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Searching and Analysis of Interface and Visualization Metaphors

Vladimir L. Averbukh, Mihkail O. Bakhterev, Aleksandr Yu. Baydalin
Institute of Mathematics and Mechanics, Inst. of Math. and Mech., Inst. of Math. and Mech.
Dmitriy Yu. Gorbashevskiy, Damir R. Ismagilov, Alexey Yu. Kazantsev
Inst. of Math. and Mech., Ural State Univercity, Inst. of Math. and Mech.
Polina V. Nebogatikova, Anna V. Popova, Pavel A. Vasev
Ural State Univercity, Ural State Univercity, Inst. of Math. and Mech.
Russia (all)

1. Introduction

This chapter is devoted to problems of interface and visualization metaphors. Really the subject-matter of metaphor is popular in modern literature on HCI and visualization. One can find hundreds interesting articles, books, technical reports and thesises on metaphors in computing. The metaphor matter is discussed regularly at workshops and seminars. The success of metaphors is apparent, all the more a well-known Desktop metaphor, which is widely used on millions and millions computers all over the world. One source of the theory of computer metaphors is classical theory of metaphor, especially the cognitive approach advanced by G. Lakoff and his colleagues. Also the sign nature of the human-computer interface and visualization allows using semiotics in the theory of computer metaphor.
Our interest in theoretical problems of a metaphor is connected with our main goal - to design specialized interactive visual systems as well as quickly. The goals of our researches are to draw up design criteria for "good" human-computer interface and "effective" visualization on the one hand and recommendations for developers of visual systems on the other hand. Our approaches are connected with our experience of design and development of specialized visualization systems including systems of scientific, informational and software visualization. The specialized systems support the decision of certain class of problems by the certain class of users (mathematicians, physicians, sociologists, etc.). Specificity of such systems frequently demands new methods of visualization and interaction that are adequate to the given task and concrete (possibly narrow) user or class of users. The practice of design and development of specialized visualization systems shows necessity of specific metaphors, and a stage of metaphor searching and designing is a part of development process. During design and development process of such systems the following aspects are distinguished:
- Computer Graphics means and means of Human-Computer Interface organization;
- Software Engineering;

- Cognitive aspects.

We consider cognitive aspects of system engineering. Cognitive aspects are the most independent from technology. There are a lot of examples, when failures with "cognitive" components of projects bring to nothing all successes and achievements in computer graphics and software engineering of projects. In connection with this we are interested in language aspects of visualization and human-computer interaction. Metaphor is considered as the source of this language, a basis of representation of visual and dialogue objects and methods of interaction with these objects. We need to search and choose "good" metaphors for specialized systems. We aim to understand how metaphors are constructed, how they work and how users interpret them. The theory of computer metaphor serves to evaluate existing visual interactive systems and to predict properties of new systems at designing stage. However in practice, there are problems both with concrete metaphor searching and with evaluation of their suitability for the given problem and user group.

Below some points of the metaphor theory are considered in connection with computer metaphors. The theory of interface and visualization metaphor is supplemented and defined more exactly. The structural analysis of concrete metaphors is carried out. Bases of the analysis are the concepts of "metaphor action" and "metaphor formula", as well as realizing the logic of metaphor choices and generations. This analysis is necessary to understand the reasons of successes of one and failures of other visualization and visual interface metaphors. In turn, it allows formulating criteria of evaluating of cognitive components of visual systems.

2. Metaphors in HCI

Above we have noted, that the theory of interface and visualization metaphor is based both on the theory of a classical metaphor on semiotics. A lot of researches are devoted to the formal description of the computer metaphor theory and to studying of interface metaphors from these positions. Now concept of metaphor is widely used for the description of concrete decisions in interactive visual systems. We have gathered near two hundreds books, articles, dissertations and technical reports on problematic of computer metaphor. Our literature sources (of course not full) can be subdivided as follows:

- general works on metaphor and semiotics;
- works on theory of interface metaphor;
- works describing the concrete systems but containing issues on metaphor theory;
- works describing the concrete systems and using the elements of metaphor theory;
- works describing the concrete systems where only the concept of metaphor is used;
- works containing the criticism of computer metaphors.

Among these works there are our researches on visualization metaphor theory as well as our specialized visualization systems where the concept of visualization metaphor using for design and development.

Studying of this literature on problems of a computer metaphor allows drawing some conclusions. One of them - the certain consensus on the computer metaphor theory takes place. First of all this consensus consists of the recognition in *cognitive* ***approach*** to metaphor theory as the base of theory of interface metaphor. (This approach is linked with names G. Lakoff and his colleagues (Lakoff & Johnson, 1980), (Lakoff, 1993)).) The cognitive approach to a metaphor considers a metaphor as the basic mental operation, as a way of cognition, structuring and explanation of the world. The metaphor essence consists in interpretation and experience the phenomena of one sort in terms of the phenomena of other sort. Metaphorization is based on interaction structures of source and target domains. During process of metaphorization some objects of target domain are structured on an example of objects of target domain and there is a metaphorical mapping (projection) of one domain onto another. That is the metaphor can be understood as a map from source domain onto target domain, and this map is strongly structured.

Secondly, Peircean semiotics is applied to user-interface metaphor (Barr et al, 2004). (Note in this connection the researches on visual semiotics and semiotics of HCI such authors as P. Andersen, J. Goguen, M. Nadin, C. de Souza (Andersen, 2001), (Goguen, 2004.), (Nadin, 1997), (de Souza, 2005.)

Some other approaches to forming of interface metaphor theory are mentioned. Among them - M. Black's *interactive* model (see, for example, (Gardenfors 1996) and (Blackwell, 2006)) and T. Kuhn's theory of scientific metaphor (see, for example, (Harrison et al 2007), (Travers, 1996)). There is also the consideration of games as a metaphor for interface systems (Stathis & Sergot, 1996). But just Lakoff's and Peirce's approaches are prevailed in forming of interface metaphor theory. The other approaches to describing of interface metaphors are less common.

Now let's copy out the main (or may be more typical and popular) positions of existing interface metaphor theory:

1) A metaphor is a rhetoric figure, whose essence is understanding and experiencing one kind of things in terms of another (Lakoff&Johnson, 1980).

2) M. Johnson defined metaphor as a pervasive mode of understanding by which we project patterns from one domain of experience in order to structure another domain of a different kind. (Johnson,1987).

3) The two domains are commonly called the source and target domains of a metaphor and the metaphorical projection is a mapping from source to target. The target consists of the concepts the words are actually referring to (also said the original idea). The source refers to the concepts in terms of which the intended target concepts are being viewed (the borrowed idea). Conventional metaphors are represented as sets of associations, or relations, between source and target concepts. Source and target concepts usually belong to different domains, and the familiarity with the source domain is exploited to understand the target concepts. The metaphor specifies how the source concepts reflected in the surface language correspond to the various target concepts. It establishes an isomorphism between the target and source domains. Interface metaphors, in this projective view, go beyond explaining unfamiliar domains to novices. They determine how labor is distributed between a user and a system, what concepts a user has to deal with, and in what terms user and system communicate. In short, they structure application domains and organize tasks. (Kuhn W. & Frank A.U., 1991), (Catarci et al, 1996).

4) A metaphor is a device for explaining some concept or thing, ***x***, by asserting its similarity to another concept or thing, ***y***, in the form ***X IS Y***.

The concept being explained is often referred to as the tenor of the metaphor, while the concept doing the explaining is called the vehicle. (Barr et al., 2004)

A typical definition of metaphors might run like this:

Given two domains A and B, taking A as metaphor for B is equivalent to providing a formal mapping from the primitives defining A into the primitives defining B.

Such definition makes the metaphor question a question about representational formats, structural primitives, and the properties of formal mappings. From the standpoint of cognitive "process" these analyses reduce metaphor to primitive pattern matching operations defined over the elements and relations of structural descriptions (Carroll J. & Mack R., 1985) Structure-mapping analysis of metaphor interprets metaphor as mapping between two (graph theoretical expressed) domains, pairing the nodes of each. The relations of these two domains are constrained to be identical (Gentner, D. 1983).
User-interface metaphor is intuitively the application of this device to the user-interface. Thus, a user-interface metaphor is a device for explaining some system functionality or structure (the tenor) by asserting its similarity to another concept or thing already familiar to the user (the vehicle). The key here is that the chosen vehicle is something already familiar to the user and so the intention is to provide a base level of comfort and knowledge without necessarily understanding the underlying system (Barr et al., 2004).
5) For Peirce the sign is a genuine triadic relationship among the elements: the representamen, the object and the interpretant. The representamen refers to the material aspect of the sign and represents the object under certain aspects or "capacities". The sign only means so because the representamen can represent another thing: the object. The interpretant doesn't refer to the interpreter of the sign but it refers to a relational process occurring in the interpreter's mind, associating representamen and object (de Oliveira & Baranauskas 1998).
The interface is defined as a collection of computer-based signs, i.e., the software parts which can be seen or heard, used and interpreted by a community of users (Andersen, P. B. 1997).
The use of semiotics will help to resolve how the metaphor functions or what the metaphor really means.
A metaphor sign involves the interaction in some way of two signs, which are the tenor and the vehicle of the metaphor. The stance we take in this paper is that a metaphor may well be composed of two signs, but can plausibly be treated as a sign in itself as well. Essentially, the meaning of the metaphor intended by its author comprises the object, while the expression of the metaphor itself, usually in language, forms the representamen. An encounter with the representamen leads a reader to form an interpretant, which is what the metaphor is taken to mean by them. (Barr et al, 2004)
5) A metaphor gives the possibility to understand new and complex concepts by means of more familiar (i.e. well-known) ones. This feature has been exploited in the interfaces of several computer systems (Marcello L'Abbate & Matthias Hemmje, 1998)
6) The process of applying our experiences on things that are new to us is called "mapping". Analogy is the most obvious kind of mapping… Metaphors are mappings from source to target domains… Metaphor is the most complex kind of mapping, where the two structures - or concepts - being compared actually explains each other. (Kuhn W. & Frank A.U., 1991), (Olle Torgny 1997) A conceptual metaphor is a set of mappings from a relatively concrete domain to a more abstract domain. Through these mappings, the more abstract domain is more readily understood. (David G. Hendry, 2006). When the domains are specified algebraically, it is natural to use morphisms, which are mappings between algebras, to define metaphorical mappings . (Kuhn W. & Frank A.U., 1991)
7) Image-schemas are image-like reasoning patterns, consisting of a small number of parts and relations, made meaningful by sensori-motor experience. There is a CONTAINER

schema (things that have an inside, an outside and a boundary), a PART-WHOLE schema (something can be seen as a whole or as its constituent parts), a LINK schema (two or more things have a link between them), a SOURCE-PATH-GOAL schema (or sometimes, just a PATH, which goes from a source along a path to a destination). There is an UP-DOWN schema, a BACK-FRONT schema and so on. Schemas are gestalts - structured wholes - that structure our direct experiences. Image-schemas may in fact be the kind of structure which is preserved by interface metaphors. This assumption agrees with Lakoff's invariance hypothesis which claims that image-schemas remain invariant under metaphorical mappings (Kuhn W. & Frank A.U., 1991), (Benyon & Imaz, 1999).

8) The best known formal theory of metaphor and analogy is Gentner's structure mapping theory (Gentner, D. 1983), (Gentner, D. 1989). It describes analogies as mappings between source and target domains, each represented by semantic networks. It does not formalize the mappings themselves, however, and rests on a syntactical distinction of different kinds of relations. While Gentner's theory deals with structural aspects, it neglects the role of tasks in metaphor use. Our formalization addresses these problems by formalizing mappings as morphisms and expressing tasks and actions through algebraic operators and their effects. Describing domains algebraically rather than relationally may only be a syntactic difference; it does, however, allow for relating metaphors to task mappings .

If an image-schema is invariant in a metaphorical mapping, it must be a common part of the source and target domains. It is therefore possible to obtain the algebraic specifications of these domains by extending a common core specification which formalizes an image-schema. Such a process of adding operators to algebraic specifications is called an enrichment. Thus, a formal version of Lakoff's invariance hypothesis is:

For any metaphor, there is an algebraic specification which describes an image-schema or a combination of image-schemas and which can be enriched toward specifications of the source and target domains.

Since an algebraic specification describes a class of algebras or category, image-schemas are formalized as categories. These categories contain the algebras of the source and target domains as well as the morphisms between them . (Kuhn W. & Frank A.U., 1991).

The common perception of the word "formalization" is connected with the derivation of some formulas and equations that describe the phenomenon in analytical form. In this case, formalization is used to describe a series of steps that ensure the correctness of the development of the representation of the metaphor. Metaphor formalization in the design of semantic visualization schemes includes the following basic steps:

- *Identification of the source and target spaces of the metaphor* - the class of forms and the class of features or functions that these forms will represent;

- *Conceptual decomposition of the source and target spaces* produces the set of concepts that describe both sides of the metaphor mapping. As a rule, metaphorical mappings do not occur isolated from one another. They are sometimes organized in hierarchical structures, in which `lower' mappings in the hierarchy inherit the structures of the `higher' mappings. In other words, this means that visualization schemes, which use metaphor are expected to preserve the hierarchical structures of the data that they display. …these are the geometric characteristics of the forms from the source space, and other form attributes like colors, line thickness, shading, etc. and the set of functions and features in the target space associated with these attributes and variations;

- *Identifying the dimensions of the metaphor* along which the metaphor operates. These dimensions constitute the common semantics. …this can be for instance key properties of the form, like symmetry and balance with respect to the center of gravity, that transfer semantics to the corresponding functional elements in the target domain;
- *Establishing semantic links, relations and transformations* between the concepts in both spaces, creating a resemblance between the forms in the source domain and the functions in the target domain. (Simoff 2001)
Formalization by itself, however, is not enough to arrive at useful theories. Concentrating on the mathematical aspects of a theory underlying an implementation can lead designers to neglect usability aspects of the resulting system and can produce undesirable effects at the user interface. Theoretical refinements sometimes burden the users with an additional load of concepts they have to master if they want to use a system effectively. Depending on the tasks and users, some concepts of a formal theory may be completely irrelevant or even unintelligible to users mappings (Werner Kuhn, 1993).
9) The structural formulation of what metaphor is allows us to define many further concepts regarding metaphor relations. [It is defined] a variety of such relations: base specificity, clarity, richness, abstractness, systematicity, validity, exhaustiveness, transparency, and scope.
"Base specificity" is defined as the extent to which the structure of the metaphor base, or source, is understood.
"Clarity" refers to the precision of the node correspondences across the mapping.
"Richness" is the density of predicates carried across the mapping.
"Abstractness" refers to the level at which the relations carried across the mapping are defined. If they are the individual predicates of the base, the mapping is less abstract than if they are relations among predicates in the base.
"Systematicity". Metaphors are "systematic" to the extent that the mapped relations are mutually constrained by membership in some structure of relations.
"Validity". Metaphors are "valid" to the extent that the base relations carry their truth values across the mapping.
"Exhaustiveness. "Base exhaustive" metaphor map each of their relations into target ("target exhaustive" metaphor are defined analogously).
"Transparency". Metaphors are "transparent" to the extent that it is obvious which relations in the base are able to be carried into the target.
"Scope" refers to the extensibility of the mapping.
(Carroll J. & Mack R., 1985)
10) The success of a metaphor depends on having a familiar domain to analogize from and on recognizing enough in the new domain so that some correspondence can be established.
Structural descriptions of corresponding domains in a comparison relation provide only an abstract set of possible mappings. The actual relevance of any of these mappings to a real and usable metaphor depends fundamentally on the needs and goals of the [user]. Put another way, we need to understand the pragmatics of the [given] situation. (Carroll J. & Mack R., 1985)
11) How can we Find Metaphor Candidates? Everybody asks this question and only few researchers or designers have proposed generalizable methods to come up with useful interface metaphors. Can there be systematic approaches to generating metaphors at all? Isn't a good metaphor the result of a strike of creative thought which cannot be planned?

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Clearly, much more can be done in a systematic way than what has been done in this area so far. Metaphors do not fall out of the blue sky. If they should be appropriate for a certain user community in a certain application area, they must have source domains which are meaningful to these people in their work environment. Such meaningful concepts are certain to appear in the language of prospective users, in their work regulations, documentation of existing technology, and many other manifestations of how these people think and act when they do their work. Finding metaphor candidates, therefore, means listening to users, observing their work and behavior, and reading their instructions and regulations. We have all become skeptical, with good reason, about clever ideas of interface designers for fancy metaphors, commands, and icons which are generated late at night while playing around with the latest interface design tool kit. They tend to disappear as fast as they were created. Useful metaphors are the work of design teams which have studied the work flow, tools, language and general culture of users over months or years. Seen in this way, finding metaphor candidates is a central part of task analysis. It can indeed be argued that the selection of metaphors constitutes the essence of task analysis, explaining why there is often much more synthesis than analysis involved in this process. Choosing a metaphor means deciding on the ontology of the user interface, i.e., on the concepts which users will have to master, the objects and operations they get to see, and the work distribution between them and the system. The more complex an application area is, the more time this process will take. A good example is, again, the much discussed desktop metaphor. It took years of very careful analysis and synthesis of work processes, based on detailed observations in actual office work environments, until the design of the Star interface was completed. Then, it took another couple of iterations to make it usable in practice (Kuhn W., 1995).

12) An account of the mechanisms of metaphorical understanding would tell us why one or more metaphors are useful and how they are generated and then used to support [interface]. What Makes a Metaphor Good or Bad? Once metaphor candidates have been found, an engineering design approach requires some kind of evaluation method to be able to select the best candidate among them. In practice, there often seems to be an "obvious" choice and a designer may feel compelled to use it without investigating alternatives. There are some plausible criteria to separate better from worse metaphors in a given context. Starting with qualities which make a metaphor "good" for an application, the first and decisive feature has to be its understandability. If a metaphor is not understandable to the users, it is really no metaphor at all, as its source domain should by definition be familiar. Understandability is not only a matter of the source concepts, however, but also of how these are presented to the users. A second, more subtle criterion is that a metaphor should create a useful ontology for the user's tasks. The ontology of a user interface is the collection of concepts which a user has to master in order to use the system productively. Another way to evaluate interface metaphors is by the suitability of the work distribution that they impose. If a metaphor satisfies these three criteria, it may still be "bad" for a user interface, if it has some undesirable properties. Among them are incomplete mappings from source to target domains. This means that there are either salient source concepts which the user expects to find, but are missing from the interface, or there are abstract user interface concepts not matched to appropriate parts of the source domain. The latter problem is fairly common in practice, confronting the user with a bewildering mix of metaphorical concepts and computer jargon. A second slippery slope is mixing metaphors. From our use of natural

language, we have a fairly good intuition about the possibilities and limitations of mixing metaphors. Simply applying this common sense to the evaluation of metaphor combinations in a user interface would already take care of many problems in existing interfaces. (Werner Kuhn 1995).

Also there are some important and concepts used in the theory of interface (and visualization) metaphor. Among them there are concepts of mental spaces and a mental model.

Mental spaces

Mental spaces provide a medium in which cognitive activities can take place. Cognitive models created through imaginative processes structure those spaces. We think by connecting different mental spaces. So for example, we may have a space that structures our experienced reality, another that is structuring future situations, another fictional situations and so on.

The concept of mental space refers to the partial cognitive structures that emerge when we think and talk. It is in these mental spaces that domains are defined, altered and merged. There is a source mental space, a target mental space and connectors that map elements from both spaces. However, the concepts of mental spaces and connectors apply to more general situations, involving more than two spaces (Benyon & Imaz, 1999).

A mental model

A mental model is a cognitive construct that describes a person's understanding of a particular content domain in the world. This contrasts sharply with much other work in cognitive psychology, which attempts to be domain-independent (Plantings, 1987).

There are three elements that work together in the interface. Two mental models: the user's model, the designer's model and finally the system image. One of the paramount interests next to usability testing of HCI is to improve the design of interfaces in first place. Therefore it is a proven good idea to use prescriptive mental models, so called conceptual models, throughout the design. The design goal is to reach as much as possible congruence of all the mental models (Weidmann, 2004).

The visual metaphor is seen as a transformation between abstract and visual information. In that case, the abstract information is the database schema. Therefore, the main elements of the formalisms are:

1) A data model that captures schemata,
2) A visual model that captures visualizations, and
3) A visual metaphor that is a mapping between data and visual models (Catarci et al, 1996).

Thus, the harmonious enough theory of the interface metaphor takes place, including (alongside with other elements) definitions of basic concepts, the description of metaphor formalization on base of semiotics and algebraic approaches, criterion of "good" metaphors and principles of their choice.

For the practice of applications of the interface and of visualization metaphors there is the following situation. The metaphor is considered in less strict manner, as some basic idea of bridging the gap between different areas (even if strict definitions also take place). Instead of precise metaphor evaluation criteria heuristic approaches are used. Here are rather typical examples of using the metaphor conception in papers on HCI and/or visualization:

i) The mapping from a program model (lower level of abstraction) to an image (higher level of abstraction) is defined through a metaphor, specifying the type of visualization. Most visualization techniques and tools are based on the graph metaphor (including the extensive research on graph layout algorithms). Other initiatives are the representation of programs as 3D city notations, solar systems, video games, nested boxes, 3D Space, Software World, etc. (Panas et al, 2003a), (Knight & Munro 2000). With the help of the metaphor, different views on the program representations are provided. These views are finally illustrated as one picture and can be interactively (Panas et al, 2003b).

ii) The Magic Mirror is a user interface technique that mimics a hand mirror. In addition to providing the optical effect of a real mirror, several non-physical extensions are also proposed. As a metaphor, the Magic Mirror is an intuitive and easy to learn interaction technique (Grosjean & Coquillart 1999).

iii) Our classification distinguishes between two basic structural metaphors differing in terms of the mental model being generated. First the theater metaphor, where the user has a static position and viewpoint and the world around changes. Second the locomotion metaphor, where the user has a dynamic position and will be moved through a structure.

Theater Metaphor

This metaphor resembles typical WIMP interfaces, since the user's viewpoint remains constant. In analogy to a stage portal this is symbolized through a static frame of reference. The 3Ddocument mainly stays in the center of interest. It does not necessarily have to remain in the field of view, but can also exit and reappear like a real actor. Whenever changing action spaces the “set” (i.e. 3D-widgets, displays, decorative elements...) changes, too.

Locomotion Metaphor

The user's viewpoint changes with this metaphor, made visible by a dynamic visual frame of reference (e.g. different rooms or floors). The rooms or action spaces are completely changed along with their interface elements. In some cases 3D-widgets can be shared with other action spaces. 3D-document of the application might remain in the last visited action space or can be taken to the next space. The locomotion metaphor is most suitable for applications consisting of various action spaces with simpler associated sub-tasks (Dachselt 2000).

iv) Roles of variables, which describe stereotypic usages of variables, can be exploited to facilitate teaching introductory programming. This paper describes the evaluation of visual metaphors for roles used in a role-based program animator. The evaluation is based on several criteria: properties of the images, metaphor recognition and grading, and effects on learning. The study demonstrates that as a whole the role metaphors facilitate learning. The results also identify ideas for further elaboration of the individual metaphors. Furthermore, the study suggests that the evaluation of animated metaphors may require special measures (Stutzle & Sajaniemi, 2005).

v) We interpret the rules governing an interactive system as the rules specifying a game. Under this metaphor, interactions made by the participants of an interactive system are interpreted as moves selected by the players of a game (Stathis & Sergot, 1996)

vi) We present WeatherTank, a tangible interface that looks like a vivarium or a diorama, and uses everyday weather metaphors to present information from a variety of domains, e.g., “a storm is brewing” for increasingly stormy weather, indicating upcoming hectic activities in the stock exchange market. WeatherTank represents such wellknown weather metaphors with real wind, clouds, waves, and rain, allowing users to not only see, but also feel information, taking advantage of our skills developed through our lifetimes of physical

world interaction. Metaphors-concrete images that illuminate abstract ideas - are common in user interface design. We propose to use the rich and well-understood natural phenomena of weather as metaphors to represent abstract information from other domains. Many people, irrespective of educational level, literacy, and profession, understand weather metaphors intuitively (Marti et al 2001).
Here are only the small part of hundreds works where the concept of metaphor is used. In our list we can't embrace all cases of computer metaphor using. Beyond our theme there is such interesting application of computer metaphor as system metaphor (or design metaphor) in software projects (especially in "Extreme Programming") (Khaled et al, 2004), (Stubblefield, 1998).
One can recognize that the certain discrepancy between theory and practice takes place. For example, in practice there are no distinctions between metaphors and metonymies (and even between analogies and metaphors) when using in HCI and visualization. Instead of the criteria of metaphor "goodness" designers use the insight when find and/or choose metaphors for their systems. Note, by the way, that some of positions in the interface metaphor theory are based on the general theory of analogy and some of criteria are applicable to every type of mapping but not just to metaphors much less to interface and/or visualization metaphors. On our opinion that is why some of criteria such as precision or completeness of metaphor are redundant. We need to study these metaphors as original phenomenon and to reveal their original characteristics. As in beginning of 90-th we again need to answer such questions as "what are user interface metaphors", "how can we find metaphor candidates", "what makes a metaphor good or bad", etc. (Kuhn, W., 1995). It means we need to supplement the theory of interface and visualization metaphor and to define it more exactly.
Below we'll describe our approach to the of computer metaphor theory.

3. The Theory of Computer Metaphor

In this section our approach to Computer Metaphors (mainly interface metaphors and visualization metaphors) are considered. We try to increase existing approaches and to construct new bases for criteria of metaphor choice and search.
Our main goal is to design "good" interaction visual systems and in this connection we are interested in the problems of a representation of model objects as well as recognition of visual objects and manipulations them.
As it has been noted above, the semiotics is one of the bases of both HCI theory and computer visualization theory (Andersen, 2001), (Goguen, 2004.), (Nadin, 1997). It is obvious that human-computer interface and visualization have the sign and language nature. Each interface and visualization system contains the language as its core. The language is understood as the systematical description of entities under consideration, methods of their representation, modes of changes of visual display, as well as, techniques of manipulations and interaction with them. The language is built upon some basic idea of similarities between application domain entities with visual and dialog objects, i.e., upon a *computer metaphor*. (We use the broad meaning of "metaphor" concept, not dividing it onto analogy or metonymy as it is usually used in practice of interface and visualization design.)
One can consider *mapping* a computer model of the entity under study into some visual representation based on the *mental model* of this entity in the mind of the user and/or the

developer of this visualization system. Also let us consider the conception of *model entity*, i.e., an object of the computer model to be studied, an object whose state and behavior, characteristics, attributes, and features are of interest to the researcher and, hence, are to be mapped (visualized).

The sign nature of the human-computer interface and visualization allows reveal sign systems, determining interactions, visualization and communications. (A *sign system* can be defined as a set of signs together with internal relationships among signs corresponding, in one way or another, to the relationships among denotations.) In these cases relations between object of representation (denotate) and visual sign are easily separated. Defining some context the user or the observer (interpreter) recognizes the idea caused by visualization that is the interpreting idea (interpretant). There are all relations described of *semiosis* (the process of interpreting signs or *sign process*).

The visual interface uses regularly the language based on one or other sign system. Human-computer interaction in this connection may be described precisely as sign process. Visualization also may be described as sign process similarly to human-computer interaction. Interpretation of an individual visual situation, which is outside of some context (as it has been made in some works, for example (Roberts, 2000), (Barr et al., 2004)), is problematic. It is more productive to consider interfaces and visualizations as sign systems. That is to choose a metaphor means to choose a sign system that will be used to define the dialog language of interaction and/or visualization.

Let's define a view as the abstraction of a graphic display, containing specification of visual objects, their attributes, their interpositions, possible dynamics and ways of interaction. It is possible to consider a view as standard or ad hoc techniques of visual data presentation, some kind of, visual procedures, which after realization in concrete visual environments and, after substitution of the real data is output on some graphic devices. In such "procedure" (that is the view) possible changes of images, including animation, and allowable ways of interactions with a picture can be provided. Changes of significant and meaning pictures during possible interaction with the image are here the external side of visualization. These pictures (concrete graphical displays) are a realization of an abstract concept of a view. For example, Cartesian ("precomputer") data visualization metaphor generates a function graph as the view. In turn after substitution of the data (x and y coordinates) the real curves on a plane are displayed.

The set of the given system views can be considered as a vocabulary of some visual (or visualization in case of computer visualization systems) language, whereas as grammar it is possible to consider rules of formation the concrete displays and specifying a sequence of image changes. Thus, it is realized with reasonable facility a separation of language elements. Semiotics analysis of the visual (visualization) language requires correct revealing of its spatial syntax and semantics. But it is especially important the description of true visualization languages pragmatics. The problem of pragmatics is tightly related to the fact that perception of the visual text is subjective and is dependent on cultural, psychological, and even physiological factors.

Interface metaphor is considered as the basic idea of likening between interactive objects and model objects of the application domain. Its role is to promote the best understanding of semantics of interaction, and also to determine the visual representation of dialog objects and a set of user manipulations with them.

Specificity of visualization, as independent discipline in frameworks of Computer Sciences, demands the distinction between visualization metaphors and interface metaphors. The concept of visualization metaphor is defined for generalization of metaphor using cases in all domains of Computer Visualization.

Visualization metaphor is considered as a map establishing the correspondence between concepts and objects of the application domain under modeling and a system of some similarities and analogies. This map generates a set of views and a set of methods for communication with visual objects. We consider the metaphoricalness of any visualization. *(In our opinion there are no "metaphorless" visualizations of computer models and program entities* (Averbukh 2001)
Thus, one can define a computer metaphor as a mapping from concepts and objects of the application domain under modeling to a system of similarities and analogies generating a set of views and a set of techniques for interaction with and manipulation by visual objects.

In terms of semiotics the metaphor is something dynamic, in contrast to a stable sign. We can describe a metaphor as the act or the process of a designation of one concept by means of a sign, traditionally connected to other concept.
Another function of a metaphor is to determine the context for a correct interpretation of language elements, and to reveal the sense of *visual texts*. Thus, interface and visualization metaphors provide understanding represented entities of the application domain, and also metaphors help to create new entities based on the internal metaphor logic.
The conception of metaphor dominating at the moment is based on representing phenomena that are new or rather untypical for the user by means of phenomena familiar from everyday life; the latter phenomena must possess the same main properties as the phenomena they explain (Tscheligi & Musil 1994). Thereby constraints of metaphor habitualness and completeness are brought forth (Richards et al, 1994). Certainly, the appeal to ordinary human experience and interest activization while using habitual analogies facilitates understanding and learning of basic moments of the source phenomenon or process. But practice of the use of visual interface metaphors gives examples of habitual and full metaphors in which designer has achieved scrupulous conformity between entities of source and target domains and excellent recognition of almost all metaphorical objects. However, these metaphors may appear practically useless because of their bulkiness or occurrences additional and undesirable analogies connected to ordinary things. On the other hand there is a set of examples obviously incomplete, but fruitful metaphors.
So when does the metaphor work well? Examples show, that not only in that case when familiar concepts and images are used. Here it is possible the occurrence of additional, "parasitic" senses. Users may connect these senses with real concepts and images harmful to interpretation. Requirement of completeness of mapping from source domain onto target domain also may not always be suitable. Metaphors are successful, when their usages reduce the complete abstractiveness of computer modeling, including the abstractiveness of user interface with the system. Interpretation of visualization and the interactive manipulations constructed on the basis of the given metaphor, reconstructs (or creates anew) for users some mental structures in which the picture of the phenomena is represented. As a matter of fact a metaphor designs for the user some world frequently by means of objects, concepts or operations, not existing in a reality, creating as though "magic" opportunities for the user. Logics of new reality on the one hand reflect user ideas about the interface and objects of the modeled domain, and on the other - should coincide

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(or to be close) with logic of development of processes and changes of objects in source domain, including logics of user activity.

We propose the approach to the understanding of metaphor as a main principle of mapping an application domain to visual universe. The understanding of metaphors as mapping from source to target domains is incomplete at least in case of interface and visualization metaphors. We offer more complex mechanism, which underlies functioning of metaphors. Our approach differs from traditional ones that in its frameworks the metaphor generates some independent metaphor domain at the expense of correspondence that puts to objects of target domain some objects from the source domain. And more exactly, structures and/or characteristics of objects from target domain are put in the correspondence structures and characteristics of objects from source domain. Cite an example of a classical metaphor LIFE IS A JOURNEY, where LIFE is target domain, and JOURNEY is source domain. Some structures of JOURNEY (beginning, ascent, descent, end, etc.) are considered in the given metaphor as a basis for the description of life structure. Similarly in other classical metaphor RICHARD - THE LION some lion qualities (for example, courage, but not tail, fangs, and claws) are transferred on a human being, who now becomes in frameworks of the metaphor domain.

An action of visualization metaphor consists of extractions of structures from target domain on the base of certain structures from source domain and transfers them in metaphor domain, which in this case has a visual nature. (Metaphorically speaking, it is possible to compare the action of a metaphor with the action of messenger RNA in molecular biology.) The visualization metaphor is mapping (more exactly operator) to certain visualization world, where unshaped objects get its visual presentations.

(There are the similar approaches to metaphor understanding, see for example (Old & Priss, 2001) or (Turner & Fauconnier, 1995). Note also that our approach is based on initial understanding of metaphorical processes. Compare with Lakoff's point of view: "*A metaphor consists of the projection of one schema (the source domain of the metaphor) onto another schema (the target domain of the metaphor). What is projected is the cognitive topology of the source domain, that is the slots in the source domain as well as their relation with each other*." (Lakoff & Johnson 1980), (Lakoff, 1993).

As we noted above computer metaphors promote the best understanding of interaction and/or visualization semantics, as well as provide visual representation of the appropriate objects and determine the user's manipulations set. A metaphor, considered as a basis of the sign system, underlies in a basis of a dialog visualization language in its turn. User formulates the problem with the help of this language and achieves its solving from the computer. The metaphor helps to describe abstraction, structures understanding of new applied area, but also assigns dialog [visual] language objects.

The use of metaphors should increase expressiveness of objects under investigation. To achieve it objects of target domain (with a set of structures, properties) are selected. As this takes place not all objects are chosen (and even not all their characteristic or structure elements), but only that, which are under interest most of all. Analogues for these objects (by way of structures, qualitative properties) are searched in source domain. Further the following operation takes place. Object of target domain together with object from source domain are located in *metaphorical domain*, or more exact in doing so the metaphorical domain is generated. In this domain the investigated object now starts to function. (It is possible to consider, that it is already a new object of a new domain.) The *metaphorical* *domain* gets autonomy from domains generated it. Many properties of its objects only mediately are connected (if at all are connected) to properties of source domain objects. There is a new logic of development metaphorical domain. So, for example, the use of the scientific metaphor of an electromagnetic field its intensity is studied. But it is obviously absent on a field of wheat. In that specific case of visualization metaphors mapping to some world of visualization, where imageless objects obtain their visual representations, takes place.

There are the questions - what are nature and structure of metaphorical domain; how its generation is produced? The natural answer to them is connected to understanding of that the consideration of a metaphor as a sign or as a pair of signs is not fruitful. First of all the metaphor generates some sign system, that is integral sign set, in which existing internal relations between signs somehow map relations between designates. Our metaphorical domain as a matter of fact is a sign system.

The understanding of *a metaphor as a sign system* gives us a basis for evaluations of metaphors offered in concrete cases. If the used affinity (comparison or a set of comparisons) matches the *systemness* requirements, then we may speak about existence of a useful metaphor. If not, if condition changes of source domain objects are connected with changes of target domain objects poorly, then such comparisons usage can't help us to understand an investigated situation better. (See the approach to semiotic model of interface metaphor in**.** (Barr et al., 2004).)

In case of a metaphor the generation of a sign system is possible to consider as the adaptation of two metaphor operators, the basic:

"*Let A is similar to B*"

and the additional operator:

"*The following attributes /elements/characteristics of A are selected for assimilation to the following attributes /elements/characteristics of B*"

Where ***A*** is a source domain, and ***B*** is a target domain.

The analysis of the use of visual interaction systems reveals that the metaphor has a "focus" making the greatest impact on the user of the visual language generated by this metaphor. Sometimes, the metaphor focus is founded upon dissimilarity between metaphoric and model entities. In other cases, the metaphor affects the user by placing an object of the metaphor to a semantic context unusual to this object. Note possibilities of presence several foci in metaphors and absences focus in the concrete metaphor. Also note that focus of the metaphor is always perceived subjectively and can be missed by some particular user.

The computer metaphor can be specified as a set consisting of the following parts:

· imagery of the metaphor;

· operations directed by metaphor both animation operations and user's manipulations (in degenerated case the observation may be considered as these operations);

· the set of similarities between model and metaphoric entities or elements of semantic discrepancy;

· the focus of the metaphor responsible for the greatest part of the impact the metaphor makes on the user.

Now when our extended approach to metaphor meaning was described, in the next section we'll consider our approach to metaphor generation.

4. Metaphors Generation

In this section the scheme of metaphors generation is considered. Note that this scheme is suitable both for computer, and for literary and rhetorical metaphors. It is necessary to determine relation between metaphor and target system of meanings, for which metaphor was formed. This relation might be expressed in the terms of "meanmarks".

Let's start with an example of a well-known metaphor "RICHARD - the LION". In this case notion "RICHARD" is the object of methaphorization. Some his qualities, in particular, bravery, nobleness, force, etc. are well known. There is some image of Richard [king] in our mind, along with insights about bravery, nobleness, force etc. Connections between Richard's image and these notions take place, so one can write down:

Richard - brave;

Richard - noble;

Richard - strong.

Note, that Richard is only simple name, which may be turned off the real world, and actually, is really free label (as, for example, "true" in classical logic). In the same time the label "brave" means an opportunity to attach the other labels or labels to a subject, or (may be) vice versa their obligatory absence. That's mean, that "brave" is the true conceptual label having the tree of implications, and as well as the tree of preconditions. If to say from the theory aspect side, one can consider it as the target domain of a metaphor. The goal here is to define a relation between the metaphor and the target system of meanings, for which the metaphor was formed. This relation might be expressed in the terms of "meanmarks". To define what meanmark is, let us consider the word "brave". The meaning of that word may be established through ***if-then*** (implication) relation of it to other words. The implication is important because it is a base for reasoning, and metaphors assist the process of reasoning. For the word "brave" one may define outgoing implications. For instance, if ***A*** is "brave" then ***A*** is "not timid". This relation is denoted with →, in the following form as *"brave" → "not timid"*. Besides outgoing arrows every word has incoming ones. So the following object emerges. ***{I}*** → "brave" → ***{O}***, where ***{I}*** is set of words implying "brave" and ***{O}*** is set of those which are implied by "brave" itself. Now the graph of such implications can be considered, and it is assumed here that the topology of graph's paths passing through node defines mean of that node. Meanmark is simple the label for node in such oriented graph. The graph may not be the graph of implication relations of words; it may depict any such relation.

We use a symbol arrow (→) to describe concepts sequence in this case. This symbol, against formal logic, designates what concepts entail the following concepts, which may be attached to the object under consideration. For example:

Richard → brave, strong; king;

or

there are red and dark blue and green → there is motley.

Concept under metaphorization is considered here as a way of meanmarks ascription to various entities, as interrelation of this meanmarks set. It's revealed - what meanmarks with what are connected in our cogitative metaphorization concepts model. Also it's detected following levels of arrows (the second, the third, the fourth etc.) that stand up for each of meanmarks in the given conceptual system. It turns out the graph consisting of meanmarks. This graph may be covered on a graph consisting of meanmarks from source domain of metaphor. It is obvious, that the sets of meanmarks in these graphs are differing, but their general structures are similar. Both metaphorical system of meanings and target system have such graphs which show how meanings are connected within them. According to that representation the correspondence between meanings at target system and meanings at metaphor can be established through homomorphism from target system meanmarks graph onto meanmarks graph of metaphor.

If we want to illustrate the target system “King Richard is brave”, firstly we must define meanmarks graph of that system. It is simple enough: “Richard → king, brave”. But the meanmarks “king” and “brave” mean nothing without their language contexts: incoming and outgoing implications in the system of meanings of English. It is very difficult to find meanmarks in some graphs which will have the same topology of implications as “king”: and “brave” in that system. So the required metaphor should include both these meanmarks. We are looking now for “somebody” → king, brave. And, of course “somebody” is “Lion”.

So the following object appears in the general case:

{I} → M → {O},

where ***M*** - considered concept; ***{I}*** - set of concepts, implying ***M***; and ***{O}*** - set of concepts, generated by ***M***.

When methaphorization proceed, the graph of meanmarks for a source domain is determined. Searching of a metaphor - is searching of the structure of interrelations which are similar to structure of interrelations in the target domain. On covering (*not exact, not one to one*) it may become, that it will be necessary to remove some bottom levels. But the additional level absent in target domain may appear. Exactly this second meanmark system with its interrelations is our metaphor to the object considered originally. It may be much more interrelations between concepts in the metaphorical system than in the source. Note that some interrelations may correspond to those arrows which are present also in the first set, but just wasn't noticed up before the metaphor construction. And here they can be seen obviously. In a considered example the required structure is “LION”, with traditionally implied bravery, nobleness, force. (Here we should notice that all these properties basically differ from similar, inherent to Richard).

The suggested model may also help to describe how metaphor allows establishing new properties of target system. One can consider implication dependence graphs not only for words, but also for other similar dependences in the same way.

Let's assume that we have certain time sequence of values ***{X}***. That is ***{X}*** is a set of elements with one linear discrete coordinate and some value. Problem of presentation of this sequence is raised. For example, let's transform these values into music notes with certain melody. It is possible because notes may be interpreted as values, and duration of music notes is always discrete. Then:

Melody → time sequence of notes → a set of elements with one linear discrete coordinate and a certain value.

Recognition ***{X}*** through a similar metaphor may lead to interesting conclusions. The sequence of notes has the special property - notes may compose (or not) beautiful melodies. And if our way of formal transformation values ***{X}*** to notes may generate melody, that, probably, ***{X}*** has interesting properties, which may be found out by means of a metaphor. (One can consider sonification as a special form of visualization see, for example, (Reed et al, 1995), (Osawa, 1998). There are examples of cognitive visualization with music in (Zenkin1991)..)

The process of metaphor generation (metaphorization) first of all includes (may be implicit) analysis of target domain of the future metaphor. The hierarchical structure of object interrelations of target domain and their properties is revealed on a basis of the metaphor objects and its properties. At the following stage a source domain and its main object are searched. Criteria of a choice are criteria of metaphor quality.

Firstly, the main object of a source domain should have the properties, similar (closed) to properties of metaphorization object. The structure of these object interrelations and its properties should be *similar* to structure of interrelations of object under metaphorization and its properties, at least on the first level of a structural tree. Secondly, a *source domain* should be **visualized**. *That's mean that the nature of the source domain should be like, that its objects have dimension, extent, length, form, color or other visual characteristics.* (For example - a metaphor of the railway for the functional description of operational systems.)

The person distinguishes any general logic in a picture, breaking it on the set (perhaps enclosed) of fragments, abstracting from minor elements. One can consider the structures of user's internal mental model. In these structures (so called "representative cognitive structures") images of external world phenomena and inward habit are presented (Chuprikova, 2003). Thus, there is the set of structures including cognitive structures, structures of entities under analysis and structures of visual objects and images. It is necessary to support conformity between these three types of visualization structures.

"Visualizeness" (in a broad sense) of source domain provides the interpretation. A process of interpretation is exactly the generation of representative cognitive structures on base of visual images. This process is inverse or more exactly dual to visualizations. Similarly to visualization principles the interpretation principles should exist. So, the metaphor's quality is connected with an opportunity of easy interpretation of the [visual] language, which is generated by this metaphor. Also the visualizeness requirement is connected with the known for a long time criterion of "good" metaphorization - habitualness, recognition of source domain objects. (The concept of habitualness and recognition in the specialized systems of the human-computer interface should be connected mostly not with everyday realities, but with potential user activity in that sphere for which the interactive system is created).

The analysis of a source domain is carried out at the next stage of methaphorization process. On the basis of the interrelations analysis and dependences in the context of a source domain, as well as on the basis of analogies with them, both the methaphorization the analysis of the object and its properties is carried out. Objects dependences in the context of target domain are revealed. It is necessary for a source domain to have the deeper structure of interrelations than target domain in order to search for new dependences in the target domain. It's one of the factors of a "successful" metaphor. (See also the examples of metaphors in (Barbosa & de Souza 2000).) It's clear, that the metaphor's success is connected first of all with interrelations concepts structure of a source domain and with a possibility to obtain on its base the new understanding of dependences in the target domain that was of interest to us initially.

The duality of interpretation and visualization processes (or any other form of representation) is shown here through a metaphor. Sign process in visual interactive systems (or more exact part of this process connected with the interface interpretation) is supported through metaphor action. Metaphor action and, in particular, the user reaction to properties and dependences carried out at objects of metaphorization are connected with imposing of rich structures of interrelations concepts of a source domain on a target domain.

5. Metaphor Analysis

Some different interface and visualization metaphors are analyzed in this section. These metaphors include popular "Desktop" metaphor, "room" metaphor, and also metaphors used in highly specialized scientific and information visualization systems. We paid attention on genesis of metaphors, opportunities of data presentation and manipulation using concrete metaphors, potential properties of metaphorical objects, and also potential opportunities of user interpretation of these objects and manipulations with them. The purpose of analysis is to reveal structures of successful metaphors and to build a basis for comparison and evaluation of metaphors. Such concepts as "metaphor action" and "metaphor formula" are considered to construct the basis of analysis (Averbukh et al, 2007).

5.1 Metaphor Action and Metaphor Formula

Let's define the concept "metaphor action". This characteristic is constructed by answers to the following questions:
"How can this metaphor assist to represent the information? "
"How can this metaphor assist to interact with data or to manipulate them? "
"What properties of metaphorical objects (that is visual and/or dialogue objects generated by the metaphor) take place?"
"What actions or ideas are arisen from the process of the user interaction (including observations of pictures) with metaphorical objects?"
It is possible to construct a "formula" of metaphor actions. **The metaphor "formula" includes simplified descriptions of source and target domains, an idea of likening using in the metaphor and results of metaphor actions.**
We begin our analysis with the most popular "Desktop" metaphor. (Note, that one of the first works on the interface metaphor formalization was dedicated to this metaphor and was published as 1991 (Kuhn W. & Frank A.U. 1991))
In the case of desktop metaphor the formula may be written as follows:
Source domain: Desk with folders containing documents (documents are structured, but folders may be disordered);
Target domain: Office automation system;
Idea of likening: "Folders with papers" = "structure of the data, a set of files";
"Opening of a folder " = "demonstration of file structures and/or files";
"Processing of documents" = "execution of functions, by means commands of the visual language".
Result: The direct access to data structures by means manipulations of icons placed on the screen; calls of some [user] predetermined functions by means a visual dialog language.
Microsoft Windows uses the extended version of this metaphor.
Addition of source domain:
A desk is combined with control panel where starting buttons are placed.
Besides the "*magic*" idea is added: All actions within the framework of system are made by means of ***double click*** on icons.
Result: icons that can represent as data structures as programs calls.

There is also one more idea - opening of new windows when program executions are begun. One can speak about carrying out of "metaphorical" interface space, constructed on the basis of desktop realities. But not all entities of real desktops (the source domain of the metaphor), which are richer and poorer than metaphorical objects in the same time, were equally useful in new metaphorical space. Often icons moving on the screen are needed only for its grouping and for concrete user work convenience. Images of folders do not play a main role in users' actions with operational system and frequently they are not placed on "desktop". But the major value (not having analogues in initial area) double "click" using for program starts has obtained. Usually double "click" results in new window opening, and, in Internet-browsers case windows are opened almost in literal sense. In result we have logical commands system of visual (iconic) language, based on basic double icon "click" operation.
The desktop metaphor became a basis of comfortable and clear users interface. Doubtless, the metaphor's success connected not only with natural icon figurativeness, clear users, but also with logicality and systemness of the visual dialog language.

5.2 Metaphor Properties

One can consider "room" metaphor as development of "desktop" metaphor. Really at first realizations of this three-dimensional metaphor for office automation systems were simple extensions of desktop successes. Then the room metaphor got its independent value and was actively used in human-computer interface systems and the software visualization (Greenberg & Roseman, 1998). The other three-dimensional metaphor - a "landscape" metaphor is also actively used in systems of software visualization and information visualization (Balzer et al, 2004), (Charters et al, 2002).
In case of "room" metaphor we can't write the full metaphor formula because there are no a common application area, successful and convincing examples of its usage, and, that is there is no a unity of target domain. However we shall result the review of ***properties*** of room metaphor. Realizations of this metaphor are characterized often by a combination of three-dimensional space of the room with bidimensionality of objects, placed on its "walls", a "ceiling" or a "floor". Such combination on the one hand preserves principles of structural correspondence between model entities and visual objects, on the other - provides successful spatial placement of images. (See for example (Reed et al, 1995) and (Bajdalin & Ismagilov 2006).)
Let's carry out the analysis of a room metaphor from two positions: the room metaphor itself and how it is possible to represent the information with its help.
The room metaphor possesses the following properties:
1. Ability to contain any objects inside itself.
The room not only represents separate object, but also is the container for others ones.
2. Restriction of a perception context. Objects inside a room are considered in a separation from "external worlds".
3. Closeness. There are no any additional elements to use Room metaphor (excepting possible inner objects).
4. Inclusion in structure. It is possible "to build buildings of rooms", that is to consider set of rooms. Therefore the room may be an element of construction of some complex construction.

5. Naturalness of a metaphor. The room is natural metaphor, with presence of corresponding objects in the real world. Functionality and characteristics of real objects are transferred in the virtual world with only minor extended understanding.
(See also analysis of "room" metaphor properties in (Dieberger, 1994).)
The "landscape" metaphor and "city" metaphor (which may be considered as the variant of landscape) are well-known in information and software visualization. This spatial metaphor can show for example structures of program projects as a map of some district. Components of the software are represented as the geographical conventions having an exact spatial site in geographical space. Such map may serve as fine means for development of projects, and also as means for visualization of program executions. (See (Balzer et al, 2004) for the full survey of landscape metaphor using in Software Engineering.) Our analysis shows following metaphor properties:
1. An unlimited context.
In case of landscape metaphor user's context is not limited by any special means. As result, an user needs in additional efforts to identify an object among set of others.
2. Naturalness of a metaphor.
Naturalness of a metaphor reduces efforts on interpretation of the resulting image. With reference to a landscape metaphor one can mention additionally to naturalness of spatial orientation, also naturalness of navigation. That is why the landscape metaphor is a good choice for using in virtual reality systems.
3. "Nesting" of landscapes, the organization of internal structure
The landscape metaphor structures the data, "putting" them in larger components.
4. Clues
The landscape metaphor may use for representing of large volumes homogeneous in visual sense data. In this case it is necessary clue elements which are "starting points" for user interpretation of complex data. For example these clues may use in debuggers to represent erroneous or other "especial" elements.
Let's note also, that the more is the volume of data the more expedient is using of the "landscape" metaphor. Thus, the landscape metaphor is good for using in debuggers and performance analysis systems.
These properties of metaphors are taken into consideration when real systems are designed for constructing ***views*** with rich methods of information representation, in particular, by means of objects accommodation inside volumes, changes of space characteristics and/or objects, etc. Landscape metaphor is used actively in visualization environments with virtual reality applying.
Below we'll show how this analysis turns out to be useful in development of specialized visual systems on the basis of new computer metaphors.

5.3 Metaphors in Specialized Visualization Systems

In the majority of the specialized visualization systems the representations of abstract per se mathematical, program, or information objects takes place. There are cases, when existing visualization methods are not applicable. Therefore search of source metaphorical domains for them is rather serious problem. So, it is necessary to search for visualization metaphor and to build a view set on its basis, including additional, assisting interpretations visual objects, and also the techniques for manipulation of these objects. There is our experience of search of new metaphors for scientific, information and software visualization systems.

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5.3.1 Germ Metaphor

Let's consider the following example of abstract metaphor which is used in visualization of one type of 4-dimensional datasets. These datasets are the result of High Performance Computer modeling of some chemical processes. It is obvious that there is no natural way to represent multidimensional sets. Another problem was that typical dataset is relatively large - about 1 million 4D points. After long research, the following metaphor was found useful. It was known that original dataset have one structural aspect, which allows making projection of 4D data onto 2D surface using first two coordinates of point and cutting out two last. For each point on this 2D surface, we can construct corresponding "germ" - another 2D surface formed by coordinates wiped during projection. Let us explain it. Original dataset contains ***{(x,y,u,v)}*** values. We remove ***(u,v)*** coordinates and thus get another dataset: ***{(x,y)}***. Each ***(x,y)*** pair of this new dataset has a corresponding set of ***(u,v)*** values. This ***{(u,v}}*** set is called "germ" of particular ***(x,y)*** point. The ***{(x,y)}*** set is called "projection".

- First, user can choose any point on projection and visually see its germ.
- Secondly, germ's properties such as width, height, radius, element's count are useful. We show these properties on a projection by color. User chooses which property he wants to visualize and sees colored projection immediately. This allows him to see the whole picture of data distribution.

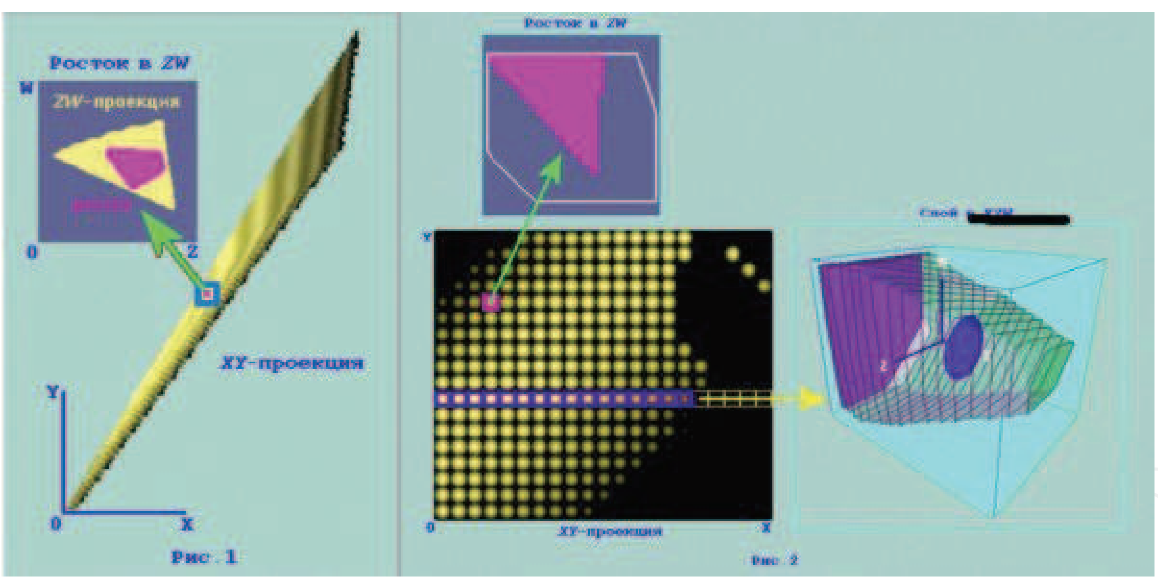

Fig. 1. The Germ in visualization of 4D set

This simple scheme of interaction allowed user to navigate inside original 4D dataset and to perceive data after each computational experiment.

One important feature of this example is that germ object has no analogies nor in application area nor in mathematical model. In spite of its abstract nature the "germ" metaphor became actually usable in practice.

Note in the metaphor analysis the abstractness of applied area models, and the abstractness of the figurativeness used in the visualization. Interpretation is made not by recognition of known images and processes, but via possibility to examine image changes in connected view areas (projection and germ) during interoperation with the system. This connection is made by user manipulation with projection when he selects current point and sees its corresponding germ.

The construction of visualization model was based on knowledge of mathematical structure of original dataset. This allowed to escape rendering difficulties - we never render 4d object as is. Metaphor's idea was created specifically for this datasets structure and nature. Implementation of this idea has allowed to achieve new results in chemical research being made (Vasev & Pervalov, 2001). (See Figure 1).

5.3.2 Molecula Metaphor

Call graphs are used in Software Visualization for performance tuning of parallel and distributed computing. They allow to observer which program functions used most part of processor time. Three-dimensional visualization techniques may improve the quality of graph structure perception. Suggested idea is to search analogies with natural objects. Let's place in nodes-functions (which is usually represented like spheres) an electrostatic charge (Averbuh et al, 2004).

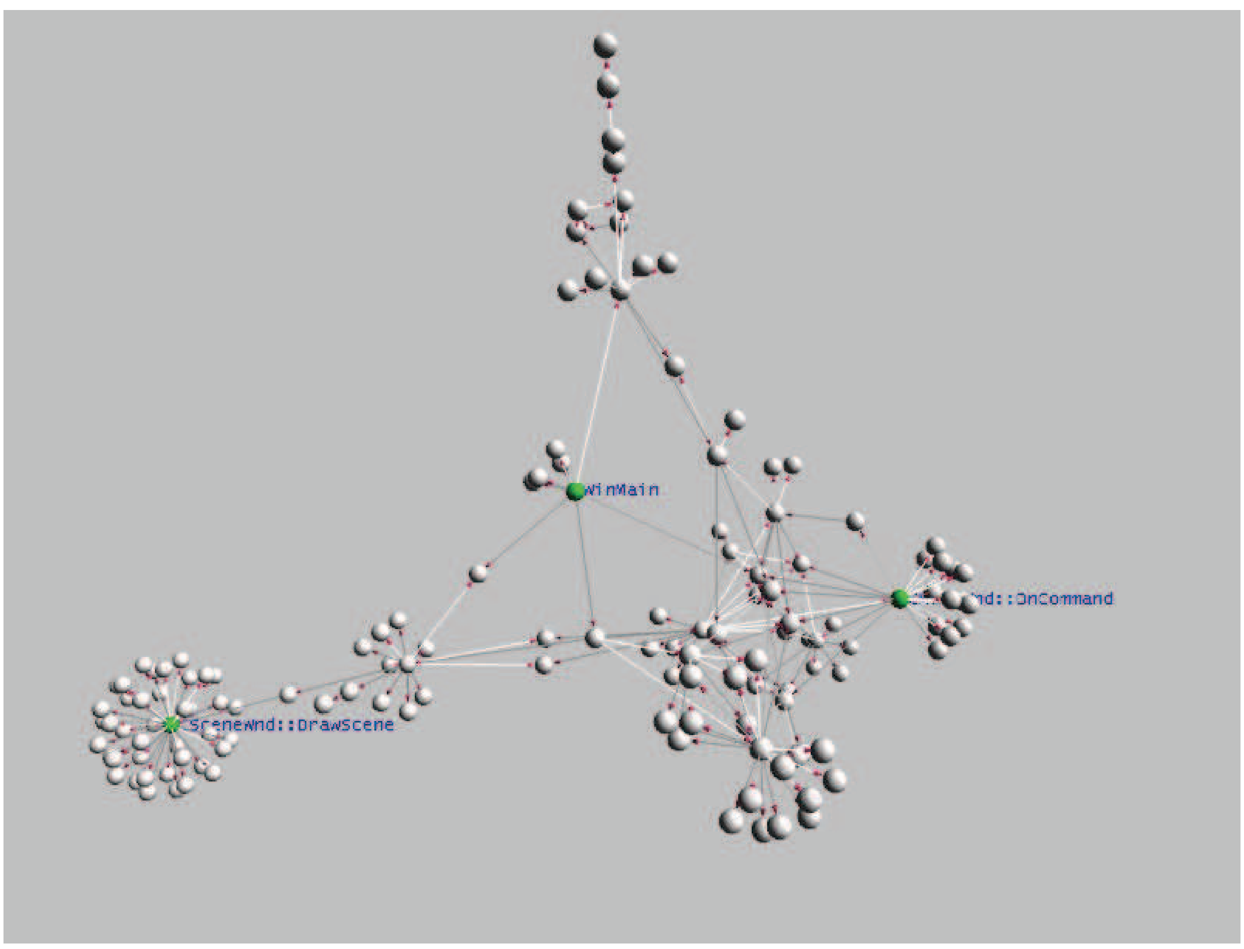

Fig. 2. Call graph of "Callgraph drawing" program

Connections between nodes are replaced by elastic interaction. Let's name the metaphor "a molecule metaphor" because at the given approach the visualization similar to the structure of benzol molecules. Thus there are two types of interactions: springy between bound nodes and electrostatic between all other nodes-“atoms”'. Electrostatic interaction may reflect temporary features of the calling functions, then springy - a number of calls. Consideration of the ″molecule″ energy allows us to construct the effective drawing algorithm for about thousand of objects. The displays meet the symmetry criteria. Animation (molecule rotation) allows exploring graph structure better. Color may be used for accentuation of interesting features of visualized graphs. The molecule metaphor is constructed on analogies to natural objects. The graph structure is looked over easily and is distinctly perceived and interpreted by the person, not demanding special intellectual efforts. At the subsequent analysis and algorithm modification it was found out that the molecule metaphor may be used successfully at visualization of large databases, and in general at representation large systems structures (See Figure 2). Thus, the effect of metaphor “reverse motion” took place in this case when properties of the metaphor are investigated, and then the target domain (and new application) for this metaphor may be found. Such approaches to metaphor construction based on “physical” conceptions are popular in Software Visualization and Graph visualization systems (Osawa, 1998), (Malloy & Power, 2005). Note also the similarity of visualization in (Malloy & Power, 2005) and (Averbuh et al, 2004).

5.3.3 Magic Lancet Metaphor

The search of effective interface led to the metaphor of human in medical information system - “a human figure in a glass cube” (Averbuh et al, 2005). In this case three-dimensional model of a human body is displayed and there are an opportunity to make visible or invisible those or other systems of an organism, for example skin integument, skeleton, nervous and blood systems, etc. Information inquiry may represent as “*semantic immersing”* to the human organism. For example circulatory system, the digestive apparatus or some other organs connected in the context of any disease, may be shown. Something like a set of semantic filters or the special virtual (“magic”) glasses, allowing to see and to isolate, for example, the ill organ with the adjoining struck tissue, turns out. Figurativeness of this metaphor is natural has three-dimensional representation. Figurativeness of this metaphor is natural has three-dimensional reflection. Due to a semantic filtration, the user obtains additional opportunities at data output that considerably reduces manipulations amount necessary for information inquiry. However without the “manipulator”, that is some device, allowing operating in this metaphor context, realization of systems on its base is pretty difficult. As an additional manipulator's metaphor the idea of “magic lancet” is offered. “Lancet” allows “to cut” this or that organism area for the profound exploring. During any human organism object “cutting”, all physical changes are visualized, as if we did it in a reality. On the other hand, one “cut” is not enough sometimes. Semantic immersing allows to come nearer to object as far as it will be necessary, passing through some systems of an organism, making it invisible and visible again. This property helps us to obtain more exact medical data visualization. In case of a combination the “magic lancet” metaphor with three-dimensional model of human body, we may obtain the virtual model of operations. On basis of these metaphors the prototype system of information visualization for the medical purposes is realized now (See Figures 3). Systems based on this metaphor may be used for example for surgery learning.

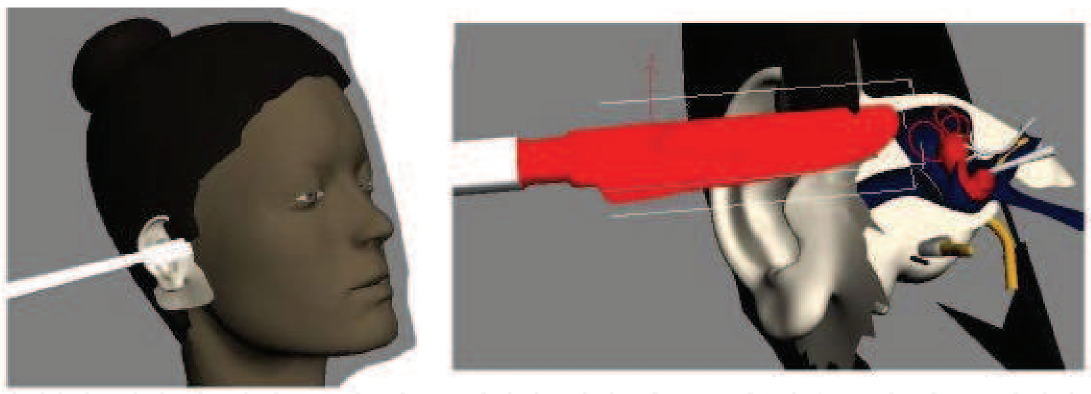

Fig. 3. Screenshots of "Magic Lancet" System

5.3.4 Using of Local Metaphors

In a number of interactive systems several interface metaphors are used at once. It can be metaphors for various widgets, or even metaphors of separate operations. Sometimes a set of additional metaphors is created for a basic metaphor enhancement. It was made in works (Kocjan, 2007) and (Trushenkova, 2007), where new interface solutions within a concept of a desktop metaphor were found for office automation tasks. Another example is in (Dieberger, 1994), where it is possible to build a lot of additional metaphors (a post, a bulletin board, etc.) within a city metaphor.

Sometimes such combination of metaphors is successful and sometimes it becomes a heap of obscure images and manipulations. There exist theoretical works on a subject of the mixed metaphors (Lee. & Barnden 1999). However they are not intended for practical application in the process of designing interactive systems.

It seems that presence of hierarchy of metaphors is a condition of success in such cases. Interface metaphors should generate a language of user-application interactions and should not conflict with each other.

Let's consider the following hierarchy:

- A global metaphor conveys the basic idea of application design (e.g. the world as an office);
- A basic metaphor of an application, such as a desktop metaphor, a landscape or a city metaphor;
- A local metaphor describes a specialization of an application (e.g. a card file metaphor);
- A metaphor for widgets and separate operations, for example, a metaphor of scissors in (Kocjan, 2007) and dashboard metaphor in RDM +(see below).

Further one can find two examples of the interface metaphors hierarchy. The first program is an office automation system and the second one is a mobile application for remote computer management.

Office Automation System for Municipality Clerks

An office automation system which is intended for registration of citizens and a housing stock of a municipality is taken up. The basic functionality consists of effective storing and processing information and report forming.

A well-known desktop metaphor was chosen as a basic metaphor of the interface. It is widespread in office automation applications as clerks (users of the system) work with documents at their desks. Some significant properties of the desktop metaphor have been specified earlier.

As a local interface metaphor the card file metaphor was chosen. The following are the most important properties of this metaphor which have affected our choice.
Property 1. A card file metaphor is a natural metaphor. It means that there is an object of the real world which is well-known to users.
Property 2. The concept of a card file implies precise data structuring.
Clerks have to obtain callers and work with the application simultaneously. It is a very important feature to note. Users, who work with people, should be stress-resistant, disciplined, and attentive both to people and to their work. A majority of users are middle age women. They are poorly familiar with operation on a computer, but they have a great paperwork experience. Thus it is very important, that they perceived a new working procedure, as something familiar, similar to in what they were engaged earlier.
Working with people and operation on a computer increase probability of mistakes, therefore data should be well-defined. Data structuring also plays an important role at forming of a mental model of the application of a user and gives positive psychological effect.
Now it is clear, that both properties of the card file metaphor are very important for the application (from the standpoint of information on functionality of the program and its users).
It's worth to mention that the metaphor was adapted for the application. The adapted metaphor changes the way of object handling. For example, searching and ordering of documents are replaced with “magic” (automatic) operations (for example, immediate returning of a card to the place after its process ending or appearing all family members at once in active cards “list”). This is an example of a metaphor action.
Let's consider another example of hierarchy of interface metaphors.

RDM+ (Remote Desktop for Mobiles)
RDM+ is an application for a remote computer management from Apple iPhone. It allows to edit documents, to get access to network resources, to surf web and many other things. It is also possible to carry out simple administrative tasks.
Besides direct manipulation with Windows' objects (icons, menus and so forth) the application allows to send shortcuts to operating system and to accelerate user's work.
A user can keep data about several computers that he or she usually connects to.
It is important to note that the interface of the program was created for a touchscreen mobile device. iPhone's screen is rather small (in comparison with a computer screen), therefore a compact representation of an information is required. And as we speak about a mobile device fast access to all functions of the application is required (especially for users on the go).
As the basic metaphor of the application a dashboard metaphor was chosen. A dashboard is a visual display of the most important information needed to achieve one or more objectives, consolidated and arranged on a single screen so the information can be monitored at a glance. (Few, 2005)

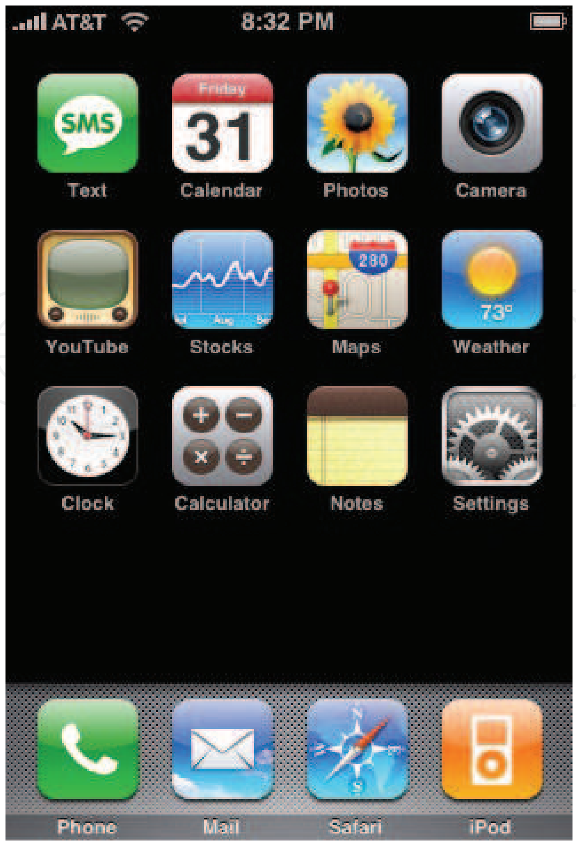

Fig. 4. A dashboard metaphor on iPhone's homescreen

Fig. 5. A dashboard metaphor on the home page of RDM+

Compactness of information representation and fast access to any information are the main properties of the dashboard metaphor.
iPhone's homescreen also uses the dashboard metaphor and to some extent this experience made for the choice of the basic metaphor.
As a local metaphor an address book metaphor was taken. The address book metaphor helps to organize a list of remote computers and its handling.
iPhone users are familiar with a telephone directory. An address book of RDM+ works on the same principle as the telephone directory. Addition, editing and deletion of computers form an address book. The choice of a concrete computer from the list starts operation of "call" to the remote computer and connection to it.
Simplicity and habitualness of the operations connected with the local metaphor of address book provide fast performance. And successful experience of other programs suggests that the use of an address book in mobile applications is effective both in the view of understanding by users, and in the view of compactness.
In this case speed of work with the application is provided with both interface metaphors and their interrelation.

5.4 New Metaphors

Yet one can't achieve the important goal of metaphor generation, that is to automate a choice of the metaphor source domain. The creation of new metaphors realizes, as a rule, by insight. We suggest examples of new invented metaphors, such as "basket" interface metaphor and "manga + anime" metaphor for information visualization.
Now the interface based on hierarchy is most popular. Realizations of the hierarchy are used such structures as a tree. However this approach is not always convenient for "end" users. One can consider other principle, the metaphors of gathering interface operations in a "shopping basket". Let a set of possible operations, depicted by icons, takes place. Users may collect them in a basket to form the interface that is essential for their work. That is an user visits "interface self-service store" and gathering of the "goods" (i.e. icons representing operations) in a "shopping basket", and then she/he assembles new interface operations using this collection.(See the similar idea in (Stuckenschmidt, 2004), where there is using a "shopping basket" to collect search results.)
"Manga + anime" metaphor is offered for information visualization systems. Manga is Japanese comics, based on well-defined visual language. This language is well and unequivocally interpreted by readers. Anime is a type of the Japanese animation films. The visual language of anime also is well understood by skilled spectators. All over the world there are a lot of fans of manga and anime. Our idea consists in using comics (manga) metaphor for the description of processes. A sequence of windows may be output on a screen the. In turn a film may be shown in each window, for example, to describe details of a process. The metaphor can be used also to design animated tutorials and user's guides.
"Magic" is often considered in design and development of the interface for "end user programming" systems and for social computing. A "magic" idea is an idea of "miraculous, impossible in a real life things, actions, situations and events. Magic ideas are interesting and useful to create interface and visualization metaphors and new techniques for dealing in virtual environments. The conception of "magic" metaphors is rather popular in the literature on HCI (for example (Poupyrev, 2001), (Kuhn, W.1995), (Rohrer, 1995), (Kim Halskov Madsen, 2000), (Grosjean & Coquillart 1999).

Even the superficial analysis shows, that in some cases the magic expands opportunities of real objects and characters, and in some cases the phenomena, essentially distinguished from habitual are described. In connection with search of metaphors both cases are interesting. Note also, that the magic ideas from literary fairy tales (fantasy stories) are the most useful for our purposes.

Examples of the metaphors generated on the basis of literary fairy tales, can be considered. Among them there are "speaking portrait" and "speaking map", that is the intellectual agents with spontaneous activity. Such agents can be used as means for the organization "end user" interface. Prototypes of specialized interactive systems based on these metaphors are under construction now.

'Magical approach does not try to incorporate properties of the physical world into the virtual environment, but rather extends them by inventing "magical" interfaces. All of these techniques are based on certain "magical" metaphors and are very easy to understand if one knows the metaphor. Many metaphors are available that can be used and they do not needed to be learned if the user already knows about them. Thus the resulting interface can be very easy to learn and used right away (Poupyrev, 2001). The virtual reality may call for the diverse magic metaphors, as it (a virtual reality) as a matter of fact also is "not fantastic" magic. Some sorts of fantastic stories may be bases of scenarios for actions and manipulations in virtual environments.

6. Discussion and Conclusion

To sum up our studies, let's consider some propositions of this chapter.

The sign nature of HCI and visualization allows applying the semiotics analysis to them. The basic idea of similarities between application domain entities with visual objects is required when visual language is designed. It is possible to speak about some idea of metaphoric representation. A metaphor is a framework of visual language which provides both depicting by an author of the visual text (that is a designer of the interactive [visualization] system) and user interpretation of the visual text.

The main approaches to Computer Metaphor Theory are based on the cognitive approach to metaphors linked with G. Lakoff and his coauthors. In frameworks of these approaches the analysis of a metaphor goes back to analysis of "Lakoff's" structures. Metaphor formalization in this case describes steps of metaphor designing.

As a rule the concept of a visualization metaphor is not separated from the concept of human-computer interface metaphor. Metaphor is considered as an usage everyday and well-known (often technical) realities. The concept of visual interface metaphor is based on presentation of new or unusual for user phenomena by means of other phenomena that are known to him from everyday life. These phenomena should have the same basic properties, as the phenomena which they explain. Thereby constraints of metaphor habitualness and completeness are brought forth. Advantages of such approach are the appeal to ordinary human experience and activation of user interest that relieves understanding and assimilation of the processes under modeling. But there are some limitations of this approach among them - potential loss of details and some specific notions, in cases when there are no analogues to them in the given domain; necessity of comparison of concepts from different domains during training; potential additional and undesirable analogies connected with everyday metaphors.

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Our approach to computer metaphor in some aspect does not comply not only traditional for philology understanding of a metaphor, as ornaments of speech and increase its informativeness due to bright comparisons, but also understanding of metaphors as an application of everyday experience for abstract conceptions as it is usual in theory and practice of HCI. Interface and visualization metaphors may be considered as a special case of scientific metaphor used for generation of new or additional senses for understanding of the new facts and the phenomena.

Interface and visualization metaphors are not completely identical to the metaphors investigated in other disciplines. Practical use of metaphors frequently does not submit to the criteria chosen at the previous stage of development of discipline. On our opinion to form the qualitative and constructive theory of interface and visualization metaphors it is necessary to update and to supplement the existing theory. Then practice applications of metaphor can base on stronger basis.

The criticism of HCI metaphors, as a rule, is caused by an unsuccessful choice of a source domain or sometimes a misunderstanding takes place, as the criticism is concerned to other aspects of using analogies and metaphors in Computer Sciences.

The conception of “metaphor action” is important for the theory of computer metaphor. This conception has formed a basis for the analysis actions of concrete interface and visualization metaphors. Techniques of data representation generated by means the given metaphor, property of metaphorical objects and results of their interpretations by users are the subject of the analysis. Also the conception of metaphor “formula” is offered. The “formula” includes simplified descriptions of source and target domains, an idea of likening using in the metaphor and results of metaphor actions and additionally some “magic” (not existing in the reality, but useful) possibilities of the interface. The purpose of analysis is to reveal metaphor structures, to understand principles of their functioning, to obtain a basis for comparison and evaluation of metaphors.

A metaphor generates some “metaphorical” domain constructed on basis of realities of source and target domains. Just in this domain the metaphorical objects exist, act and interact and just its logic determines their behavior and relations. Another function of the metaphor is to specify a context for better interpretation of elements of the given interaction and visualization language. The computer metaphor helps to understand entities of the application domain that are being modeled, as well as to create new entities based on the internal logic of the metaphor. The components of the metaphor are the imagery (and/or a set of dialog objects) it generates and actions it dictates for updating visual images and manipulating visual objects.

On our opinion one can formalize the suggested concepts, including concepts of the “metaphor action” and “metaphor formula” within the framework of the theory computer metaphor for example on Natural Deduction logics (Pelletier, 2000). The formula of already existing metaphor and the description of the structure of its source domain may help to find objects corresponding to the target domain which satisfies qualitative criteria. One can choose a metaphor, as well as construct on its base a correct set of views for a visual interactive system. Criteria of a choice may be considered as criteria of metaphor quality. The analysis of metaphor properties shows applicability for our goals the conceptions of image-schemas and representative cognitive structures.

Criteria of correctness choice (or designing) of views are necessary. In particular, construction of views can be based on a rule that *the constructed structure of the visual image* *should not contradict to the structure of the initial entity*. Interpretation of the visual object representation should not result in relations that are absent in the initial entity originally. For example representation of the modelling entity with a bidimentional structure as 3D object may lead to wrong interpretation. Though the increase of an image dimension is often useful for better interposition of represented objects in a scene. While a reduction of dimension, as well as a reduction of all structures is not a mistake provided that the user (interpreter) is informed about it. The criteria of metaphor and view quality can be considered in more general context of cognitive principles of visualization design. (See (Tversky et al, 2007), (Tversky et al, 2002) and also Lakoff's ideas of image schemata (Kuhn W. & Frank A.U. 1991)

The analysis and formulas of known metaphors set the general rules of their genesis and functioning. These rules will help to estimate and compare already known metaphors, as well as to search and/or to generate new ones. What are criteria of success for visualization and interface metaphors?

Ability to generate sign systems can be considered as an attribute of quality of metaphors. Classical requirements such, as habitualness, completeness, and smaller abstractness of a source domain in comparison with a target domain should be supplemented and formulated anew.

Let's write out a set of versatile requirements to a choice of metaphors.

First of all one can specify the requirement of entirety and systemness of interface and/or visualization. This requirement is connected with the sign nature and visualization and human-computer interactions as a whole. HCI and visualization should describe as sign systems, instead of separate sign situations. Generation of sign system of an interactive environment occurs due to a choice of corresponding metaphor. The problem of the designer is the description of the whole visual language, instead of its separate dialogue elements. Some unrelated to each other metaphors describing details and components of a dialogue, cannot become a basis of such language.

It is necessary to conform to the main metaphors used in system, and also to global metaphors. It is known, that the metaphors basing on jargons and, especially, on the slangy verbs are not good.

The successful HCI and visualization are constructed on base of "good" metaphors, and they should be supported on the already existing user model of phenomena and/or processes (representative cognitive structures).

It is necessary *to depict entities under visualization, but not to describe them*.

Magic fairy tales and fantasy stories are one of sources for metaphor searching.

Now let's do assumption about the sign nature of computer modeling. One can hold that a process of computer modeling is a process of generation of sign systems. Really, in some model one can easily isolate objects of the modeled phenomenon or processes as a set of denotates, that makes possible to consider model objects as signs. True, this consideration is not necessary for the purposes of the modeling; however it allows doing the further derivation of a theory. Next one can consider the hierarchy of computer models such as physical, mathematical, algorithmic, programming. There is the cycle of computer modeling including these stages and providing possibilities of returns on each cycle stages. The level of abstraction increases naturally at each modeling hierarchy level. It is possible to consider a metaphor (and, in particular, a visualization metaphor) as scientific model, and as the stage of computer modeling. The goal of the visualization in modeling process is to provide

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interpretation and the analysis of data, and also to support all stages of the computer modeling cycle. A visualization metaphor, and more precisely the visualization generated by metaphor is the last sign system in hierarchy of models. After the whole series of abstraction, which are inherent in modeling process, it is necessary to provide a specificity inherent visual images (that is really perceived by eyesight). Generally visualization should reduce (and not increase) the general abstractness level of all modeling hierarchy. We suggest considering the idea of "disabstract operations" (reducing of abstractness) by means of visualization. In terms of semiotics it is possible to consider "disdesignation" by means visualization. That is the removal of levels of designation (and abstractness) takes place during visualization. These several levels of designation are linked with series of sign systems, inherent to given hierarchy of models. The "disdesignation" is the most explicit when direct visualization of source object of modeling takes place. Visualization should support direct connection between a picture, which in this case is an iconic sign (in Ch. Peirce's sense), and designated objects. It is possible to consider the purpose of visualization as the removal at least one abstraction layer for needs of better (more adequate) interpretation of modeling results, instead of occurrence of additional layers. Also there are successful examples of visualization that support the modeling process without increasing or reducing of abstractness levels. A quality evaluation of a visualization metaphor may be considered in connection with the account of abstractness levels assigned on the number of layers (levels of hierarchy), laid between the examined model and the first entity under modeling (for example, a partial differential equation system and a fluid flow modeled by these equations). Then one can estimate how many layers of model abstractness the visualization have lowered to evaluate quality of a visualization metaphor. (Note that a graph of functions lowers an abstractness level on several layers all at once.) One can evaluate metaphor quality through its opportunity to lower an abstractness level of models. (However one can estimate only metaphors, rather then visualization systems themselves since in concrete systems there are a lot of external circumstances connected with realization.) Success and failures of visualization systems may be explained with the help of these evaluations. One can consider a set of requirements to a choice of metaphors and views.

The metaphor has to generate integral and systematic interface and/or visualization systems. As we mentioned above, it means an undesirability of the interface based on several fine metaphors describing details and components of dialog. This requirement means also necessity to conform as to others already existing computer metaphors, and to general ideas of global metaphors. Reduction of interpretation complexity is considered as a condition of "good" metaphor. Therefore direct interpretation of images is required, but decoding and interpretation of complex [visual] texts is considered as a source of failures.

A set of the criteria, imposed on initial and target domains in a process of metaphor generation includes:

- similarity of object properties in source and target domains,
- ability to visual presentation for object in the source domain,
- habitualness (recognition) of objects in the source domain,
- rich set of interrelations between objects in the source domain.

In the interactive visual systems a metaphor is realized as a system of *views.* Just this system of views defines the visual language of the system. Also one can write out criteria of generation for views based on metaphors. These criteria include such well-known

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requirements, as truthfulness, laconicalness, expressiveness, clearness. It is necessary to add in this list the interdependency between views and good manipulation abilities for their dialog elements.
Researching metaphors, views and their structures allows to analyse and evaluate existing design decisions and to project interactive visual systems with necessary properties. This is the main goal of Computer Metaphor theory. On our opinion both semiotics and metaphor theory are only the tools for analysis of computer metaphors, but not the main object of research on Computer Metaphor domain.
Thus, we know how metaphors are structured and how they are generated. We are able to find new metaphors and to evaluate their properties and opportunities. We have an experience in design and developing of specialized interactive visual systems which are based on these metaphors. Now we design specialized visualization systems based on virtual reality environments. One of our future research directions is connected with problems of metaphors for virtual reality environments. On the one hand we need in metaphors to write scenarios for user's activities in virtual reality. On the other hand we need in interface metaphors for new (real and virtual) devices to manipulate virtual reality objects. We have to take into consideration that users of specialized visualization systems are first of all the "problem solvers", and these problems may be connected with very abstract mathematical problems. The question is: what metaphors may help users to navigate and manipulate in virtual reality environments especially dealing with abstract computing models.

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The book consists of 20 chapters, each addressing a certain aspect of human-computer interaction. Each chapter gives the reader background information on a subject and proposes an original solution. This should serve as a valuable tool for professionals in this interdisciplinary field. Hopefully, readers will contribute their own discoveries and improvements, innovative ideas and concepts, as well as novel applications and business models related to the field of human-computer interaction. It is our wish that the reader consider not only what our authors have written and the experimentation they have described, but also the examples they have set.

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中国上海市延安西路65号上海国际贵都大饭店办公楼405单元
Phone: +86-21-62489820
Fax: +86-21-62489821

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