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# Applicative Methods of Interpretation of Graphically Oriented Conceptual Information

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**Abstract**
The paper deals with the interpretation of the graphically oriented conceptual information, which is treated as the information concerning the entities and relationships of the problem domain represented in the graphical form. The paper proposes the approach based on the applicative computational systems, which allows evaluating the graphical attributes of the conceptual objects according to its semantic structure. This feature distinguishes the proposed system from the Database Management System scheme design tools which typically represent the conceptual information in the predefined way. A prototype applicative system for the graphical conceptual information treatment is proposed. The system includes basic semantic domains for the conceptual constructions and an interpretation for evaluating the values of graphical attributes of the represented objects. The applicative character of the proposed model allows offering the way of its future implementation.

*Keywords:* Domain model, concept, concept dependences, conceptual construction, conceptual domain, type theory, graphical format, graphical objects, diagramming, Applicative Computational Model (ACM), conceptual visualization

# 1 Introduction

Constructing the processing systems of graphically oriented conceptual information suggests determining the types of such information and ways to work with it. The paper understands - as graphically oriented conceptual information - the conceptual information, which is oriented to graphical representation of data on the subject area, presented in the form of structured and unstructured descriptions of subject area objects and their relationships. From here the problem arises to work out conceptualized tools of graphical representation of the subject area objects and their processing. The correct way to solve this problem [1, 3, 5] involves the creation of a computational model of graphically oriented conceptual data and support tools of this model.

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The essential feature of the problem is the need to ensure the extensibility of modeling tools, which is achieved, first of all, through providing the computational character of the model. One of the most convenient for this formalisms are applicative computational systems [1, 2, 5, 9], which would provide an opportunity to calculated graphic images in the context of the adjustment to represent the entities of subject area corresponding to the user's needs. The use of lambda calculus, providing a more compact description of abstraction, which is one of the conceptualization basic operations, seems to be promising at the level of fixing the subject area objects. At the level of describing the support mechanisms the use of methods of the theory of combinators, ensuring the means to manipulate the computing environment free of variables, is more justified.

An important advantage of the applicative computational systems is the possibility to provide flexible schemes for typing objects. One can use typing methods adopted in the simple theory of types, which is convenient to describe the types of basic graphical objects. Basing on the use of different kinds of polymorphism the definition of generics is provided; the generics are used for specifying the processing methods applicable to classes of structures that describe the subject area, which are uniform in one or another sense. Depending on the adopted applicative formalism the introduced structures may be parameterized, both the terms of the applicative language (corresponding to constructions of subject area description) and the types of these terms being exposed to parameterization [9]. The most flexible parameterization scheme is provided by the applicative computational system, known as calculus of constructions [3].

# 2 Related work

The approaches to the conceptualization of graphical information were undertaken earlier from different positions. The essential characteristic feature of conceptual information, including the graphically-oriented one, is the possibility to use conceptual models; this suggests constructing the interpretation tools of conceptual information. The possibilities of the interpretation tools support can be correlated with both the features of various graphical formats and the classes of instrumental means of support to graphical processing.

It is natural to relate the ways of interpretation of graphically oriented conceptual data to, primarily, the existing graphical data representation formats. Although there are two major classes of graphical formats - raster and vector [6], yet in the context of this paper the vector formats are of great interest. The existing vector formats represent the graphic information either as a set of individual graphic elements (DXF), or as a hierarchical nested structure (SVG). More advanced means to work with vector graphics (PostScript) also use a graphical representation model in the form of a set of graphical elements [8]. The natural representation of a set of graphical elements appears to be the representation in the form of a list, which is taken, in particular, in AutoCAD system that is potentially able to provide for the computed variability of graphic representations, and the relevant instrumental mean – the processing languages of the Lisp lists [5].

One of the ways of the graphic information interpretation that can be comprehended at a conceptual level is used in pattern recognition systems. Such systems, based on the analysis of low-level graphics primitives of the given object, produce its interpretation in terms of a higher level. It should be noted, however, that the allocated images usually have the standard character (letters and other font characters, symbols, etc.). Furthermore, the conceptualization is performed only in one direction - from low level to high level, and the reverse transition is typically not supported.

The opposite approach is demonstrated by systems of a general-purpose conceptual modeling, which include the number of, in particular, ontologies support systems [10]. In such systems any conceptual model can be interpreted, in principle, including the graphically oriented one. However, such systems are not usually equipped with a standard binder with graphical information processing subsystem (means of viewing, editing, etc.) and therefore the direct possibility of work with graphics during conceptualization faces difficulties.

The intermediate level is occupied by the design systems of CAD type. Within them a fairly high level of conceptualization is combined with advanced possibilities of the graphics processing. However, such systems are usually oriented to quite specific application areas (machine-building industry, architecture, etc.), this leading to the construction of interpretive tools with high specialization and making difficult to use them in the subject areas of a general nature.

The schematization systems of the type [7] demonstrate an interesting approach. Such systems make possible to create specialized graphic descriptions using widely rather rich graphical tools. In particular, it is possible to display different types of conceptual structures, description of hierarchies, classifications, etc. While such systems may be regarded as universal for a given class of subject areas, they usually provide poor extensibility of the used graphical tools (especially methods of means composition) and ways of their communication with the semantic information when necessary to clarify the description of the subject area.

This paper proposes an approach oriented to the description of graphically-oriented conceptual information at a higher level than that was foreseen in the image data format or pattern recognition systems. At the same time it provides for a more detailed description of graphical primitives than in the conceptualization systems of general purpose.

# 3 Semantic domains of conceptual constructions

Let us use the object that contains a set of properties presented in the form of a pair of the property type and its value as an idealized representation of the graphical environment object. Further, such an object will be called the conceptual construction. This structure of object corresponds rather well to the actual formats of the image data (SVG, DXF) and at the same time allows to be distracted by non-essential in the context of the present paper image details. The pair of the type and value of the property will be considered as the basic unit of conceptualization and will be called the conceptualizator of graphical objects.

Let us introduce the necessary classes of expressions in the form of semantic domain [4] for a formal presentation of graphical objects conceptualizators. The use of the semantic domains provides, on the one hand, the possibility of an elementary description of the data on the basis of their structural characteristics within the framework of the set theory, on the other hand, the possibility of transition to a powerful technique of the lattices theory and other richer structures (unbroken lattices, etc.), allowing to use the developed methods of manipulation of such structures, including the algebraic type. We will use the following semantic domains as basic ones:

CGIType – types of graphical objects conceptualizators;

CGIVal – values of graphical objects conceptualizators.

Further on we will introduce the semantic domain GCIBag of the sets (bags) of the graphical objects conceptualizators attributed to a particular conceptual construction at the stage of determining the representations of objects, semantic domain SBag of bags of conceptual constructions, as well as the semantic domain GValBag of bags of conceptual constructions values. The semantic domain of the graphical objects conceptualizators attributed to a particular conceptual structure, GCIBag can be described in the form of an inductive class as follows:

(i) $\{\} \in$ GCIBag

(ii) if $t \in$ CGIType, $v \in$ CGIVal, $b \in$ CGIBag, then $(t, v) + b \in$ GCIBag.

The semantic domain CBag of bags of conceptual constructions describes potential states of the sets of conceptual constructions. It may be described in the form of an inductive class as follows:

(i) $\{\} \in$ CBag

(ii) If $c \in$ CGIBag, $b \in$ CBag, then $c + b \in$ CBag.

The introduced semantic domain CBag describes the initial specifications for computing the specialized conceptual operations. Next it is necessary to describe the result of computing, which represents itself as the bag of conceptual constructions values. The semantic domain CValBag of bags of the conceptual constructions values may be described in the form of an inductive class as follows:

(i) $\{\} \in$ CValBag

(ii) If $v \in$ CGIVal, $b \in$ CValBag, then $v + b \in$ CValBag.

It should be noted that the applied method for determining the bags uses parametric polymorphism significantly [11]. In particular, the operation "+" is determined polymorphically and is used to design the appropriate type bags. Later on when describing the work tools with the values we will use "value belongs to the corresponding type" and "value is an element of the corresponding domain" as synonymous ones.

# 4 The formalization of the interpretation results

The interpretation of conceptual constructions can be directed to obtaining results of various types:

- construction of a graphic image of the conceptual constructions on the screen;
- creation of a printed image of the conceptual constructions;
- obtaining syndicated image of a number of conceptual constructions or images of secondary conceptual constructions synthesized on the base of the initial specifications.

For the formal construction of the interpretation result we will use the semantic domain GVal – domain of graphical values as the basic one. To determine the conversion of graphic representations of objects we will use the functions of the form

$$\text{fsem} : \text{GVal} \to \text{GVal}$$

In view of this, we do not assume the presence of any attributes in the graphic values. On the contrary, the graphic value is considered to be "indivisible". The conversions correspond to the change of the representation way of the graphic value, for example, drawing a path of a certain thickness (color, style, etc.), filling a certain color, etc.

To link the graphical objects conceptualizators with the transformations of graphic representations we introduce a graphical environment

$$\rho G : \text{CGIVal} \to (\text{GVal} \to \text{GVal})$$

Let us think that the graphical environments form the semantic domain GEnv

# 5 Means of interpretation of conceptual constructions

Means of interpretation will be constructed in the form of evaluating display:

$$\| \cdot \| \ \cdot : \ \text{GCIBag} \times \ \text{GEnv} \to \text{GVal}.$$

In accordance with the definition of the semantic domain GCIBag the interpretation may be determined in the following way:

$$\|\{\}\|\ \rho G = \text{GV0}$$

$$\|(t, v) + b\| = \ \rho G\ (v)\ (\|b\|\ \rho G),$$

where GV0 – a kind of "initial" graphical value.

However, this way of the interpretation determining does not correspond to the agreements, which are usually taken when building the applied graphically oriented systems. Indeed, as a rule, a set of attributes is allocated that define the basic graphic form of the displayed object, and the following image conversions are performed with this form.

To get a specified description, we will introduce the semantic domain U, containing a single value (). Note, that the introduction of such a domain is a standard way of describing the functions without arguments [1, 9]. We will change the type of conversion functions of graphic representations of objects as follows:

fsem : GVal + U → GVal,

where + means the operation of disjoint union of domains.

For simplicity we will assume that the basic graphic form of the object is determined by one conceptualizator of the type t0. Now the specified interpretation can be defined as follows:

||(t0, v) + b|| ρG = ρG (v) ()

||(t, v) + b|| = ρG (v) (||b|| ρG),

The determined earlier evaluating display now can be disseminated to the domain CBag. The dissemination is performed as follows:

||{}|| ρG = GVbg

||c + b|| = ||c|| ρG (||b|| ρG),

where GVbg – a certain beforehand fixed “background” image.

The received evaluating display can be used for getting graphical primitives that make up a graphical image of the “output”. In principle the computation can be carried out up to determining the color of individual pixels of the image.

# Conclusions

An approach is proposed to the construction of conceptualized tools for graphical presentation of the subject area objects and their interpretation on the basis of computing model of the applicative type. The constructed model provides for the extensibility of modeling tools, which is achieved at the expense of ensuring computational character of the model. The extensibility allows the possibility to introduce the schemes of typing objects adequate to the formalization of the description of the subject area. The standard tasks of processing and related means of attribution have been considered.

The applicative nature of the proposed computational model allows offering a way of its further implementation using tools of the applicative type. The considered combinators may be nested in typeless lambda calculus, and then calculated by any of the well known methods of applicative systems implementation, which opens the way to build practical systems of processing of graphically-oriented conceptual information.

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