# SOFTWARE FOR THE RECOGNITION OF POLYHEDRON CONTOUR IMAGES IN THE FRAMEWORK OF LOGIC-OBJECTIVE RECOGNITION SYSTEM

**Natalya Bondar, Tatiana Kosovskaya**

**Abstract.** The paper is devoted to the implementation of logic-objective approach to the solving of a polyhedron contour images (in particular partially covered images) recognition problem in a complex scene represented on the display screen. A way of predicate value calculation for representation the display screen is described in the paper. Examples of a program run constructing descriptions of both separate pictures and classes of objects are presented. For recognition of partially covered objects on the complex scene the concept of partial deducibility is used. Additionally the certainty level of the correct recognition is calculated.

***Keywords***: *artificial intelligence, pattern recognition, predicate calculus.*

***ACM Classification Keywords***: *I.2.4 ARTIFICIAL INTELLIGENCE Knowledge Representation Formalisms and Methods – Predicate logic.*

## Introduction

The problem of recognition and analysis of a situation is one of the central problems of artificial intelligence. To formalize such a problem a logic-objective approach is proposed in [1]. This approach uses a language of predicate calculus and logical deduction in it.

Difficulties that appear during solving the problem of an object recognition in a complex scene are connected with the presence of a ”vicious circle”: to distinguish an object on the scene it is necessary first of all to single it out. And to single it out it is necessary to recognize it. On the first approach it seems that the way out from the “vicious circle” is only one – the full exhaustion of all elements of the image situated on the screen. Although, a deeper analysis of the problem allows to formulate and solve it as a problem of logical deduction search [1].

Just such an approach is implemented by programs represented in this paper.

## Logic-objective approach to the pattern recognition problems

Let $\Omega$ be a set of finite sets $\omega = \{\omega_1,...,\omega_n\}$, that will be called below recognizable objects (here $t = t(\omega)$, that is in different sets there may be a different number of its elements). Any subset (not necessarily proper) $\tau$ of the set $\omega$ will be called its part. Let also a collection of predicates $p_1,...,p_n$ that characterizes properties and relations between elements of object $\omega$ Is done.

Let $\Omega$ be a union of $K$ (may be intersected) classes $\Omega = \bigcup_{k=1}^{K} \Omega_k$ .

Below the notation $\bar{y}$ is used for a list of all the elements from the set $y$. In particular, $\exists\bar{y}_{\neq}(P(\bar{y}))$ means that there is the set of values $\bar{y}=(y_1,...y_m)$ that $y_1 \in \omega \,\&...y_m \in \omega$ ($m$ is the number of free variables in formula $P$) for which the formula P is valid and such a formula is used as a notation for the formula

$\exists y_1,...\exists y_m(\&_{i=j}...\& \, y_1 \neq y_j \,\& \, P(y_1,...y_m)$.

A set of all the true constant formulas of the type $p_i(\bar{\tau})$ or $\neg p_i(\bar{\tau})$ written out for all possible parts $\tau$ of the object $\omega$ will be called logical description $S(\omega)$ of the object $\omega$.

A formula $A_k(\bar{x})$ with free variables $\bar{x}$ is called a logical description of the class $\Omega_k$ if

1. $A_k(\bar{x})$ contains only formulas of the type $p_i(\bar{y})$ as atomic (where $y \in x$);
2. $A_k(\bar{x})$ does not contain quantifiers;
3. $A_k(\bar{x})$ is a disjunction of elementary conjunction;
4. if for a list (an ordered set) $\bar{\omega}$ of all the elements of the set $\omega$ the formula $A_k(\bar{\omega})$ is valid then $\omega \in \Omega_k$.

Using the created descriptions the following pattern recognition problems may be solved. **The identification problem:** to check if the object $\omega$ or its part belongs to the class $\Omega_k$. **The problem of classification:** to find all the numbers $k$ of classes $\Omega_k$ such that $\omega \in \Omega_k$. **The analysis of a complex object problem:** to find and to classify all parts $\tau$ of the object $\omega$ for which $\tau \in \Omega_k$. The solution of these problems is reduced to the proof of the formulas $S(\omega) \Rightarrow \exists x_{\neq} A_k(x)$, $S(\omega) \Rightarrow \vee_{k=1}^{K} A(x)$, $S(\omega) \Rightarrow \vee_{k=1}^{K} \exists x_{\neq} A_k(x)$ respectively.

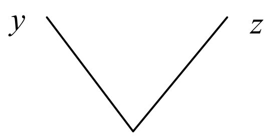
The solution of every of these problems is based on the proof of a logical sequence

$$S(\omega) \Rightarrow \exists x_{\neq} A(x) \qquad (1)$$

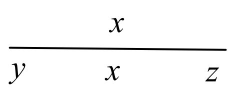
where $A(x)$ is an elementary conjunction.

## Setting of a polyhedron contour images recognition problem

Consider a set of display screen images formed by segments of a straight lines defined by their ends. Two predicates $V$ and $L$ are done and defined in the following way.




$V(x,y,z) \leftrightarrow$ "$\angle yxz < \pi$"




$L(x,y,z) \leftrightarrow$ "$x$ lies on the segment with the ends $y$ and $z$"

Two classes of objects are done: $\Omega_1$ – a class of images of “boring machines”, $\Omega_2$ – a class of images of “turning machines”. Examples of standard images are represented in the Fig. 1.

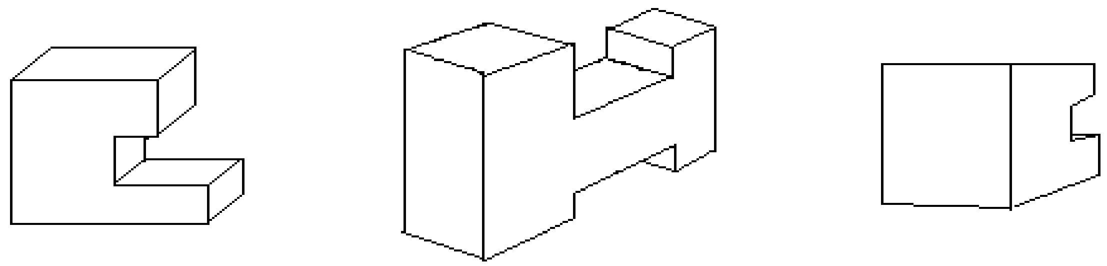


Fig. 1. Examples of standard images

Every image is represented on the display screen and defined by an intensity matrix.

## Description of pictures and classes

According to the intensity matrix defining the image on the display screen we extract segments of straight lines forming a contour image. In such a case the straight line is represented on the screen of the display as a step figure. To resolve this problem a block of a program that implements smoothing was developed. In particular there were introduced two parameters: parameter *length* which permits to identify points the distance between which is less than the value of this parameter; and parameter *eps* that determines the minimal distance when the point belongs to the line.

If the real crosspoint of lines was displayed by three pixels then the gluing of these pixels was carried out.

In allocating the points of intersection that satisfy the predicate $L$ it often occurred that the point of intersection of real lines are absent on the screen. To resolve the problem the gluing of the pixels was done.

After defining atomic formulas that are valid for the the image we receive the necessary set $S(\omega)$.

To obtain the description of the class according to the description of a standard object an elementary conjunction is build. In such a conjunction all the atomic formulas are obtained from the atomic formulas of object's description by replacement of different constants by different variables. The description of a class is a disjunction for all the standard objects of elementary conjunctions received in such a way.

## Example of the program run creating descriptions of objects and classes

The lines forming the contour image on the display screen are allocated and the values of the initial predicates are calculated.

In the left upper corner in Fig. 2, 3 and 4 there are objects to be analyzed. In the lower part there is the result of allocation of the contour image vertxes by the program. In the right window there is the description of the picture.

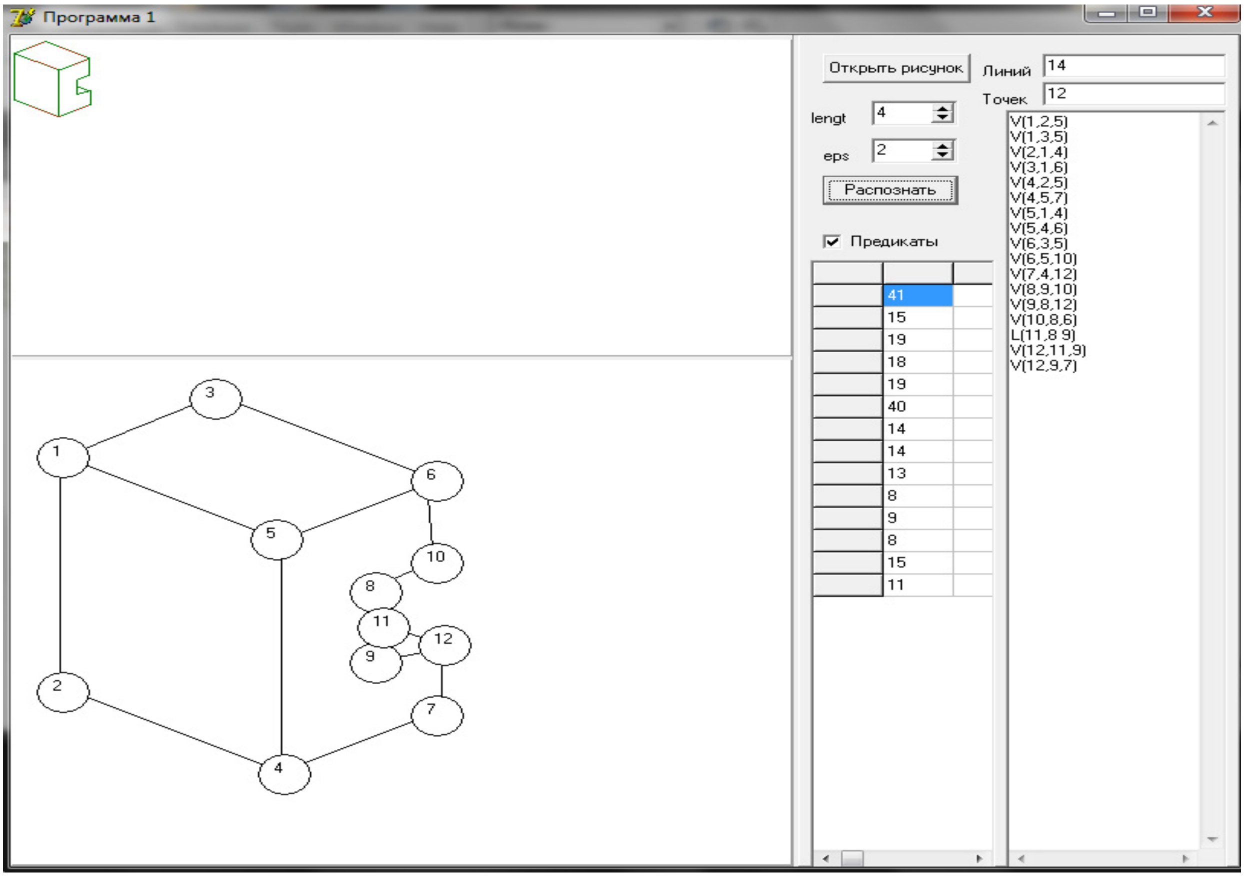



Fig. 2. The result of the program run creating the object description.

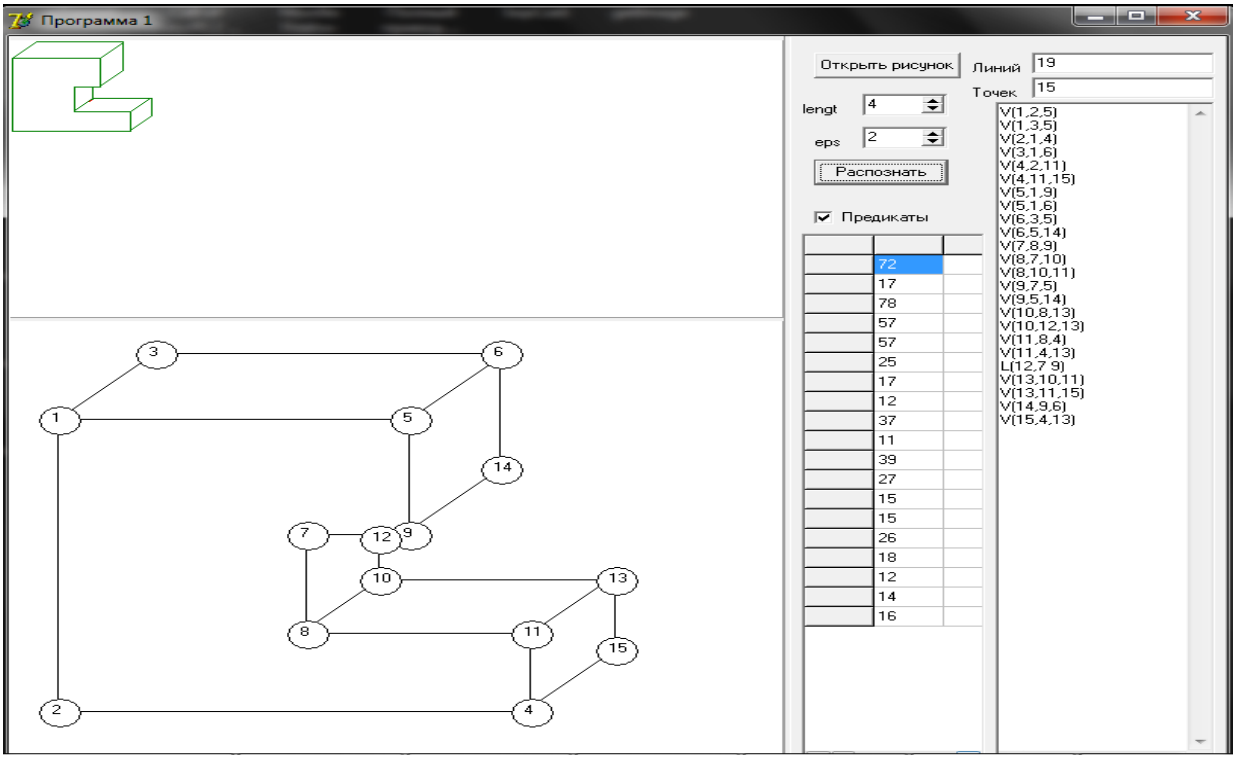



Fig. 3. The result of the program run creating the object description.

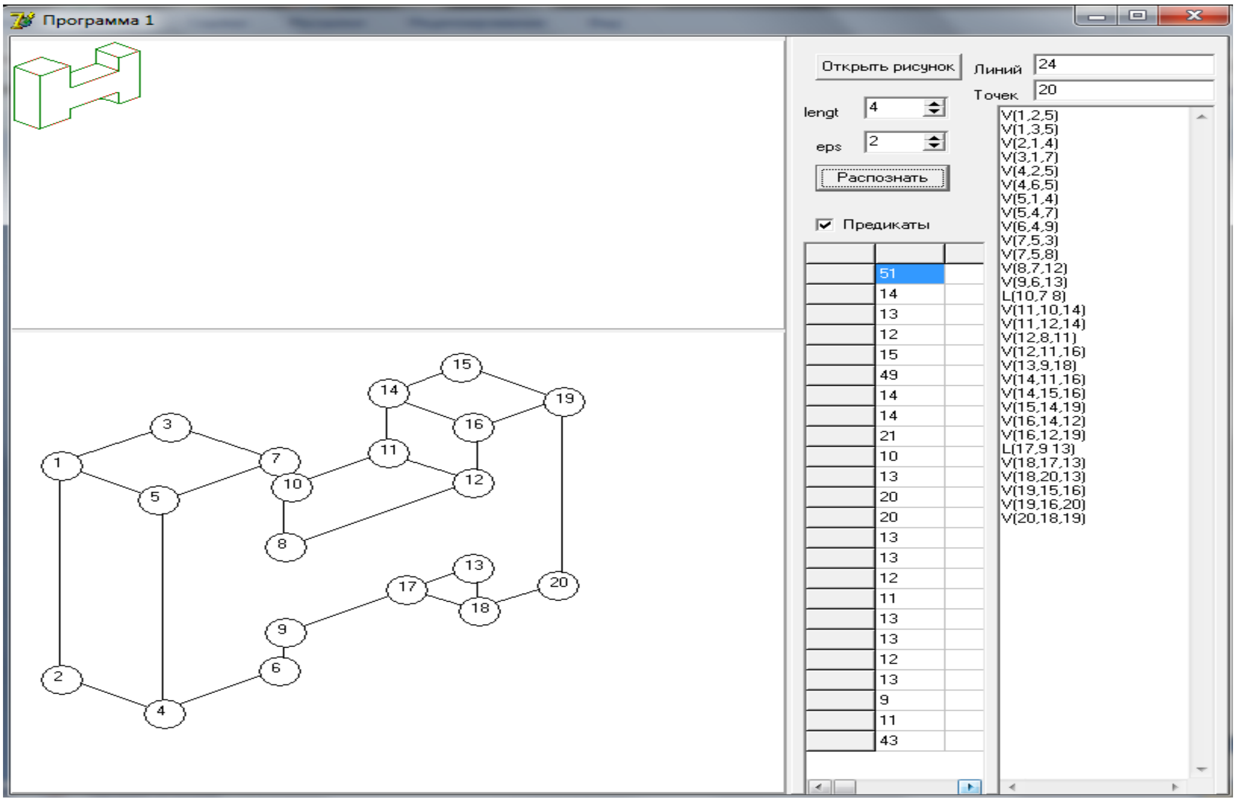



Fig. 4. The result of the program run creating the object description.

For the efficient run of the recognition program predicates shall be grouped in groups with the same names both in the set $S(\omega)$ and in the description of the class [2].

For the images in Fig. 2, 3 and 4 the following descriptions were respectively obtained:

$$S_1(\omega) = \{V(1,2,5), V(1,3,5), V(2,1,4), V(3,1,6), V(4,2,5), V(4,5,7), V(5,1,4), V(5,4,6), V(6,3,5), V(6,5,10), V(7,4,12), V(8,9,10), V(9,8,12), V(10,8,6), L(11,8,9), V(12,11,9), V(12,9,7)\}$$

$$S_2(\omega) = \{V(1,2,5), V(1,3,5), V(2,1,4), V(3,1,6), V(4,2,11), V(4,11,15), V(5,1,9), V(5,1,6), V(6,3,5), V(6,5,14), V(7,8,9), V(8,7,10), V(8,10,11), V(9,7,5), V(9,5,14), V(10,8,13), V(10,12,13), V(11,8,4), V(11,4,13), L(12,7,9), V(13,10,11), V(13,11,15), V(14,9,6), V(15,4,13)\}$$

$$S_3(\omega) = \{V(1,2,5), V(1,3,5), V(2,1,4), V(3,1,7), V(4,2,5), V(4,6,5), V(5,1,4), V(5,4,7), V(6,4,9), V(7,5,3), V(7,5,8), V(8,7,12), V(9,6,13), V(10,7,8), V(11,10,14), V(11,12,14), V(12,18,11), V(12,11,16), V(13,9,8), V(14,11,16), V(14,15,16), V(15,14,19), V(16,14,12), V(16,12,19), L(17,9,13), V(18,17,13), V(18,20,13), V(19,15,16), V(19,16,20), V(14,11,16), V(20,18,19)\}.$$

## Recognition of the standard image

Check of $S(\omega) \Rightarrow \exists \bar{x}_{\neq} A_k(\bar{x})$, can be realized by a derivation in a predicate sequential calculus.

An example of the run of the program that recognizes standard images is represented in Fig. 5.

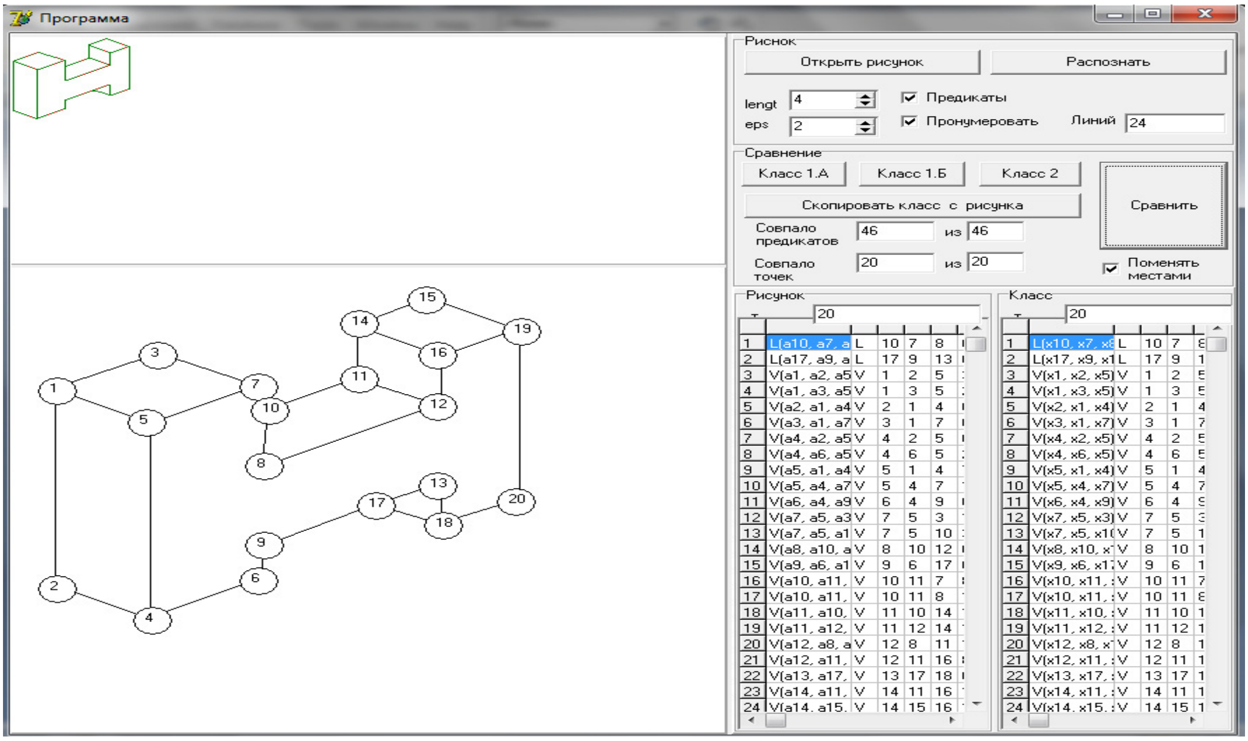



Fig. 5. Recognition of a standard image.

The object is recognized. In the left lower working window of the program result there is a description of the object. In the right lower working window there is a disjunctive member of the description of the class that is valid for this image. In the working windows above the descriptions the number of “coincided” predicates and arguments are given. In this example all 46 per 46 predicates and all 20 per 20 arguments coincide.

## Recognition of partially covered image

Consider a solution of the above formulated recognition problems when not a full description $S(\omega)$ of the object $\omega$ is done but only a subset of it $\tilde{S}(\omega) \subseteq S(\omega)$. Such a situation corresponds to the recognition of a partially covered object. To resolve the problem a concept of partial deduction was introduced in [3].

While solving the identification problem in spite of checking validity $S(\omega) \Rightarrow \exists \bar{x}_{\neq} A_k(\bar{x})$ one has a possibility to check only $\tilde{S}(\omega) \Rightarrow \exists \bar{x}_{\neq} \tilde{A}_k(\bar{x})$ where $\tilde{A}(\bar{x})$ is a sub-formula of the formula $A_k(x)$. Besides that the “reminder” of the formula $A_k(x)$ must not be in the contradiction with $\tilde{S}(\omega)$.

Let $a$ and $a'$ be the numbers of atomic formulas in $A(x)$ and $A'(x')$ respectively, $m$ and $m'$ be the numbers of objective variables in $A(x)$ and $A'(x')$ respectively. Then partial deduction means that the object $\omega$ is an $r$-th part ($r = m'/m$) of an object satisfying the description $A(x)$ with the certainty $q = a'/a$.

More precisely, the formula $S(\omega) \Rightarrow \exists x_{\neq} A_k(x)$ is partially $(q,r)$-deductive if there exists a maximal sub-formula $A'(x')$ of the formula $A(x)$ such that $S(\omega) \Rightarrow \exists x'_{\neq} A'(x')$ is deducible and $\tau$ is the string of values for the list of variables $x'$ but the formula $S(\omega) \Rightarrow \exists x_{\neq} [DA'(x)]_{\tau}^{x'}$ is not deducible. Here $[DA'(x)]_{\tau}^{x'}$ is obtained from $A(x)$ by deleting from it all conjunctive members of $A'(x')$, substituting values of $\tau$ instead of the respective variables of $x'$ and taking the negation of the received formula.

The result of solving the identification problem of “turning machine” (i. e. an object of the 1st class) is presented on the Fig. 6. The first object was identified almost completely because 20 points (points 1,...,20) taken for arguments of the 1st class description satisfy 26 atomic formulas of 30 in the class description. Hence, the object defined by points 1,...,20 with the certainty 26/30 belongs to the 1st class.

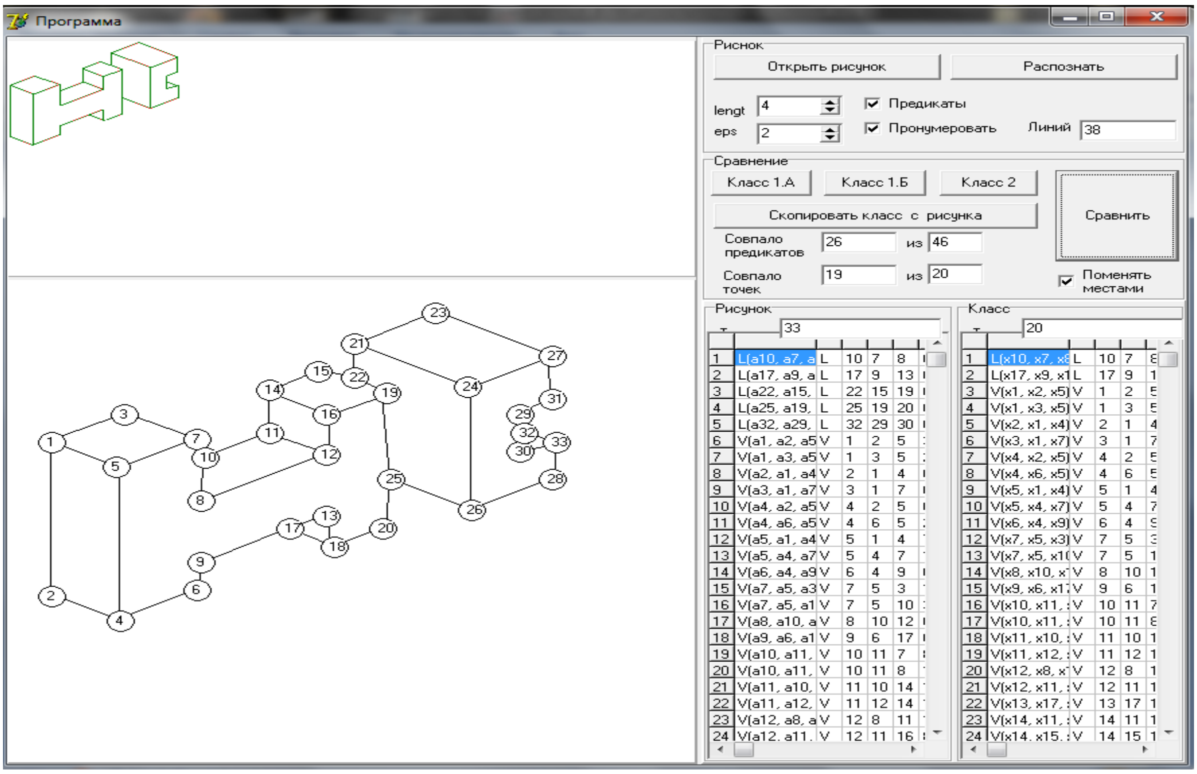



Fig. 6. Recognition of partially covered contour image

The result of solving the identification problem of “drilling machine” (i.e. an object from the 2-nd class) is presented on the Fig. 7. Points 21,23,24,26,...,33 and 22 or 25 taken for arguments of the 2nd class description satisfy 16 atomic formulas of 17 in the class description. Hence, the object defined by points 21,23,24,26,...,33 and 22 or 25 with the certainty 16/17 belongs to the 2nd class.

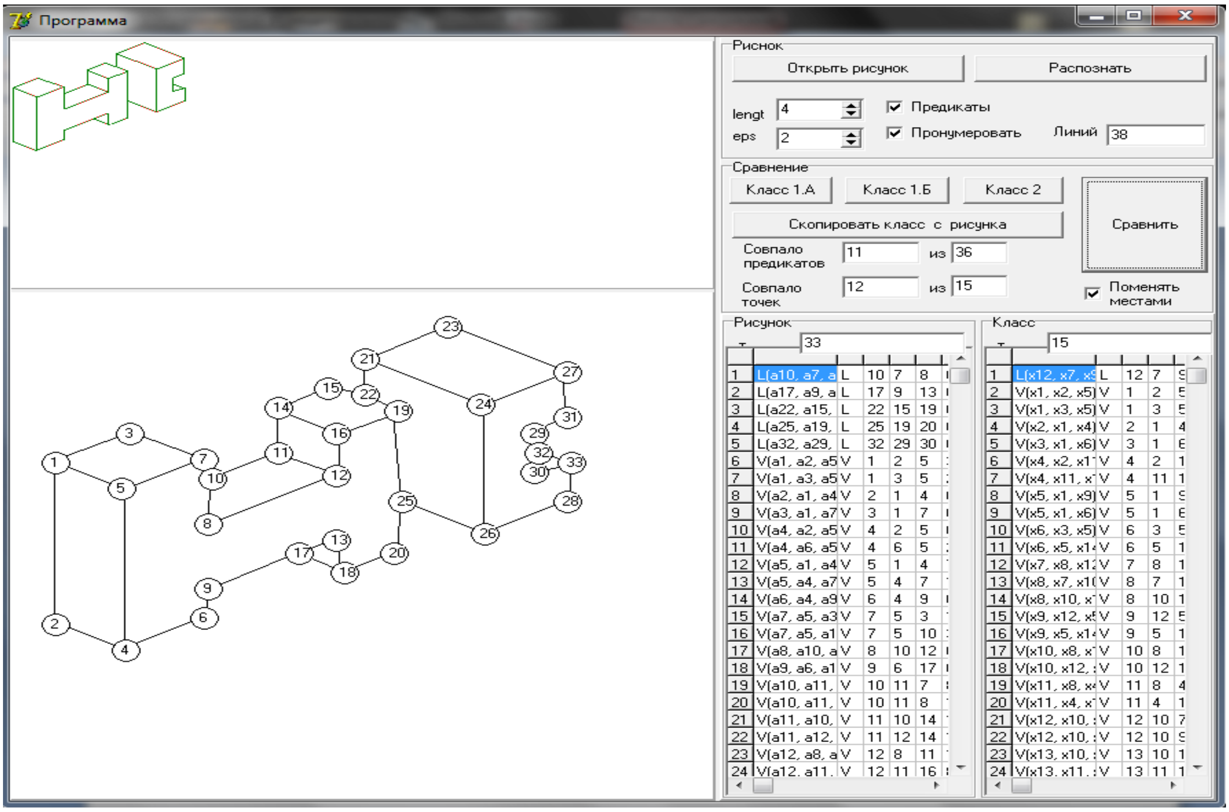



Fig. 7. Recognition of partially covered contour image

## Conclusion

The proposed in [1] logic-objective approach permits not only to recognize separate contour objects on a display screen but also to allocate and to recognize in the same time objects in the complex scene. The use of the concept of partial deducibility [3] permits to recognize partially covered objects and to calculate the degree of certainty of their correct recognition.

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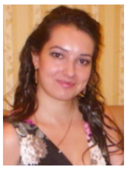
## Authors' Information

***Tatiana Kosovskaya*** *– Dr., Senior researcher, St.Petersburg Institute of Informatics and Automation of Russian Academy of Science, 14 line, 39, St.Petersburg, 199178, Russia; Professor of St.Petersburg State Marine Technical University, Lotsmanskaya ul., 3, St.Petersburg, 190008, Russia; Professor of St.Petersburg State University, University av., 28, Stary Petergof, St.Petersburg, 198504, Russia, e-mail: kosov@NK1022.spb.edu*

*Major Fields of Scientific Research: Logical approach to artificial intelligence problems, theory of complexity of algorithms.*



*Natalia Bondar – PHD student, St.Petersburg Institute of Informatics and Automation of Russian Academy of Science, 14 line, 39, St.Petersburg, 199178, Russia;, e-mail:*

*Major Fields of Scientific Research: Logical approach to pattern recognition problems.*

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