Spatial Modeling of Resources, Events and Situations in Complex Dynamic Systems by Methods and Tools of Cognitive Semiotics and Geoinformatics

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Abstract

In the paper, we represent sign spatial modeling of resources, events, and situations in systems with high dynamics of technological processes. An analytical overview of the main directions of spatial modeling is given. It includes topological modeling (geosituational direction with spatial objects, models and actions with data coordinated in space) and algebraic modeling (logic-linguistic direction, pseudophysical logic of space and time, spatial logic, models and action with mathematical symbols). The subjective and visual coding of the locativeness of static and dynamic resources, events, and situations on the example of spatial modeling of the area of the regional electric power system is considered.

Keywords

Cognitive semiotics, spatial modeling, subject-visual coding, static and dynamic resources, events, situations, operational dispatch management, regional electric power system

1. Introduction

The development of mathematics in the XVII-XIX centuries illustrated the fact that mathematical concepts do not directly relate to reality, but are rather constructed by the mind itself, than extracted from experience by abstraction [1]. Corresponding to the physical sciences, where the principle of additivity is fulfilled, mathematics has stopped in front of the ontological barrier of system and humanities laws, where such a principle is violated due to the emergence (synergy, non-positionality) of complex systems, in particular electric power systems (EES).

In respect to the operational dispatch management (ODM) of anthropogenic and heterogeneous EES, where the electrostatic and electrodynamic processes in power elements are closely linked to information exchange in relay protection and emergency control devices, collective activity of people, the influence of the main elements of natural environment, space, ionosphere and atmosphere, the ontological barrier is overcome by the transition to an "intelligent control system", the subject of which contains an "automatic partner" - hybrid system over a variety of mathematical models for calculating mode parameters and heuristic models in the "Space-Time-Knowledge" triad: simulation statistical models, expert, fuzzy, precedent and geoinformation systems, artificial neural networks and genetic algorithms. It means that the ontological barrier is overcome on the principles of the development of hybrid intelligent systems (HIS) [2]: there is not a single, definitively developed method for explaining or solving a complex, heterogeneous problem; nevertheless, there is a subset of the already developed

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set of methods and models (heterogeneous model field – HMF), which can be used for situational synthesis of the method (model) of its solution.

A necessary element of knowledge and activity, especially operational, professional and technical, reflected in the HMF is the concept of spatial and spatiotemporal properties and relations [3]. The degree of generalization and schematization of a spatial image depends on the nature of the reflected resources spatial properties, the tasks of activity, as well as on the ability of the human operator to reproduce spatial properties of resources in the form of a figure, drawing, scheme, symbolic notation, etc.

In the cognitive-oriented two-tier model of the decision support process using the methods and tools of the HIS, spatial representations are encoded in a schematized (subject-image) and symbolic (predicative) notation.

This work is dedicated to the spatial modeling and subject-image coding of static and dynamic relations "resource-resource" on the example of the HMF of the supervisory district of a regional EES. Spatial relations are basic for semantic relations: temporal (assuming a change of events), of conditionality, etc. in models-elements of HMF [4].

2. Spatial knowledge and modeling, cognitive semiotics of a heterogeneous model field

The human operator acts in real space, the figurative, psychological reflection of which is spatial knowledge [5] of cognitive base [4], that is studied by linguistics, topology, geometry and mathematical logic, and is manifested in the information correspondence of spatial images and their location. The complexity of spatial knowledge is characterized by the following components: configuration, position, and relative position of resources, which are formed on the relations of shapes, coordinates, and relative positions. Morphological knowledge uses relations of form. Positional knowledge uses the relationship of the object and the origin. Mutual static and dynamic spatial knowledge in a group of objects describes the situation and uses topological and set-theoretic relations. Spatial modeling [6] of geographically distributed resources and energy flows of EES is performed by HIS methods and means: visual control [7], cognitive semiotics, geoinformatics and geoinformation systems [8-12].

Sign spatial modeling (maps, schemes, diagrams, drawings, plans, graphs, formulas, etc.) is cognitive semiotics object of study [13, 14], which is an interdisciplinary science that includes methods for studying synthesis and analysis of senses, meanings, sign structures, processes of understanding signs and world condition through sign systems, which will allow for the "conceptual integration" of cognitive and semiotic modeling. The term "cognitive semiotics" was introduced in the 90s of the XIX century by Thomas Daddesio (Th. C. Daddesio, «On Minds and Symbols: The Relevance of Cognitive Science for Semiotics"), and in Russia it was first used by V. V. Rykov [13-18].

Cognitive semiotics in the science of hybridization is an integrator of cognition by means of: 1) mathematics (from Greek: μάθημα, 'study, science'), the art of measuring things; 2) morphology (from Greek. μορφ "form" + λγος "study"), the art of identifying relationships and their configurations; 3) semiotics (from Greek. σημεῖον – sign; feature"), the art of transferring meanings [19]. Thus, the methods and tools of cognitive semiotics comprise the methodology and technology for the development of a heterogeneous model field of HIS, over which a multi-model semiotic system is always re-synthesized for an arisen problem situation as a method for solving a complex, heterogeneous operational dispatch task. One of the tools of cognitive semiotics is isographs.

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3. Main directions of spatial modeling in cognitive hybrid systems

If we interpret the statement of French mathematician A. Weil that the angel of topology and the devil of abstract algebra are fighting for the soul of every mathematician, through the prism of thinking in terms of mathematics, morphology and semiotics to the spatial modeling of EES and electrical installations, then all publications on this topic are conditionally attributed to: 1) "topological" (geosituational direction, spatial resources, models and actions with spatially coordinated data); 2) "algebraic" (logical-linguistic direction, pseudo-physical logics of space and time, models and actions with mathematical symbols).

The logical-linguistic direction of spatial modeling in relation to the EES is rather general-theoretical and is represented by the pseudo-physical logics of D.A. Pospelov and the spatial logic of V. Ya.Tsvetkov (geometric, topological, set – theoretic and figurative) [5, 20-22].

In linguistics, M. V. Vsevolodova and E. Yu. Vladimirsky obtained significant results on spatial relations and ways of expressing them by name forms [23] by describing the problems of semantics and ways of expressing circumstantial relations in Russian. Spatial relations are a juxtaposition in space of a resource, an action (event), a feature, and some spatial reference point – a locum (space or resource, relative to which the location of the resource, action, feature and the nature of their relationship is determined: static, dynamic). Modern linguistics regards locativity as a semantic category, a linguistic interpretation of mental category of space, and as a means of language that interact in the expression of spatial relations [4]. The relations of the resource and its environment, expressed in a specific statement, are considered within the locative categorical situation. Prepositional-nominal constructions express the semantics of locativity and the resource-localizer, and the locative categorical situation is described by known landmarks, and the human operator, who does not perceive the situation sensually, can figuratively see the location or movement of the resource in his environment [24].

A prominent representative of the logic of relations was S. I. Povarin, who distinguished between judgments about belonging (relations of definition, *S-P*) and judgments expressing relations of space, time, magnitude, causality, interrelationship, etc., i.e., judgments about relations (*aRb*) [25]. Pseudo-physical logics [26] are deductive systems, logics of relations-variables that reflect not an objective physical world, but its subjective human perception. Pseudophysical logics on topological and metric scales include a model of visions of space and time [21].

V. Ya. Tsvetkov connects spatial logic [22, 27] with spatial analysis and logical reasoning in geoinformatics, and distinguishes between geometric, topological, set-theoretical and figurative logic.

The geosituational direction of geoinformatics and geomatics is represented in the electric power industry by geoinformation systems: GIS of JSC "MOESK" [28, 29]; federal state information system about the state and forecast of the development of the fuel and energy complex GIS of FEK [30], GIS of developing electric networks ElecNet [31], GIS of "ROSSETI" [32], GIS of monitoring the electric grid complex for PJSC " IDGC of the South "(PJSC "Rosseti South" [33-37]). The problems of standardization of the spatial data infrastructure have been solved (for example, GOST R 58570-2019, GOST R 58571-2019). The Federal STC of Geodesy, Cartography and Spatial Data Infrastructure appeared [38], and the Kaliningrad Regional Spatial Data Portal was launched in test mode on 17.09.2020 [39]. An important aspect of the use of GIS methods and models for the development of automatic partner GMF is to teach operational workers to think spacely in order to provide effective information support for the maintenance and repair of ETL and electrical installations. The most important advantage from the introduction of GIS for power grid companies is the ability to simulate emergency situations-reflection at the situation screens of a sequence of events in an emergency, taking into account weather conditions, as well as locatively and taking into account the configuration of buildings and structures [29].

Map is abstraction, scheme, model of spatial phenomena, the most successful graphical tool for transmitting spatial information in HMF [8] Mapping of spatial phenomena in the KHIS involves the development and inclusion in its heterogeneous model field [40] of another class of models-geomodels, another class of variables-a visual variable (fr. variables visuelles, eng. visual variables) of graphic semiology of J. Bertin [41], and the autonomous basis needs to be supplemented with GIS methods and technologies.

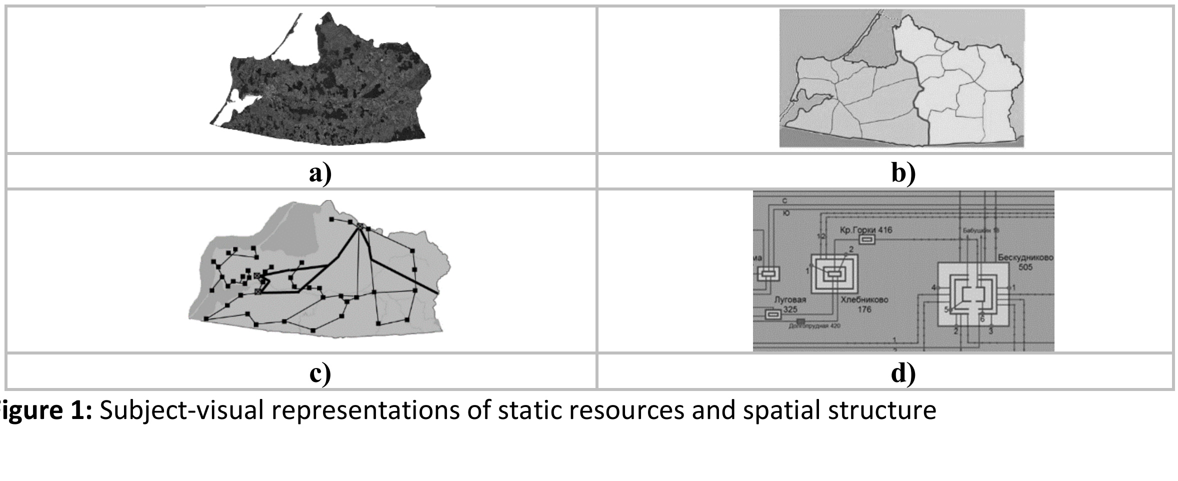
The geoinformation model (geomodel) in the HMF HIS EES is a symbiosis of two data models underlying the vision of spatial and semantic, attributive information about resources in relational DBMS [37]: $G = \{O_l, O_e, T(O_e), M\}$, where O_l is resources-territories on an electronic map (natural environment, transport networks, dividing into districts, zones, land plots, administrative-territorial division, settlements, etc.); O_e – energy resources (anthropogenic power resources, electricity consumers, field service teams of electricians; special vehicles, devices and equipment of field teams; devices for technical diagnostics; systems and devices for relay protection; systems and devices for emergency automation); $T(O_e)$ – topological relations (intralayer and interlayer) of energy resources localized on resources-territories; M – metadata, the structure of attributive information and digital terrain model [42]. The theoretical basis of geomodels is algebraic topology and graph theory [10].

The basis of spatial modeling in GIS is the basic raster layer (substrate) and the layers of the electronic vector map, over which compositions are built using overlay operations: combining, combining for a separate area, spatial and thematic problem-oriented selection. GIS provides collection, storage, processing, analysis and display of spatially coordinated data, as well as the acquisition of new information and knowledge based on them. A typical recent tendency is a rapid expansion of the capabilities of main updating of geodata, and the growth of the volume of open spatial information: OpenStreetMap, VMap0, VMap1 projects, satellite images with a detail of 10-30 m LANDSAT and SENTINEL, digital terrain models SRTM and ASTER GDEM. The main component of GIS in the EES is digital spatial data about the area, territory, energy resources, their word and verbal descriptions, digital images, digital maps, etc. Spatial data are locatively-co-ordinated to the Earth's surface by means of mathematical models, as well as of coordinates, for example, WGS-1984 and Pulkovo1942.

4. Subject-visual coding of static resources and spatial structure

The semantic category of locativity is a kind of functional-semantic field, which includes static and dynamic localization of the subject and the movement of the object by the subject [43]. In Russian, static, including spatiotemporal and dynamic relations are distinguished [23]. Gordon's worldview "about ongoing transactions" – abstract dynamic objects characterized by spatiotemporal location and features – launched the beginning of a rapid perception of interaction processes and, 60 years later, serves faithfully to the ideas of visual thinking [44]. Consideration of natural and natural-anthropogenic objects, installations, devices, transport, human factor as resources of operational visual thinking in the EES inevitably distinguishes and creates the impression of immobility, steadiness, calmness, stability, balance of static nature of some resources (from Greek: statos – the meaning of standing, motionless, confident, calm, stopped, they are called static resources) and the visual impression of movement, speed, change and time (from Greek: dynamis – the potentiality of movement, dinamikos – the meaning of power, moving, mobile, energetic, they are called dynamic resources). The first type is relatively stable in location (position) relative to each other and the coordinate system. The second one moves relative to the static ones and each other, and their location is relevant in the spatial environment. In any case, the word-verbal and subject-visual codes of the HMF element models should answer the question: "Where is the resource located?" meaning: 1) the location or area of the resource; 2) the location of the resource in the natural environment; 3) the position of the resource relative to other static resources [45]. These aspects are connected with each other and in practice they usually do not differ.

Place is a part of the space occupied by a resource in its natural environment. The physical place is shown in connection with its natural characteristics and the immediate surrounding (Fig.1a), and the formalized one demonstrates technical clarity (Fig.1 b – d).



a) **b)** **c)** **d)**

Figure 1: Subject-visual representations of static resources and spatial structure

Fig. 1 shows representations of: physical location "Kaliningrad region (KR), Russia" - a); boundaries of the administrative districts of KR, Russia and the division of the power system into "western" and "eastern" - b); power networks of KR, Russia (fat line – 330 kV, thin line – 110 kV; the location is shown conditionally approximate)-c); example of displaying the plan (configuration, topology) of electrical substations depending on the switching state of bus systems and transformer connections [46] – d).

Location is the spatial relationship between a resource and its environment, also a resource. In the graphic image, the resource-environment acts as a coordinate system for the resource, the size of which is usually minimal, so that attention is focused on its location. Related (connected) locations show the spatial characteristics of similar elements of the resource, relative to the common environment. The location of the components of the resource is usually called a plan (Fig. 1 d). The location of routes – resources expressed by lines and a diagram of directions relative to the environment; networks (road, electric) – a generalized scheme (routes, stops, stations, electrical substations, generation and consumers) in relation to their environment (Fig.1c). Static resources can be formalized, symbolized, or presented descriptively. The location of the area (Fig. 1b) shows the place of the resource in a specific relation to a detailed geographical or political reference system.

The location of movement reflects the movement of the resource along the route-stationary network in relation to its environment. Both the route of movement and its quality and quantity can be shown. A visual differentiation is needed between the form of active and passive movement of dynamic resources, static network structure through which it passes (Fig. 2).

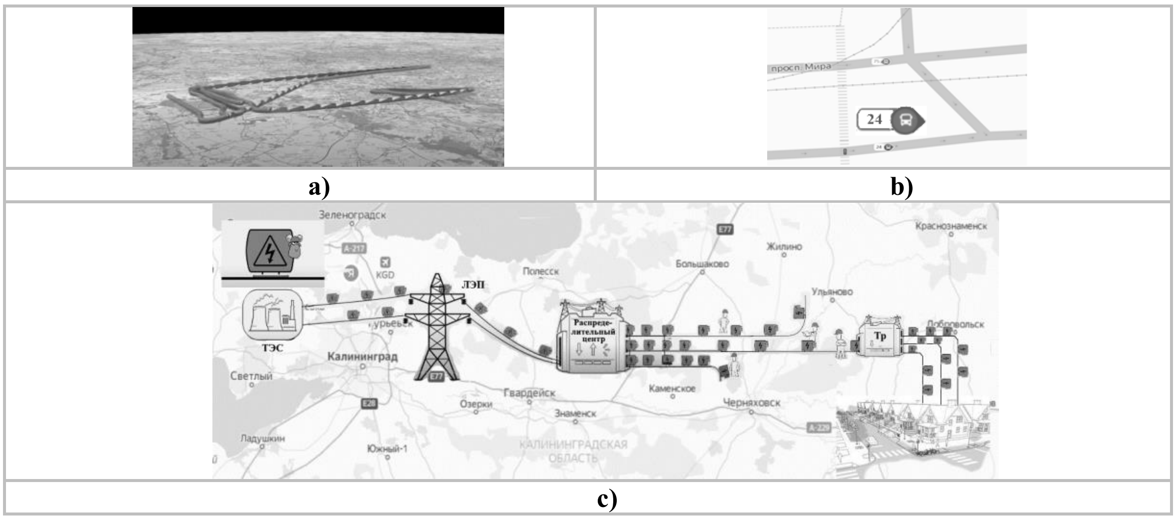


Figure 2: Location of movement

Fig.2 presents: interactive dynamic 3D visualization of data on georeferenced movements of passenger aircraft and visual analysis of their paths in the area of airport dispatchers [47] – a); dynamic 2D visualization of georeferenced movement of passenger buses in the area of Pobeda Sq. in Kaliningrad, Russia in Yandex.Maps (dynamic resource – the bus is indicated by an arrow-shaped symbol, and is shown above it in an enlarged view) [48] – b); georeferenced conventional diagram of the movement of electric current energy from a source (TPP) to a consumer (dynamic resource – electricity is indicated by an "electric snare" running along the power lines, shown above the TPP in an enlarged view) – c).

Subject-pictorial coding of static resources and spatial structure in the GMP KHIS is possible with GIS tools. In this case, the substrate is a geographic map of the world OpenStreetMap under free license, over which layers with isographs [16] of static resources and the spatial structure of EES are built. A graphic overlay, as a composition of a substrate and isographs, is considered as a spatial model of the static relations of an ODM object.

The designations of static resources and their switching states in the layers of ODM spatial models by an area of regional EES, coded by isographs, are shown in Fig. 3.

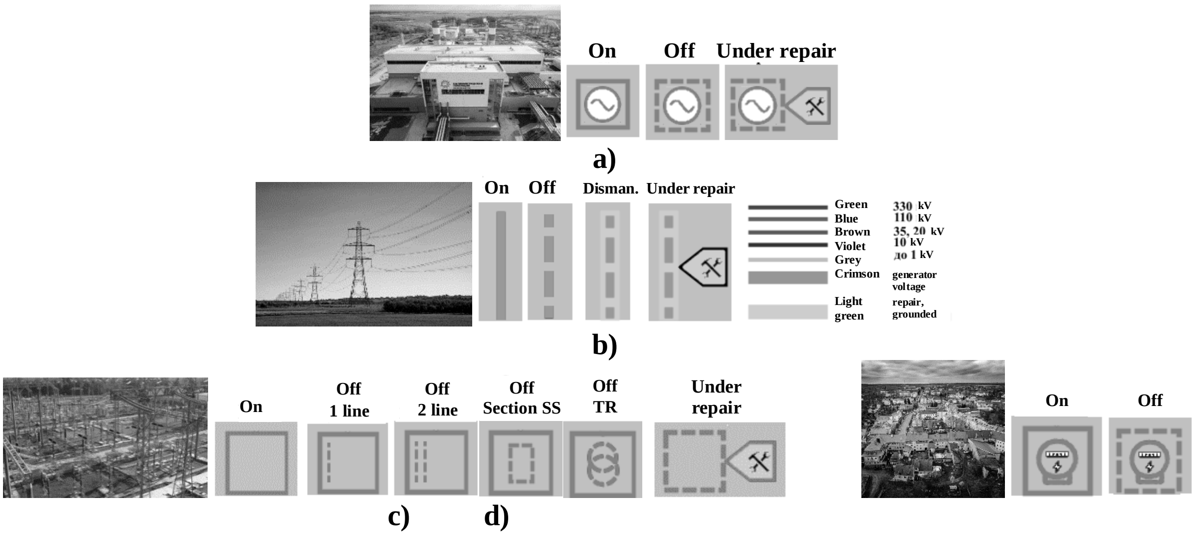


Figure 3: Designation of static resources of ODM RES and their switching states on spatial models

Fig. 3 shows photographs and conventional signs of: power plants – a); overhead transmission lines (OTL) – b); power distribution substations – c); consumer of electricity – d).

If the operator needs a specification of the cognitive image of a static resource, it is enough to point to its sign (Fig. 3), and an isograph of a multi-role visual relation of resource definition will be displayed in the associated table: "resource *be* resource ∧ resource *have (property) name* name property ∧ resource *have (property) parameter* parameter ∧ resource *have (property) characteristic* characteristic ∧ resource *be intended for* action ∧ resource *have (mode) state* state ∧ resource *contain* resource".

5. Representational coding of dynamic resources, events and situations

The main dynamic resource of the ODM RES EES is invisible energy of a moving electromagnetic field, characterized by voltage (volts), frequency (hertz) and power (watts). In a figurative form, the energy is "carried" by an electromagnetic wave, and it rushes from the source (power plant) to the consumer in the space surrounding the power line wire at lightspeed along the wires, and not in the wires. The latter only direct the flow of energy of the electromagnetic field. That's why the wires of power transmission lines with current are not "pipes" with energy flowing through them, but rather "rails" that direct energy flow (Fig. 2 c). However, in the RES EES there are other dynamic resources with significantly lower, and therefore visually observable, speeds of movement in space: mobile generator sets, operational field repair crews, their devices and equipment, special vehicles, completion and consumable electrotechnical materials, devices of technical diagnostics. "Negative" dynamic resources include weather, atmospheric, ionospheric and space impacts.

The approach to spatial modeling of resources with radically different dynamics can be solved in the "discrete – continuous" opposition (Fig. 4). Fig. 4 shows local movements of aircraft on the radar screen of the airport dispatching service – a); the flow path of the aircraft, tied to the geomodel – b); changing the position of the aircraft on the dispatcher's online monitoring screen with animation effects of flashing diverging arcs – c); traffic flows of various density tied to urban geomodel – d).

Energy flows of electromagnetic waves spreading in the surrounding space of the power transmission line are contrasted and made "visible" for human operator by the color coding method (Fig. 3 b) and the type of a line: a solid line means that the electricity is moving and the state of the power transmission line is "On"; a dash line means that the electricity is not moving and the power transmission line state is "Off" A similar approach is applied to coding the signs of resource-sources, resource-distributors (converters) and resources of electricity consumers (Fig. 3 a, c, d).

The concept of the interaction of static and dynamic resources among the operational dispatching personnel is formed on the basis of speculative models: "events" and "situations" [49].

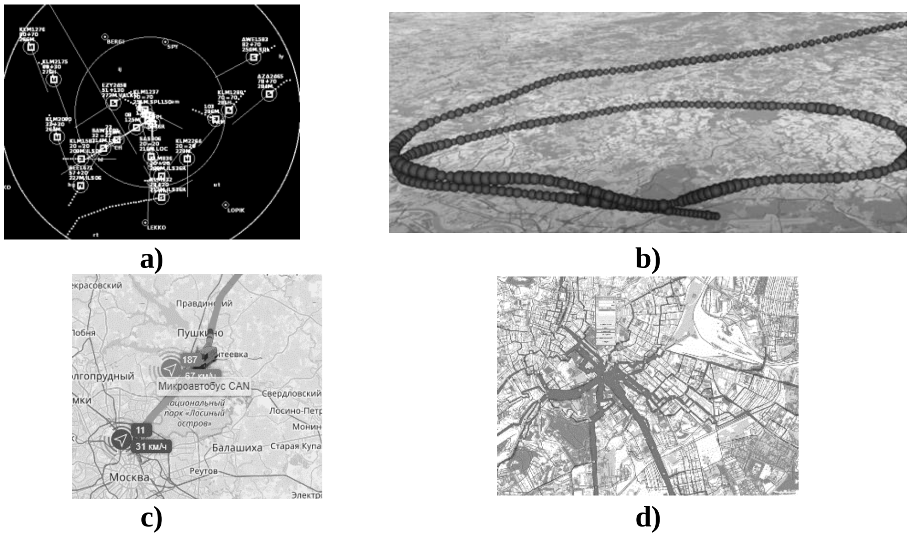


Figure 4: Representation of the movement of dynamic resources in the opposition "discrete-continuous"

According to O.N. Seliverstova [50] an accident is an instant action with parameters: fact, change, time and space. The “change” parameter includes a change in states through the manifestation of a certain property by a resource in time, or a change in the quantity and quality of resources, properties and relations. The "time" parameter characterizes events as "temporary entities" organized, ordered and interconnected along the time axis. The parameter "space" correlates the flow of events with spatial landmarks, localizes its components (Fig. 5).

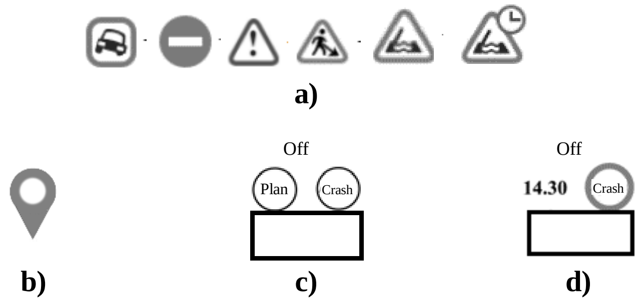


Figure 5: Signs of spatial modeling of events (by pointing to the icon, you can see the message about the event)

Fig. 5 shows the signs (from left to right): traffic accidents, traffic closures, other, road works, bridge raising, the event "the bridge will be lifted" in Yandex.Maps – a); power outages on the map of outages of the portal of "Rosseti" power grid services [51] – b); as well as isographs of "outage" events in the cognitive – c) and operational – d) images of the R-situation of the ODM RES EES.

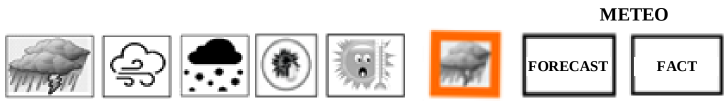
Situation (from ancient lat. Situatio – position) - a combination of conditions and circumstances that create certain atmosphere, position [52]. The concept of "situation" arises when the subject of ODM RES interacts with the surrounding reality and includes: the subject itself, the environment and interactions between them.

The cognitive-graphic representation of the situation in [53] is determined by the triple $G = < V, D, L >$, where V is a set of indicators (visual signals), D is the relative position of indicators, L is a set of levels of subsystems hierarchy in the observed object. The visual signal is a six v = <*Color, Form, Size, Position, Change, Orientation*>.

In the context of the categorization and conceptualization of the language of relations and connections of the human operator in the ODM RES, the semantics of conditions and circumstances is revealed by the concept of "R-situation".

R-situation (situation on resources) is a set of spatial relations on resources used in production operations, weather R-situation and "outage" events (planned or emergency) in current time and in the context of the spatial structure of the control object.

Weather R-situation (Fig. 6 c) is a subject-visual representation (predictive and actual) of the interaction of "negative" dynamic resources (Fig. 6 a) with resources (dynamic and static) in a localize area. It is calculated according to Internet data and is characterized by a scale of color values of the weather: "Green" – not dangerous, no adverse events are expected; "Yellow" – potentially dangerous, adverse events are possible; "Orange" – dangerous, probable natural disasters, damage; "Red" – very dangerous, large destruction and catastrophes are possible.



a) b) c)

Figure 6: Designation of "negative" dynamic resources

In fig. 6 (from left to right) the impact of thunderstorm atmospheric overvoltages, wind effect, ice and frost formations, the impact of geomagnetic storms and heat waves – a); orange level of hazard of thunderstorm atmospheric overvoltages – b); weather R-situations – c). An example of a fragment of the cognitive (odd) image of the R-situation of ODM RES EES is shown in Fig. 7.

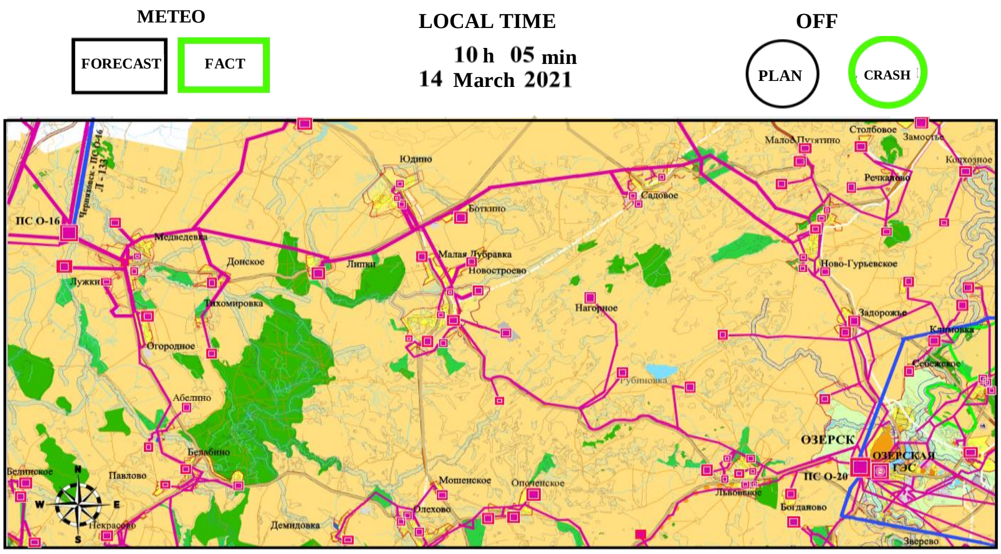


Figure 7: R-situation (a fragment of a cognitive image) in RES EES, implemented by isographs in the graphic editor Paint.net v.4.2.15

Fig. 7 shows an overlay with a substrate - the general plan of the municipal Ozersk urban district of Kaliningrad Oblast, Russia (map of the planned location of local facilities, 1:50 000 scale) [54]; a layer of overhead transmission lines (110 kV, 15 kV, "On" state), substations (110/15 kV; 15 / 0.4 kV; "On" state), Ozerskaya HPP ("On" state); a layer of the weather R-situation (the color of the contour "meteo in fact" is green, "the weather is not dangerous"); a layer of events "outage" (planned, emergency); local time layer.

The prevailing part (80-90%) of the undersupply of electricity occurs in accidents in electrical networks [55], which dispatchers call "outages". Disconnection of this power line leads to the drawing of consumers in a limited area and is eliminated by searching and allocating the damaged section and turning on the remaining network segments from backup supplies. When the KHIS, automatically controlling the mode of the control object, through a functional element – a fuzzy expert system, detects a shift in the parameters of its state from the “normal mode” cluster to the "emergency mode" cluster, an operational image of the R-situation is presented to the human operator of ODM RES (Fig. 8). Since the automatic partner knows the resources, the properties of which have gone beyond the permissible intervals, first of all it calculates the reduced operational image of R-situation to a fragment containing information only about the location of the emergency resource in its natural immediate environment.

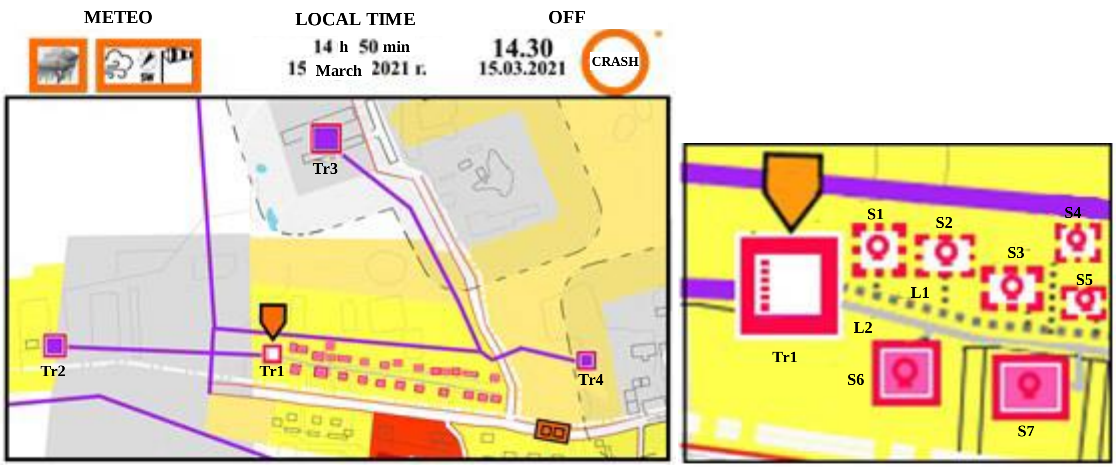


Figure 8: Modeling of the R-situation (a fragment of the operational image) in the RES EES, implemented by isographers in the graphic editor Paint.net v.4.2.15

Fig. 8 shows an overlay with a substrate – a map of the planned placement of local facilities in Yablonovka, S1: 2000 – a [54]: a layer of overhead power lines (15 kV, the states of all is "On"; 0.4 kV, state L1 is "Off", state L2 is "On"); transformer substations (Tr2 - Tr4 15 / 0.4 kV, state is "On", Tr1 – "Off line 1"); consumer layer (S1 - 5, etc. on line L1 the state is "Off", S6, S7, etc. on line L2 the state is "On"); a layer of the weather R-situation (thunderstorm atmospheric overvoltages, wind effect, the color of the contour "meteorological in fact" is orange, "the weather is dangerous"); the event layer "emergency outage" (14.30, 15.03.2021); local time layer – 14h 50m, March 15, 2021. Fig. 8 b shows an enlarged image of a section of the territory adjacent to the transformer substation Tr1.

At the same time, on the representation of the operational image of the R-situation, arrow-figures of operational actions are displayed, pointing with their sharp end to the icons of emergency resources and tying to the place the local actions-operations proposed and recommended to the human operator. Flashing arrow outlines require operator approval, planning and organization of execution. If the operator agrees with the recommendations, points to one or several (or alternately all) of the flashing icons, then a subject-visual image of "action-arrows" appears, which in this case acts as a subject-oriented action plan with already automatically partially filled part of roles in relations "action-resource" and "action-property". After constructing the subject-visual sign "action", the script-scheme is automatically recoded into a verbal-predicative command statement - one or a set of dispatching commands, displayed to the operator and transmitted via communication means to the performers. If the operator rejects the actions recommended by the automatic partner, then he can select the subject-visual representation from the schemes available in the library and specify the role relationships "manually".

6. Conclusion

The influence of the methods and tools of cognitive semiotics, geoinformatics, hybrid and synergetic intelligent systems on the design and practice of automated systems for the ODM RES of a regional EES is not satisfactory. Two facts are contrasted in the course of research of "Space-Time-Knowledge" triad on the example of the operational work of electrical networks dispatchers.

Fact one: high speed of emergency process occurrence of emergency processes practically excludes the possibility of human participation in the management of emergency modes in electrical systems. Therefore, the metaphorical part of the "pilot" of power grids, transporting energy produced at a power plant along the "rails" of power transmission lines to consumer's target "power outlet", is played not by the human factor, but by spatially distributed local automata: relay protection devices, emergency control devices and regulators. This also explains the situation when military pilots understand the meaning and relevance of the concept of "flight image", and the lexicon of energy dispatchers does not have such a concept, and their work is more similar to the conductor of an orchestra of musicians working in a remote mode.

Fact two: the successful "piloting" of power grids up to the present time is a tremendous success of mathematics and theory of automatic regulation of the 19th and 20th centuries. Trends of the XXI century: smart power supply networks, intelligent power engineering, active-adaptive networks convincingly show that: 1) mathematics has reached a fundamental limit of progress towards describing reality and, we can only talk about saving the knowledge of "piloting" power grids, accumulated by it and automation; 2) mathematical models should cooperate with the heuristic knowledge and accumulated experience of the human operator in hybrid and synergistic systems, both in localize digital distribution substations, sectioned power transmission lines with the use of intelligent power electronics, and as "automatic partners" of operational workers for joint solving tasks and problems of process control at time intervals accessible to human perception, thinking and responding.

Spatial modeling and subject-visual coding by means of cognitive semiotics and geoinformatics in hybrid intelligent systems makes the invisible when "conducting an electric grid orchestra" not just visible, but locally visible, contrasting with the location of static and dynamic resources, and finally situationally visible, which contributes to an instant understanding of the features of the current situation and the accelerated development of operational actions with resources to eliminate the changes and violations that have arisen.

The opposition "subject-operational" knowledge in displaying information on dispatch screens is solved in the correlation of cognitive (redundant) and operational (laconic) images of static and dynamic resources, events and situations, depending on the state and mode of the network and equipment.

For spatial modeling, isographs are used – an extension of the theory of graphs specifying the relation of incidence in topological, geophysical and metric spaces, using set-theoretic and predicative representations.

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8. References

[1] V.Ya. Perminov, "Matematika i real'nost': Gnoseologicheskie problemy matematizacii znaniya" [Mathematics and Reality: Epistemological problems of knowledge mathematization]. Vestnik MGU [MSU Bulletin] (2014) 7(1): 42 – 68.

[2] A.V. Kolesnikov, and etc., Metodologiya i tekhnologiya resheniya slozhnykh zadach metodami funkcional'nykh gibridnykh intellektual'nykh system [Methodology and technology for solving complex problems using functional hybrid intelligent systems], Moscow, IPI RAS, 2007.

[3] I.M. Kondakov, Psikhologiya. Illyustrirovannyj slovar' [Psychology. Illustrated dictionary], St. Petersburg; Moscow, Prajm-EVROZNAK, 2003.

[4] M.A. Elivanova, Kategoriya lokativnosti i ee vyrazhenie v detskoj rechi [The category of locativity and its expression in children's speech], multi-authored monograph “Semanticheskie kategorii v detskoj rechi” [Semantic categories in children's speech], Ed. S.N. Cejtlin - St. Petersburg, Nestor-Istoriya (2007) 1-21.

[5] V.YA. Cvetkov, Prostranstvennye znaniya i prostranstvennaya logika [Spatial knowledge and spatial logic], Informacionnye tekhnologii v nauke, obrazovanii i upravlenii [Information technologies in science, education and management] (2019) 3: 17-26.

[6] S.V. Bulgakov, Osobennosti prostranstvennogo modelirovaniya [Spatial modeling features], Vestnik MGTU MIREHA [MSTU MIREA bulletin] (June 2014) 2(3): 145-155.

[7] A.V. Kolesnikov, Funkcional'nye gibridnye intellektual'nye sistemy vizual'nogo upravleniya [Functional hybrid intelligent visual control systems], Gibridnye i sinergeticheskie intellektual'nye sistemy; materialy IV Vserossijskoj Pospelovskoj konferencii s mezhdunarodnym uchastiem [Hybrid and synergetic intelligent systems: proceedings of the IV All-Russian Pospelov Conference with International Participation], Kaliningrad, BFU im. I. Kanta [BFU named after I. Kant] (2018) 18-81.

[8] M.N. DeMers, Fundamentals of geographic information systems, Moscow, 1999 (in Russ.)
[9] A. Mitchell, The ESRI Guide to GIS Analysis: Geographic Patterns and Relationships v. 1 [A. Ishchuk, I. Chepushtanova, Kiev, ECOMM Co., Stylos, 2000 (in Russ.)].
[10] A.M. Berlyant, Teoriya geoizobrazhenii [Geoimage theory], Moscow, GEOS, 2006.
[11] V.S. Tikunov (ed.), Osnovy geoinformatiki [Fundamentals of geoinformatics]. Book 1, Moscow, tsentr “Akademiya” [centre “Academy”], 2004.
[12] V.S. Tikunov (ed.), Osnovy geoinformatiki [Fundamentals of geoinformatics]. Book 2, Moscow, tsentr “Akademiya” [centre “Academy”], 2004.
[13] Yu.R. Val'kman, V.B. Tarasov, Ot ontologii proektirovaniya k kognitivnoi semiotike [From design ontologies to cognitive semiotics], Ontologiya proektirovaniya [Design Ontology] (2018), vol.8, 1(27): 8-34.
[14] V.Ya. Tsvetkov, Kognitivnaya semiotika i informatsionnoe modelirovanie [Cognitive semiotics and information modeling], Perspektivy Nauki i Obrazovaniya [Prospects of Science and Education] (2016) 6(23): 17-22.
[15] Yu.R. Val'kman, O kognitivnoi semiotike [About cognitive semiotics], Intellektual'nyi analiz informatsii. Sbornik trudov XII mezhdunarodnoi konferentsii im. T.A. Taran [Intellectual analysis of information. Proceedings of the XII International Conference named after T. A. Taran] (IAI-2012, Kiev, May 16-18, 2012), Kiev, Prosvita (2012) 19-30.
[16] A.V. Kolesnikov, S.B. Rumovskaya, A.V. Yasinskii, Predmetno-izobrazitel'noe predstavlenie znanii v tekhnicheskoi semiotike i iskusstvennom intellekte: izografy [Subject-visual representation of knowledge in technical semiotics and artificial intelligence: isographs], Gibridnye i sinergeticheskie sistemy: materialy V Vserossiiskoi Pospelovskoi konferentsii s mezhdunarodnym uchastiem [Hybrid and Synergetic systems: proceedings of the V All-Russian Pospelov Conference with International Participation], scientific electronic publication - Kaliningrad, BFU im. I. Kanta [BFU named after I. Kant] (2020) 155-218.
[17] G.S. Osipov, N.V. Chudova, and etc., Znakovaya kartina mira sub"ekta povedeniya [Symbolic picture of the world of the subject of behavior], Moscow, FIZMATLIT, 2018.
[18] M.N. Burdyaev (ed.), Kognitivnaya mashinnaya grafika v sistemakh kosmicheskogo i meditsinskogo naznacheniya [Cognitive machine graphics in space and medical systems], Moscow, LENARD, 2019.
[19] M.V. Il'in, I.V. Fomin, I smysl, i mera. Semiotika v prostranstve sovremennoi nauki [Both the meaning and the measure. Semiotics in the space of modern science], Politicheskaya nauka [Political Science] (2016) 3:30-46.
[20] D.A. Pospelov, Logiko-lingvisticheskie modeli v sistemakh upravleniya [Logical-linguistic models in control systems], Moscow, Ehnergoatomizdat, 1981.
[21] E. Yu. Kandrashina, L. V. Litvintseva, D. A. Pospelov, Predstavlenie znanii o vremeni i prostranstve v intellektual'nykh sistemakh [Representation of knowledge about time and space in intelligent systems], Ed. D.A. Pospelov, Moscow, Nauka, 1989.
[22] V.Ya. Tsvetkov, Prostranstvennaya logika v geoinformatike [Spatial logic in geoinformatics], Vektor GeONauk [Vector of Geosciences] (2020) 3(2): 91-100.
[23] M.V. Vsevolodova, E.YU. Vladimirskii, Sposoby vyrazheniya prostranstvennykh v sovremennom russkom yazyke [Ways of expressing spatial expressions in the modern Russian language], Moscow, LKI, 2008.
[24] E.V. Martynova, Vyrazhenie semantiki prostranstvennykh otnoshenii det'mi s pomoshch'yu predlozhno-padezhnyi konstruktsii [Expression of the semantics of spatial relations by children with the help of prepositional-nominal constructions], Vestnik CHGPU [ChSPU bulletin] (2008) 4: 261-272.
[25] V.F. Asmus, Logika [Logic], Gosudarstvennoe izdatel'stvo politicheskoi literatury, 1947.
[26] D.A. Pospelov, Situatsionnoe upravlenie: teoriya i praktika [Situational management: theory and practice], Moscow, Nauka, 1986.
[27] S.V. Shpirko, Primenenie prostranstvennoi logiki D.A. Pospelova v zadache vospolneniya prostranstvennoi informatsii, soderzhashcheisya v srednevekovykh tekstakh (na primere istoriko-geograficheskogo traktata Khudud al-'alam) [Application of D. A. Pospelov’s spatial logic in the task of filling in spatial information contained in medieval texts (on the example of the historical

and geographical treatise Hudud al - ' alam)], Istoricheskaya informatika [Historical Computer Science] (2014) (2-3): 94-108.
[28] GISPROEKT. GIS MOEHSK. URL: http://www.gispro.ru/gis-moesk/.
[29] O. Marinicheva, GIS prikhodyat v seti [GIS come online], Ehnergetika i promyshlennost' Rossii [Energy and industry in Russia] (June 2014) 12 (248).
[30] GIS TEK. URL: https://gis-tek.ru/.
[31] O.M. Popova, Postroenie geoinformatsionnoi sistemy ehlektricheskikh setei [Building a geoinformation system of electric networks], Vestnik IRGTU [IrSTU bulletin] (2006) 2 (26): 101-104.
[32] GISINFO. Geoinformatsionnaya sistema "Rosseti" – nadezhnost' i ehffektivnost' upravleniya ehlektrosetevym kompleksom. [Geoinformation system "Rosseti" – reliability and efficiency of management of the electric grid complex]. URL: https://gisinfo.ru/newspages-news-2133-0.
[33] Datum SOFT. GIS monitoringa ehlektrosetevogo kompleksa dlya PAO “MRSK YugA” (PAO “Rosseti YuG”). [GIS of monitoring of electric grid complex for PJSC MRSK Uga (PJSC Rosseti Yug). URL: https://datum-soft.ru/projects/4089/.
[34] V.V. Ryabinin, and etc., Vizualizatsiya kharakteristik ehlektricheskikh setei s pomoshch'yu binirovannykh kart [Visualization of characteristics of electrical networks using combined maps], Vestnik IGEHU [IGEU Bulletin] (2014) 5: 1-8.
[35] S.G. Slyusarenko, and etc., Primenenie GIS-tekhnologii v ehlektroehnergeticheskikh sistemakh [Use of GIS technologies in electric power systems]. Traktat mezhdunarodnoi nauchno-prakticheskoi konferentsii «GEOINFORMATIKA-2000» [The treatise of the international scientific and practical conference " GEOINFORMATIKA-2000»], Tomsk, September 12-14, 2000 - Tomsk, TGU, 2000, pp. 234-236.
[36] A. Seknin, GIS v ehlektroehnergetike. Intellektual'nye ehnergosistemy [GIS in the electric power industry. Intelligent power systems], Informatsionnye sistemy [Information systems] (2014) 1: 26-29.
[37] V.V. Tripulina, Modelirovanie i razrabotka GIS-servisov dlya zadach issledovanii v oblasti ehnergetiki [Modeling and development of GIS services for research tasks in the field of energy], Vychislitel'nye tekhnologii [Computing technologies] (2008) 13 (special issue 1): 78-87.
[38] Federal'nyi NTTS geodezii, kartografii i infrastruktury prostranstvennykh dannykh [Federal STC of Geodesy, Cartography and Spatial Data Infrastructure]. URL: http://cgkipd.ru/.
[39] Geoportal Kaliningradskoi oblasti [Geoportal of the Kaliningrad region]. URL: https://geoportal.gov39.ru/.
[40] A.V. Kolesnikov, Gibridnye intellektual'nye sistemy. Teoriya i tekhnologiya razrabotki [Hybrid intelligent systems. Theory and technology of development], Ed. A.M. Yashin, St. Petersburg, SPbSTU, 2001.
[41] J. Bertin, Semiology of Graphics: diagrams networks maps / translated by W. J. Berg, New York: Esri Press, 2011.
[42] I.G. Zhurkin, and etc., Geoinformatsionnye sistemy [Geoinformation systems], Moscow, KUDITS-PRESS, 2009.
[43] S.L. Savvina, Sredstva vyrazheniya staticheskoi lokalizatsii v russkom yazyke [Means of expressing static localization in the Russian language], Izvestiya gosudarstvennogo pedagogicheskogo universiteta im. A.I. Gertsena [Izvestia: Herzen University Journal of Humanities & Sciences] (2008) 237-241.
[44] A.V. Kolesnikov, N.A. Chemeris, Visual Event 2.0: yazyk programmirovaniya gibridnykh intellektual'nykh sistem i sistema neodnorodnogo modelirovaniya [Visual Event 2.0: programming language of hybrid intelligent systems and the system of heterogeneous modeling], Sbornik traktatov mezhdunarodnoi NK, posvyashchennoi 70-letiyu osnovaniya KGTU [Collection of treatises of the international NC dedicated to the 70th anniversary of the foundation of KSTU], Kaliningrad, KGTU (2000) 241-243.
[45] U. Boumen, Graficheskoe predstavlenie informatsii [Graphical representation of information], Moscow, Mir, 1971.
[46] L.S. Shteinbok, Situatsionnaya tekhnologiya otobrazheniya informatsii [Situational technology of information display], Moscow, Nauchnye tekhnologii, 2017.

[47] S. Buschmann, M. Doller J. Trapp, Real- Time Visualization of Massive Air- Traffic Trajectories , CW'14: Proceedings of the 2014 International Conference on Cyberworlds Santander, Spain, Santander: IEEE (2014) 174-181.
[48] Yandex Service Symbols. URL: https://yandex.ru/support/maps/concept/map.html.
[49] S. Bir, Management science, Moscow, Ehnergiya, 1971 (in Russ.)
[50] O.N. Seliverstova, Semanticheskie tipy predikatov [Semantic types of predicates], Moscow, Nauka, 1982.
[51] Portal ehlektrosetevykh uslug gruppy kompanii "Rosseti" [Portal of electric grid services of the Rosseti Group of Companies]. URL: https://портал-тп.рф/platform/portal/tehprisEE_about_portal.
[52] Akademik. Filosofskaya ehntsiklopediya. Situatsiya [Academician. Philosophical Encyclopedia. Situation]. URL: https://dic.academic.ru/dic.nsf/enc_philosophy/3312/%D1%81%D0%B8%D1%82%D1%83%D0%B0%D1%86%D0%B8%D1%8F.
[53] Kognitivnaya mashinnaya grafika v sistemakh kosmicheskogo i meditsinskogo naznacheniya [Cognitive machine graphics in space and medical systems], Ed. M.N. Burdaev, Moscow, LENARD, 2019.
[54] General'nye plany munitsipal'nykh obrazovanii. Ozerskii gorodskoi okrug [General plans of municipalities. Ozyorsky city district]. URL: https://gov39.ru/vlast/agency/aggradostroenie/genplans/09_ozersk/.
[55] O.A. Masterova, A.V. Barskaya, Ehkspluatatsiya ehlektroehnergeticheskikh sistem i setei [Use of electric power systems and networks], Tomsk, TPU, 2006.