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PROPOSED DEVELOPMENT TASKS

FOLLOW-ON TO PROJECT [ ] 25X1

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PROPOSED DEVELOPMENT TASKS

SUMMARY:

In this proposal, eight tasks are described, all related to the development of an Automated Stereo Scanner. These tasks are as follows, in our estimated order of priority:

1. Extension of Stereo Scanner capability to a pointing camera acquisition system.
2. Production of Correlator Test Photography.
3. Correction of higher order distortion in scanning system.
4. Servo Stability investigation.
5. Correlation with partially obscured images.
6. Search Simulation.
7. Determination of the optimum sequence for distortion removal.
8. Investigation of magnitude of incorrected second order Y-parallaxes.

The first five tasks are of most importance in that the results will significantly influence the performance of the automated stereo scanner. The results of tasks 6 and 7 will also affect performance of the system, but to a somewhat lesser degree.

The results of task 8 will determine whether a second-order optical distortion correction capability is desirable for operator viewing comfort and efficiency, and is therefore, somewhat forward looking in that the results will affect the next generation of stereo viewing instruments.

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TASK DESCRIPTIONS

AND

WORK STATEMENTS

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TASK (1) - EXTENSION OF STEREO SCANNER CAPABILITY

The purpose of this task is to add to the capability of the stereo scanner by developing the programs required for a pointing camera acquisition system.

The stereo scanner control computer is currently being programmed to handle panoramic and strip materials. An extension of its capabilities to pointing frame materials requires development of a system model, reformatting the INS data tapes and the development of specific control computer programs.

A complete description of these tasks is contained in [redacted] Document 9609-39, 15 May, 1967. STAT

WORK STATEMENT:

1. Development a model of the system from which distortion coefficients can be calculated (General Purpose computer, Fortran Program).
2. Reformat the INS data tapes to allow their use in the above program.
3. Development of control computer programs specific to the pointing system.

TASK (2) - CORRELATOR TEST PHOTOGRAPHY

The development and performance evaluation of the automated stereo scanner will be considerably aided if a pattern or series of patterns were available which would allow some determination of correlation reliability. The use of such patterns is analogous to the use of resolution targets to evaluate the optical performance of imaging systems, although of course, the patterns themselves would be quite different and would be made in pairs.

In general, image correlation devices are subject to the limiting effects of two classes of image stress factors:

1. Image factors (frequency content, anisotropy, contrast) and,
2. Relief or terrain factors (slope, curvature, high order relief distortions, and blind spots).

At present, image correlation systems can only be evaluated by using photography of real terrain, which includes various combinations of these stress factors in uncontrolled and often unmeasurable quantities. To perform meaningful tests on the stereo scanner and to diagnose potential causes of failure of correlation, it is necessary to use controlled test imagery which contains clearly separated known amounts of these stresses. While it would be impractical to devise test patterns for all the above stresses and combinations of stresses in a limited program such as this one, certain important items would be of interest.

While a more detailed study should be made of the exact order of importance of each stress, a reasonable set might consist of samples with controlled slopes, samples with controlled curvatures, samples with higher order terrain roughness, samples of flat terrain with variable anisotropy (frequency content versus direction), samples with varying frequency content, samples with varying contrast. In order that the number of samples not be prohibitive, experimental parameters would be grouped about values corresponding to actual photography which will be used in the Automatic Stereo Scanner System.

WORK STATEMENT:

1. Analyze the types and magnitudes of image stress factors likely to be encountered in the actual photography and specify a matrix covering the likely combinations in the most economical manner.
2. Devise methods for generating photographically a set of test patterns as specified in 1.
3. Produce a sample set of test patterns for use on the Automated Stereo Scanner.

TASK (3) - CORRECTION OF HIGHER ORDER DISTORTION IN SCANNING SYSTEM

Scan distortions presently used in the peak and valley correlator are of six kinds: Zero order x and y translations and four first order distortions, x and y scale, and x in y and y in x skews. These distortions can be transformed exactly into optical counterparts, x and y parallax, differential zoom, differential rotation, and anamorphic distortion. These optical counterpart distortions have exactly the same number of degrees of freedom as the scan distortions used in the peak and valley correlator/ distortion analyzer. The quality of correlation is a direct function of the amount of similarity between the two signals being correlated. Therefore, if the signals to be correlated contain terms originating from higher order distortions than those mentioned above, i.e. keystone distortion or terrain curvature, these higher order distortions represent disagreements between the two video signals and correspond to a kind of noise. Some of these higher order distortions are relatively easy to generate electrically, but have no optical counterparts; indeed only those transformations relating to projective transformations can be removed optically.

While second and high-order x- distortions that are present in the viewed image are easily accommodated by the operator and do not degrade stereo fusion, correlation reliability would be improved if these distortions were cleared in the electronic scans of the image dissectors in the correlator. The value of including these higher orderterms may be investigated initially by simulation on the PDP-1 computer, and then if positive results are obtained, by modifications to the present video breadboard.

WORK STATEMENT:

An investigation of this problem requires work in the following areas:

1. A theoretical study with two aims;
   a) to predict the order of magnitude of improvement in correlator signal to noise ratio when higher order distortion terms are included.
   b) to determine which distortions have the greatest effect on correlator signal to noise ratio.
2. Preparation of convergent and rectified pseudo convergent (2 x 2 inch) slides for test material. Pseudo convergent distortion is produced by rectifying the same picture with two opposite projective distortions so that the effect of convergent photography of perfectly flat terrain is produced. This eliminates the higher order disturbances produced by terrain relief.
3. Design of a PDP-1 computer program for trapezoidal and/or quadratic scans for correlation of convergent stereoscopic imagery.
4. Integration of trapezoidal and/or quadratic scan distortion circuits into the present correlation system breadboard.
5. Correlation tests, preferably using material from Task 2.
6. Write a final report summarizing the findings of this investigation.

TASK (4) - SERVO STABILITY INVESTIGATION

The purpose of this task is to investigate the optical servo system, particularly the anamorph servo loop to optimize the response time and stability.

The basic instrumentation equations for the optical servo have already been derived. (See Appendix 18 of Vol. II,"Project 9609 Studies and Tests".) These equations indicate that the loop gain of the servo depends greatly on the orientation of the two anamorphic lenses. In addition, singular points occur when either $2\alpha = 0$, $2\beta = 0$, or $2(\alpha - \beta) = 0$ where α and β are the anamorph orientation angles. While the present system has been shown to operate satisfactorily in the EROS breadboard, it is likely that an improvement in stability and tracking speed could be obtained by further investigation.

The proposed investigation will be directed at analyzing the effects of the above noted singularities on system performance and if necessary, modifying the equations in order to obtain the maximum rate of change of anamorphism consistent with system stability. The primary investigation will be mathematical, but it is also proposed to make a practical test of the instrumentation using EROS as a breadboard.

WORK STATEMENT:

1. Analyze operation of the anamorph servo system in the regions $\alpha = 0$, $\beta = 0$, and $(\alpha - \beta) = 0$. Evaluate schemes for reducing the effect of the singularities at these points and maintaining constant servo loop gain.

2. Design and assemble a breadboard servo system to be used with EROS to evaluate the new control scheme.
3. Conduct a test program on EROS using photography in which the anamorphic distortion lies near or crosses through the singular points.
4. Write a final report covering the analysis, design and test results.

TASK (5) - CORRELATION WITH PARTIALLY OBSCURED IMAGES

At present if half of the field of view in one member of a conjugate pair is obscured by clouds or a frame edge, the Electronic Correlator cannot operate. This is because the first order distortion error signals depend on receiving valid information from both halves of the field of view. However, it may be possible in this case to operate with only zero order (parallax) corrections, and thus to stay locked in.

A proposed technique involves using four disagreement summers instead of one for determining correlation thresholds to insure correlation on two halves of the field of view before closing the distortion loops. The parallax loops would be closed if correlation were present in any quadrant of the field of view.

Another technique for approaching an edge would be to apply parallax shifts to both rasters in the same direction (away from the edge) such that while the eyepiece field of view would include the edge, the rasters would be offset to only look at the area of good correlation.

These techniques can be investigated with the image dissector breadboard.

WORK STATEMENT:

1. Investigate techniques for maintaining correlation when approximately half of the scanned area is obscured or otherwise uncorrelatable.
2. Design and assemble modifications to breadboard scanning system to evaluate these techniques.
3. Write a report summarizing the findings of this investigation.

TASK (6) - SEARCH SIMULATION

The purpose of this task is to use the PDP-1 correlation simulation program to develop a search strategy to be implemented in the Stereo Scanner.

The following process is used to obtain estimates of distortion settings. A point is selected in the master frame and its coordinates determined. These coordinates are used in the camera system model with the data pertaining to the geometry of the exposure to project this point to the datum and thence, up to the second exposure station. The zero and first order coefficients of this transformation are computed and instrument settings determined. The instrument is set to these values and correlation is attempted.

The error sources in this process are (1) the coordinates in the master frame are imperfectly known, (2) the data of the taking situation contain errors, (3) the model does not account for relief and hence the coordinates of the "conjugate" are in error, (4) there are, finally, errors in setting the instrument. All of these combine to introduce errors in the estimated distortion settings.

The magnitude of the contribution from each of these sources must be evaluated so that search routine requirements can be specified. It should be noted that as there are six distortions to be corrected, the search must be made in a mathematically six-dimensional space.

In actual practice, should the computer position the optics outside of the pull in range of the correlator, the operator will be able to clear parallaxes and fuse the images. The search routine will eliminate the need for human intervention except in the most extreme error conditions when a search would consume too much time.

To effectively implement such a search we must determine those parameters and their thresholds which indicate existence or imminence of correlation lock-on, and those system characteristics which indicate likely trouble conditions.

Finally, a search strategy must be defined which includes defining search increment size, region to be searched, configuration of search and policy alternatives.

Since we will have little time to experiment with decision schemes once the control computer is mated to the stereo scanner, we should gather as much information as possible from a computer simulation of the search process. A series of experiments should be constructed utilizing this simulation, which will yield answers to the questions raised above, and which will lead to the design of a workable search strategy.

WORK STATEMENT:

1. Evaluate magnitude of expected position and distortion errors in setting up the stereo scanner.
2. Devise suitable search routines, taking advantage of any systematic associations between the various errors to reduce the volume of the space or the dimensions that must be searched.
3. Program the PDP-1 computer for the most suitable search routines and evaluate them under varying conditions.
4. Write a report summarizing the work and the results achieved.

TASK (7) - DETERMINATION OF THE OPTIMUM SEQUENCE FOR DISTORTION REMOVAL

The PDP-1 correlation tests performed to date indicate that it is desirable to reduce the zero order x and y translation errors to essentially zero before operating on the first order distortion errors. Further tests indicate that among the first order distortions there is, for any given image, an optimum sequence in which errors should be removed. Results so far are inconclusive as to whether the optimum sequence for one image provides an optimum sequence for a wide range of input photography.

It is anticipated that as photographs with more and more relief are inserted into the system, the correlation reliability will decrease, but that significant improvements may be possible if an optimum sequence can be determined.

We are, therefore, proposing a test and data analysis program using existing PDP-1 computer programs and techniques, on photographs containing varying degrees of relief. The purpose of the investigation will be to determine the behavior of the correlation system and to arrive, if possible at a sequence for distortion removal which will optimize correlation reliability.

WORK STATEMENT:

1. Using the existing PDP-1 computer program for distortion correction, investigate the rate of correction of the six distortion parameters with stereo pairs containing varying amounts of vertical relief.
2. Investigate the effect of different distortion correction sequences on the speed and reliability of the distortion correction process.

3. Determine, if possible, an optimum sequence that is effective over the greatest range of input material.
4. Write a report summarizing the findings of this task.

TASK (8) - INVESTIGATION OF MAGNITUDE OF UNCORRECTED SECOND ORDER Y-PARALLAXES

An optical distortion correction system consisting of zoom lens, image rotator, and anamorphic lenses can correct only first-order distortions. In convergent photography second-order systematic distortions are present, as well as higher order distortions due to terrain relief. Distortions in the x direction of the second- and higher-orders can be accommodated visually in the stereo model and do not present a problem. However, uncorrected Y-parallaxes do present a potential viewing problem, as these distortions do not correspond to any realizable terrain model. Correction of second- and higher-order distortions in an optical viewing system is difficult to implement and should only be undertaken if absolutely necessary. We therefore, propose to investigate the magnitude of residual second- and higher-order Y-parallaxes in the various photographic formats to be used in the stereo scanner.

The results of this investigation will determine whether uncorrected Y-parallaxes do in fact constitute a problem in stereo viewing, and will indicate whether work on optical second-order correction is necessary.

WORK STATEMENT:

The formats of the three photographic systems to be used in the stereo scanner will be examined and the magnitudes of the uncorrected Y-Parallaxes for the worst cases of practical interest, will be calculated. These results will be compared with the values of acceptable Y-parallax already determined and published in the literature.

A conclusion will then be drawn on the desirability of attempting to correct second order Y-parallaxes in future stereo viewing equipment.

SCHEDULE

The duration of all proposed tasks is four months with the exception of task 2 which is seven months.

Tasks 1 through 5 will be commenced simultaneously at the start of the contract. To obtain efficient utilization of available manpower and the PDP-1 computer, the starting dates of tasks 6 and 7 and 8 are staggered as shown in the bar chart.

All tasks will be completed within eight months.

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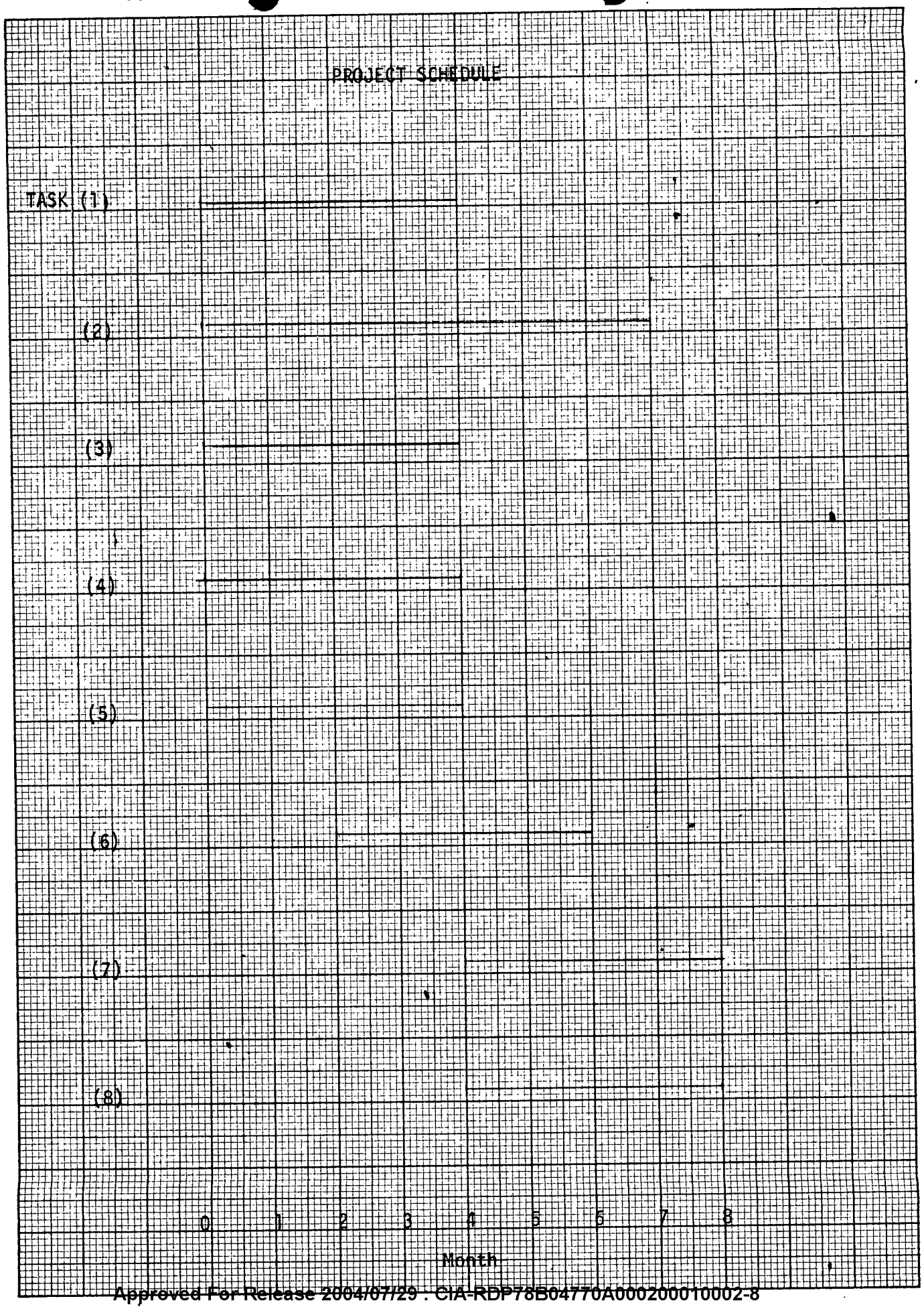

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