2

2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making

Anna Yankovskaya
Tomsk State University of Architecture and Building, Tomsk, Russia
National Research Tomsk Polytechnic University, Tomsk, Russia
National Research Tomsk State University, Tomsk, Russia
Tomsk State University of Control Systems and Radioelectronics, Tomsk, Russia

Synonyms

2-Simplex prism; Cognitive graphics tool; Decision-making; Geoinformation system; Intelligent dynamic system; Justification; n-simplex

Definition

The following definitions from the papers (Yankovskaya 2011; Yankovskaya et al. 2015a) are used:

A cognitive graphics tool (CGT) visually reflects a complex object, phenomenon, or process on a computer screen, enabling the users to form a new decision, idea, or hypothesis based on the visuals.

2-Simplex is an equilateral triangle.

3-Simplex is a regular tetrahedron.

2-Simplex prism is a triangular prism which has identical equilateral triangles (2-simplexes) in its bases.

The height of the 2-simplex prism (Yankovskaya et al. 2015a) in intelligent dynamic systems corresponds to the dynamic process time interval under consideration. It is divided into a number of time intervals. The number of time intervals corresponds to the number of diagnostic or predictive decisions.

The distance between two adjacent 2-simpleces is proportional to the time interval between adjacent 2-simpleces.

In this case the distance between two adjacent 2-simpleces corresponds to the distance between two points on a map.

Learning axis is an independent direction of student evolution, e.g., theory knowledge level, ability to practical tasks solving, ability of electric circuit design, and research.

Test result is a set of coefficients, numerically representing the student's assessment achieved. Each coefficient corresponds to a particular learning axis.

Prediction result is a set of coefficients, numerically representing the student's assessment which he is likely to achieve in a preassigned time interval.

N. Lee (ed.), *Encyclopedia of Computer Graphics and Games*,
https://doi.org/10.1007/978-3-319-08234-9_285-1

Introduction

Cognitive graphics tool (CGT) was developed as part of AI research in the 1980s of the twentieth century in the works of Pospelov (1992) and Zenkin (1991). A large number of CGT have been created and developed, including cognitive maps (Axelrod 1976), cognitive graphics system (Albu and Khoroshevskiy 1990), medical CGT (Kobrinskiy 1996), radar plots (Saary 2008), Chernoff faces (Raciborski 2009), the ternary diagram (Wang et al. 2012), 2-simplex (Yankovskaya 2011), and others (Yankovskaya et al. 2015a; Yankovskaya 2017). CGT allows representing the content of the object or process under investigation on a computer screen. CGT visually and clearly reflects the essence of a complex object (phenomenon, process) and is also capable of providing a fundamentally new decision (idea, hypothesis). An important feature of CGT is targeted influence on the intuitive imaginative thinking mechanisms.

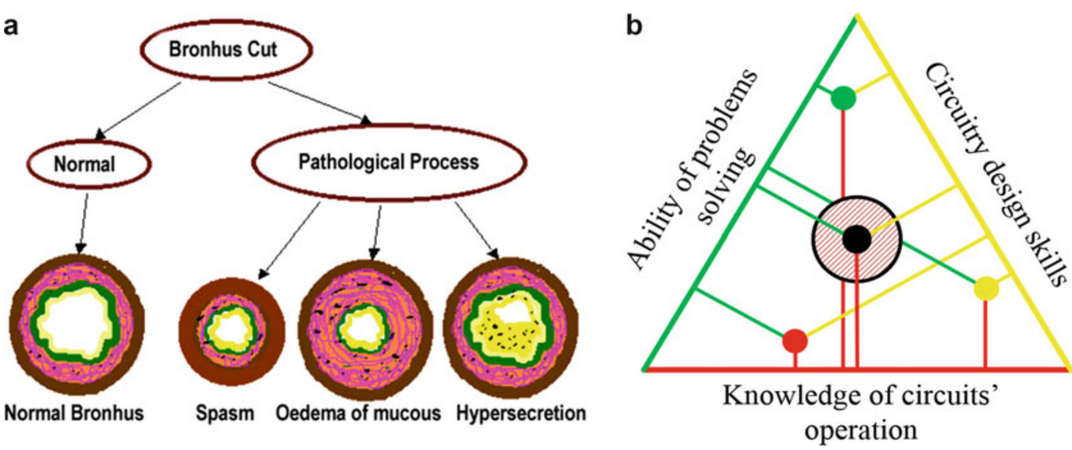
Cognitive graphics tools are used in a variety of intelligent systems for analysis of information structures of knowledge and data, revealing of different kinds of regularities in data and knowledge, and decision-making and its justification. Possible areas of application are medicine (diagnosis of diseases, treatment and preventive measures, rehabilitation of patients as well as solving organizational and managerial problems), education, geology, engineering, electronics, sociology, psychology, psychiatry, ecobiomedicine, ecogeology, etc. Dynamism represented by CGT can effectively reflect the dynamics of the patterns of objects under investigation in time.

Problem Background and Mathematical Basics of Intelligent Systems Construction

We suggest the following classifications of CGT by ways of representation (Yankovskaya and Galkin 2009; Yankovskaya 2011):

1. Naturalistic CGT, familiar graphic images of real objects. For example, visualization of tree data structure of pathological processes in bronchus (bronchial asthma, Fig. 1a).
2. Abstract CGT, CGT that does not have a mapping in the ordinary reality. For example, visualization of current level of students' knowledge by applying 2-simplex (Fig. 1b).

We use test pattern recognition to create the intelligent systems (Yankovskaya 2011), based on nontraditional (unusual) matrix method of data and knowledge representation; deep optimizing logic-combinatorial transformations in feature space; logic-combinatorial and logic-probabilistic, logic-combinatorial-probabilistic,



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 1 Examples of naturalistic-based CGT (**a**) and CGT that does not have mapping in the ordinary reality (**b**) and genetic methods of test pattern recognition; methods of complex decision-making; cognitive means of decision-making; and justification of decision-making results.

We use unusual matrix model (Yankovskaya 2011) for the data and knowledge representation, example of which is given in Fig. 2.

Q – integer descriptions matrix.

$z_1, z_2, \ldots, z_{11}$ – characteristic features.

R – integer distinguishing matrix.

k_1, k_2 – classification features.

R′ – one-column matrix whose elements are the numbers of patterns. Each pattern is associated with the final decision.

Rows of ***Q*** are mapped to objects from learning sample of a problem field.

Columns of ***Q*** are mapped to characteristic features, which describe each object.

The element q_{ij} of the matrix ***Q*** determines the value *j*-th feature for *i*-th object if the value is defined and "–" if the value is undefined.

Each row of ***R*** is corresponded to the row of the matrix ***Q*** having the same index.

Columns of ***R*** are corresponded to distinguishing levels that represent classification features.

The set of all nonrepeating rows of the matrix ***R*** is compared to the number of selected patterns presented by the one-column matrix ***R′***.

The distinguishing matrices can be of three types (***R1***, ***R2***, and ***R3***). The rows of ***Q*** are put in correspondence with the rows of ***R1***, ***R2***, and ***R3*** and the levels of distinguishing (classification) features, with the columns of these matrices. ***R1*** represents the included classification mechanisms. ***R2*** determines the sequence of actions which must be performed for each object. ***R3*** represents independent classification mechanisms corresponding, for instance, to the opinions of different experts.

The matrix of transition ***P*** (Yankovskaya et al. 2001; Yankovskaya 2011) is intended for the representation of dynamic knowledge about the investigated objects. Its rows are associated with the rows of ***Q***, and columns are associated with the instants (intervals) of time or control actions (Fig. 2).

The weight coefficients of the features characterizing their individual contribution to the distinguishability of objects from certain patterns (Yankovskaya 2011) and the information weight defined on the subset of tests used for a final decision-making (Yankovskaya 2011) with use the definition from Zhuravlev and Gurevitch (1990) is also regarded as regularities.

The following approaches are used when revealing regularities (Yankovskaya 2011): (1) with the construction of the irredundant matrix of implications; (2) with the partial construction of the irredundant matrix of implications; and (3) without the construction of the irredundant matrix of implications.

An irredundant matrix of implications (***U′***) is constructed on the base of matrices ***Q*** and ***R*** and defines distinguishability of objects from different patterns (classes at the fixed mechanism of classification). The rows of ***U′*** are associated with characteristic features, and its columns, with the results of comparison of all possible pairs, pattern–pattern, object–pattern, and object–object, from different patterns.

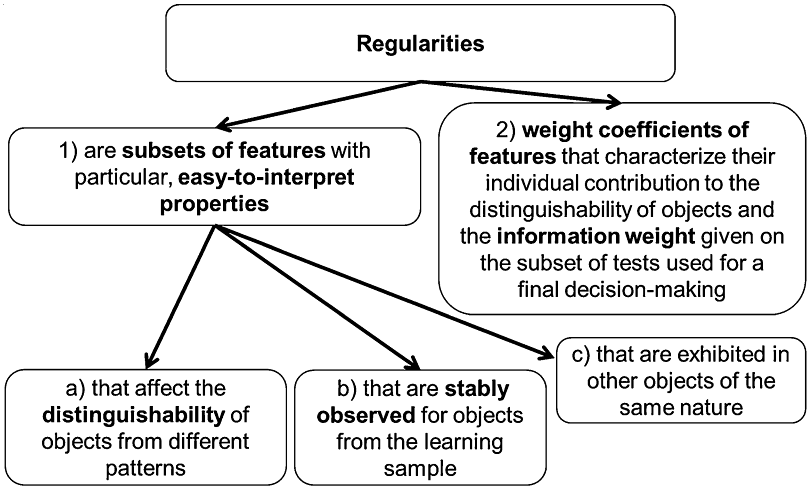
A diagnostic test (DT) is a set of features that distinguishes any pair of objects that belong to

2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 2 Matrix model for the data and knowledge representation

Q =, ***R*** =, ***R′*** =

z_1	z_2	z_3	z_4	z_5	z_6	z_7	z_8	z_9	z_{10}	z_{11}		k_1	k_2	***R′***
1	4	6	3	2	2	1	2	3	4	1	1	1	2	1
4	4	5	2	3	2	7	8	3	4	1	2	1	2	1
3	4	5	3	3	2	4	5	3	4	1	3	1	2	1
3	4	4	1	4	4	2	3	1	5	1	4	2	1	2
2	4	2	1	6	3	4	5	2	3	1	5	2	1	2
2	4	5	1	3	–	4	3	1	2	1	6	2	1	2
1	4	3	2	5	2	1	2	3	4	1	7	1	3	3
3	4	2	2	6	2	2	3	3	2	1	8	1	3	3
5	4	2	2	6	3	5	6	2	4	1	9	3	2	4
4	4	6	1	2	5	5	6	1	4	2	10	3	2	4

2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 3 A block diagram of regularities definition



different patterns and constructed on the base of irredundant implication matrix with application of logical-combinatorial algorithms (i.e., column coverings findings).

The DT is called “unconditional” if all features of the investigated object included in test are used simultaneously in decision-making process.

Decision-making on belonging of object under study to one or another pattern for every irredundant unconditional DT (IUDT) is performed out with use of threshold value of conditional degree of proximity of the object under study to the patterns.

Mixed DT (MDTs) present a new paradigm of development of intelligent systems based on test methods of pattern recognition (Yankovskaya 1996).

MDT is a compromise between unconditional and conditional components which are used for decision-making in intelligent systems as well as in blended education and training.

Respondent is a person participating in learning and testing.

Definition of a membership object x under study to pattern k is defined based on the coefficient of conditional degree of proximity (a_k) of object under study to the pattern (class) k, calculated by the formula (1):

$$a_k = \frac{S_k^x}{S_k},$$

where x – object under study

k – pattern (class),
S_k – coefficient of interclass similarity (similarity of objects inside the pattern (class)),
S_k^x– coefficient of similarity object x under study with pattern (class) k.

The rules for decision-making are constructed using coefficients of conditional degree of proximity a_i (Yankovskaya 2011).

Applied intelligent system is constructed on the base of intelligent instrumental software (IIS) IMSLOG (Yankovskaya et al. 2003). Purposes of IIS IMSLOG are formation of knowledge about objects in concrete problem or interdisciplinary area; regularities revealing in data and knowledge; decision rules construction on the basis of revealed regularities; recognition of object under investigation; and decision-making and its justification with CGT.

Mathematical Basis for Construction of Cognitive Graphics Tools

Theorem for the Construction of a Cognitive Graphics Tool n-Simplex

In 1991, Yankovskaya (1991), it was proposed using cognitive graphics tool 2-simplex for decision-making about object under investigation in the characteristic feature space to a certain pattern in intelligent systems for decision-making.

Theorem Suppose $a_1, a_2, \ldots, a_{n+1}$ is a set of simultaneously non-zero numbers where n is the dimension of a regular simplex. Then, there is one and only one point that following condition $h_1: h_2: \ldots: h_{n+1} = a_1: a_2: \ldots: a_{n+1}$ is correct, where h_i ($i = 1, 2, \ldots, n + 1$) is the distance from this point to the i-th side (Yankovskaya 1991).

Coefficient h_i, ($i = 1, 2, \ldots, n + 1$) represents the degree of conditional proximity of the object under investigation to the i-th pattern. The advantage is that n-simplex possesses the property of the constancy of the sum of distances (h) from any point to each side and the property of ratios preservation $h_1: h_2: \ldots: h_{n+1} = a_1: a_2: \ldots: a_{n+1}$.

The main function of n-simplex is a representation of an investigated object disposition among other objects of a learning sample (Yankovskaya 2011).

Construction of Cognitive Graphics Tools: 2-Simplex, 3-Simplex, and 2-Simplex Prism

We construct CGT 2-simplex and 3-simplex to visualize objects of 3 (4) patterns and the object under investigation using the formulas (1) given below.

For 2-simplex (3-simplex), distances h_1, h_2, and h_3 (h_1, h_2, h_3, h_4) are calculated on the basis of coefficients a_i and normalization operation from the following relations:

For 3-simplex distances h_1, h_2, h_3, and h_4 are calculated on the basis of coefficients a_i and normalization operation from the following relations:

$$\begin{cases} h = \sum_{i=1}^{4} h_i \\ h = \alpha \sum_{i=1}^{4} a_i \\ \frac{h_1}{a_1} = \frac{h_2}{a_2} = \frac{h_3}{a_3} = \frac{h_4}{a_4} \end{cases} \quad (1)$$

by the formula

$$h_i = \frac{h \cdot a_i}{\sum_{i=1}^{4} a_i} \quad (2)$$

Edges of 2-simplex (equilateral triangle edges), shown in Fig. 1b, are associated with three patterns (classes); the circle with big radius is the investigated object, and small circles are sample objects. Each pattern corresponds with some color. The distance from an object to a side is directly proportional to the object proximity to the pattern corresponding to the side. The distance for the investigated object is displayed as color perpendicular lines to 2-simplex sides. Color of each line corresponds to the pattern color. An object color is mapped with an associated pattern (the nearest pattern or pattern determined by an expert.

We use dashed 2-simplexes to illustrate the accuracy of the pattern recognition on the Fig. 4.

The edges of 3-simplex, shown in Fig. 5, are associated with four patterns. We demonstrate in Fig. 5 the objects of four patterns (A, B, C, D) and the investigated object related to pattern A within 3-simplex. Objects related to pattern A are red, to pattern B are yellow, to pattern C are brown, and to pattern D are green.

The results of each of the diagnostic, predictive decisions are shown in the form of points in 2-simplexes disposed on cross sections of 2-simplex prism.

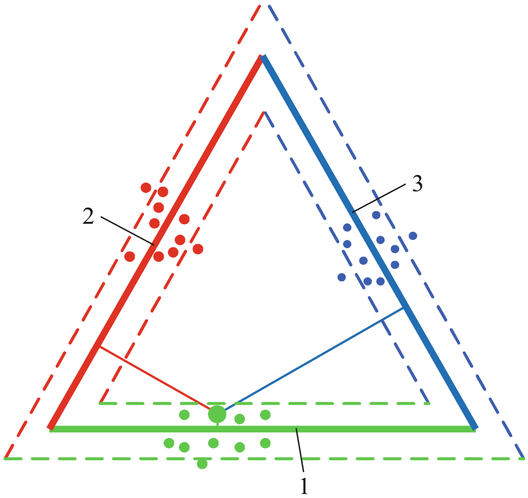
Distance from the basis of the prism to i-th 2-simplex h_i' corresponds to the fixation moment of object under investigation features, and it is calculated based on the following formula:

$$h_i' = H' \cdot \frac{T_i - T_{\min}}{T_{\max} - T_{\min}},$$

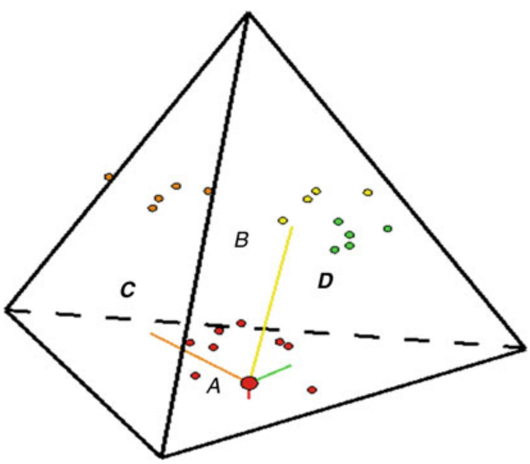
where H' – length of 2-simplex prism preassigned by a user and corresponded to the investigation duration

T_i – timestamp of features fixation of object under investigation for i-th examination

$T_{\min}$ – timestamp of features fixation of object under investigation for the first examination



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 4 2-Simplex with learning sample objects and the object under investigation



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 5 3-Simplex with learning sample objects and the object under investigation

$T_{\max}$ – timestamp of features fixation of object under investigation for the last examination.

Since 2-simplex prism construction is based on 2-simplex, then the description of all 2-simplex objects is also correct for 2-simplex prism.

For intelligent geoinformation systems (GIS), the height corresponds to the distance from initial point to final destination. In this case the distance between two adjacent 2-simpleces corresponds to the distance between two points on a map.

Learning trajectory construction via 2-simplex prism is given in Fig. 6.

The edges of the 2-simplexes correspond to assessments satisfactory (red), good (yellow), and excellent (green).

We demonstrate learning path in the 2-simplex prism in Fig. 6. Height $\boldsymbol{H}'$ corresponds to time interval of learning, T_i ($i \in \{1, 2, 3, 4\}$).

Software implementation of these models for intelligent system (IS) includes development of corresponded mathematical apparatus for transformation feature space to pattern space.

Using 2-Simplex Prism and 3-Simplex for Dynamic Diagnostic, Forecasting Processes and Dynamic Geoinformation Systems

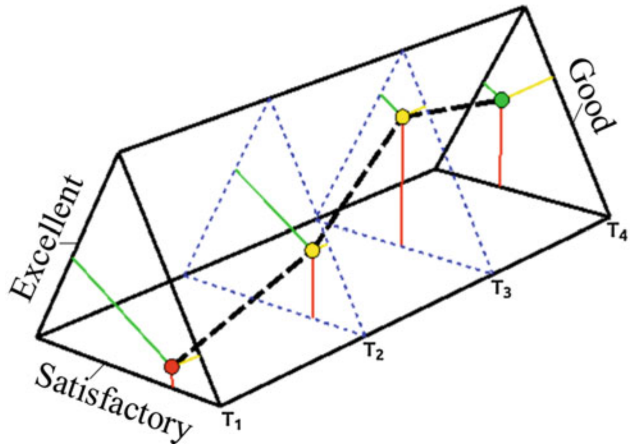
Application in Learning-Testing Systems

Until 2015, we used 2-simplex and 3-simplex to make and justify decisions for dynamic processes visualization, modeling, and prediction (Yankovskaya 1997, 2011; Yankovskaya et al. 2003, 2015b; Yankovskaya and Semenov 2012). In 2015 we started to use 2-simplex prism for these purposes in various problem areas.

This section describes visualization of testing knowledge result in learning-testing system with estimation coefficients usage (Yankovskaya et al. 2016a, b, 2017a, 2018). In learning-testing system developed by us, respondent, after studying selected discipline, should pass MDT. During solution of this test, respondent actions map (RAM) is forming, which determines how well the respondent cope with different tasks based on the following abilities (skills):

1. Storage and reproduction of the material in unmodified form.
2. The reproduction of the material in modified form.
3. Extraction of new knowledge based on the studied material.
4. Problem-solving, etc.

It should be noticed that the different set of these parameters (a_1, a_2, a_3) can be transformed in same distances h_1, h_2, h_3 in case when sums of



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 6 Learning trajectory construction via 2-simplex prism cognitive tool

a_i for different sets are equal. So for that and similar cases, it is necessary to introduce the new parameter: a color saturation of point corresponded to the sum of $a_i : a_1 + a_2 + a_3$.

Example of 2-simplex prism usage for learning-testing systems is given in Fig. 6.

2-Simplex prism allows to represent dynamics for ability development of a respondent or a group of respondents. But it should be noticed that representation of test results of a big group of respondents with the usage of 2-simplex prism can be too complex and inconvenient.

Prediction of Students' Learning Results and Cognitive Graphics Tools for Its Visualization

We represent 3-simplex that visualizes dynamical process of learning and subdivides the respondents into two subgroups with close levels of learning abilities in Fig. 7.

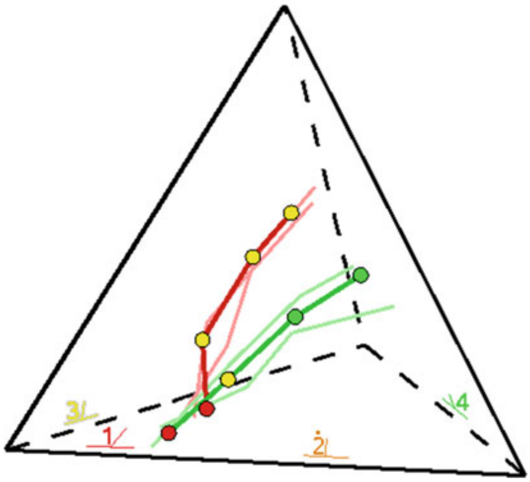
One of the main research tasks is a fast creation of a simple prediction model prototype for a learning process. It allows to solve the following problems: (1) remove obstacles for solving other tasks of the current research; (2) get an estimation of an influence of learning process trajectory and its prediction visualization given for students on the speed of their learning; and (3) integrate a visualization library in the Web-based learning platform (Moodle). As a result, the main attention is focused on inputs and outputs of this model.

The prediction model has the following inputs: (1) a history of previous student testing results, which are obtained by MDT, described before, and (2) a time stamp of prediction. The output of the model is a predicted result which student should get at testing in preassigned time stamp.

Learning intelligent system (Yankovskaya et al. 2017b) is a good example of intelligent dynamic system. Control and prediction of students' learning results are the ones of the "hottest" problems in modern learning process. The respondents assess their results within a particular course module and explore the prospects for further intellectual development based on assignment performance and test results at each stage of learning cycle. The system implements the learning result prediction and suggests to students the next development directions: (1) research, (2) practical, (3) teaching, and (4) management activities.

We use 2-simplex prism to visualize and justify students' learning trajectories. The sides of prism correspond to the theoretical knowledge evaluation, skills to solve problems, and laboratory performance skills. A point in the space of these components at a particular time instant corresponds to the current evaluation of the above components combinations. In the process of learning, the point position can vary depending on the students' values correction. Preferably, this position should be within the tolerance area.

The prediction model has the following inputs: (1) a history of previous student testing results, which are obtained by MDT, described before, and (2) a timestamp of prediction. The output of the prediction model is a predicted result which



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 7 3-Simplex for dynamic processes cognitive visualization

student should get at testing in preassigned timestamp.

In the current research for a prediction, a simple extrapolation polynomial function is used. Polynomial degree p is configurable and can be used for its influence estimation on a prediction quality. For a polynomial function, the last $p + 1$ results of already performed tests by a student for each axis are used. A system of linear equations is constructed based on them and is solved via Gauss method. Confidence region prediction is calculated as delta between predicted and real result for the last performed test.

An example of student learning trajectory visualization and different prediction models is given in Fig. 8. By varying different models in the prediction process, it was found that for the majority of the respondents, the best prediction is achieved by using a linear polynomial model (the polynomial of the first power). In most cases this simple prediction model shows better quality of prediction than any other investigated model (using quadratic polynomial).

Decision Support for Diagnostics and Correction of Psychosomatic Disorders with Usage of 2-Simplex Prism

Diagnosis and intervention of organization stress with the usage of 2-simplex prism is another interesting example of CGT usage (Yankovskaya and Yamshanov 2016). The idea of diagnosis is based on a three-step diagnostics for each stage of organization stress (1, intenseness; 2, adaptation; 3, exhaustion) on the base of G. Selye conception. This scenario is interesting because there are four patterns used (0 – for absence of organization stress) which is more that can be visualized and justified in 2-simplex prism. So two 2-simplex prisms can be used: one for the beginning of intervention (Fig. 9a) and another one for the ending of intervention (Fig. 9b).

The first test (T_1) reveals a level between the stage of exhaustion and the resistance stage and prepotency of the stage of exhaustion over the resistance stage. The second test (T_2) reveals that illness is decreasing from the exhausted stage (pattern 3) to the resistance stage (pattern 2). The third test (T_3) reveals that illness is decreased to a level between the resistance stage (pattern 2) and alarm stage (pattern 1). The fourth test (T_4) reveals prepotency of the alarm stage (pattern 1).

The second 2-simplex prism (Fig. 5) represents the transformation process from the resistance stage (pattern 2) to the absence of stress (pattern 0).

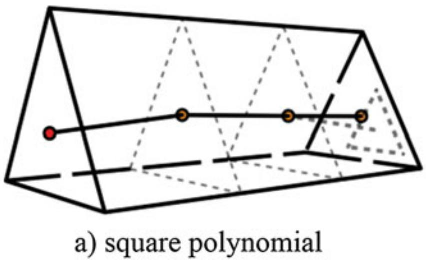
The fifth test (T_5) reveals the absence of the stress organization.

It should be noticed that the cognitive property of color is used in 2-simplex prism to represent dangerous diagnoses and patterns.

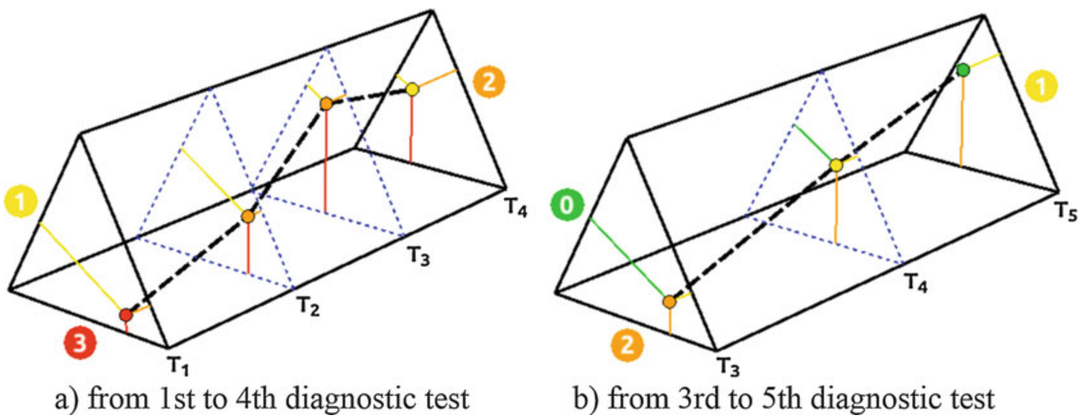
Cognitive Modeling

The cognitive modeling of a decision-making in the intelligent systems is one of the most important directions for creating intelligent systems (IS) in some priority areas of science researches and developing as medicine, psychology, sociology, environmental protection, energetics, systems of transport and telecommunication, control systems, etc. Manipulating some parameters of an object under investigation and using cognitive tools of decision-making and its justifications in IS, we can perform a cognitive modeling based on the different kinds of knowledge representations.

An example of the modeling result on the base of prediction and therapeutic intervention with the use of 2-simplex prism (Yankovskaya and



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 8 Influence of the polynomial degree on the prediction quality



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 9 Results of diagnostic tests for organizational stress revealing using 2-simplex prism

Yamshanov 2016) is presented in Fig. 10. After the first patient examination (T_1), the diagnosis is revealed – stage 3 (exhausted) of organization stress – and strategy of recovering is changed. With usage of mathematical model of a patient recovery process, it is possible to predict progress of patient recovery, which is shown in Fig. 10 as polyline of a light-blue color.

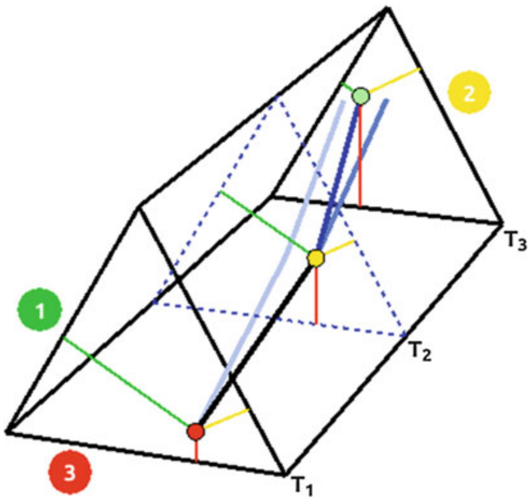
After the second examination (T_2), a progress of psychology stress recovering is diagnosed – organization stress is moved from stage 3 to stage 2 (resistance), but a real progress is worse than the predicted one. At this moment the doctor has two different strategies for continuation of recovering: purple and blue. The doctor uses this cognitive representation of different recovering strategies. He can choose one which gives the best result in the future. At this moment a strategy associated with a polyline of a purple color is more reasonable, because this strategy is applied to a patient. The model predicts full patient recovery until the moment of the next examination (T_3).

The cognitive modeling of decision-making is based on mathematical and computer methods with applying n-simplex family that allows optimizing a choice of influence of investigated object in accordance with a dynamical model of parameter change.

Using 2-Simplex Prism, 2-Simplex, and 3-Simplex for Geoinformation Systems

GIS (Ryumkin and Yankovskaya 2003) are widely applied practically in all spheres of human activity.

There are different scenarios for CGT usage in GIS. First common scenario is combination of ordinary reality objects (naturalistic CGT) and CGT, for example, map with real object and



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 10 Visualizing of a modeling result in 2-simplex prism

CGT overlay. Intelligent system of road-climatic zoning of territories (Yankovskaya and Sukhorukov 2017; Yankovskaya and Yamshanov 2014) is good example for this scenario. The free-distributed open-street maps with information layer overlay for the presentation of common information are used. Information layer presents road regions with borders and some information about its. This information is a number of zone and subzone which are determined for road region. A CGT for GIS visualization is presented in Fig. 11. Note that for the mapping of decision-making results with the usage of CGT, we use 3-simplex for the zone representation and 2-simplex for subzone representation in case when the number of subzones equals 3. The information layer is denoted by number 1. It is a transparent layer over the map. The thin black lines separate the different road regions. The different color tones are used for labeling the different zones (red color tone is used for zone 2; blue color tone is used for zone 3). Each color of the road region in every zone is unique color gradation from zone base color given from color transformation in the hue-saturation-bright palette (HSB palette). The wide black lines are used to separate the different zones. Hatching over road region shows subzone type. Only three hatching types are used and only two types from them presented in Fig. 11.

Another interesting scenario of usage is the investigation of dependency of some object parameters on the base of distance from some point. It is also reasonable to use 2-simplex prism for decision-making and its justification in intelligent geoinformation systems (Yankovskaya 2017). An example of health problem diagnosis on the base of distance is given in Fig. 12.

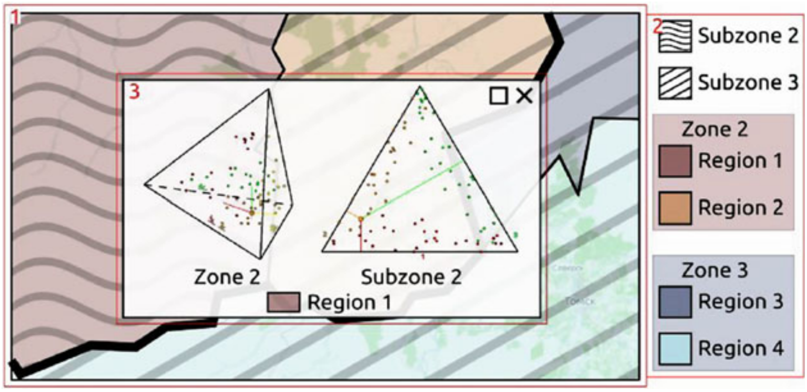
Conclusions and Discussion

Cognitive graphics tool (CGT) is one of the directions of artificial intelligence which is reasonable to use for any problem solution. CGT described in the paper are efficient for decision-making and its justification for pattern recognition problem in big number of software systems.

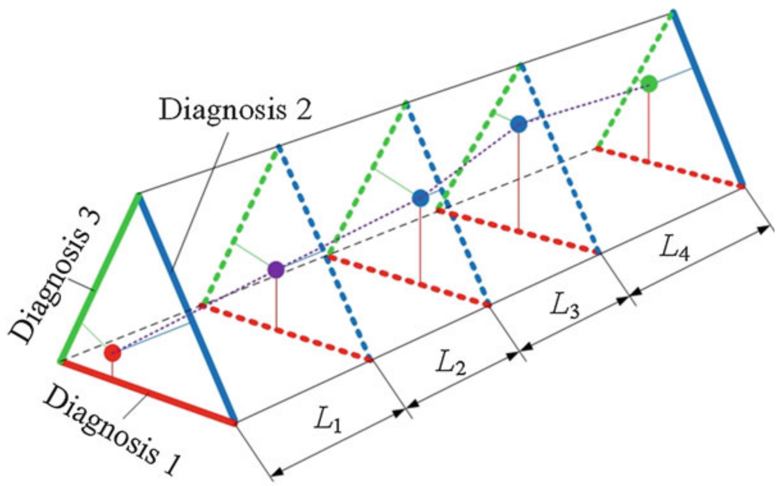
The most important advantage for the information visualization in 2-simplex prism is the opportunity to analyze in dynamics the object under investigation. It allows users to make decisions, justify them, and analyze changes of object parameters.

The new approach to the prediction of students' learning results based on MDT and 2-simplex prism is examined. Simple prototype of the prediction model for a learning process is given. Specificity of confidence region visualization for CGT 2-simplex and 2-simplex prism are described. The mixed DT (MDT) tools were verified on third year students' test results of speciality "Electrical Power Engineering." Variation of prediction polinome degree shows that for the majority of students the prediction results obtained using linear polynome is better than that obtained using square polynome. On this basis the following hypothesis can be formulated: the second derivative is not constant for a learning process and cannot be used for correct prediction.

A lot of intelligent systems constructed on the base of intelligent instrumental system IMSLOG (IIS IMSLOG) shows that CGT usage is very reasonable for big number of problem and interdisciplinary areas.



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 11 Visualization tool for representation of the map with zoning results



2-Simplex Prism as a Cognitive Graphics Tool for Decision-Making, Fig. 12 Results of diagnostic tests for intelligent geoinformation systems. L_1, L_2, L_3, L_4 – distances between geographical points

The research was conducted in such universities as Tomsk State University of Architecture and Building, Tomsk State University of Control Systems and Radioelectronics, Tomsk State University, Tomsk Polytechnic University, and (, Tomsk State Pedagogical University.)

Cross-References

- ► Computer Graphics, Video Games, and Gamification Impacting (Re)habilitation, Healthcare, and Inclusive Well-Being
- ► Overview of Artificial Intelligence
- ► Teaching Computer Graphics by Application
- ► Theory of Information Images, Basic Principles and Approaches

Acknowledgment The research was funded by RFBR grant (Project No. 16-07-0859a).

References

Albu, V.A., Khoroshevskiy, V.F.: COGR – cognitive graphics system, design, development, application. In: Russian Academy of Science Bulletin, Technical Cybernetics, pp. 12–20, 1990 (in Russian)

Axelrod, R.M.: The Structure of Decision: Cognitive Maps of Political Elites. Princeton University Press, Princeton (1976)

Kobrinskiy, B.A.: Why should we take in account imaginary thinking and intuition in medical expert systems. In: Artificial Intelligence – 96, Proceedings of the 5th National Conference with International Participation, pp. 207–210, 1996 (in Russian)

Pospelov, D.A.: Cognitive graphics – a window into the new world. In: Software Products and Systems, pp. 4–6, 1992 (in Russian)

Raciborski, R.: Graphical representation of multivariate data using Chernoff faces. Stata J. **9**(3), 374 (2009)

Ryumkin, A., Yankovskaya, A.: Intelligent expansion of the geoinformation system. In: The 6th German-Russian Workshop "Pattern Recognition and Image Understanding" OGRW-6-2003, Workshop Proceedings, Russian Federation, Novosibirsk, pp. 202–205, 2003

Saary, M.J.: Radar plots: a useful way for presenting multivariate health care data. J. Clin. Epidemiol. **61**(4), 311–317 (2008)

Wang, B., Feng, X., Chu, K.H.: A novel graphical procedure based on ternary diagram for minimizing refinery consumption of fresh hydrogen. J. Clean. Prod. **37**, 202–210 (2012)

Yankovskaya, A.E.: Transformation feature space into pattern space on the base of logic-combinatorial methods and properties of some geometric objects. In: Pattern Recognition and Image Analysis, Minsk, pp. 178–181, 1991

Yankovskaya, A.E.: Design of optimal mixed diagnostic test with reference to the problems of evolutionary computation. In: Proceedings of the First International Conference on Evolutionary Computation and Its Applications (EVCA'96), Moscow, pp. 292–297, 1996

Yankovskaya, A.: Decision-making and decision-justification using cognitive graphics methods based on the experts of different qualification. In: Russian Academy of Science Bulletin, Theory and Control Systems, vol. 5, pp. 125–128, 1997

Yankovskaya, A.: Logical Tests and Means of Cognitive Graphics. LAP LAMBERT Academic Publishing, Saarbrigge (2011)

Yankovskaya, A.: 2-Simplex prism as a cognitive graphic tool for decision-making and its justification in intelligent dynamic and geoinformation systems. In: Proceedings of 4th International Conference "Computer Graphics and Animation," p. 42, 2017

Yankovskaya, A., Galkin, D.: Cognitive computer based on n-m multiterminal networks for pattern recognition in applied intelligent systems. In: Proceedings of Conference GraphiCon'2009, MAKS Press, Moscow, pp. 299–300, 2009. ISBN 978-5-317-02975-3

Yankovskaya, A., Semenov, M.: Computer based learning by means of mixed diagnostic tests, threshold function and fuzzy logic. In: Proceedings of the IASTED International Conference on Human–Computer Interaction, Baltimore, pp. 218–225, 2012

Yankovskaya, A.E., Sukhorukov, A.V.: Complex matrix model for data and knowledge representation for road-climatic zoning of the territories and the results of its approbation. In: International Conference Information Technology and Nanotechnology, Samara, pp. 264–270, 2017

Yankovskaya, A., Yamshanov, A.: Bases of intelligent system creation of decision-making support on road-climatic zoning. In: Pattern Recognition and Information Processing (PRIP'2014): Proceedings of the 12th International Conference, UIIP NASB, Minsk, vol. 340, pp. 311–315, 28–30 May 2014

Yankovskaya, A., Yamshanov, A.: Family of 2-simplex cognitive tools and their applications for decision-making and its justification. In: Computer Science and Information Technology (CS & IT), pp. 63–76, 2016

Yankovskaya, A.E, Gedike, A.I., Ametov, R.V.: Intelligent dynamic system. In: Knowledge-Dialog-Solution (KDS-2001), Proceedings of International Science –Practical Conference, vol. 2, Pub. "Lan," Saint-Petersburg, pp. 645–652, 2001

Yankovskaya, A.E., Gedike, A.I., Ametov, R.V., Bleikher, A.M.: IMSLOG-2002 software tool for supporting information technologies of test pattern recognition. In: Pattern Recognition and Image Analysis, vol. 13, no. 4, pp. 650–657, 2003

Yankovskaya, A., Yamshanov, A., Krivdyuk, N.: 2-Simplex prism – a cognitive tool for decision-making and its justifications in intelligent dynamic systems. In: Book of Abstracts of the 17th All-Russian Conference with International Participation: Mathematical Methods for Pattern Recognition, Svetlogorsk, p. 83, 2015a

Yankovskaya, A., Dementyev, Y., Yamshanov, A.: Application of learning and testing intelligent system with cognitive component based on mixed diagnostics tests. In: Procedia – Social and Behavioral Sciences, Tomsk, vol. 206, pp. 254–261, 2015b

Yankovskaya, A., Dementyev, Y., Yamshanov, A., Lyapunov, D.: Prediction of students' learning results with usage of mixed diagnostic tests and 2-simplex prism. In: Intelligent Data Processing: Theory and Applications: Book of Abstracts of the 11th International Conference (Moscow/Barcelona), Torus Press, Moscow, vol. 238 pp. 44–45, 2016a

Yankovskaya, A., Dementyev, Y., Lyapunov, D., Yamshanov, A.: Intelligent information technology in education. In: Proceedings of the 2016 Conference on Information Technologies in Science, Management, Social Sphere and Medicine (ITSMSSM), Atlantis Press, Tomsk, vol. 51, pp. 17–21, 2016b

Yankovskaya, A.E., Dementev, Y.N., Lyapunov, D.Y., Yamshanov, A.V.: Learning outcomes evaluation based on mixed diagnostic tests and cognitive graphic tools. In: Proceedings of the XVIIth International Conference on Linguistic and Cultural Studies: Traditions and Innovations, Advances in Intelligent Systems and Computing (LKTI 2017), Tomsk, vol. 677, pp. 81–90, 11–13 Oct 2017a

Yankovskaya, A.E., Shelupanov, A.A., Shurygin, Y.A., Dementiev, Y.N., Yamshanov, A.V., Lyapunov, D.Y.: Intelligent learning and testing predictive system with cognitive component. In: Open Semantic Technologies for Intelligent Systems, pp. 199–204, 2017b

Yankovskaya, A., Dementyev, Y., Yamshanov, A., Lyapunov, D.: Assessing student learning outcomes using mixed diagnostic tests and cognitive graphic tools. In: Open Semantic Technologies for Intelligent

Systems: Proceedings of International Conference, Minsk, vol. 2, pp. 351–354, 15–17 Feb 2018 (ISSN 2415–7740. http://proc.ostis.net)

Zenkin, A.A.: Cognitive Computer Graphics. Nauka, Moscow (1991). in Russian

Zhuravlev, Y.I., Gurevitch, I.B.: Pattern recognition and image analysis. In: Pospelov, D.A. (ed.) Artificial Intelligence in 3 Books, Book 2: Models and Methods: Reference Book, p. 149191. Radio and Comm, Moscow (1990). in Russian