UDC 004.93

DOI: 10.25140/2411-5363-2021-2(24)-67-74

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## TECHNOLOGY OF PRIMARY PROJECT INFORMATION PROCESSING AND RECOGNITION BY ANDROID OPERATING SYSTEM

The paper considers the syntactic model of recognizing the structures of UML-diagrams, defines the main methods and algorithms for working with images and basic methods of recognizing figures and texts, proposes its own algorithm for analysis and recognition based on the method of flexible comparison on graphs. The proposed algorithm can be used on any platform. As a result, a technology for analysis and recognition of primary design information, namely – UML diagrams, was developed. The proposed technology allows to reduce time and financial costs, increase the speed of modelling and design.

Keywords: shape recognition; UML diagrams; design; design documentation.

Fig.: 4. References: 11.

Urgency of the research. Currently, there are several solutions for recognizing UML diagrams drawn by hand on paper. They allow speeding up the design and modelling process without spending time on transferring diagrams from paper to electronic form. However, none of the known solutions can be used in modern smartphones, particularly with the Android operating system. The article proposes chart recognition technology that can be used under any platform.

Formulation of the problem. The development of any application, system, service, etc., is a complex technological process that requires much effort, time and careful preparation. Planning and design processes are integral steps in product development [1]. This requires solving such tasks as accelerating the design, dynamic addition of new information, updating obsolete or deleting incorrect information, reducing time and financial costs without losing product quality. One way to solve the problem is to create documentation at the stage of origin of the idea and product analysis.

It is clear that it is easier and faster to draw UML diagrams by hand, but in this case, there is a problem with their recognition and transfer to the digital version.

Usually, innovations and changes in projects are discussed at retrospectives or project rallies, where they express ideas and opinions about the implementation of customer needs or improving the functionality of the product, draw diagrams, charts, notes, etc. It is necessary to make changes to the existing UML diagrams as soon as possible, or create new ones, adjust the test documentation to reduce the time of the task. Recognizing and digitalizing text is not a big problem at the moment, but hand-drawn diagrams are a non-trivial task. Note that none of the considered systems for recognizing hand-drawn charts can be implemented by the Android operating system, which increases the time for information processing. Using such systems requires other tools to create and transfer images.

The analysis of recent research and publications. Recognition of complex diagrams requires not only the recognition of elementary figures but also the determination of the relationships between these figures. Most of the available sketch recognition systems are limited to a specific application or specific forms.

The [2] describes a developed and implemented system for online recognition of drawn UML diagrams. Input data comes from an electronic board, mouse or tablet for data transfer. A sophisticated segmentation algorithm groups bar images into symbols, overcoming inaccuracies in drawing typical of manual input.

In work [3] the use of methods of recognition of the drawn images is covered. Based on the analysis of corner points and their joints, squares and two types of joints are recognized, which differ not in the geometric features of the drawn strokes, but in their location relative to each other. Thus, you can recognize the whole set of figures.

The Tahuti [4] is a two-screen thumbnail recognition environment. The system is based on a multi-level recognition structure of UML diagrams, which allows to recognize multi-line images by their geometric properties and to draw images in an accessible manner without any restrictions.

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An application for recognizing complex diagrams drawn by hand online [5] is a system for recognizing manually displayed complex diagrams, which create a dynamic and intelligent relationship between the various components of the diagram.

Uninvestigated parts of the general problem. The main problem with these and other publications is the lack of chart recognition in the Android operating system, which leads to the need to have the means to create an image and transfer it to another device with chart recognition. It reduces the speed of analysis, design, increases time and money.

The purpose of the article is to review the technology and develop a system for recognizing and processing primary design information using the Android operating system to increase efficiency and speed up design without losing product quality.

The statement of main material. Primary project information is a document formed during the work on the project and is finally arranged at the final stage. Note that visual modelling is almost always used alongside textual information. The image allows you to create and maintain a single image when thinking, i.e. in the process of analysis and design. When drawing a diagram, we use abstract space, creating arbitrary relationships between objects in a particular system. With linear text, this is much harder to do. Also, the pictures allow you to concentrate better. With the help of a diagram, we can focus on a specific problem being worked on, and switching between different objects takes a fraction of a second. Therefore, you can focus on the details you need at the moment without worrying that you will lose other details. Charts are also an effective means of exchanging information during a discussion, which is now an integral part of the documentation.

Today, UML charts are widely used [6]. In general, UML is a unified graphical modelling language for describing, visualizing, designing, and documenting object-oriented systems.

UML is designed to support the process of software modelling based on an object-oriented approach, to organize the relationship of conceptual and software concepts, to reflect the problems of scaling complex systems. UML models are used at all stages of the software life cycle, from business analysis to system maintenance. Different organizations can apply UML at their discretion, depending on their problem areas and technologies used and based on international standards [7; 8].

**Syntactic model of structure recognition UML-diagram**. If users can create images of such characters as natural so that the thumbnail recognition system can determine the grammar definition for each character in the domain language, the grammar that simulates abstract syntactic languages may have a character relationship.

The syntactic model (grammar) of UML-diagrams will be understood as an ordered five [9]:

$$(N, T, L, R, N_0),$$
 (1)

where N- a finite set of auxiliary variables (non-terminal characters);

T – a finite set of graphic symbols of the term;

L – a finite set of predicate labels;

R – a finite set of substitution rules;

 $N_0 \in \mathbb{N}$  – the initial character.

The set *T* of terminal graphic symbols can be represented as a combination of sets:

$$T = V \cup F_T \cup C_T \cup W_T, \tag{2}$$

V – a finite set of basic graphic symbols;

 $F_T$  – a finite set of figures created based on essential graphic symbols V;

 $C_T$  – a finite set of relations between figures and text;

 $W_T$  – a finite set of text words associated with text word shapes and relationships.

In the process of recognizing UML-diagrams associated with  $F_T$ ,  $C_T$ ,  $W_T$  in the ordered sets F, C, W, lists of text attributes represented by the ordinal numbers of the corresponding figures, combining communication lines and word blocks, their type, signatures and spatial coordinates are stored. Nodes located on the plan Img(x, y) image UML charts. Most of the text attributes in the form of a report are stored in the source text file.

Recognition of the image structure of UML-diagrams taking into account the grammar of its construction to obtain a formalized text description F, C, W is a recursive procedure for updating the original sentence from terminal symbols ( $F_T^*$ ,  $C_T^*$ ,  $W_T^*$ ), auxiliary variables with N and attributes with F, C, W by applying to its current value the rules of substitution R and the set of predicates L.

$$(F, C, W, N, F_T^*, C_T^*, W_T^*)_{t-1} \stackrel{R,L}{\Longrightarrow} (F, C, W, N, F_T^*, C_T^*, W_T^*)_t.$$
 (3)

Note that the substitution rules with *R* at each step of the recursive UML pattern recognition procedure determine possible variants of its further structure. For example, the contour of a figure can be followed by lines of communication with other figures and then - their contours.

Thus, recognizing the structure of the UML-diagrams, based on parsing the correct construction of the latter (generative method), allows you to divide the input images into "correct" UML-diagrams and "incorrect" UML-diagrams. While maintaining the appropriate formalism of structural recognition algorithms, they can, in contrast to discriminant methods, generate a set of newly formed UML diagrams.

**Basic methods and algorithms for working with images.** To solve the problem discussed in this article, it is necessary to find a diagram in the image, namely – the essence and relationships between them. Recognition problems do not have a universal solution that would allow you to recognize any objects and inscriptions on them. You can create a general algorithm, but the cost of creating it will be too high. Typical image is also not very suitable for analysis. It is necessary to carry out some manipulations and prepare for analysis.

There are methods and algorithms for image recognition in the image, which can be divided into three groups [6]. The first group is image filtering and preparation. The second group is the processing of filtering results. Third – decision-making algorithms based on filtering data. The third group includes methods of recognizing figures and texts.

Basic methods of recognizing figures and texts:

- 1) the method of flexible comparison on graphs (Elastic graph matching);
- 2) neural networks;
- 3) hidden Markov models (CMM, HMM);
- 4) principal component analysis method;
- 5) active appearance models (AAM).

Machine learning techniques are most commonly used in large object recognition projects. Algorithms need to build a model that allows them to analyze the input image and decide which objects are in the image. The construction of the algorithm is based on the analysis of several specified features. The classifier needs data sampling and fine-tuning to learn. There are many classifiers that differ in use and results in solving different problems.

In low-budget projects, the algorithms are much simpler and are based on the analysis of the main features of the object. This can be a closed-loop, the number of angles and breaks, the size and position relative to other objects.

There are several tools for image analysis. The most famous are MATLAB Image Processing Toolbox, OpenCV library and numerous analogues.

Note that in the development of technology was used the method of flexible comparison on graphs [10].

**Recognition technology.** The general recognition algorithm is shown in Fig. 1.

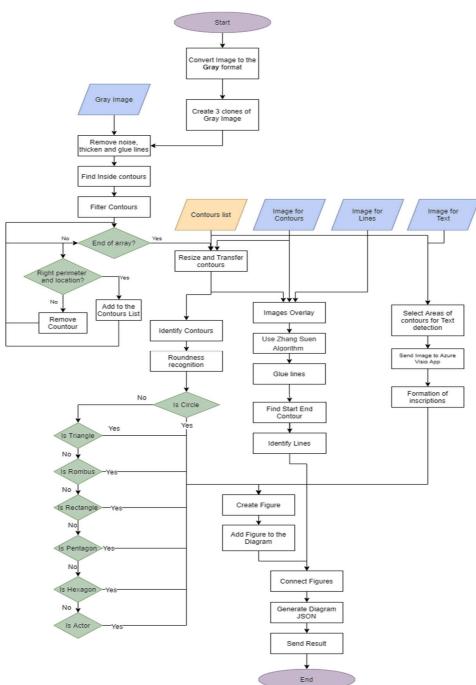


Fig. 1. The general algorithm for recognizing shapes in the image

The main steps of this algorithm are as follows:

- 1) Obtaining the input image (Fig. 2);
- 2) Conversion of the image to Gray format;
- 3) Creation of copies of the image for the distributive analysis of essences of communications and the text;
  - 4) Initial image blur to remove noise and pass the binarization algorithm;
  - 5) Search for internal contours of figures;
- 6) Filtering of contours on the maximum and minimum perimeter, and also on the centre of figures;
  - 7) Increase the size of the contours;
  - 8) The use of the method of filling contours;

- 9) Usage of the disjunction negation method for the original image and the clone with figures to obtain an image containing only the lines of connection;
  - 10) Usage of the Zhang Suen algorithm [11];
  - 11) Search for lines and increase them by vector;
  - 12) Search for intersections between lines. Virtual glueing;
  - 13) Search for the beginnings and ends of lines belonging to the recognized figures;
  - 14) Identification of figures;
  - 15) Identification of lines;
  - 16) Request for handwriting recognition;
  - 17) Formation of chart objects based on the received coordinates;
  - 18) Adding objects to the chart;
  - 19) Generation of the JSON scheme of the created diagram.

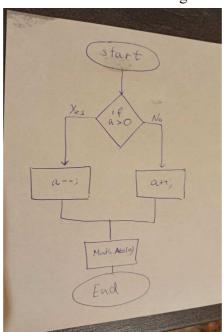


Fig. 2. Example of an input image

To effectively recognize the shapes in the image, you need to have separated objects. Therefore, one of the first tasks is to separate figures and connections. You need to make copies of the converted image to continue working with them. Also, when working with the image, it is necessary to monitor the size of the canvas because the modification and analysis will be carried out based on information positioning data.

One of the main tasks of developing an algorithm is to unify the analysis of objects in different images because you can draw a diagram on paper in different ways: by connecting figures with connections or by not connecting lines. It should also be borne in mind that a person can indistinctly draw a figure, for example, draw an oval with an open contour. To unify, an algorithm for glueing all lines by blurring and binarization was created.

To highlight the entities, it was decided to analyze the inner contour of the closed figures in the image. After all, thinning algorithms for selecting shapes can increase the level of errors and errors in image analysis. Since at this stage the type of figure is not important, but only its relative position in the figure and the contour, it is necessary to increase the size of the contours of the figures to overlap the blurred lines for further work with images.

A discrete exclusive disjunction operation was used to highlight the links for two images: the main grey image after binarization and the image with enlarged contours of the figures. As a result, we obtain only the selected lines on the white canvas.

To analyze the text, fragments of figures on the main grey image are selected. The generated image is sent to the Azure Visio application for handwriting recognition. As a result, we have a JSON schema with text and location coordinates.

To identify the figures, we use the method of estimating the convexity of the figure and vector construction, as well as calculating the angles (points of intersection).

Based on the obtained data, we can create a chart and convert it into a JSON scheme for further use.

The results of the individual stages of the algorithm are presented in Fig. 3 and 4.

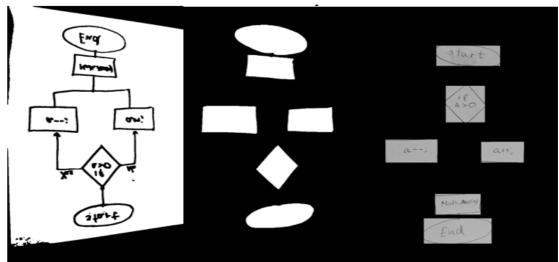


Fig. 3. The results of the algorithm for recognizing entities

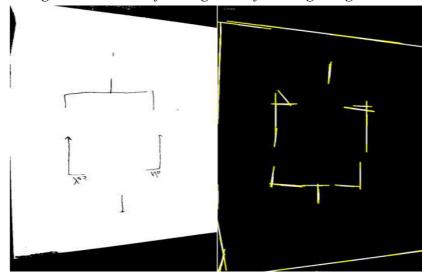


Fig. 4. The results of the relations recognition algorithm

**Implementation tools.** C # programming language, Visual Studio 2019 development environment, Vuforia augmented reality platform, Azure Computer Vision API character recognition service, Aspose.Diagram file manipulation framework, Emgu CV were used to implement the system.

**Conclusions.** The paper considers and implements the technology of processing and recognising project information, namely – UML-diagrams, which is based on the method of flexible comparison of objects. The technology can be used on any platform, including Android, which will speed up the stages of analysis, planning and design in the development of information systems, applications, web applications and more.

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УДК 004.93

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# ТЕХНОЛОГІЯ ОБРОБКИ ТА РОЗПІЗНАВАННЯ ПЕРВИННОЇ ПРОЄКТНОЇ ІНФОРМАЦІЇ ЗАСОБАМИ ОПЕРАЦІЙНОЇ СИСТЕМИ ANDROID

На сьогодні існують декілька рішень для розпізнавання UML-діаграм, намальованих від руки на папері. Вони дають змогу прискорити процеси проєктування та моделювання, не витрачаючи час на перенос діаграм із паперу в електронний вигляд. Проте жодне з рішень не може бути використано в сучасних смартфонах, зокрема, з операційною системою Android. У статті запропоновано технологію розпізнавання діаграм, яку можна використати під будь-якою платформою.

У світі велика кількість проєктів із розробки програмного забезпечення виконуються з перевищенням початкового бюджету і строків. Причинами зриву строків та перевищення витрат можуть бути різні фактори— від складності проєкту, зміни в архітектурі, бізнес-логіці до непрофесійності спеціалістів. Можливим вирішенням проблеми є підвищення ефективності та прискорення проєктування без втрати якості та продукту, динамічне доповнення новою інформацією, оновлення застарілих або некоректних даних, скорочення часових і фінансових витрат. Запропонований алгоритм обробки та розпізнавання первинної проєктної інформації дає змогу зменшити часові та фінансові витрати, збільшити швидкість моделювання та проектування.

Нині існує декілька систем та додатків, що використовують технології аналізу та розпізнавання діаграм на основі зображень, проте жодне із відомих рішень не може бути використано на пристроях з операційною системою Android.

 $\Gamma$ оловною проблемою  $\epsilon$  відсутність алгоритмів для розпізнавання діаграм, що можуть бути використані під операційною системою Android.

Розглянуто синтаксичну модель розпізнавання структур UML-діаграм, визначено основні методи та алгоритми роботи з зображенням та основні методи розпізнавання фігур і текстів, запропоновано власний алгоритм аналізу та розпізнання на основі методу гнучкого порівняння на графах.

Розроблено технологію для аналізу та розпізнавання первинної проєктної інформації, а саме — UML-діаграм. Запропонований алгоритм може бути використаний під будь-якою платформою.

Ключові слова: розпізнавання фігур; UML-діаграми; проєктування; проєктна документація.

Рис.: 4. Бібл.: 11.

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