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DEVELOPMENT OF AN EFFECTIVE STRATEGY FOR REGIONAL SOCIO-ECONOMIC DEVELOPMENT

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Abstract

The study of mountain areas has always received great attention from science. However, the lack of a unified model for the development of mountain areas leads to a variety of recommendations that may not always be consistent. To achieve sustainable development, it is necessary to conduct a comprehensive assessment of the natural resource potential and level of economic development of the analyzed territory. The object description is an m-dimensional vector, where m is the number of signs used to characterize the object, with the *j*-th coordinate of this vector equal to the value of the *j*-th feature, $j = 1 ,. .., m.$ In the description of an object, the absence of information about the meaning of a particular feature is permissible. The combination of a certain number of objects and their attributes is a sample on which n algorithms (proposed development models) have been worked out. The quality of operation of each algorithm is assessed (the model is estimated by the Boolean function). None of the algorithms considered performed perfectly on all the set of specified objects. A logical method is proposed for constructing a new algorithm (correction model), which is optimal on the entire set of recognized objects. The result of the study is the optimal model which includes the positive properties of the previously considered models and corrects their shortcomings. The proposed approach may be the basis for obtaining expert assessments and recommendations in order to build an optimal strategy for the development of mountain areas.

Keywords: Algorithm, training set, knowledge base, subject domain, variable-valued logic, decision rule

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1. Introduction

In the earlier ages of pattern recognition study in theory and practice, intended to solve rational problems, a large number of methods and algorithms were applied without any justification. Such methods were checked experimentally. Meeting the challenges of medical and technical diagnostics, computer predictions of deposits, as well as the creation of expert systems produced a large number of incorrect (heuristic) algorithms. Need for development of the theory of adjusting operations, synthesis of correct algorithms with minimum complexity and their stability issues resulted.

> Zhuravljov and Rudakov (1978) says: We find that the logical approach can be the basis in building of the synthesis theory for the recognition correct algorithms with the help of the existing algorithm families. These methods, despite the lack of adequate mathematical models of the studied dependences between an image and its properties, incompleteness and discrepancy of data, allow creating the algorithms which produce expert's reasonings. (p. 34)

As a rule, the mathematical logic is usually applied to the statement validity assessment (SVA). We use the apparatus of mathematical logic that proceeds from the real qualities of the objects in solving our problem stated in this paper. Since the object is described with a number of characteristics broken corresponding to the number of states, so it is convenient to encode each characteristic by variable value predicates.

The ultimate goal of using the variable value predicates is to define to what class or object researched data belong.

A logical approach to the theoretical justification of the construction of correct algorithms that expand the field of solutions based on these algorithms is the subject of this article.

2. Problem Statement

We take socio-economic aspects, potential and resources of the region, etc., as development features of the territory, and formally we refer to them as objects (Tumenova et al., 2018). All objects possess their own characteristic features. For example, the resource potential includes land, water, biological diversity, energy, labor and others. Since there are characteristic varieties and different measurement scales, it seems convenient to encode them with variable-valued predicates. In the framework of our method, the task for searching the best strategy of mountainous regions development can be formulated in the language of mathematical logic (Fagin et al., 1998; Obeid, 1996).

The description of object represents an m-dimensional vector $X = \{x_1, x_2, \dots, x_m\}$, where m is a number of characteristics that describe the object and j-th coordinate of this vector is equal to j-th of j=1,...,m. In the object description, absence of information on this or that characteristic value is admissible. A set of some number of objects and their properties is a selection that has worked n of algorithms (proposed development models). The performance quality of each algorithm (models) is evaluated using Boolean function $a_j(X_i, y_i)$. None of the algorithms under consideration performed ideally on all the set of specified objects. None of the algorithms under consideration recognized the whole set of the predetermined objects

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(Renegar, 1986). We propose logical method in creation of a new algorithm valid within the entire set of recognizable objects. For this purpose, we used existing algorithms and decision rules made for the study domain.

3. Research Questions

A logical approach to the theoretical justification of the construction of correct algorithms that expand the field of solutions based on these algorithms is the subject of this article.

4. Purpose of the Study

The purpose of this work is to build an optimal strategy for the development of mountain areas based on previously known models by extracting the most optimal solutions from them.

5. Research Methods

As a working method, we propose a logical analysis of a given subject area, in which the objects are various spheres, determining the level of development of mountain territories, and signs are their characteristics in predicates of variable-valued logic. The characteristics of the development of the territory can be the economy, the social sphere, the resource potential of development, etc. These areas of development will be referred to as objects in the formal formulation of the problem.

6. Findings

We consider a number of algorithms A_1,A_2,...,A_n. with the task of recognition within the scope, which consists of objects and their characteristics.

Suppose $X = \{x_1, x_2, \dots, x_m\}$, is variable of $x_i \in \{0,1,\dots,k_r - 1\}$, where $k_r \epsilon [2,\dots,N], N \epsilon Z$ is a set of functions considered within the framework of logic with a variable value; $X_i = \{x_1(y_i), x_2(y_i), \dots, x_m(y_i)\}, i = 1,\dots,l$ is the feature characterizing vector, $y_i \in Y$, $Y = \{y_1, y_2, \dots, y_l\}$ is the set of objects; $A = \{A_1, A_2, \dots, A_n\}$ is the set of algorithms, $a_j\,(X_i, y_i) \in \{0,1\}$; $i = 1,2,\dots,l; j = 1,2,\dots,n$ is the quality of algorithm execution on a given set $X_i = \{x_1(y_i), x_2(y_i), \dots, x_m(y_i)\}, i = 1,2,\dots,l$: formulated as follows:

$$a_j(y_i) = \begin{cases} 1, & A_j(X_i) = y_i \\ 0, & A_j(X_i) \neq y_i \end{cases}, \; i = 1,2,\dots,l, \; j = 1,2,\dots,n,$$

that is, this type of algorithm operation is evaluated by Boolean algebra:

1 - the algorithm can determine the object $y_i$by the characteristics of X_i,

0 - the algorithm A_j cannot determine the object y_i by the characteristics of X_i.

These data can be represented as a two-dimensional matrix (Table 01):

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Table 1. Recorded data in a two-dimensional matrix

x_1	x_2	…	x_m	Y	A'_1	A'_2	…	A'_n
$x_1(y_1)$	$x_2(y_1)$	…	$x_m(y_1)$	y_1	$a_1(y_1)$	$a_2(y_1)$	…	$a_n(y_1)$
$x_1(y_2)$	$x_2(y_2)$	…	$x_m(y_2)$	y_2	$a_1(y_2)$	$a_2(y_2)$	…	$a_n(y_2)$
…	…	…	….	...	…	…	…	…
$x_1(y_l)$	$x_2(y_l)$	…	$x_m(y_l)$	y_l	$a_1(y_l)$	$a_2(y_l)$	…	$a_n(y_l)$

$\mathrm{A'}_i = \{a_i(y_1), a_i(y_2)), \dots, a_i(y_l)\}, i = 1,2, \dots, n.$ this is a vector that shows the values when evaluating the operation of the algorithm A_i.

It turns out that not all objects specified in the selection are recognized by at least some algorithm. You can imagine it like this:

$$\exists\ \mathrm{y}_i \in Y \mid A_1(X_i) \neq y_i, A_2(X_i) \neq y_i, \dots, A_n(X_i) \neq y_i,\ \ i = 1,2, \dots, l, j = 1, \dots, n\,.$$

We need to create an algorithm that can find and identify all objects in the subject area $A_{n+1}(X_i) |\ A_{n+1}(X_i) = y_i$ and $A_{n+1}(X) |\ A_{n+1}(X) = Y$.

Hypothesis: the algorithm is correct on a set of objects Y, with characteristics X when $\forall\ \mathrm{y_i} \in \mathrm{Y}$: $\mathrm{a_j(X_i, y_i) = 1, i = 1,2, \dots, l;\ j = 1, \dots, n}$. That is, the algorithm works with the set of objects that it can identify.

To analyze the domain, we use the algebra of logic with a variable value (Timofeev & Ljutikova, 2005; Vorontsov, 2000), which offers an approximate coding of information. We do this because each characteristic $\mathrm{x_i} \in \{0,1, \dots, \mathrm{k_r} - 1\}$can be encoded by a predicate of any value that is suitable for this characteristic.

The apparatus of variable-valued logic is suitable for simple and visual encoding and decoding of the properties of the objects under study. This makes it possible to simplify fuzzification and defuzzification in terms of fuzzy logic. In addition, it simplifies the process of creating logical constructions that should identify the correspondence of objects and their properties. In our case, we use these logical constructs as production rules.

6.1. Variable-valued logic operations

Hypothesis: Statements of variable-valued logic are statements whose truth is determined by values:$\{0,1,\dots,k_r - 1\},\ k_r\, \epsilon[2, \dots, N],\ N \epsilon Z, B$ is the statements formula defined with three operations:

- negation or generalized inverse (unary operation),
- & conjunction (binary),
- disjunction (binary).

We also use constants: 0,1 … $k_r - 1,\ k_r\, \epsilon[2, \dots, N],\ N \epsilon Z.$

Supposing Xi is an independent multi-valued variable Xi∈[0,…,kr-1], which is one of the object characteristics. We enter a few more functions and properties of variable-valued logic.

Here are the functions of the variable-valued logic called elementary

Variable value:

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$$x_i^j = \begin{cases} j, & x_i = j \\ 0, & x_i \neq j \end{cases},$$

Generalized inversion:

$$\overline{x^j} = x^0 \vee x^1 \vee \ldots \vee x^{j-1} \vee x^{j+1} \vee \ldots \vee x^{k-1}.$$

The inversion set thus allows all possible interpretations of negation in various multi -valued logic systems.

Supposing variables $X \in [0, \ldots, k_i - 1], Y \in [0, \ldots, k_j - 1]$ are of various values, then the generalized disjunction:

$$X \vee Y = \max\left[\frac{X}{k_i - 1}; \frac{Y}{k_i - 1}\right] * l$$, where (5) $$l = \begin{cases} k_i - 1 & when \quad \dfrac{X}{k_i - 1} > \dfrac{Y}{k_i - 1} \\ k_j - 1 & otherwise \end{cases}$$

And generalized conjunction:

$$X \,\&\, Y = \min\left[\frac{X}{k_i - 1}; \frac{Y}{k_j - 1}\right] * l$$, where $$l = \begin{cases} k_i - 1 & when \quad \dfrac{X}{k_i - 1} < \dfrac{Y}{k_j - 1} \\ k_j - 1 & otherwise \end{cases}$$

We define implications for the variable-valued logic, using following expression: $X \to Y = \overline{X} \vee Y$.

The elementary function of the variable-valued logic has the following properties:

$$x^j \& x^k = \begin{cases} x^j, & j = k \\ 0, & j \neq k \end{cases}$$

Rules for making certain decisions and the function of evaluating the quality of responses

Hypothesis: Let us call the statement:

$$\&_{j=1}^{m} x_j(y_i,) \to y_i,$$

$i = 1, \ldots, l,\ \ x_j(y_i) \in \{0,1, \ldots, k_i - 1\}, k_i \epsilon [2, \ldots, N],\ \ N \epsilon Z$ decision rule

The main rule here is production. From the point of view of logic, it looks like this: an object follows from a set of its characteristics.

Let's assume that there are no algorithms that can recognize this domain in parts. Then we need to build a function to evaluate the quality of the algorithms for each set under consideration. Then we get a set of vectors $\mathrm{A}'_j = \{a_j(y_1), a_j(y_2)), \ldots, a_j(y_l)\},\ j = 1,2, \ldots, n,$. They are presented in column A'_j. We get

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the results of the algorithm for each row corresponding to the object y_i, the production rule coincides with this

$$\&_{s=1}^{m} x_s(y_i) \rightarrow y_i, \qquad x_s(y_i) \in \{0,1,\dots,k_r-1\},$$

$$i = 1,\dots,l,\ s = 1,\dots,m.$$

The resulting column can be assumed as a partially defined Boolean function on $\{X, Y\}$.

6.2. Algorithm design for solutions area expanding

While data processing the choice of algorithm with: $a_j(X_i, y_i) = 1$ is a proper thing. If it turns out that at least one algorithm has a solution, we see: $A_j(X_i) = y_i$, then $\vee_{j=1}^{n} a_j(y_i) = 1$. If the algorithm has no solution, then y_i, $\vee_{j=1}^{n} a_j(y_i) = 0$.

Let's imagine that all the examples make a decision according to the rule:

$$i = 1,\dots,l, x_s(y_i) \in \{0,1,\dots,k_r-1\}, k_r \epsilon [2,\dots,N],\ N \epsilon Z.$$

For each algorithm, we choose the decision-making rules for object recognition if $\exists\ a_j(y_i) = 1$,

then $\&_{s=1}^{m} x_s(y_i) \rightarrow y_i, i = 1,\dots,l, x_s(y_{i,}) \in \{0,1,\dots,k_r-1\}, k_r \epsilon [2,\dots,N],\ N \epsilon Z.$

It turns out that we have created a function that represents all the variants of the decision-making rules in this algorithm. Based on a logical law: algorithm A_j recognizes object y_i, and algorithm A_j recognizes objecty_p and all other objects.

$$F_j(X_i) = \&_{a_{j(y_i)}=1}(\&_{s=1}^{m} x_s(y_i) \rightarrow y_i) = \&_{a_{j(y_i)}=1}(\vee_{s=1}^{m} \overline{x_s(y_\iota)} \vee y_i).$$

In the following steps, we propose to apply a reduction algorithm for multivalued logic.

- - If DEF has some unambiguous disjunct x_i^j, we delete all x_i^j& ..., disjuncts (law of absorption).

It turns out that the previously recognized F_j works according to the decision-making rule. This function creates a knowledge base for this algorithm by dividing the solution area into classes.

The theorem. The equality that is necessary and sufficient for the conditions that are defined by the characteristics {Xj} for K r is :

Proof:

Suppose F1(X)= Kr . Since $f(X) = f_1(X) \vee f_2(X)$ then f (Xj)= Kr.

f(X) - definitely characterizes the given DB. It is possible to claim that the specific characteristic set {Xj}, describes a class of Kr with data provided in the DB

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Assume that the feature set {Xj}, describes an object of the class Kr and this agreeable with basic data, then the f (X) equal to $f(X_i) = f_1(X_i) \vee f_2(X_i)$,…. f(X)= Kr. Since f2(Xj does not hold disjuncts containing classes, it is possible to state that f1(X)= Kr.

Having developed the functions $\mathrm{F_j}$, $\mathrm{j} = 1,2,\dots,\mathrm{n}$ for each algorithm, we get $\mathrm{F_1},\dots,\mathrm{F_n}$.. Based on this, we can construct a general function that will be a conjunction for $\mathrm{F_1},\dots,\mathrm{F_n}$: $\mathrm{F} = \&_{\mathrm{i=1}}^{\mathrm{n}}\mathrm{F_i}$.. Perform calculations and transformations and get:

$F(X,Y) = f_1(X) \vee f_2(X,Y)$,

where $f_1(X)$ is a function that holds only x_s variables ; $f_1(X)$ is a tuning function; and its disjuncts are tuning elements. They do not matter for the development of a new algorithm that will work with hitherto unrecognized objects. ; $f_2(X,Y)$ is a function with functions and objects that can determine the features of these objects.

In order to work out an algorithm that will work with data not yet recognized, we use the function $f_1(X)$. It turns out that this new algorithm consists of $f_1(X)$ and the rules for making decisions about an object that is not recognized by other algorithms. Its result is a new, not previously presented characteristic of the object and its features that have not previously appeared.

$$A_{n+1} = f_1(X)\&(\&_{s=1}^{m} x_s^j \to y_j) \vee_{j=1}^{n} A_j$$

Example 1

Let $X = \{x_1, x_2, x_3\}$ be a set of attributes; all values of characteristics are encoded in a three-digit logical system $x_s \in \{0,1,2\}$, $s = 1,2,3$.

be a set of attributes; all values of characteristics are encoded in a three-digit logical system

The input data ratio (objects features), objects and recognition algorithms results are provided by the following matrix (Table 02).

Table 2. The ratio of input data (characteristics of objects), objects and results of recognition algorithms

x_1	x_2	x_3	Y	A'_1
0	1	1	a	1
1	2	2	b	0
0	1	2	c	1
1	0	0	d	0

Based on the above relations:

$$A_1\colon\ F_1 = (x_1^0\&x_2^1\&x_3^1 \to a)\&(x_1^0\&x_2^1\&x_3^2 \to c)$$

(algorithm A_1 recognizes object a and c)

$$A_2\colon\ F_2 = (x_1^1\&x_2^2\&x_3^2 \to b)\&(x_1^0\&x_2^1\&x_3^2 \to c)$$

$A_3\colon\ F_3 = (x_1^0\&x_2^1\&x_3^1 \to a)$

$$f_1(X) = x_1^2 \vee x_2^0 \vee x_3^0 \vee x_1^1x_2^1 \vee x_1^1x_3^1 \vee x_2^2x_3^1$$

$$f_2(X,Y) = bx_1^1 \vee bx_2^2 \vee ax_3^1 \vee cx_1^0x_3^2 \vee cx_2^1x_3^2 \vee bcx_3^2 \vee ax_1^0x_3^1 \vee ax_2^1x_3^1 \vee ab$$

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$$A_4 = f_1(X)\&(x_1^1\&x_2^0\&x_3^0 \to d) =$$
$$= x_1^0x_2^0 \vee x_2^0x_3^1 \vee x_2^0x_3^2 \vee x_1^0x_3^0 \vee x_2^1x_3^0 \vee x_2^2x_3^0 \vee x_1^1x_2^1 \vee x_1^1x_3^1 \vee x_2^2x_3^1 \vee dx_2^0 \vee dx_3^0$$

Algorithm A_4 identifies individual features of the object d, namely $x_2 = 0$ and $x_3 = 0$.

6.3. A logical approach to designing an algorithm based on the rule based on this data

If we add a rule requirement to the algorithm $A_{n+1}(X)$ it will be improved (Table 03):

Table 3. Correct algorithm design on the given following matrix

x_1	x_2	…	x_m	Y	A_1'	A_2'	…	A_n'	A_{n+1}'
$x_1(y_1)$	$x_2(y_1)$	…	$x_m(y_1)$	y_1	$a_1(y_1)$	$a_2(y_1)$	…	$a_n(y_1)$	1
$x_1(y_2)$	$x_2(y_2)$	…	$x_m(y_2)$	y_2	$a_1(y_2)$	$a_2(y_2)$	…	$a_n(y_2)$	1
…	…	…	….	...	…	…	…	…	…
$x_1(y_l)$	$x_2(y_l)$	…	$x_m(y_l)$	y_l	$a_1(y_l)$	$a_2(y_l)$	…	$a_n(y_l)$	1

So, for $A_{n+1}(X)$ values are $a_{n+1}(y_i) = 1,\ i = 1,2,\dots,l.$

Since we can consider $a_j(y_i)$ in Boolean algebra then $A_{n+1}'(\mathrm{A'}_1, \mathrm{A'}_2 \dots \mathrm{A'}_n)$ is the Boolean function (value = 1) everywhere $(\mathrm{A'}_1, \mathrm{A'}_2 \dots \mathrm{A'}_n)$. So, we conclude:

$$A_{n+1}'(\mathrm{A'}_1, \mathrm{A'}_2 \dots \mathrm{A'}_n) = \vee_{i=1}^{l}\&_{j=1}^{n}A^{\sigma'}{}_j(y_i),\ .i = 1,2,\dots,l,\ \ j = 1,2,\dots,n$$

$$A^{\sigma'}{}_j(y_i) = \begin{cases} \mathrm{A'}_j, & a_j(y_i) = 1 \\ \overline{A'_j}, & a_j(y_i) = 0 \end{cases}$$

We assume that $\mathrm{A_j}'$, is a recognized set of decision, $\overline{\mathrm{A'_j}}$ is a un recognized set of decision

$\mathrm{A_j'} = \ \&_{i=1}^{l}\ (\&_{s=1}^{m}\mathrm{x_s}(\mathrm{y_i}) \to \mathrm{y_i})$ when $\mathrm{a_j}(\mathrm{y_i}) = 1,$

$\overline{\mathrm{A'}_j} = \overline{\&_{i=1}^{l}\ (\&_{s=1}^{m}\mathrm{x_s}(\mathrm{y_i}) \to \mathrm{y_i})}$ when $\mathrm{a_j}(\mathrm{y_i}) = 0,$

Through implication we obtain the following expression:

$\mathrm{A}_j' = \ \&_{i=1}^{l}\ (\vee_{s=1}^{m}\overline{x_s(y_i,)}\vee y_i)$ when $a_j(y_i) = 1,$

$\overline{A'_j} = \&_{i=1}^{l}\ (\&_{s=1}^{m}x(y_i)\&\overline{y_l})$ when $a_j(y_i) = 0.$

The whole study data domain can be presented as decision

rules:$\&_{s=1}^{m}x_s(y_i) \to y_i, i = 1,\dots,l,\ \ x_s(y_i) \in \{0,1,\dots,k_r - 1\}, k_r\ \epsilon[2,\dots,N],\ \ N\epsilon Z$ (1)

Theorem: We define a set of decision rules of the form

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$\&_{j=1}^{m} x_s(y_i) \to y_i, i = 1, \dots, l, x_j(y_i) \in \{0,1, \dots, k_r - 1\}, k_r \epsilon [2, \dots, N],\ N \epsilon Z$

which represents a specific subject area being studied

$A'_{n+1}(\mathrm{A'}_1, \mathrm{A'}_2 \dots \mathrm{A'}_n) = \vee_{i=1}^{l} \&_{j=1}^{n} A^{\sigma'}{}_j(y_i) = 1, i = 1,2, \dots, l,\ j = 1,2, \dots, n$

Proof:

Each algorithm introduces the proposed disjunction andA'_j, or $\overline{A'_j}$. If this does not happen, then it becomes universal. Since A_j are the decision-making rules recognized by the A_j algorithm, then $\overline{A_j'}$ is a set of decision-making rules that were not recognized by this algorithm. Their separation is an opportunity to fully describe all areas of research.

When create DNF

$$A'_{n+1}(\mathrm{A'}_1, \mathrm{A'}_2 \dots \mathrm{A'}_n) = \vee_{i=1}^{l} \&_{j=1}^{n} A^{\sigma'}{}_j(y_i)$$

Thanks to the known method, it can become a deadlock. Next, we apply an algorithm reduction for multivalued logics.

If a variable is included in DNF with one value in all disjuncts, the variable is not informative

If DEF has an unambiguous disjunct x_i^j, we use the absorption rule.

As a result, each disjunct receives a minimized knowledge base corresponding to the set of rules described by this disjunct. Such disjuncts have a number of properties (Shibzukhov, 2014). They break down the information about the solution domain into all possible IT classes. By combining these areas, we minimize the knowledge base for the entire given area.

Example 2.

Let $X = \{x_1, x_2, x_3\}$, $x_i \in \{0,1,2\}$.

Then we have

$$F = A'_{n+1}(\mathrm{A'}_1, \mathrm{A'}_2 \dots \mathrm{A'}_n) = \vee_{i=1}^{l} \&_{j=1}^{n} A^{\sigma'}{}_j(y_i)$$

$$F = A_1 \& \overline{A_2} \& A_3 \& \overline{A_4} \vee \overline{A_1} \& \overline{A_2} \& A_3 \& A_4 \vee \overline{A_1} \& \overline{A_3} \& A_2 \& A_4 \vee \overline{A_1} \& \overline{A_2} \& \overline{A_3} \& \overline{A_4}$$

here we can already write an algorithm based on the decision-making rules, transform and get this:

$$A_5 = (x_1^0 \& x_2^0 \& x_3^1 \to a) \& (x_1^0 \& x_2^2 \& x_3^1 \to b) \& (x_1^1 \& x_2^2 \& x_3^0 \to d) =$$
$$= x_1^2 \vee x_3^2 \vee x_2^1 \vee x_1^1 x_2^0 \vee x_1^1 x_3^1 \vee x_1^0 x_3^0 \vee x_2^0 x_3^0 \vee$$
$$\vee x_3^0 d \vee b x_1^0 x_2^2 \vee b x_2^2 x_3^1 \vee b d x_2^2 \vee a x_1^0 x_2^0 \vee a x_2^0 \vee a x_2^0 x_3^1 \vee x_1^1 d$$

The algorithm A_5 selects personal features of object d.

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7. Conclusion

The results of the logical analysis of the predetermined domain and decision rules that describe objects make clear that complexity of the obtained algorithm depends on the algorithms quality that has already been given and regularities that are hidden in the subject domain. The proposed logic synthesis method allows building of a correct algorithm on the entire data area, simulating the knowledge base, minimizing it, and selecting unique set of features for each object. The result obtained could also form the basis for obtaining expert assessments and recommendations in order to build an effective development strategy for the mountain regions.

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