INTELLECTUAL SYSTEM OF PROCESSING AND ASSESSMENT OF THE RESULTS OF THE TEST EXAMS

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Abstract *Pattern recognition is increasingly used in large information systems. The development of the theoretical base of image processing and the widespread use of free open source libraries make it possible to use new solutions in a variety applied problems. One of these tasks is the automatic machine processing of the answers of massively conducted test exams. This paper describes the developed system, used in processing the results of mass exams, which showed the ability for reliable, rapid and objective assessment.*

Keywords: *information processing, intelligent system, evaluation of results, image processing, multithreading recognition, automatic response processing*

1. INTRODUCTION

Optical Marker Recognition (OMR) [1-4] technologies using optical scanners are widely used to automatically process the results of mass test exams. OMR scanners are popular mainly because of their high execution speed and appreciable accuracy. Analysis of exam results using such technologies allows an objective assessment of the responses of a huge number of forms in a short time and to achieve almost one hundred percent recognition accuracy. However, this processing technology has the following significant disadvantages:

- very sensitive to the size and quality of used paper, work only for specific color of the form;
- does not allow the use of custom sizes of forms;
- expect the form to be in perfect condition; even a slight damaged, crush or fold would be rejected
- processing of handwritten form is not possible;
- high cost and maintenance.

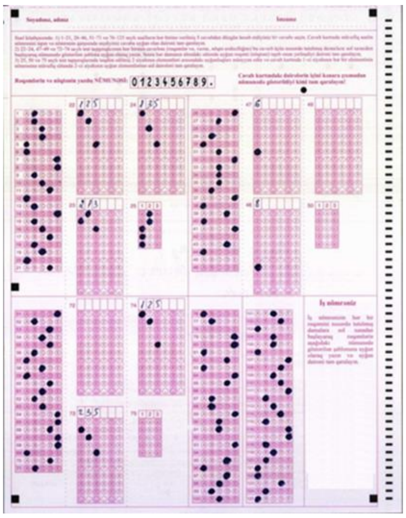


Fig 1. Sample of recognized form

To eliminate these problems, a system of processing, independent and anonymous assessment of responses has been developed. All forms (of arbitrary size) are scanned by high-speed scanners and converted into graphic form. Further, the system, on the basis of predefined templates, determines cards with questionably filled markers answers. Samples of cards with such information in parallel mode are displayed on the screens of independent experts without specifying the author of the examinee and the system makes a decision on an objective assessment of the answer based on expert assessments. At the same time all actions of experts are recorded and archived.

2. DESCRIPTION OF THE PROCESSING SYSTEM.

First, we give a more detailed description of the stages of functioning of the developed system. All exam materials obtained from exam sites are sent to the scan area. Each examination form has a unique identifier and is protected from fraud. Using high-performance scanners, the scan operator scans all forms. After completing the work, the operator compares the number of scanned forms with the declared quantity, and also selectively checks the quality of the scan. Then, for processing electronic materials, the administrator of the project processing group starts the recognition process.

Recognition is carried out in batch mode and does not require the presence of operators. The process of recognition of examination forms, like many other industrial systems of forms recognition, consists of the following main steps [2,5,6]:

A. Generation of a set of templates.
B. Definition of reference points in the graphic image of the form.
C. Definition and align of the template.
D. Recognition
E. Verification

A. Generation of a set of templates

At this stage scanning and import of the image of the empty form is executed. Then the system automatically or manually finds the certain elements of the form - control fields: lines, the static text (repeating on all forms), checkboxes, "black squares" and bar codes. These elements of the form are necessary for exact definition of a template of the form and the sure overlapping of a template with the image. After that fields which should be recognized are specified. Thus the type of a field, its format and rules of the control is underlined. Rules of the control include check on a database to guarantee correctness of input of the information; rules of unification of representation of dates, the financial data etc.; a pattern of filling of a field as regular expressions; check under the user dictionary. If export of recognition results to a database is required, then for each of these fields the column in the table of a database which corresponds to this field is set.

B. Definition of reference points in the graphic image of the form.

In the process of printing and scanning forms, linear distortions that are not detected by the eye always occur along the height and width of the paper. For their definition and exact align of a template, reference points are used. As such objects 4 black squares located at the corners of the shape are usually used (Fig. 1).

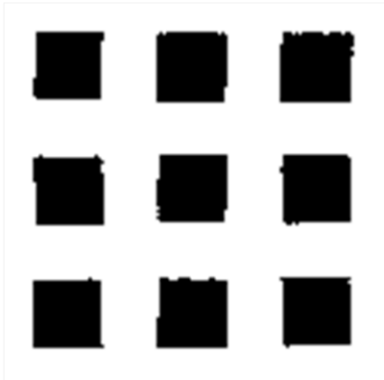


Fig 2. Samples of black squares

To find the black squares the following processes are carried out:

- the scanned form is converted to black and white mode;
- in the assumed zone, where the reference points are located, all connected objects are determined;
- black squares are determined among all objects, which correspond to the size of the squares defined in the template. Due to the conversion of the original image to black and white, the contours of the square are not straight, but with “notches”. Therefore, during determination of the square, a certain amount of deviation of linear dimensions from the original is allowed, specified on template generating.

C. Definition and align of the template.

Based on the coordinates of the reference points determined at the previous stage, the examination template is matched with a graphic image. Depending on the number of defined black squares, various transformation algorithms are used to match the pattern.

Note that the system allows you to determine the pattern when finding at least 3 reference points. Otherwise, the form is postponed for the manual template matching subsystem and requires operator intervention. This usually happens when the image scanned incorrectly or the paper is scrapped. Note that the system is not linked to a specific template, but allows you to create and edit various forms of templates.

For precise matching of the template, various geometric transformations are used. At the same time, the coordinates of the exact location of the recognized fields on the graphic image are determined.

This is a very important stage and the more accurately this process has been carried out, the more accurate will be the results of recognition. Therefore, for a more accurate alignment, the choice of the transformation algorithm will be carried out depending on the number of defined reference points (black squares).

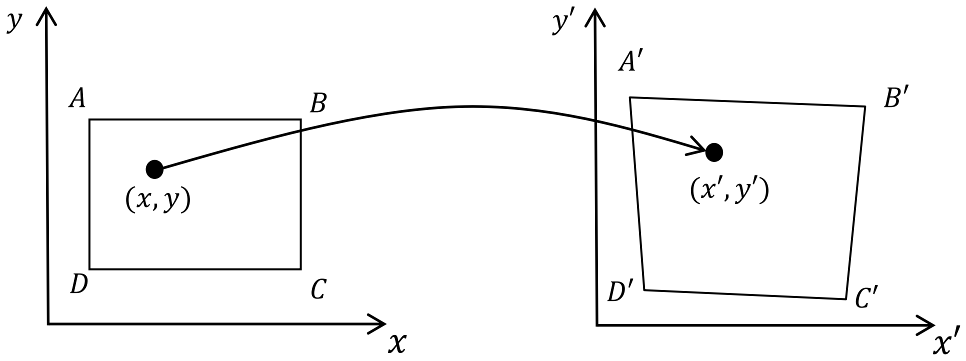


Fig 3. Bilinear transform

In the case of using four squares as reference points for their determination, a bilinear transformation was applied, which is expressed as follows:

$$\begin{cases} x' = a_0 + a_1 x + a_2 y + a_3 xy \\ y' = b_0 + b_1 x + b_2 y + b_3 xy \end{cases}$$

where (x, y) и (x', y') – source and converted coordinates, $a_i, b_i, i = 0..3$, – coefficients of transformation.

To accurately determine the parameters, it is enough to know the initial and transformed coordinates for 4 points. In this case, two systems of linear algebraic equations are solved:

$$\begin{cases} A'_x = a_0 + a_1 A_x + a_2 A_y + a_3 A_x A_y \\ B'_x = a_0 + a_1 B_x + a_2 B_y + a_3 B_x B_y \\ C'_x = a_0 + a_1 C_x + a_2 C_y + a_3 C_x C_y \\ D'_x = a_0 + a_1 D_x + a_2 D_y + a_3 D_x D_y \end{cases} \qquad \begin{cases} A'_x = b_0 + b_1 A_x + b_2 A_y + b_3 A_x A_y \\ B'_x = b_0 + b_1 B_x + b_2 B_y + b_3 B_x B_y \\ C'_x = b_0 + b_1 C_x + b_2 C_y + b_3 C_x C_y \\ D'_x = b_0 + b_1 D_x + b_2 D_y + b_3 D_x D_y \end{cases}$$

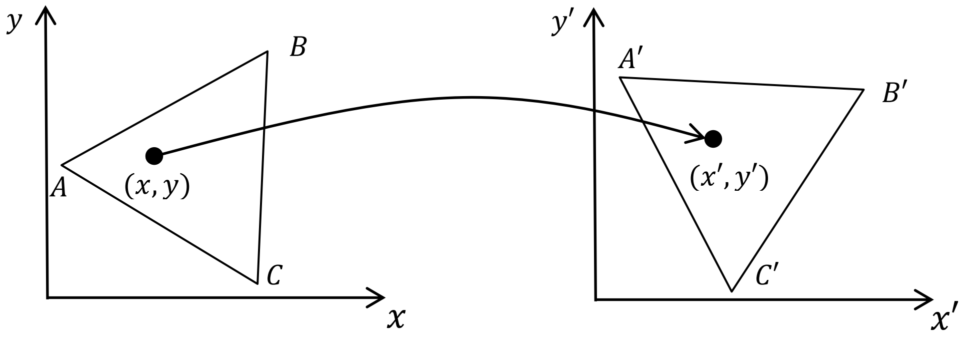


Fig 4. Affine transform

In the case of using three squares as reference points for their determination, a affine transformation was applied, which is expressed as follows:

$$\begin{cases} x' = a_0 + a_1 x + a_2 y, \\ y' = b_0 + b_1 x + b_2 y, \end{cases}$$

where (x, y) и (x', y') – source and converted coordinates, $a_i, b_i, i = 0..2$, – coefficients of transformation.

Pic 5. Type of fields a) checkbox and radio groups; b) handwritten text

To accurately determine the parameters, it is enough to know the initial and transformed coordinates for 3 points. To find coefficients, two systems of linear algebraic equations are solved:

$$\begin{cases} A'_x = a_0 + a_1 A_x + a_2 A_y \\ B'_x = a_0 + a_1 B_x + a_2 B_y \\ C'_x = a_0 + a_1 C_x + a_2 C_y \end{cases} \qquad \begin{cases} A'_x = b_0 + b_1 A_x + b_2 A_y \\ B'_x = b_0 + b_1 B_x + b_2 B_y \\ C'_x = b_0 + b_1 C_x + b_2 C_y \end{cases}$$

D. Recognition.

Based on the template defined in the previous step, the system recognizes each form field. The system allows you to recognize the following types of fields (Figure 5):

- checkboxes – ☐,☒,☑,○,●;
- radio groups – only one mark has to be filled, for example - ○●○○;
- handwritten text - text written in block letters.

To recognize checkboxes or radio groups, statistical recognition methods are used [7,8]. Upon recognition, the system compares the statistics of this field with the template and, if a certain threshold is exceeded, it makes a decision about marking or not marking the item.

During filling out the points, applicants often make the following mistakes:

- filling two or more points - multiple choice;
- incomplete filling of the circle;
- using any other mark instead of filling the circle.

To solve these problems and reduce the number of calls to the operator, the system uses the following threshold values:

- minimum percentage of filling - percentage of completion at which a lesser field will be deemed to be empty;
- minimum percentage of filling for rejection of recognition - percentage of fullness at which a lower field fullness will be marked by the system as uncertainly recognized;
- the threshold of multiple choice - the threshold, with a larger difference between the maximum filled and another filled field, the system will automatically take the value of the maximum filled field as the result of recognition.

Fig 6. Incorrectly filled answers

For the recognition of hand-written text, we used a multilevel recognition system based on neural networks (NS) [9-13]. The system is focused on the recognition of the Latin alphabet and the Azerbaijani language, although these requirements are not fundamental and the system is not difficult to retrain into another alphabet and language.

The Peripheral Directional Contributivity (PDC) is used as feature extraction method [14,15]. This feature reflects well the complexity, the orientation and the relative positioning of strokes in symbols. Directional Contributivity (DC) of each point of a symbol represents 8 (or 4)-dimensional vector. Each component of a vector represents distance from this point up to a symbol border in one of

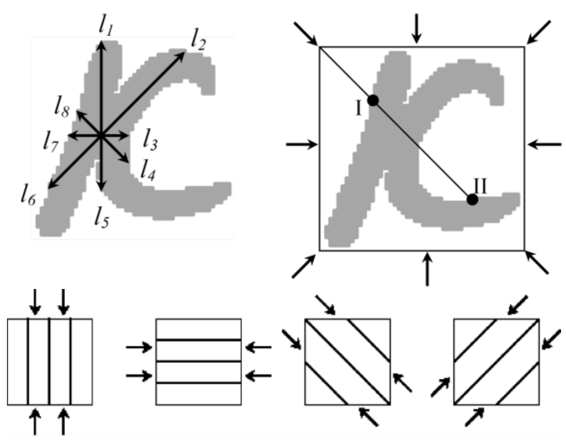


Fig. 7. Feature extraction method.

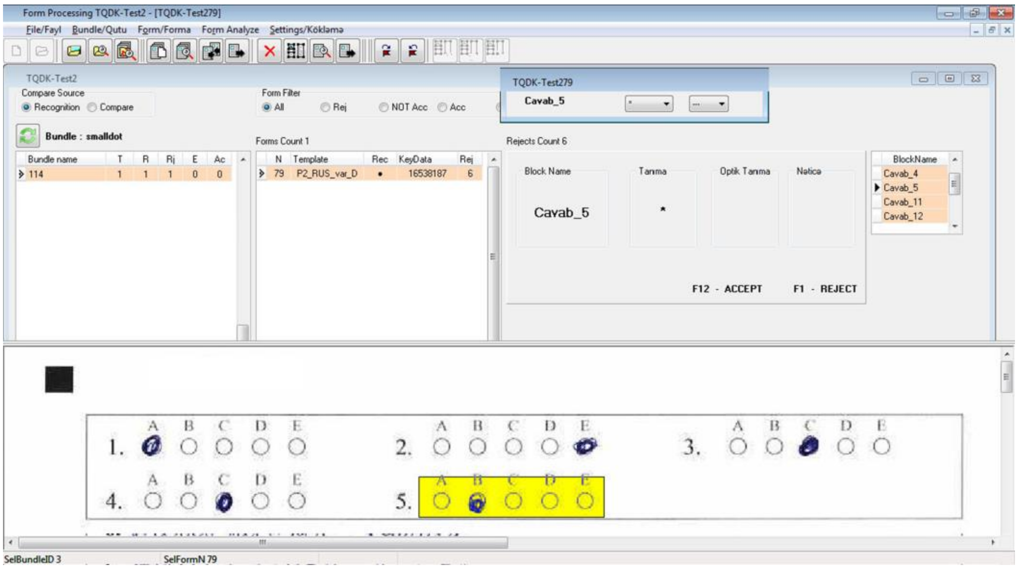


Fig 8. Verification Screen

possible 8 directions (or a maximum of distances on 4 directions: vertical, horizontal and two diagonal). Then values of a vector are normalized. At movement from border on one of four directions we shall meet a point in which white color passes in black. We shall name such point as the 1st order peripheral point (or the peripheral point of depth 1). If we move further, we shall meet the 2nd order peripheral point (Fig. 7). As a feature, we use DC for all the 1st and 2nd order peripheral points on four directions.

The hierarchical recognition system of handwritten character consists of several levels differing on time and laboriousness of recognition. In the given system we used two recognition levels. As a preliminary, from initial set {ABCÇDEƏFGĞHIİJKLMNOÖPQRSŞTUÜ VXYZ}, consisting of 32 symbols, the symbols with strokes and points above (ĞİÖÜ) are deleted, since their recognition is divided into two stages: recognition of the top and bottom part. Recognition of the bottom part is carried out by means of our recognizing module by recognition of G,I,O and U characters, and the top part can be realized by means of other "easy" algorithms. So, our initial set from 32 symbols was reduced up to 28. Then we make clusterization of recognized symbols and our initial set from 28 symbols will break up to the 15 classes: {A}, {B}, {CÇG},{DOQ}, {EFP}, {Ə}, {HMN}, {IT}, {J}, {KRX}, {L}, {SŞ}, {UV}, {Y} и {Z}. On the 1st recognition level the neural network should determine a belonging of a symbol to one of 15 groups. If the found group contains more than one element, then the neural networks of the 2nd level should find the given symbol within the group, defined on the 1st level. So, in our case, at the first level we have one NN and on second level - eight NN.

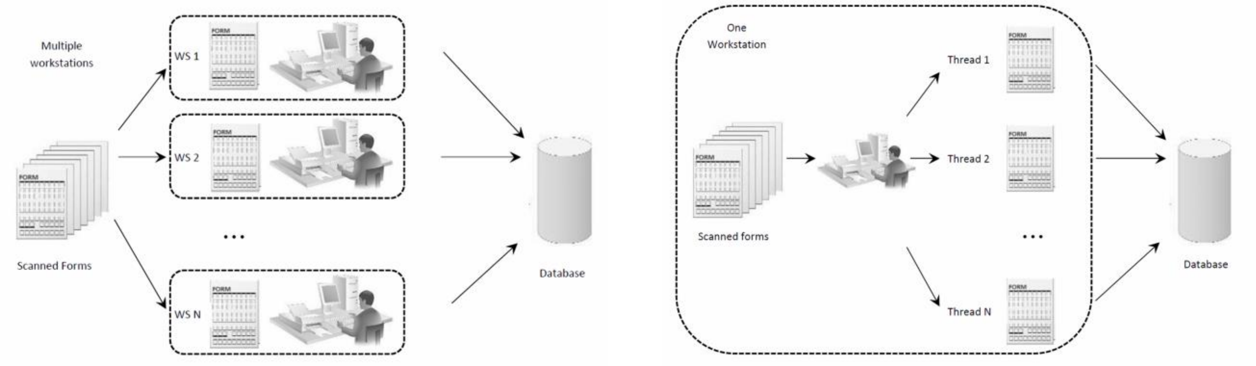
In the process of recognition, information on the number of confidently and doubtfully recognized forms and fields are stored. Relevant form areas are noted for further consideration and expert evaluation.

F. Verification.

All recognition results go to the verification zone. At this stage, the following procedures are performed:

- Define templates of forms deferred in the previous step for manual determination.
- Doubtfully defined fields are checked by the operator and the correct values are set. Verification is carried out by comparing the graphic image with the recognition results on the monitor screen. The operator verifies the recognition and, if necessary, makes corrections (Fig 8).

After completing the stage of recognition and verification of examination forms, the data enters the area of expert assessments for written answers. In parallel mode, the areas of written answers in



a) parallel usage of multiple workstations b) usage multithreading within single workstations

Fig 9. Approaches to performance improvement

graphical mode are displayed on the screens of independent experts. Moreover, for objectivity, this information is shown without indicating the author of the examinee. After rating by all experts, the system automatically decides on an objective assessment of the response. At the same time, full logging and archiving of all expert actions is carried out.

After a complete determination of the results of the examination form, the data enters the system for assessing the correctness of determining test questions. Here, the results of the examiner's answer are compared with the correct answers and, using special algorithms, the final assessment of the examination form is set.

To ensure the transparency and objectivity of exams, all data (graphical form of the examination form, exam results and correct answers) are placed online to the personal account of the examinee.

3. PERFORMANCE IMPROVEMENT

One of the important criteria of form processing systems is the speed of form processing. For an existing system, this can be achieved using the following approaches

a) Parallel use of recognition process on multiple workstations;
b) Using the multicore/multithreading property of modern processors to parallelize processes within a single workstation

In this paper, the 2nd approach for increasing productivity is investigated, because its implementation does not require additional equipment and increase productivity is achieved on existing equipment.

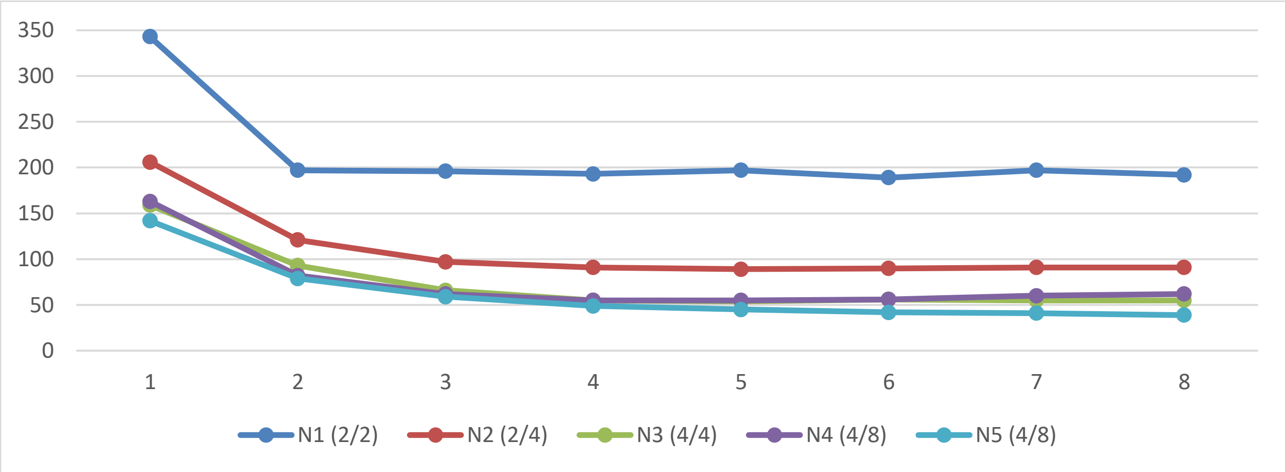
To implement multithreading in the developed system, the stages of pattern matching and recognition were ran in parallel by a separate thread (Fig. 9), because only these stages allow to exclude the mutual use of the same data by different streams.

For comparative analysis, workstations with the same configurations and the following CPUs were used:

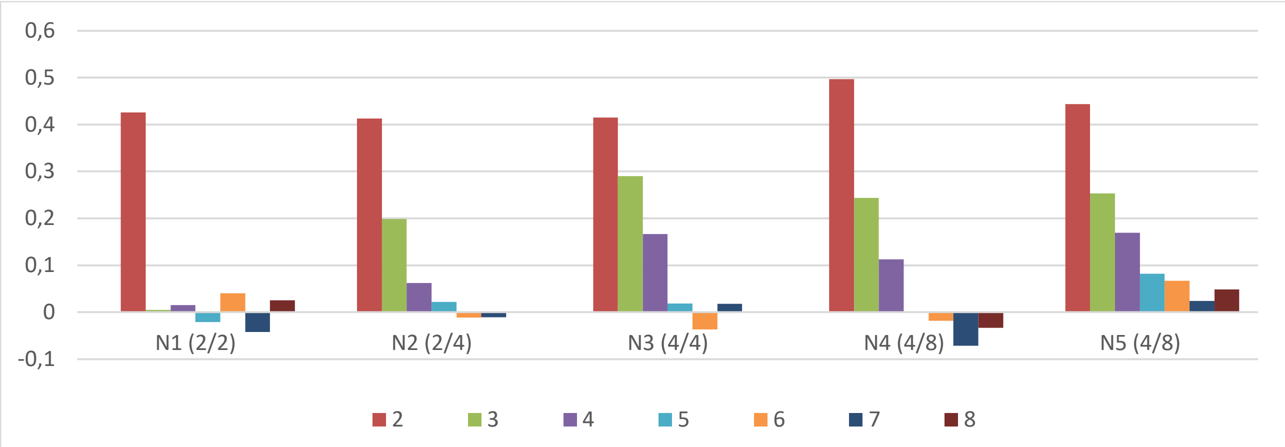
N	CPU	Core quantity	Thread quantity
1	Intel Core 2 Duo T6570 2.10GHz	2	2
2	Intel Core i3-2120 3.30GHz	2	4
3	Intel Core i5-4590 3.30GHz	4	4
4	Intel Core i7-3770 3.40GHz	4	8
5	Intel Core i7-2600K 3.40GHz	4	8

In each experiment the system processed 1000 forms. For comparative analysis, recognition was carried out sequentially from 1 to 8 threads. Below are the experimental results.

Graph 1. Recognition time (in sec) depending on the thread count



Graph 2. Efficiency of recognition time on increasing of threads



As a result of experiments, it was found that the transition to multi-threaded recognition can increase productivity up to 3.5 times in comparison with single-threaded. Increasing the number of threads more than physical cores does not give significant progress.

4. CONCLUSION

The developed system for processing and objective evaluation of test exam allows conducting mass exams and providing reliable and objective assessment of them. This system can be configured on almost any type of form. Its use also allows you to abandon the expensive and difficult to use OMR scanners.

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