diffraction data by using the Kristall [3] and Rentgen-70 [4] program systems. The Kristall system allows realization in the automatic mode of the superimposed method of interpretation of the function of the interatomic vectors [5, 6, 7]. For automatic translation from a rough model of the structure being studied to the coordinates of the basic atoms, which are suitable for further refinement by the method of least squares, a procedure for refinement of the phases of structural amplitudes has been developed and is being used very effectively [8]. In the Kristall system, an abundant set of programs for definitive refinement of structures by the method of least squares has been developed and is used. These programs make it possible to consider the anisotropy of the thermal oscillations of atoms, the anomalous scattering of X-rays by the atoms of the structure, extinction and some other effects of the interaction of X-radiation with matter [9, 10]. Formulation of results of the structural definition of crystals and intermediate analysis of the models derived are performed by using the plotter controlled by the HP-2100 computer [11]. The software developed allows drawing a projection of the structure on arbitrary surfaces with illustration of the anisotropy of the thermal oscillations of the atoms and stereo pairs for the direction of the beam of view specified by the researcher.

The system for automation of structural research at the Institute of Crystallography continues to be developed and improved by connecting new facilities for conducting experiments as well as by developing new techniques implemented by programs to enrich the system software.

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MAGNETIC AND MAGNETIC-SEMICONDUCTOR COMPONENTS FOR INFORMATION PROCESSING

Moscow MAGNITNYYE I MAGNITNO-POLUPROVODNIKOVYYE ELEMENTY DLYA PERERABOTKI INFORMATSII in Russian 1981 (signed to press 20 Jan 81) pp 118-120

[Abstracts from collection "Magnetic and Magnetic-Semiconductor Components for Information Processing", edited by M. A. Rozenblat, Order of Lenin Institute of Control Problems, USSR Academy of Sciences, Ministry of Instrument Building, Means of Automation and Control Systems, Izdatel'stvo "Nauka", 2,000 copies, 120 pages]

UDC 681.333:519.2(088.8)

PRINCIPLE OF DESIGNING OPERATIONAL AVERAGING DEVICES

[Abstract of article by Rozenblat, M. A., Romashchev, A. A., Aref'yev, Yu. I. and Kreshtal, A. N.]

[Text] A recursion algorithm of the stochastic approximation type is considered to analyze the mean value of random processes. The principle of designing corresponding devices distinguished by adequate simplicity and intended for averaging both digital and analog random processes in real time is proposed. A block diagram and the characteristics of technical realization of the main assemblies of the averaging device are presented. Versions of devices constructed on the basis of analog and analog-digital integrators, including those based on magnetic storage components with analog memory, are considered. The results of experimental investigations and a number of examples of using the developed devices are presented.

UDC 681.332:612.172.2

USE OF DEVICES FOR OPERATIONAL ANALYSIS OF RANDOM PROCESSES IN MEDICAL AND BIOLOGICAL RESEARCH

[Abstract of aricle by Rozenblat, M. A. and Romashchev, A. A.]

[Text] General problems of constructing specialized devices for operational analysis of medical and biological processes that are probable in nature are considered. Noise-protected algorithms are presented for determining the estimates of the mean value and standard deviation of random processes. A device based on them for operational analysis of cardiac rhythm Kardioritm is described and the areas of its feasible application are indicated.

UDC 65.012.122

GENERALIZED METHOD OF FORECASTING BY AVERAGED VALUES

[Abstract of article by Ageyev, Yu. V. and Romashchev, A. A.]

[Text] A method of forecasting by averaged values presented in the form of the sum of products of values of the monitored value for corresponding coefficients provided that the sum of coefficients is equal to unity is considered. Generalized formulas of forecasting by different averaged values, for example, by exponentially smoothed, sliding mean values and so on are derived. The proposed algorithms are convenient for design of forecasting devices based on analog memory components, specifically, magnetic components.

UDC 65.012.122:621.396.664

CHARACTERISTICS OF FORECASTING BY EXPONENTIALLY SMOOTHED AND SLIDING MEAN VALUES

[Abstract of article by Ageyev, Yu. V., Kreshtal, A. N. and Romashchev, A. A.]

[Text] The characteristics of forecasting by exponentially smoothed and sliding mean values in designing forecasting devices based on analog memory devices, specifically, magnetic devices, are considered. The effect of noise in the input signal and of information storage errors in analog storage devices on the accuracy of forecasting is estimated. Methods of increasing forecasting accuracy are considered.

UDC 621.396.664

A MAGNETIC ALTERNATING CURRENT PRESTART CHECKING SENSOR

[Abstract of article by Voronichev, P. P.]

[Text] The paper is devoted to design of an alternating current prestart signal checking sensor of commercial frequency on the basis of pulsed modulators. The transfer characteristic is calculated and the conditions for achieving maximum stability are considered.

UDC 656.256.3:621.398.53.084.2.004.5

SOME PROBLEMS OF TECHNICAL DIAGNOSIS OF AUTOMATIC BLOCK DEVICES IN RAIL TRANSPORT

[Abstract of article by Aleshin, V. N., Voronichev, P. P. and Sopel'nyak, A. G.]

[Text] A device for checking a single numerical code automatic block signal unit on the basis of magnetic prestart sensors is considered. The proposed arrangement of the sensors makes it possible to detect the main failures of the signal unit and the track circuit. The operating principle is described and a schematic diagram of an individual sensor is presented. Selection of prestart field settings of the parameters being checked is justified.

UDC 681.142.61

SWITCHING COMPONENTS OF DIGITAL-ANALOG CONVERTERS

[Abstract of article by Kerbnikov, F. I., Vishkarev, A. B. and Mengazetdinov, N. E.]

[Text] The principles of designing switching components for switching resistive dividers in digital-analog converters are discussed in which multiplication of the input analog signal by a constant coefficient with given error is achieved either by constricting the dynamic range of the analog signal or by switching fixed direct current sources.

UDC 621.318.681.327

CHARACTERISTICS OF CYLINDRICAL MAGNETIC DOMAIN BEHAVIOR DURING MOTION ALONG MAGNETIC CONTROL STRUCTURES

[Abstract of article by Il'yashenko, Ye. I., Matveyev, S. N., Karmatskiy, N. I., Parinov, Ye. P. and Chirkin, G. K.]

[Text] The results of experimental investigation of moving structures for cylindrical magnetic domain devices made by the electrooptical method are described. The trajectories of motion of cylindrical magnetic domains along the most propagated structures are given and the Θ and S-characteristics taken with control field of 40 Oe and at frequency of 10 kHz are presented. The measurements were made on closed shift registers using Bi-substituted ferrite-garnet films with nominal cylindrical magnetic domain diameters of 7 and 2.8 microns. The effect of an increase of the intercomponent gap on the patterns of the trajectories and of the Θ-characteristic for "asymmetrical herringbone" and semidisk structures is also considered.

UDC 621.318.681.327

EFFECT OF NONUNIFORM MOTION OF CYLINDRICAL MAGNETIC DOMAINS ON DYNAMIC VARIATION OF THE PARAMETERS OF THE STABLE OPERATING ZONE FOR PERMALLOY COMPONENTS WITH A SINGLE DISCHARGE GAP

[Abstract of article by Kleparskiy, V. G. and Romanov, A. M.]

[Text] The principles of the dynamics of motion of cylindrical magnetic domains for some configurations of permalloy components with single discharge gap were investigated by the stroposcopic observation method. Comparison of the derived principles to the nature of frequency variation of the stable operating zone of test motion circuits made on the basis of these same components made it possible to estabish the relationship between the degree of nonuniform motion of the cylindrical magnetic domains in the system of moving components and a dynamic decrease of the stable operating zone, which becomes especially appreciable at rotational frequency of the control field greater than 100 kHz.

UDC 538.221

INVESTIGATING THE STEADY MOTION OF CYLINDRICAL MAGNETIC DOMAINS AROUND A CIRCLE

[Abstract of article by Yurchenko, S. Ye.]

[Text] A method of measuring the dynamic characteristics of a cylindrical magnetic domain during steady motion around a circle under the continuous effect of moving gradient fields is described. The results were compared to those for translational motion of a cylindrical magnetic domain achieved by the method of high-speed photography of cylindrical magnetic domain dynamics. The effect of dynamic variation of the wall structure of the cylindrical magnetic domain and the field in the plane on the nature of motion of the cylindrical magnetic domain around the circle was investigated.

UDC 621.318

MAGNETIC SYSTEM FOR INVESTIGATING CYLINDRICAL MAGNETIC DOMAIN DEVICES WITH MICRON DIMENSIONS OF DOMAINS

[Abstract of article by Karmatskiy, N. I. and Matveyev, S. N.]

[Text] A new design of a rotating magnetic control field system intended for visual investigation of cylindrical magnetic domain devices, the domain diameter of which is close to 1 micron, is proposed. The method of calculating the system is given.

UDC 621.318:681.327

MATHEMATICAL MODELLING OF THE INTERACTION OF CYLINDRICAL MAGNETIC DOMAINS AND CONTROL COATING

[Abstract of article by Tsyganov, O. A.]

[Text] Static and quasi-static modelling of the interaction of a cylindrical magnetic domain and a periodic control coating comprised of "asymmetrical herringbone" components by calculating the magnetic lines of force of traps and numerical solution of the equations of motion was carried out on the basis of a model of magnetization distribution in the control coating and on model representation of the energy dissipation mechanism in the domain wall. Comparison with experimental data is given.

UDC 681.327.621.318

SOME APPLICATIONS OF CYLINDRICAL MAGNETIC DOMAIN STORAGE DEVICES IN MULTIPROCESSOR COMPUTER SYSTEMS WITH SINGLE INSTRUCTION FLOW

[Abstract of article by Veselovskiy, G. G. and Rozenblat, M. A.]

[Text] Problems of efficient use of cylindrical magnetic domain storage devices in the configuration of multiprocessor computer systems with single instruction flow are considered. It is shown that, besides standard applications of cylindrical magnetic domain storage devices (as systems program stores, microprogram files and so on), their use as second-level memories of elementary processors is effective in systems of the type considered. Parallel exchange of information between the internal stores of elementary processors and the second-level memory becomes possible in this case due to the possibility of synchronizing the cylindrical magnetic domain storage devices, which permits a considerable increase in the carrying capacity of the input/output channel.

UDC 621.318.681.327.66

RESULTS OF EXPERIMENTAL INVESTIGATION OF CYLINDRICAL MAGNETIC DOMAIN GENERATORS FOR CIRCUITS WITH MAGNETIC CONTROL COATINGS

[Abstract of article by Il'yashenko, Ye. I., Parinov, Ye. P. and Chirkin, G. K.]

[Text] The results of investigating cylindrical magnetic domain generators are presented in which the magnetic application is in the form of a "tapir" component. It is shown that the minimum generation currents in generators of this type do not exceed 250 mA with generation pulse length of 100 nanoseconds. It is also found that the stable operating range of this central magnetic domain generator easily combines with that of the information file based on "tapir" components during motion.

UDC 681.322.65

ORGANIZATION OF READOUT IN CYLINDRICAL MAGNETIC DOMAIN STORAGE DEVICES

[Abstract of article by Rubchinskiy, A. A.]

[Text] Special organization of the queue of requests for words from a storage device is proposed to increase the data transmission speed from cylindrical magnetic comain storage devices. The request whose address is found at minimum distance (in the sense of search time) from the address of the preceding request is selected as the next request. The main characteristics of the queueing system under consideration: distribution of the length of the queue and response time, are determined.

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ADAPTIVE COORDINATE-PARAMETRIC CONTROL OF TRANSIENT OBJECTS

Moscow ADAPTIVNOYE KOORDINATNO-PARAMETRICHESKOYE UPRAVLENIYE NESTATSIONARNYMI OB"YEKTAMI in Russian 1980 (signed to press 2 Oct 80) pp 2, 240-243

[Annotation and Table of Contents from book "Adaptive Coordinate-Parametric Control of Transient Objects", by Boris Nikolayevich Petrov, Vladislav Yul'yevich Rutkovskiy and Stanislav Danilovich Zemlyakov, Order of Lenin Institute of Control Problems, USSR Academy of Sciences, Izdatel'stvo "Nauka", 1,300 copies, 244 pages]

[Text] Problems of controlling objects whose dynamic characteristics vary over a wide range in time during operation are considered. A class of coordinate-parametric control systems is introduced which is capable of significantly expanding the capabilities of adaptive control of transient objects. The main results were found with respect to a class of adaptive coordinate-parametric control systems constructed on the basis of searchless self-adjusting systems with a standard model.

The book is intended for specialists involved in design and introduction of control systems and scientific workers in the field of control theory. It may be useful to students of senior courses and graduate students specializing in the field of control of transient objects.

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