The Features of Generations of Solutions by Intellectual Information Systems

Stanislav Belyakov, Marina Belyakova, Alexander Bozhenyuk and Igor Rozenberg

Abstract The paper analyzes the characteristics of the informational support of decision-making by geographic information systems. The problem of the accumulation of experience and the use of decision-making in the previously observed situations is analyzed. The situations are spatiotemporal and they can be described by maps. The main objective of the research is development of the data model that provides the upgrade of reliability of decision-making on the basis of experience. The peculiarity of the model of the experience proposed by the authors is its description by a set of transformations. The concept of the image of the situation which has a center and a neighborhood is introduced. The allowed transformations of situations and solutions are determining in the description of decisions and the conditions of their making. The coordinates in the feature space are not determining. With such an approach traditionally used precedent analysis gets a peculiarity associated with the logic of determining the similarity of situations. The information model of precedents' image and the problem of actualization of the image in the process of searching for solutions are described in the paper. The example of figurative representation of the experience for the implementation of the logistics project is given in the paper.

Keywords Geographic information systems · Case analysis · Figurative representation of experience · Decision making

S. Belyakov (✉) · M. Belyakova · A. Bozhenyuk
Southern Federal University, Nekrasovsky 44, 347922 Taganrog, Russia
e-mail: beliacov@yandex.ru

I. Rozenberg
Public Corporation "Research and Development Institute of Railway Engineers", 109029 Moscow, Russia
e-mail: I.rozenberg@gismps.ru

A. Abraham et al. (eds.), *Proceedings of the First International Scientific Conference "Intelligent Information Technologies for Industry" (IITI'16)*, Advances in Intelligent Systems and Computing 451, DOI 10.1007/978-3-319-33816-3_22

1 Introduction

Geographic information systems (GIS) are widely used in the systems of decision-making as facilities of time-space data processing [1–4]. An important advantage of GIS is the rendering engine, which gives a special opportunity of real-world situations' analysis. Using geo-information services, specialists of different application areas get spatial data and cartographic images of data. It stimulates their professional intellectual activity.

The map databases are extensive knowledge of events and phenomena of the real world. At the same time, this knowledge is not enough, when decisions must be made in specific situations. The dynamism of the real world and the incompleteness of knowledge does not allow to construct reliable solutions of problem situations. Despite the rich arsenal of software tools of spatial and statistical analysis [1], it is not possible to make compensation for the uncertainty of the environment's state characterization. For this reason, the usage of the experience of decision-making is more important.

An important feature of the presentation and usage of knowledge in the GIS is the ability of their visualization. Visualization allows you to simulate creative thinking [5]. Knowledge representation by iconic image-mapping models and the use of knowledge by their specific comparison can be considered as the implementation of the conceptual semantics principles [5]. The features of the procedure for constructing intelligent GIS solutions using figurative representation of decision-making experience are analyzed in this paper.

2 The Conceptual Model of Decision-Making Experience

The concept of decision-making experience representation can be selected in different ways, based on the mode of the intellectual system's usage [2, 3]. The systems operate in mode of precedent analysis in many circumstances [4]. Case-analysis [6] is based on superficial knowledge, limited description of the characteristic features of objects or phenomena. The process of finding the solution is finding previously observed similar precedent in the knowledge base and the adaptation of decision to the concerned precedent. Using the analogy, as known, gives probable but no reliable conclusions [7]. In an effort to improve the accuracy, we can intellectualize as follows.

Supposing that $D(s)$ there is a dependency that is used for generation solutions for a given set of environmental parameters s. If you have experience in decision-making $d_0 = D(s_0)$ with the parameter values s_0, the spreading of this experience to the problematic situation s_p with the parameters means obtaining the decision $d_p = D(s_p)$. The condition of the positive effect of usage of the solution d_p in a problem situation is the inequality:

$$W(d_p) \geq W(d_0) \quad (1)$$

where W is the criterion of solutions' quality. It is obvious that the applicability of the solution d_p—only a hypothesis, the accuracy of which is higher, s_p and s_0 closer. This follows from the continuity property of the real world. If

$$|s_p - s_0| \to 0,$$

inequality (1) becomes valid equality. It is observed in the surroundings s_p where

$$D'(s_p) = D'(s_0) = 0 \quad (2)$$

as it ensures no solutions' quality loss.

As the dependence $D(s)$ is not known, the Eq. (2) can be regarded as a conceptual basis for knowledge representation, which is the accumulation of knowledge about deviations (transformations) of situations' parameters and solutions. The knowledge of variations is an opportunity to construct a fair solution $D(s)$ in a neighborhood Δs of place s with a probability of

$$\sum_{s_k \in \Delta s} P(D(s_k)) > 0,$$

where as the absence of such knowledge is

$$\forall s_k \in \Delta s : P(D(s_k)) = 0.$$

The condition (2) can be regarded as a formal basis for the concept of knowledge representation in the form of the transformation of situations. Reflection of the happened events and analysis of the decisions taken are the experience of mental activity. This experience has a high value.

Let us call the character of precedent information structure that reflects the experience of mental activity that occurs during the analysis of the essence of precedent. Conceptual model of the precedent I_p includes two components [8]

$$I_p = \langle I_s, I_d \rangle,$$

the first of which (I_s) is the image of the situation, the second (I_d)—the image of solutions.

The image of the situation I_s is a set of admissible transformations of the situation, the transformation does not change the essence of the situation and the decision-making. The image describes a class of situations that are identical in meaning with the observed singular situation. Possible conversions of the specific situation always contain a generalization. It is arguable that the fragment of "picture of the world" is laid in the image of the precedent. The "picture of the world" is very essential for getting a reliable solution.

The image of the solution is a set of admissible transformations of solution I_d, it preserves its essence. The image of solutions sets a class of solutions, each of which is applicable to essentially identical situations I_s. Any decision of the class is a certain "reasonable" reliable solution.

Images of situations and solutions can be visualized in the GIS. This feature plays an important part in the described approach. Cartographic representation of transformation of point locations, trajectories, zones of placement and zones of influence are point, line and area objects of the map. Reflecting the transformation of the specific situation, the expert transfers the knowledge to the map. The representation of knowledge gets metric properties, which allow you to estimate the position, the shape and the size of transformations.

3 The Internal Structure of the Images and the Modeling of Visual Thinking

Using the ideas of conceptual semantics [5], let us consider the process of generation of solutions as the comparison of images. This operation simulates visual thinking. Technical implementation of the operation requires the definition of the metric [9]. The metric of the distance between the images $N(I_1, I_2)$ should be built to take into account the subjectivity of experts' visual thinking. Subjectivism appears, on the one hand, in the individual interpretation of the present situation, on the other hand, it appears in the estimation of its modifications in the future. For this we represent the substructure of the image in the form of

$$I_s = <c, H(c)>,$$

where c is the center of the image $H(c) = \{h_1(c), h_2(c), \ldots, h_M(c)\}$ is the set of its transformations. The center is the real situation that served as the basis for the inception of the image. Let us explain this through the example. Figure 1 shows a precedent of moving a cargo from the point A to the point B. This precedent creates the image of the matter of moving goods from the one area of the village to the other (Fig. 2). The areas reflect the possible locations of points A and B, the points does not affect the selected path and possibly the method of transportation.

The center of the image is a pair of points A and B with the description of the goods and the method of its transportation.

Figure 3 illustrates the image of solution. It includes a center—the trajectory AB—and possible conversions of trajectory. The transformations are shown by dotted lines.

There are the factors that influence on the form of metric $N(I_1, I_2)$:

1. The relative position of boundaries and centers of conversions;
2. The degree of generality of conversions' fields.

Fig. 1 The example of the precedent of moving goods

Fig. 2 The example of the precedent of moving goods

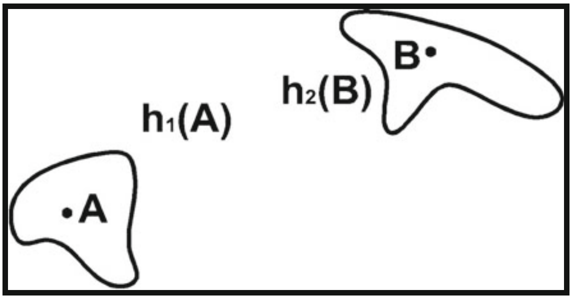
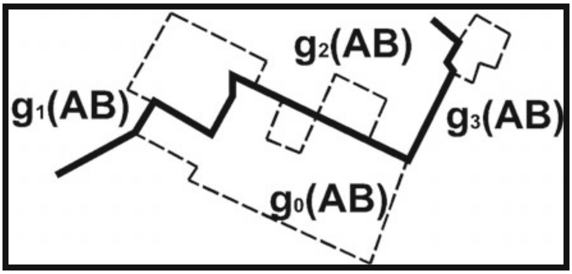


Fig. 3 Shows the image of decision of the precedent



The first factor is considered by using the proposed classification. Figure 4 shows the diagrams of the mutual arrangement of the pair of images. Ovals mean the areas of transformation, points inside ovals are the images' centers. The classes of topological relations arising during the comparison are labeled by $N_i(i = \overline{0, 5})$. The analysis of practical cases showed that the location of the centers of the images towards the intersection of transformations' areas is greatly influences on the subjective conclusion about the proximity of the situations. The distance between the centers is not important. The region of the intersection in which these centers are located is important. Class N_0 corresponds to the comparison of images without

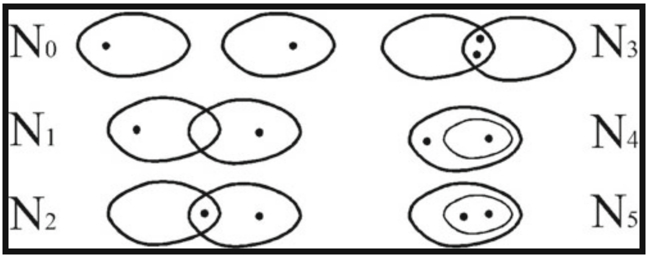


Fig. 4 The classes of the mutual position of the images

common variants of conversions. Class N_1—the presence of common changes that are not confirmed by practice so any of the centers is not included in them. The class N_5 includes a situation in which the conversion of one of the images is included in the conversion of another, and this is confirmed by the experience: the centers of the images are placed in the area of the intersection. It concluded that preferences when choosing the next image to the stated one would be described by the expression

$$N_0 \prec N_1 \prec N_2 \prec N_3 \prec N_4 \prec N_5$$

Thus, the proposed classification of topological relationships allows realizing a "reasonable" procedure of the assessment of vicinity.

The presence of the intersection regions in the analysis of changes suggests that there is some similarity of possible changes in the situation. The characterization of the degree of similarity of the transformation h_i of two images I_1 and I_2 is expressed by the formula

$$\alpha = \frac{2S(h_i^{(I_1)} \cap h_i^{(I_1)})}{S(h_i^{(I_1)}) + S(h_i^{(I_2)})},$$

where $S(x)$ is the area of the field x. The value $\alpha = 1$ holds in case of the coincidence of possible transformation, $\alpha = 0$ otherwise.

Comparative examples of situations for the determined problem is shown in Fig. 5. The proximity of the image I_1 is compared for a pair of points (A, B) with the images I_2 for a pair of points (C, D) and I_3 for a pair of points (E, F). The image I_1 is closer to the image I_3 although the centers A and C are located closer and the degree of generality $\alpha_{12} > \alpha_{13}$, because the relative location I_1 and I_3 is classified as a more preferable one.

Comparison of images of situations results in getting an image of solution. The center of image is practically tested solution. The example is shown in Fig. 3. The specific solution can be generated in several ways. In the simplest case, the solution is any transformation of the center of image. The result is reliable, as it is inferred from the generalized knowledge of possible solutions. However, the level of

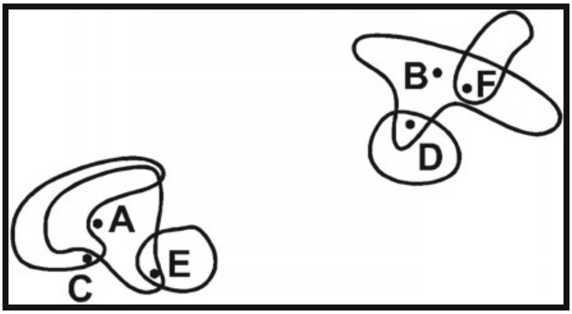


Fig. 5 The example of comparison of the situations

confidence of solution can be increased because the mapping basis cannot represent the real world at the time of analysis. The experience of reflection of expert about the situation cannot give an accurate forecast of the state of the environment. The reliability of the solution can be enhanced if the rapid mapping of the area of the problem situation is done. A comparison of the solutions with the state of the real world and the assessment of the feasibility of the solution is an independent task of intellectual GIS.

4 Conclusion

The analyzed graphic model of solutions' generation uses a special form of knowledge representation in the form of admissible transformations of situations and solutions. The purpose of the transition to this form of knowledge is the desire for a higher level of confidence of solutions generated by the intelligent system. The reliability is provided by the different quality of knowledge. Instead of sets of parameters of the observed situation the experience of reflecting on the situation is fixed. At the same time the real fact in not ignored; it becomes a key element of the image emerged. Using the key element has its own specifics, it reflects the psychology of creative thinking. The relative position of the centers and borders of transformation underlies the logic of matching images.

Analyzing the process of case analysis in relation to the processing of images, it can be concluded that the conservation of solutions generated in the process of case analysis is not appropriate. It is known that the accumulation of precedents is the implementation of training via examples. This mechanism does not involve such training. The main thing is the sense of situations and solutions expressed in admissible transformations.

Acknowledgments This work was supported by the Russian Foundation for Basic Research, Projects № 15-01-00149a, № 15-07-00185a.

References

1. Shashi, S., Hui, X.: Encyclopedia of GIS. Springer, LLC, New York (2008)
2. Zhi-Hua, H., Zhao-Han, S.: A decision support system for public logistics information service management and optimization. Decis. Support Syst. **59**, 219–229 (2014)
3. Fernandes, S., Captivo, E., Clímaco, J.: A DSS for bicriteria location problems. Decis. Support Syst. **57**, 224–244 (2014)
4. Haghighi, P.D., Burstein, F., Zaslavsky, A., Arbon, P.: Development and evaluation of ontology for intelligent decision support in medical emergency management for mass gatherings. Decis. Support Syst. **54**(2), 1192–1204 (2013)
5. Lakoff, J., Women, F., Dangerous, T.: What Categories Reveal About the Mind. University of Chicago Press (1987)
6. Eremeev, A., Varshavskiy, P.: Case-based reasoning method for real-time expert diagnostics systems. Int. J. Inf. Theor. Appl. **15**, 119–124 (2008)
7. Vagin, V.N., Yeremeyev, A.P.: Modelling human reasoning in intelligent decision support systems. In: Proceedings of the 9th International Conference on Enterprise Information Systems, Madeira, pp. 277–282 (2007)
8. Belyakov, S., Savelyeva, M., Rozenberg, I.: The construction of fuzzy based on case-based reasoning. In: 19th International Conference on Soft Computing MENDEL, Brno, pp. 273–276 (2013)
9. Belyakov, S., Belyakova, M., Rozenberg, I.: Approach to real-time mapping, using a fuzzy information function. In: Geo-Informatics in Resource Management and Sustainable Ecosystem, Wuhan, pp. 510–521 (2013)