The Computer: Capabilities, Prospects and Implications

Intelligence negotiates the services of an obtrusive, demanding, but enormously competent mechanical slave.

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Computers and auxiliary machines for the electronic processing of data are emerging as potentially revolutionary intelligence tools to extend and multiply the human skills of the community. The intelligence agencies have already committed huge sums of money for research and development and the design of advanced systems. Eventually this action is certain to produce radical changes in the ways intelligence information is collected, transmitted, stored, and utilized.

There are two main classes of computers, digital and analog. The analog computer, given measurements of a continuum, notably time, direction, distance, or velocity, processes them mathematically as desired and displays the results in some measurable form. An automobile speedometer is a mechanical form of very simple analog computer; it measures the rotation of a car's wheels and continuously translates this into a miles-per-hour reading on the dashboard. For electronic computation the input measurements may be represented by the voltages of electrical signals and processed by addition and subtraction of these voltages. One fruitful application of the analog computer is in a missile guidance system. It converts measurements of wind and missile velocity, launching angle, position, time, etc., into a chain of output signals for adjusting the valves and control surfaces of the missile. Through a feedback loop to the missile these make instantaneous correction of abnormal trajectory variations. They may also be used to drive a data-plotter on the ground for charting the trajectory or displaying it on a TV screen.

Because they work with measurements, which can never be infinitely precise, the analog computers are less accurate than digital computers, which process discrete numbers. And since numbers may be used to represent the letters of the alphabet or verbal symbols, the digital computer is the machine that has the major promise for handling the verbal data of intelligence. It is possible, however, to pass the signal voltages of the analog computer's output through a converter which turns them into discrete numerical quantities in digital codes that can be processed by a digital computer.

The Digital Computer

The abacus is a simple digital computer, using beads to represent numerical quantities and providing a place to add and subtract these and one to store results. With practice a person can do arithmetic on an abacus much faster than on paper. Electronic computers like Remington Rand's UNIVAC or IBM's 700 series provide essentially the same facilities; but they process numbers at speeds measured in millionths of a second, have an immense storage space or "memory," function precisely and accurately, and can process letters of the alphabet when these are numerically coded, treating them internally as if they were numbers.

The really unique feature of a digital computer is what is called its "logic," its ability to choose for itself one of a number of alternative procedures according to the outcome of previous computations. This feature is the one mainly responsible for the notion that digital computers are endowed with near-human or even superhuman qualities. The fancy is encouraged in the vocabulary used by the computer people: you "instruct" and "query" the machine in its own "language"; it "accepts," "differentiates," "searches its memory," "analyzes," even "evaluates." A seasoned computer operator will argue on occasion that the machine has a personality of its own, and his emotional involvement with the machine is such that research is being done in man-machine relationships to arrive at the right mix of human factors for happy and efficient work with a machine as colleague or subordinate. Nevertheless, although it is true that man can evolve ways to make a digital computer perform operations that closely resemble human thought, and although the machine can digest more information than a man and process it faster and more accurately, the parallel with human skills should not be carried past the point of fanciful analogy. The machine does not "think"; it is driven through a predetermined set of operations.

Digital computers are used for solving complex mathematical equations, for engineering calculations, for statistical analysis, for experiments in machine translation and information retrieval, and for other precise processing of numbers or letters as in business accounting and banking systems. They also make it possible to run a wide range of tests on sophisticated system simulations called mathematical models. Such a model is a set of mathematical equations governing a system, say an economic system. If the equations used are valid, it is possible, by subjecting the synthetic model to variable data representing impingements on the economy, to determine and analyze the effects of these, and thus to predict what is likely to occur in a real situation. Whereas hand calculations to simulate all phases of economic interaction would not be feasible because of their sheer bulk, the job can be done on a computer in a matter of minutes.[1]

Major weapons systems can be and are similarly reduced to mathematical models in order to help determine their strategic implications. The models, incorporated into computer programs, are put through mathematical war games which test variant opposing strategies, weapons, tactics, logistics, etc., and make possible a rapid evaluation of war plans on a scientific and realistic basis. This is the only comprehensive peacetime test of the effectiveness of military forces, equipment, and resources and of the way they are employed.[2]

The language of a digital computer is usually a binary number system, which substitutes the base 2 for the customary 10 of our decimal system. Instead of running from 0 to 9 before carrying over to a second digit, it goes only from 0 to 1 and then back to zero as it registers in the next position. Instead of 1, 2, 3, 4, 5, it counts 1, 10, 11, 100, 101, etc. It is used in digital computers because their circuits, switches, tubes, transistors, and other electronic components are most efficiently designed to have only two alternate states--on/off, transmitting/non-transmitting, magnetized /unmagnetized, etc. There is a simple formula for converting from the decimal system to the binary, but the computer user does not need it: decimal and alphabetical data coded on input media such as punched cards and perforated paper tape are automatically converted to binary numbers on the way into the machine.

Electronic Data Processing

A complete EDP system based on a computer generally has the following components:

- Input equipment-devices such as key punch machines and flexowriters for putting the data into acceptable form; machines that convert punched card and paper tape code to binary numbers; and equipment, usually magnetic tape units, to take data into the main storage area of the computer.
- The computer, performing all arithmetic and logical operations. Its flexible ability to accept, store, select, and compare data, to calculate, follow logical rules, and release results makes it the heart of the EDP system.
- A storage area, containing not only the data to be processed but also the set of instructions-program-governing the entire operation of the system and a place to hold intermediate results for later use.
- A control mechanism that electronically supervises and synchronizes the operations of the several machines and provides for manual interruption of the program from the operator's console.
- Output devices, those carrying the final results. They may produce punched cards or perforated paper tape, magnetic tape, printouts on paper or microfilm, or TV displays.

Most present-day EDP systems use magnetic tape for input and output. But storage on magnetic tape would entail scanning a reel of it from the beginning to find any particular stored item, and several EDP systems therefore use a different storage medium, say a magnetic disk, in order to provide random access to individual items. Every item on the disk has its own electronic pigeonhole or "machine address," and when the machine is given that address it can proceed directly to the item without scanning any other data in the file.

The conditioning of an EDP system to solve a particular kind of problem or render a particular kind of processing is I the job of a programmer. He analyzes the problem, makes certain it is well defined, redefines it if necessary, and attempts to preconceive all eventualities. Then, step by step, he meticulously prepares the machine's instructions, using a special set of symbolic notations furnished by the manufacturer along with the list of operations the system will perform. The program thus prepared contains not only the instructions for the computer but directions for moving the data from machine to machine or place to place within the system.

Automatic programming, a recent innovation designed to make programming simpler for the user, is illustrated in IBM's FORTRAN. It supplies a small and rigid natural-language vocabulary--FORTRAN contains only 38 statements and some simple rules of usage--in which the user writes his program. A prepackaged program called a compiler enables the computer to convert these to machine language as its own instructions.

The concept of automatic programming is being taken a step farther by a committee of the Department of Defense. This group is engaged in producing a compiler that can automatically convert a program set up for one manufacturer's equipment to the right form for another's. Each manufacturer of EDP equipment also sponsors a users organization aimed at pooling the experience and the programs of all for mutual benefit. SHARE, for example, the organization of IBM's 709 customers, maintains a library of programs written by individual members but available for use by any one. This kind of cooperation conserves costly programming manpower and saves time.

Even though computer applications and programming have only begun to scratch the surface of potential capability, hardware technology continues to forge ahead. The main, trend is to design faster and smaller computers, an aim that; ultimately involves the use of cryogenic techniques--operating temperatures near absolute zero--and microminiaturization of circuitry. The very low temperatures increase their computer's switching speeds to a point where the circuits operate with almost no electrical resistance. Microminiaturization is achieved by reducing circuits optically or electronically to their smallest reliable size and depositing an image of the network on the surface of a wafer-thin foil. Very complex circuitry can thus be built into a cube of stacked wafers the size of a lump of sugar.

Looking ahead, designers foresee the day when refrigerated computers the size of a portable TV set will operate on wall socket power. It is symptomatic that one of the serious design problems facing computer engineers is that of minimizing the length of connecting wires, which becomes more and more critical as components get smaller and signal speeds approach the speed of light.

Intelligence Applications

It is clear that these machine capabilities can be applied at a number of points in the intelligence process to improve and accelerate it. Not that computers and other EDP machines constitute any kind of panacea for our ills; they are not glamorous Aladdin's lamps to do our bidding while we recline at ease. Properly applied, they merely provide extensions of human skills, and the calibre of intellectual effort that goes into these applications will determine the net value of the changes now certain to be thus wrought over the next few years in intelligence methods and procedures.

We cannot yet begin to catalog the future points of application, much less describe in just what way machines are going to be used, but we can speculate about some of the intelligence processes likely to be affected by them.

Reporting Media. EDP's first logical prerequisite is likely to be felt in the reporting of collected information. If we are to do any kind of large-scale electronic processing of intelligence information, the natural-language cables and documents that convey it to Washington must be converted to digital form. This could theoretically be done in Washington by manual copying onto punched cards or perforated paper tape or by an automatic optical scanning machine; but retyping is too monumental a task to be considered, and character-recognition conversion machines have not yet been made practical. The realistic and efficient thing to do is to capture a suitably coded version of reports as a by-product of their original typing in the field.

Teletype equipment produces such a version on perforated paper tape, and standard-keyboard typewriters can be modified to produce one; the best known tape-producing typewriter is the Flexowriter, in use in many parts of the intelligence community. Its tape can be used to drive automatic equipment for duplicating itself, for producing hard copy, or for telecommunications; and it can be used as input to an electronic data processing system. If such tape were the regular by-product of report typing in the field, it could serve as the medium for electric or physical transmittal to Washington, as the means for automatic reproduction of hard copy for dissemination, and, converted to magnetic tape, as input to an EDP system for automatic indexing, abstracting, and analysis in a central document repository. Experiments are already being conducted in the intelligence community to develop procedures based on getting machine-usable versions of reports directly from the field for immediate headquarters processing.[3]

Dissemination. The fact that a machine program can be designed to compare the words in the text of an article with words in a table in the computer's memory suggests its potential use with an intelligence analyst's "watch list." NSA is experimenting with this notion and developing analyst "profiles" consisting of select words and phrases. These are compared by machine with incoming information, and the matches therein are flagged for the analyst's attention. The Air Force has also developed an automatic disseminator which scans incoming information against analyst requirements in essentially the same way.[4]

Document Recovery. The intelligence officer depends on a central library to supply him with documents he cannot keep in his own files and with lists of documents bearing on any subject he may have under study. The provision of this service is no mean task, with documents being acquired at the rate of about 1500 per day to be indexed, stored as compactly as possible, and made susceptible of rapid recovery in some l form suitable for use. Machines are a potential aid in all these three phases of the library problem. The semi-mechanized CIA Intellofax files are now being examined with a view to conversion to a magnetic tape and photographic system, and the Minicard installation in AFOIN uses advanced equipment designed to meet a similar Air Force filing problem.[5] It is hoped that successful machine development will reduce the need for individuals to keep their own files by providing better central service.

Specialized Files. A critical problem with the general document files of a central library, one aggravated as size and complexity require the use of machine methods, is the semantic and projective difficulties in providing precise and comprehensive indexing by subject matter. These difficulties do not occur in some specialized intelligence files, like those for air target data and for name checks, which can be indexed according to unambiguous features like names, nationalities, and locations; and these are the logical ones on which to try the first EDP applications. Air Targets is already using EDP,[5] and for CIA's millions of biographical records used in name checks a special-purpose machine complex with random-access storage and very large capacity is being built in prototype under the code-name WALNUT. Smaller specialized files can be processed with general-purpose EDP equipment currently on the market, some of it accompanied by manufacturer's generalized programs which need be supplemented only by a few punched cards defining the data sought, how it should be sorted, merged, or matched, and in what form the answers should print out.

In these and other applications to alphabetical data one should still not lose sight of the arithmetic capability of the machines. On demand the computer can supply significant statistical data for management planning and action-predicting a file's rate of growth, detecting gaps which warrant increased collection effort, revealing patterns of user interest, etc. The answers can be rendered in a variety of formats ranging from numbers on paper to graphs on a TV screen. The complex reports accounting necessary in the management of some collection systems may be particularly amenable to such a dual attack by machine.

Abstracting. Beyond their evident applicability to the handling of large files, machines have a less obvious potential for performing a number of operations which now burden the human analyst. One of these is the abstracting done as a library service or by individual analysts for their own needs. Computer programs have been written to do word frequency counts of the text of an article, separate common words from those of graded substantive significance-"notion words"and after some statistical analysis print out the four or five sentences ranking highest in notion words. When perfected such programs will produce automatic abstracts from texts in any language. The Army's Project ACSIMATIC, among others, is experimenting with machine abstracts of ACSI Information

Reports.

Translation. There has been a good deal of publicity for the progress toward a machine solution of the bulk translation problem, particularly of Soviet scientific literature. Somewhat sensational newspaper reports have described "breakthroughs" and demonstrations leaving the impression that all machine translation problems have been solved. It is true that an ability to do a bulk output job intelligible to the reader has been achieved. Smooth-prose translation by machine is not yet a reality, however, and may not be for many years to come. Considerable language research remains to be done, and there are still serious questions concerning an output quality adequate for intelligence needs. But progress is being made toward the day when large-scale machine translation coupled with high-speed printing equipment will give wide and rapid dissemination of foreign texts to researchers. The process could also be reversed and used to convert English to other languages for propaganda and other objectives.

Statistical Analysis. Wherever there is a need to correlate large samples of data involving many variables, statistical inference techniques can be applied with good results, and computers can be used to make the bulk manageable or to speed and improve the work. The economic researcher, for example, who may be loath to apply statistical methods to much of the data he has because it is such a tedious and time-consuming job, will find computers more and more useful in the future, aiding him to reorganize his data quickly into different forms for analytic review. Eventually he may even make a regular practice of devising mathematical models of economic situations and using machines to help him forecast the effects of anticipated changes in conditions.

Photo interpretation is a natural for machine handling because the interpreter usually begins by solving certain complex mathematical equations used in photogrammetry. He needs computations to obtain the precise geographic orientation of his photo and then to get accurate measurement of objects on the ground. It is feasible to store programs in a computer to solve any number of these equations and yield rapid, exact results when given the parameters of the particular problem. Hand calculations may be economical and fast enough while photo-intelligence ground coverage remains limited, but the prospect of tremendous increases in coverage through satellite reconnaissance programs suggests that machines are likely to play a dominant role in the PI process in the future.

The several experimental applications of EDP thus far tried show that the powerful tools of mathematics and statistics can advantageously be used on verbal information through machine processing, which guarantees not only speed but unprecedented uniformity of product by ensuring that prescribed rules are followed consistently and precisely. In time, particularly if incoming intelligence information begins to arrive in digital form, there is good reason to believe that more complex analytic tasks can be undertaken by the machine through the making and matching of logical combinations of words and phrases. Machine correlations may give rise to new hypotheses not suggested by the uncorrelated data. And farther ahead lies the possibility of using machines to perform elementary types of problem-solving.

Warning Systems

For the past several years the Defense Department has been developing tactical and strategic command control systems. The most widely publicized of these is SAGE (Semi-Automatic Ground Environment), an air defense system. Items received by a machine and dealt with in some way in the SAGE system include such things as aircraft availability, weapons availability, base capability, weather, and radar sightings. When hostile aircraft have been detected a manual calculation of the best distribution of weapons and interceptors to meet the particular threat is almost impossible because of time constraints. The computer, however, can calculate distances, compute intercept times, assess the number and kind of bogey aircraft present, and make a weapons assignment within tolerable time limits. In the present system, while the computer handles most of the routine data processing, it is monitored and assisted by personnel who also make the more important decisions on threat evaluation and tactical action.

As in SAGE, other command control systems of the future are being planned so that an array of the information, including intelligence information, necessary for action can be displayed in readily usable form at command centers. EDP machines will be an integral part of such systems because the volume of data with which a commander must deal is enormous and its interrelations so complex that it can no longer be correlated reliably and rapidly enough by manual means. Vast collection programs will back up these new systems, providing intelligence data for their input from radar, ELINT, and other reconnaissance programs, most of it reduced to analog or digital form beforehand.

It seems reasonable to assume that data may some day also be included from non-technical intelligence products such as estimates, broadcast intercepts, communications activity assessments, agent reports, etc.; but these would presumably first have to be computerized to be compatible with the other data displayed for the commander's evaluation. Otherwise this intelligence contribution would be likely to follow rather than precede action decisions. Ideally, the indications intelligence channel should feed information directly and continuously into the command control system to form an integral part of the display pattern presented to the commander and provide him with a reliable index of the enemy's immediate intent to attack. Although it does not necessarily follow that today's indications intelligence process should be fully automated to mesh smoothly with command control systems, there is sufficient justification for serious exploration of the possibilities. Since it is already evident that EDP machines are destined ultimately to play the major role in command control, plans for an automatic intelligence relationship need to be laid early in order to ensure smooth parallel development.[6]

Impact on the Community

If we profit by the experience of industry during the past few years we should be prepared for some radical changes organizational structure as a result of the introduction of machines. The literature is filled with reports of business organizations being turned upside down getting ready to use automatic equipment. There are problems of conversion, parallel processing, work rearrangement, staffing, space, etc. From a data-processing viewpoint, the objective is to achieve a balanced flow of information through the whole organization, and this invariably cuts across departmental lines. It is possible to prepare against problems of this kind in the intelligence organization if it is examined as a total, integrated, functional system. An examination of the necessary scope and the implementation of a coordinated plan will require a time of from five to seven years, an investment that may run into tens of millions of dollars, and the probability of outside contractual assistance.

Another kind of impact is that of machines on personnel. People are wary of the prospect of the machine "taking over," and they set up defenses to prevent it. Perhaps they can be reassured by the fact that the introduction of computers in business, while speeding up information and improving management's control, has neither reduced personnel in number nor replaced individuals: with no experienced pool to draw on for EDP staffing, the pattern has been to do a great deal of internal training of the old staff. But training takes time, and intelligence should be planning an enlightened training program chronologically coordinated with the rest of the change-over effort.

The next five or ten years will be the period for planning, and experimenting with machine processing of intelligence data that will ultimately make magnetic tapes as common a form of dissemination as paper. It will be a period of careful and deliberate systems analysis, simulation, and testing. The problem of organizing and manipulating information in intelligence is far more complex than in business or scientific activity. It stands in a class by itself and challenges solution.

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1 Cf. "Developments in Air Targeting: The Military Resources Model" by Robert W. Leavitt, *Studies* 11 1, p. 51ff.

2 See "Developments in Air Targeting: The Air Battle Model" by Robert H. Adams, *Studies* II 2, p. 13ff.

3 For the description of such an experiment see "Design for Jet-Age Reporting" by William Earling, *Studies* IV 2, p. 7ff.

4 See "Developments in Air Targeting: Progress and Future Prospects" by Kenneth T. Johnson, *Studies* III P. 53ff.

5 See "Developments in Air Targeting: Data Handling Techniques," by Outten J. Clinnard, *Studies* III 2, p. 95ff.

6 For a description of the indications intelligence process see "The Monitoring of War Indicators" by Thomas J. Patton, *Studies* III 1, p. 55ff.

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