ONE SYSTEM FOR SIMULATION OF PATTERN RECOGNITION ALGORITHMB

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ABSTRACT

A general purpose system for a computer simulation of pattern recognition algorithms is proposed that consists of a universal scanner for optical images input to the computer, a display for visual output, and software. A characteristic feature of the system is a blok structure of the hardware and software. The system allows carrying out most of the data processing necessary for simulating the algorithms of recognizing the optical images of objects of various physical natures.

1. Present-day pattern recognition is developing several trends, one being different from another in the mathematical formalism of formulating and solving the recognition problems. In particular one can point out among the trends a statistical learning and recognition theory, a theory of iterative learning procedures for linear or piecewise-linear pattern separation, a structural (or linguistic) approach to pattern description and so forth. Anyone of them has demonstrated significant achievements in solving individual problems or particular classes of the problems. Nevertheless, the general level of pattern recognition has not yet been sufficiently high to warrant assuming the solvability of most applied problems. The practical significance of the known algorithms is often vague due to comparatively small attention spared for their investigation. In practice we mostly encounter a situation when it is necessary to combine different processing and recognition methods for approximating the solution of a particular problem. The combining mode is mors frequently selected on a "heuristic" base rather than as a result of a strict formal deduction. So the task of creating developed means for experimental investigation, combination, and performance analysis of the various pattern recognition algorithms acquires even greater importance.

The main way of investigating the algorithms is a digital simulation, i.e the simulation by means of a general-purpose digital computer equipped with necessary I/O devices and a software. Let us enumerate the principal (in our opinion) points to be used for comparing and choosing the simulation mode:

(1) Expenditures of time, material, and man-power re source a for designing and constructing the simulation system;

(2) Expenditures for making changes in and additions to the simulated algorithms in the process of investigations

(3) Possibilities of simulating the distinct classes of the algorithms;

(4) Possibilities of comparing the performance of the different algorithms using the same real material to be recognized;

(5) Possibilities of working out the well-founded technical requirements for the recognizing devices that should realize the selected algorithm.

▲11 the indices being taken on the whole, the advantages of the digital simulation become obvious in comparison with the competing investigation methods (e.g. with the direct modelling of the recognizing device). To meet these quirements the ideal simulation system should possess the following features:

(1) Universality (i.e. an ability to realize any arbitrary path of picture scanning with a variable resolution power across the scanning field);

(2) Possibility of picture insertion from different carriers (paper, film, real-world scenes);

(3) Effective means for experimenter - system interaction that allow interfering with the functioning of the simulated algorithm, making alterations and amendments on the base of the analysis of intermediate results and obtaining a visual representation of these results in a convenient form (e.g., graphical);

(4) Developed software which allows simulating the investigated picture processing and recognition methods by means of the computer.

Completeness and flexibility of the software structure are the principal factors in estimation of the extent to which the particular simulation system could meet the formulated requirements.

It should be noted at once that we have in mind a system being designed only for simulating the recognition algorithms and investigating their performance. These systems have been almost for sure found cumbersome and of little efficiency as the applied means for solving a practical recognition problem. Experience of adapting a similar system to introduce technical drawings into the computer has provided a clear example; to work out the necessary and sufficiently effective software for solving this problem turned out to be incredibly difficult(1). An intention to build up a special-purpose software for simulating the algorithms which solve the recognition problems within the bounds of a fixed method(2) seems also not to be justified enough.

The construction of "general-purpose" software including unified subroutines for the input, output, processing, and recognition of a pictorial information shall answer the specific character of the simulation system to considerably greater extent. The principal feature of such software should be its "multilevel" structure, the current input, output, and prepooessing procedures being concentrated on the lower levels, and the more ramified and complicated picture processing and recognition algorithms placed on the higher ones. The subroutines from the lower levels are used as components of the higher-level subroutines. This "multilevel" structure allows building and modifying various algorithms by simply joining the separate blocks-subroutines and co-ordinating values of their parameters. Such a structure also permits extending easily the potentialities of the system by adding the corresponding procedures to each of the levels.

An analysis of the known trends both in pattern recognition theory and in the design of the recognizing devices shows that the aim of creating the "general-purpose" software is quite practicable. In spite of all the peculiarities of different approaches it seems to be possible to reveal in them a considerable number of common or uniform processing and recognition procedures. The latter could serve as a base for the "standard" blocks of the software.

For example, a vast variety of the recognition problems solutions could be easily shown(3,4) as reduced to the same linear separation in a multidimensional feature space. One pole of the such problems is joined to statistical recognition theory, the other one is associated with learning schemes like the Rosenblatt perceptron. The distinctions between the competing trends which are represented by these algorithms become apparent in the mode of choosing the coefficients for the linear discriminant functions. There are several such modes: from the direct statistical estimation of the unknown values to the sequential corrections belonging to a family of relaxation optimizing processes for the functions of many variables. Any of them could constitute the individual block on the corresponding software level.

The like linear Beparation("mask--matching") plays first fiddle also in a number of modern optical reading devices(5). The coefficient sets form here so-called "templates'* or "masks" defining the recognized classes of alphanumerical characters. For matching, the character should be placed in a certain position with respect to the template. This operation is called "character positioning".] One could distinguish between several positioning methods, for example, by shifting the character until its border black points ("edges) reach the given limits, or its "center of gravity" reaches the given point, or by finding the position of the best matching, etc. These procedures could be in turn considered as the blocks of the system software. Having combined the similar blocks one can simulate the most part of the recognition methods laid at the foundation of these reading devices. Such a detailed analysis is obviously possible for any known trend in pattern recognition.

The stated principle of the software construction will close up in the end with the problem of developing special-purpose languages for simulating the pattern recognition algorithms.

2. The proposed general-purpose system for the computer simulation of the pattern recognition and picture processing algorithms consists of the following parts:

(1) Local control unit for interconnecting the computer and I/O units;

(2) Scanner for inserting pictorial information from film or paper carriers;

(3) CRT display for multi-shade output of the pictorial information;

(4) System software subdivided into three levels:

(a) input-output procedures;

(b) basic picture preprocessing;

(c) certain recognition algorithms

The hardware has been designed as separate units(Fig.1). The local control unit receives from the computer control signals and co-ordinates codes of the picture point to be scanned, forms control signals for the scanner and display, encodes and transmits to the computer grayness values of the scanned points and produces signals allowing the reception and transmission of the information obtained. The scanner is divided into two isolated units: for paper carrier processing and for film carrier processing. The scanner has the following featuress

— field of vision of the paper processing unit (measuring a reflectance in a scanned point): 10 x 10 and 40 x 40 mm^2;

— field of vision of the film processing unit (measuring a transparency in the scanned point): 16 x 22 mm^2;

— maximai scanning raster} 1024 x 1024 points;

— maximal resolution power in the center of the field of visions up to 40 lines per mm;

controlled variation of the solution power in the scanned point: up to 32 times;

— discernible values of the measured grayness in the scanned point: 32;

— maximal processing time for one scanned point (a complete cycle until readiness for the next point processing): 180 microsec;

— maximal time for setting the new value of the resolution power: 1 millisec.

The magnetic-controlled GBTs have been used in the scanner units as sources of the scanning light spot. The setting of the resolution power has been carried out by changing the spot diameter on the CRT screen. The spot diameter and position on the screen are given by the computer as a part of the simulation system, the corresponding 5-bit grayness code being inserted directly into the computer core memory.

In spite of the small field of vision, the paper processing unit can scan sufficiently large pictures: up to 210 x 300 mm^2. For this purpose the unit has been equipped with a special movable carriage which the picture is fixed on, shifts of the carriage being controlled by the computer. A shifting rate (simultaneously in both directions) is about 25 mm/sec. An accuracy of the carriage setting in a given position is not worse than 0.1 mm. The computer has also controlled displacements of the film frames, the rate of displacement being about 1 frame per sec and the accuracy of the frame setting — about 0.02 mm. A block diagram of the scanner units and connections with the local control unit is given in Fig.2. The display unit has been equipped with the CEP having the screen working area about 200 x 200 mm^2 Visually discernible gradations of the point brightness are about 12 to 14.

The system software possesses a block structure allowing an operative interference with the design of the simulated algorithms. The first-level software includes:

— subroutine for the special modifying of the computer supervisor which ensures the system functioning on the whole;

subroutines for setting the necessary working rates and controlling the system units;

— subroutine for inserting parameter values into the first-level batches in the process of system functioning by means of the computer control board;

— subroutines for forming scanning rasters with arbitrary parameters and searching for the separate images on the scanning field;

— subroutines for compressing and decompressing the digital information obtained by scanning during its insertion into the computer memory and processing;

— subroutines for geometrical transformations (translation, rotation, scaling) of the I/O pictures, and so forth.

The second-level software accomplishes the basic picture preprocessings

— quantization, i.e. a changeover from 32-gradation grayness scale to any lesser number of gradations:

(a) the quantization with arbitrary given bounds of the new gradations;

(b) the adaptive quantization where the bounds are variable and chosen to minimize a certain "distance" between an initial picture and the picture obtained as a result of the quantization (6)

discretization, i.e. a changeover from an initial rectangular raster used for the picture representation to the new raster representation with any lesser number of the points:

(a) the discretization with arbitrary given bounds of the new raster cells;

(b) the iterative discretization where the bounds are variable and chosen to provide a local minimum of a certain "distance" between an initial picture and the picture obtained as a result of the discretization;

(c) the similar iterative discretization providing the local minimum of the "distance* between a given prototype and a picture after the discretization;

— digital filtering with an arbitrary rectangular filter. By assigning the definite weights to the filter points one could realize a number of the known procedures of isotropic and anisotropic filtering, for example, a "contour line extraction" on the black-white pictures.

Furthermore the second-level software covers geometrical transformations of the pictures given as numerical arrays, computations of a 2D autocorrelation function and 2D moments for these pictures and so on.

The up-to-date third-level software is less developed. It contains various modifications of the character recognition algorithms based on the correlation method, correlation algorithms for identification of the corresponding points on stereophotographs, algorithms for such identification using the directed search through possible geometrical transformations of the corresponding parts on the stereophotos, etc.

In preceding years the first version of the system described (7) was used to investigate a number of recognition problems, e.g., for a comparative performance analysis of the correlation and similar character recognition methods (8,9,10), an examination of statistical models of typed characters (9,10), researches in different hand-print recognition procedures (11), and the like.

Now the described system is serving as an experimental tool for research in automatic stereophotogrammetry, cursive script recognition in the process of writing, etc.

In the future the system is intended to be supplemented with several modifications:

— introduction of pictures from broad film carriers (with a width up to 500 mm);

— TV input of real-world scenes;

— buffer memory (8 to 16K) to expand the system potentialities and improve the interconnection with the computer;

expansion of the software mainly towards the analysis of real-world scenes and the recognition of 3D objects.

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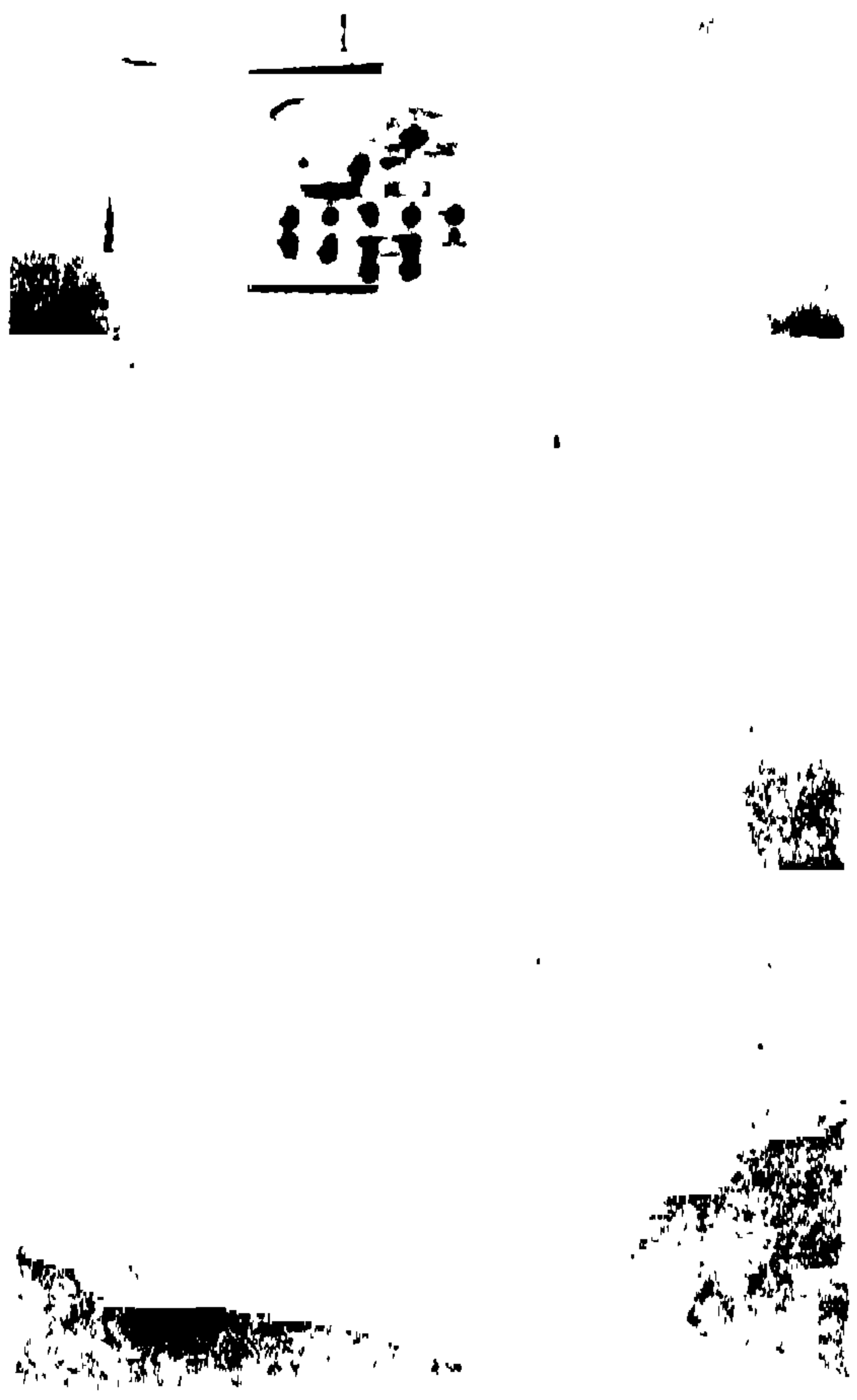
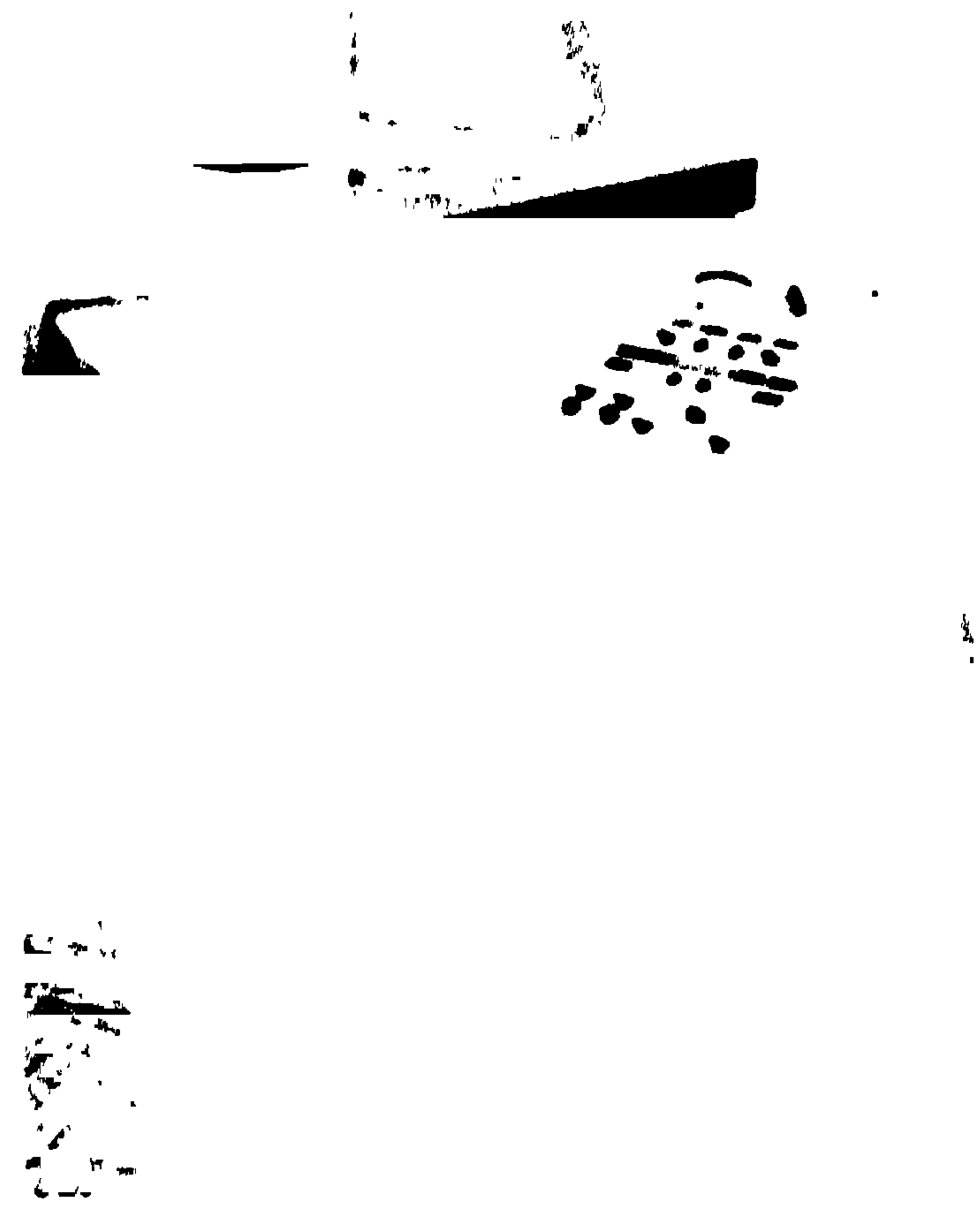


Film Processing Scanner Unit



Paper Processing Scanner Unit

Local Control Unit and Display Unit

Fig.1 Hardware of the System for Simulation of Pattern Racognltian Algorithms

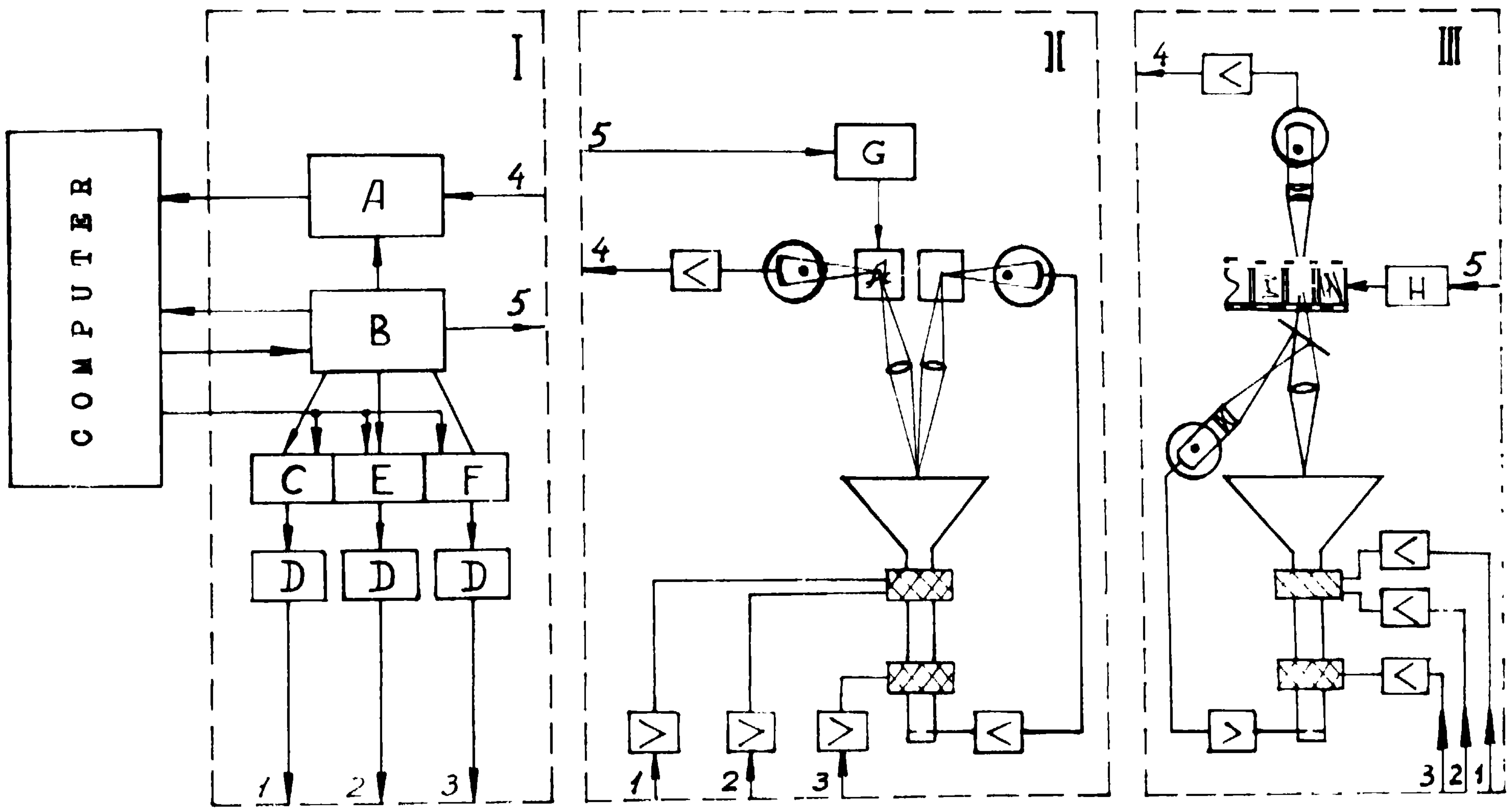


Fig.2 A Block Diagram of the Scanner Units and Connections with the Local Control Unit

i local control unit, 11 paper processing unit,
ill film processing unit

A — voltage-to-digital converter, B control logic.
C,E — co-ordinate registers, D — digital-to-voltage converter, F — focus register, G — paper-transporting mechanism, H film-transporting mechanism

The figures 1,2,3,4,5 mark the connections to be commuted when switching on the corresponding unit