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AUTOMATIC PROCESSING SYSTEM FOR SHADOWGRAPH AND INTERFERENCE PATTERNS

I.A. Vereninov, V.D. Lazarev, S.S. Popov, and V.S. Tarasov

Translation of: "Sistema avtomatizirovannogo obmera tenevykh i interferentsionnykh kartin," from the "Optical investigation methods in a ballistic experiment" in Izdatel'stvo Nauka, 1979, pp. 221-6

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16. Abstract
The design and operation of automatic system for the processing of shadowgraph and interference images are described. The system includes a two-coordinate processing table with an optical system for the projection of transparent images onto the photodetector plane, an array-type photodetector, an image filter in the photodetector field, and a device for controlling the movement of the table and transmitting information to the minicomputer.

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AUTOMATIC PROCESSING SYSTEM FOR SHADOWGRAPH AND INTERFERENCE PATTERNS

I. A. Vereninov, V. D. Lazarev, S. S. Popov and V. S. Tarasov

Optical methods are widely employed in physics. One only has to mention optical spectral analysis, interferometry and photographic methods of recording the position of moving bodies. The photo image is the intermediate result in all of these fields. Quantitative processing of the photo images requires a lot of time. In the known systems for automatic processing of photo images [3, 5], line scanning of the entire image or its greater part when entered in a computer are usually used. This method makes it necessary to store large information files, and leads to difficulties in searching for the parts of the image needed for processing and considerable time outlays even when fast-response computers are used. /221*

We have developed an automatic system to process transparent photo images. We used local processing of image fragments to solve this problem. Most of the processing is down by programmers and apparatus while the operator only participates to a small degreee in image analysis. The operator selects the details to be processed while the actual processing is done in a dialogue mode. Switching to local processing of image fragments permits the use of a minicomputer.

The automatic photo image processing system includes a two-coordinate processing table with optical system for projecting the transparent photo image into the photodetector plane, MF-6 array-type photodetector, device for filtering the image in the photodetector field; devices for controlling table movement and information exchange with the computer.

The table with attached film moves in relation to a fixed optical system. Stepped electric motors move the table on both

*Numbers in right margin indicate pagination in original text.

coordinates. In one step of the motor it moves 5 μm on one coordinate and 3 μm on the other. The maximum size of the viewed frame is 360 x 360 mm. The image is projected into the photo-detector plane with 12-fold magnification. Details which are closer than 0.02 mm to each other are distinguished with this magnification of the photo matrix with elements 0.1 x 0.1 mm^2 in size and distance between them 0.25 mm. The signals taken from the photo array elements depend on the integral illumination in the window of each element and the exposure time. /222

Potentials from the photo array element outlets are fed to the threshold devices which separate all the signals (and at the same time the images within the window of the elements) into two classes: black and white. The concepts "black" and "white" image points refer to the image of the size of the photo element window. The concept is naturally a conditional one: with the same illumination it depends on the level of comparison of the threshold devices and the exposure time selected. Changing these two quantities correctly determines the boundary between the black and white on images of different density.

Before the image is entered into the computer, it is filtered within the photo array field. The filtering has a dual purpose: weaken the effect of interferences and indicate the position of the black and white boundary on a field made of 16 x 16 dots. It is found by correlation. In this case the presented image is compared with the set of references. The reference which is the most similar to the image is selected in two stages. The first determines those references for which the number of coinciding points exceeds a specific level; the second selects the best of them. This reference also determines the position of the boundary on the dot field. The situation in which the presented image is "not similar" to any of the references in the set is a particular one. The system provides for two levels of comparison with the reference: "approximate" and "precise" (75 and 87% of the coinciding dots respectively).

A generator of references which forms over 600 different references for the boundary on the dot field is included in the boundary correlation analyzer. It is assumed in this case that the boundary within the field of 16 x 16 dots (in a natural scale this is 0.3 x 0.3 mm) can be represented by a segment of a straight line. Then the position of the boundary is characterized by two quantities, slope and shift. The slope has 32 gradations (the slope of the boundary of neighboring references differs by 360°/32), and the shift has from 16 to 24 gradations depending on the slope of the boundary. The original scheme of the reference generator permits rapid formation of the references on a permanent program. At worst, analysis of the boundary position takes less than 0.3 sec.

The result of determining the boundary position is entered into the computer as a six-digit decimal number. One digit codes four possible situations: no boundaries have been found, the image is white, the image is black, there are boundaries. The other digits contain the code for the position of the linear boundary. This arrangement of the data accelerates analysis of the information entering the computer.

Movement of the table to a specific point, taking of the counter readings recording the movements (the magnitude of the movements is measured by the number of steps made by the motor) and taking of the boundary analyzer readings are done by commands from the computer by special devices. /223

When functions are distributed among the elements of an automatic photo image processing system, and also among humans, consideration must be made for requirements for fast response, simplicity of operator work, volume of equipment and reliability of the results. The proposed program support has been developed with regard for these requirements. The program support for such systems [2] can be presented in the form of three functionally different sections (fig. 1).

The systems section is common and needed for solving any problems of photo image processing. It is designed to set up

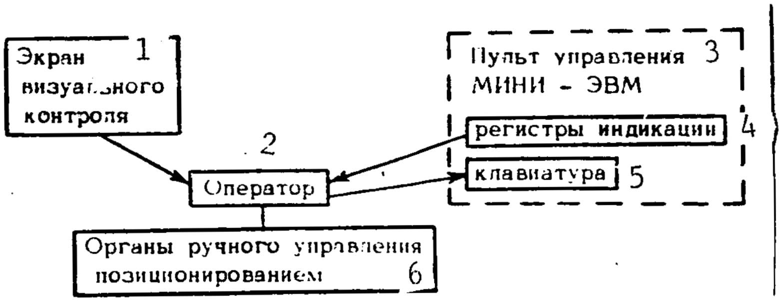

Figure 1. Program Support Set-Up

Key:

1. Visual monitoring screen
2. Operator
3. Minicomputer control panel
4. Indication registers
5. Keyboard
6. Positioning manual control organs

interaction between specialized apparatus and the minicomputer. When a section of a photo image is processed, two types of scanning are used: electromechanical scanning of the processing table in relation to a fixed optical system, and electronic in the field of the array-type photodetector. Consequently, the coordinates of the boundary dots of the image details are formed from data regarding the position of the table and the boundary in the photodetector field. The CHAN2 and CHAN3 exchange subprograms ensure transfer of these data to the computer.

The table movements are controlled by the CHAN1 subprogram by which values of coordinate increments are sent to the blocks to control table movement.

Any exchange of information between the computer and special apparatus is initiated by a program. In addition to the three main exchange subprograms, the system section includes subprograms for transforming the computer-received codes.

Features of the computer - operator dialog depend on the specific processing problem and are taken into account in the section of special program support.

General purpose program support for solving problems of setting up measurements consists of programs used once during specific processings, and subprograms used repeatedly in compilation or interpretation. /224

AXIS performs orthogonal transformation of coordinates and is used to determine the dot coordinates in the axes related to the photograph when it is randomly arranged on the processing table. The AXIS program is used to enter the photograph coordinate axes and compute the position of the dots of interest in relation to new axes. The number of dots entered belonging to the axes, and their arrangement are selected by the operator. Each straight line entered is processed by the method of least squares, and the beginning of the coordinates is found as the meeting point of the axial straight lines.

ANGLE computes the coordinates of the angular points in cases where strong distortions exclude their direct measurements. The coordinates of the angular points are computed in the same way as the beginning of the coordinates in the AXIS program.

RAST interprets the code of boundary signs entering the computer on the CHAN3 subprogram, and forms corrections which are taken into consideration in computing the boundary coordinates from the data on the position of the processing table.

DIRECT is designed to set up image processing in any direction and forms the direction of the processing by dots specified by the operator.

SCAN guarantees movement of the table in the direction formed by the DIRECT program. The absolute error of positioning does not exceed the magnitude of the step of the motor driving the table.

POINT forms an increment in coordinates with movement of the processing table from one point to another, and by using CHAN1, implements this movement.

LINE controls movement of the table to a point belonging to line F(x,y) = 0.

CATCH controls movement of the table along a selected image boundary. In order to reduce the likelihood of interruption in tracking, two contours of sliding smoothing on intervals of varying length are used. For this purpose there are searching movements of the table perpendicularly to the boundary if it is lost.

Special program support includes resident programs which are called up to organize a specific type of processing. Each resident program has several sections; when they operate they call up the corresponding main programs which control the processing. All specific processing programs have manual and semi-automatic modes. Figure 2 clarifies the operator functions.

Processing is controlled by minicomputer, however at the most important moments of processing (with possible errors because of an abrupt change in the image quality) the programs provide for stopping. When a stop occurs, the results of viewing the fragment are lit up on the computer indication registers, and the operator /225
specifies one of the possible variants for further processing from his panel. The observations of the operator of the general course of the measurements on the visual monitoring screen exclude gross oversights.

The section of special program support is the least closed of all three, and the list of processing tasks could be significantly expanded. Programs for processing interferograms and shadowgraphs obtained in gas-dynamic experiments have currently been developed and are in use. All programs of the previous sections are utilized in this case.

When interference patterns are processed, the boundaries of the line are smoothed out by the method of least squares. The coordinates of the bands along the decoding section are found as

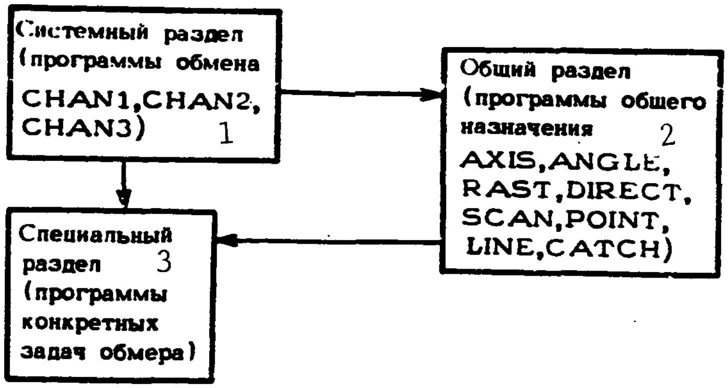

Figure 2. Block Diagram of Control and Monitoring of Automatic Processing System

Key:
1. System section (program exchange)
2. General section (general purpose programs)
3. Special section (programs of specific processing problems)

intersection points of the lines of the boundary and decoding, which improves the processing accuracy. The results of this processing are used to interpret interference patterns [4]. Processing of shadowgraphs determines the positions of a body in space [1].

The primary result of using the automatic photo image processing system is increased speed and precision of processing 2 - 10-fold as compared to processing on a universal measurement microscope of type UIM-23 and UIM-24. The speed and precision of the processing are determined significantly by the quality of the images to be processed.

The system of automatic photo image processing can also be used to process patterns of optical spectral analysis, process results of movie theodolite tracking of aircraft, etc.

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