Semantic Visualization for Business Process Models

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Abstract

Based on an analysis of the requirements for visualizations of business process models and the foundations of the concept of Semantic Visualization it is shown how different Ontological Visualization Patterns can be specified and semantically linked to business process conceptualizations to achieve the vision of semantically described visualization services.

1. Introduction

When regarding the environment in which business decision makers have to accomplish their tasks today it becomes immediately obvious that the notion of a *knowledge and information society* is not only a common catch word but clearly highlights the challenges that have to be faced when aiming for the success and therefore the sustainability of an enterprise.

To enable decision makers to master the huge amounts of knowledge and information that circulate on all levels of modern businesses several disciplines have developed methods and procedures which encompass technical as well as organizational approaches. The use of visual representations is a common way that is applied to facilitate the comprehension of complex processes and interrelated data in many of these approaches.

The field of Enterprise Modeling is an area that provides methods of resolution for the representation, management, and analysis of the strategic goals, activities and organizational relationships as well as the technological basis of a business. The visual representation of business processes shall be selected in the following to serve as an exemplary application field. However, the statements made here are applicable to a wide range of enterprise modeling approaches that make use of visual representations (e.g. in performance management [12], workflow management or integrated process and IT architecture management [10]).

The goal of the approach presented in this paper is to introduce an innovative view on visualizations that is exemplarily applied to Business Process Models. The approach is seen as an evolutionary step that is fully compatible to existing ways of specifying visualizations but takes into account new paradigms such as service orientation and automated information processing. It is envisaged that the way of dealing with visual representations is thereby leveraged to the level of open, standardized and therefore interchangeable components, i.e. in the sense of technology independent, semantic visualization services.

2. Related work

The foundations for this work lie in the field of visual language theory (c.f. [11, 9, 1]), which can be viewed as a starting point of analysis for every type of visual representation, and information visualization [8]. The idea of tracing back visual representations to their very core elements has a long philosophical and geometric tradition (cf. the axioms in Euclid's Elements) and has recently regained attention by attempts of defining ontologies for visualizations [3], which, however, seem to be to generally formulated to lead to actual implementations but are rather taxonomies for clarifying terms in the area of visualization. Related approaches for business process methodologies are seen in Event Driven Process Chains [7] or recent efforts for a worldwide standardization of business process modeling such as BPMN [2].

3. Semantic Visualization

As stated in the introduction the concept of Semantic Visualization is positioned as a unification and extension of previous approaches for defining visualizations. In analogy to the well known semantic web stack visualizations in this approach are specified in a hierarchical order based on primitive entities that can be combined to generate complex dynamic representations (see figure 1). These representations can then be enriched with a distinct semantic specification of their state and behaviour which permits not only an automated assembly of visual representations based on domain conceptualizations but also for the realization of technical visualization formats that can be exchanged between different parties (similar to current XML based document formats).

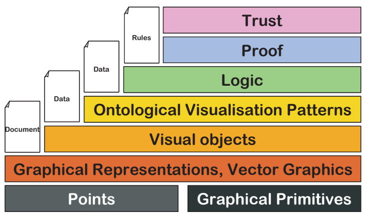

Figure 1. Semantic Visualization Stack

In detail the Semantic Visualization stack contains on its bottom layer the core elements of any visualisation: *Points* as the smallest visual entity and *Graphical Primitives* that are composed of a number of points. On the next layer reside *Graphical Representations* in the form of vector graphics that are composed of graphical primitives. To allow for a dynamic change of the graphical representations the *Visual objects* layer adds variables and control structures to the graphical representations. Thereby a representation can be changed according to a variably assigned value. On the *Ontological Visualizations Patterns* layer one or more visual objects are combined and positioned according to a layout procedure. The internal variables of the visual objects are either directly exposed as variables of the pattern or via a transformation function. The Ontological Visualization Pattern therefore also has to contain control structures and variables, but in contrast to the visual objects the variables as well as the pattern itself are enriched with a semantic specification. On the basis of this semantic specification that describes the nature and properties of a visualization a mapping to an ontology can be established that is the basis for possible visual inferencing mechanisms on the higher layers such as *Logic*, *Proof* and *Trust*. By the linkage to an ontology a visual language can be specified: Syntax and semantics of the visual language are defined by the ontology, the appropriate graphical representation by the Ontological Visualization Pattern.

To show the approach in details these concepts and the linking to a semantic description can be formally expressed as follows: A Point P has coordinate values in $\mathbb{R}^2$ (1), and a variable V in $\mathbb{R}$ (2). Points can then either be specified in the standard way by values or by variables (3) by which variations of the graphical representation are realized. Primitives $PRIM$ can either be described by standard points (4) or in visual objects by a combination of variable or standard points VO (5). The variables within the point primitives are used to influence the graphical representation, the additional variables are required for the normalization of the point variables to allow for a mapping to ontology values[1]. This abstract specification can then be instantiated (6).

A simplified ontology O consisting of classes C, object properties OP, datatype properties DP and values V (8-13)[2] can also be instantiated and then linked in the simplest case to the visual object as shown in (14,15), thereby establishing a semantic relationship with a class of the ontology and a variable of the Ontological Visualization Pattern.

$$P = (x, y \,|\, x, y \in \mathbb{R}) \tag{1}$$
$$V = (z \,|\, z \in \mathbb{R}) \tag{2}$$
$$P^{VO} = (\alpha, \beta \,|\, \alpha, \beta \in \mathbb{R} \vee V) \tag{3}$$
$$PRIM = \{P_1, P_2, \ldots, P_n\} \tag{4}$$
$$VO = \{E_1, E_2, \ldots, E_n \,|\, E \in P \vee P^{VO} \vee V\} \tag{5}$$
$$VO_1 :: VO \tag{6}$$
$$VO_1 = \{P_1, P_2^{VO}, V_1\} \tag{7}$$
$$O = \{C, OP, DP, VAL\} \tag{8}$$
$$C = \{C_1, C_2\} \tag{9}$$
$$OP = \{OP_1\} \tag{10}$$
$$DP = \{DP_1\} \tag{11}$$
$$OP_1 = \{C_1, C_2\} \tag{12}$$
$$DP_1 = \{C_2, VAL_1\} \tag{13}$$
$$C_2 \leftrightarrow VO_1 \tag{14}$$
$$VAL_1 \leftrightarrow V_1 \tag{15}$$

To fully realize the vision of Semantic Visualization, which is seen in the availability of semantically described visualization services that can on demand and automatically create dynamic visualizations that are appropriate for a specific use case the mapping between Ontological Visualization Patterns and a domain conceptualization such as an ontology or a meta-model has to be further specified. For this purpose four dimensions have been identified that characterize this mapping: The *Functional Implementation*, the level of *Standardization*, the type of *Deployment*, and the *Time Reference* (see figure 2). The Functional Implementation describes whether the mapping takes place fully automatically (e.g. through intelligent agents that receive a request for a visualization and deliver the result), semi automatically (e.g. by offering visualization alternatives that can be chosen by the user) or manually (e.g. when the visualizations for the mapping are manually selected based on the subjective assessment of a user). The Standardization dimension determines to which amount the mapping

[1] A simple example that shows this normalization requirement would be the graphical height of a bar in a barchart that has to be normalized to e.g. a range from 0-100 to be able to represent percentage values.

[2] This would correspond to a simplified conception of an ontology as existent in the Web Ontology Language OWL.

is performed by using standardized technology for the description of the conceptualization of the Ontological Visualization Patterns, the description of the domain conceptualization and the mapping itself. Again, for fully realizing Semantic Visualization standardized technologies are required to enable the direct cooperation of all three parts. The two types for the Deployment reflect whether the visualization can be dynamically altered after the deployment (whereby e.g. the change of an attribute status in the domain conceptualization can influence the visualization after the mapping has been defined) or whether the mapping is static and cannot be changed. The Time Reference dimension expresses whether the visualization is assembled on demand (i.e. directly upon the request of a user) or is pre-configured and then accessed at a later point in time.

Functional Implementation	*Automatic*	*Semi automatic*	*Manual*
Standardization	*Fully Standards based*	*Partly Standards based*	*Proprietary*
Deployment	*Static*	*Dynamic*	
Time Reference	*On demand*	*Pre-configured*	

Figure 2. Dimensions of the Mapping

4. Requirements of Business Process Modeling

To practically illustrate the approach of Semantic Visualization the field of Business Process Modeling has been selected as a field of application that is not only very well researched but is certainly (as stated in the introduction) of major interest for meeting future business challenges.

The modeling of business processes is a complex task that does not only require sound knowledge of the field of business that shall be depicted but also of the used modeling method and its application procedure. From the viewpoint of visualization we have identified three main influence factors that determine the requirements for the visual representation of business processes: First, the *Modeling Method* as the basic definition which elements may occur in a business process model, how they are syntactically arranged and what semantics is assigned to them as well as the used notation (e.g. graph based) [6]. Second, the aspects of *Human Computer Interaction*, i.e. how the interaction of a user and the representation of the business process model takes place and thirdly which *Technology* is available and suitable for implementing the visualization.

To narrow down the large number of possible approaches for modeling methods in business process management we build in this paper upon the concepts of Business Graphs [5] as an elementary and intuitive approach for representing business processes and their organizational embedding.

A Business Graph is a formal representation of a clearly structured and comprehensible design of a business process including all important elements [5]. These elements are structured in two components: a business process model and a working environment model. The business process model contains *activities*, i.e. atomic units of a process (e.g. the working units which cannot or should not be divided any more), *subprocesses*, i.e. the combination of activities in order to achieve reusability and a higher level of abstraction which are both necessary for distinctely structuring the process, and a *control flow* which is characterized by variables and predicates that determine the logical subsequence of the activities and allow for the description of parallelisms (or synchronizations), decisions, sequences and loops. As the focus of this paper is visualization the control flow is limited to three elements (*start*, *end*, and *decision*). The working environment model consists of *actors* (persons), that represent the performers of activities, *groups* which are used to describe organizational structures such as positions, functions, roles, responsibilities and units of organizations, and *resources* which are defined as all means that are necessary for the realization of activities such as documents, data or services. Between the business process and the working environment model mappings can be established such as *responsibilities*, i.e. the definition who is carrying out an activity or *requirements*, i.e. the regulations which resources are required to perform an activity.

Formally Business Graphs can be described as follows: Let $\Gamma = \{\beta_j, \omega, \rho_{ij}\}$ be a Business Graph with

- a number of i business processes $\beta_i = \{\theta_i, \kappa_{ij}\}$ in which θ_i signifies process element $i, i \in \{1, 2, 3, \ldots, n\}$ and κ_{ij} stands for a control connector $ij, i \in \{1, 2, 3, \ldots, n\}, j \in \{1, 2, 3, \ldots, n\}$ between process elements. Process elements are defined as $\theta_i = \{A_i, \beta_j, \sigma, \eta, \delta_k\}$ where A_i signifies activity $i, i \in \{1, 2, 3, \ldots, n\}$, β_j signifies subprocess $j, j \in \{1, 2, 3, \ldots, m\}$, σ signifies start, η signifies end, and δ_k signifies decision where $k \in \{1, 2, 3, \ldots, l\}$.
- a working environment $\omega = \{P_i, G_j, R_k, \pi_{ij}\}$, with $i \in \{1, 2, 3, \ldots, n\}, j \in \{1, 2, 3, \ldots, m\}, k \in \{1, 2, 3, \ldots, o\}$ and where P_i signifies a person $i, i \in \{1, 2, 3, \ldots, n\}$, G_j signifies a grouping $j, j \in \{1, 2, 3, \ldots, m\}$, R_k signifies a resource $k, k \in \{1, 2, 3, \ldots, o\}$ and π_{ij} the relations between the elements of P_i, G_j and R_k with $i \in \{1, 2, 3, \ldots, n\}$, $j \in \{1, 2, 3, \ldots, m\}$
- and the relations ρ_{ij} between the elements of β_i and ω.

Business Graphs are a syntactical conceptualization of the domain of business process models. For a concrete usage the semantics of the entities of a Business Graph has to be specified e.g. by mapping them to an ontology as shown

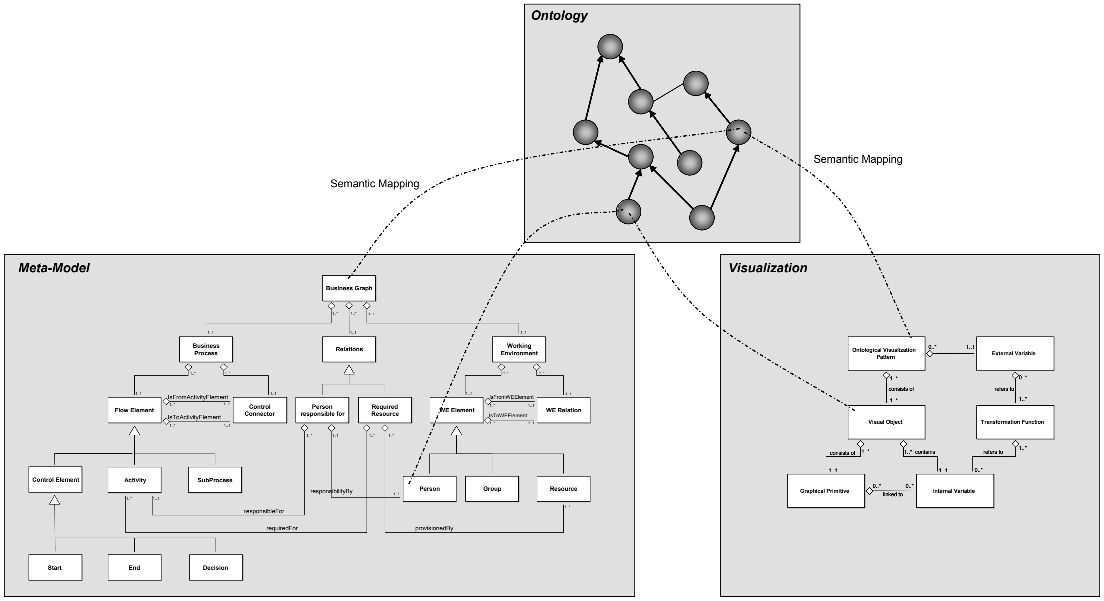

Figure 3. Semantic Visualization Framework for Business Process Models

in figure 3 and distinct rules for the arrangement of the elements in the business process models have to be defined. For the purposes of illustrating the relation to the visualization of the models we have instantiated the formal concepts to a meta-model (figure 3) that defines the cardinalities between the entities and can also provide a basic definition of syntax and operational semantics via a meta-meta model from which it is instantiated and that defines the core elements of the underlying directed graphs (as e.g. described in [4]).

For the discussion of the impacts of human computer interaction (HCI) we refer to the definition of HCI as "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them." (by ACM SIGCHI[3]) and focus on three aspects that are derived from the accomodations to human diversity as described by Shneiderman [13]. These are: *Semiotic aspects*, *Pragmatic aspects*, and *Physiological aspects*.

By Semiotic aspects we take into account human cultural factors that determine either the meaning of as well as the interaction with visual representations. This is particularly relevant in today's international business environment where the exchange of information concerns many different countries and cultures. Culture in this context refers not only to national culture (e.g. as expressed by different orientations in parsing text and visual representations) but also to group cultural factors (e.g. by different professional views on the functioning of an enterprise where technical experts prefer clear 'engineering'-like representations they are used to (as the UML notation) vs. managerial decision makers who require visual representations that can be used for special argumentation purposes e.g. to shareholders who are not familiar with technical visualizations). For examples of different visualizations of business processes see figure 4 that shows in (A) a standard business process model based on the Business Graph concepts in the ADONIS BPMS notation, in (B) a UML activity diagram and in (C) a visually enhanced version of (A) that additionally encodes activity costs by color gradients.

This directly leads to the Pragmatic aspects of business process visualizations. Here the requirements concern the purpose of the visual representation which might range from knowledge codification and transfer to professional analysis (cf. the methods of information visualization) and public communication purposes and strongly depends on the role of the recipient (e.g. technicians, external stakeholders or customers).

By the Physiological aspects it has to be considered how interaction possibilites can be met so that a wide range of users can access the visualization in the intended way - which may for example be achieved by reverting to common interaction metaphors as used by standard software that also brings the advantage of defining extensions for disabled people.

The third requirement concerns the technological factors that need to be considered when deploying visualizations of business process models in an enterprise. An important fac-

[3]See the website of ACM SIGCHI Curricula for Human-Computer Interaction at http://sigchi.org/cdg/cdg2.html.

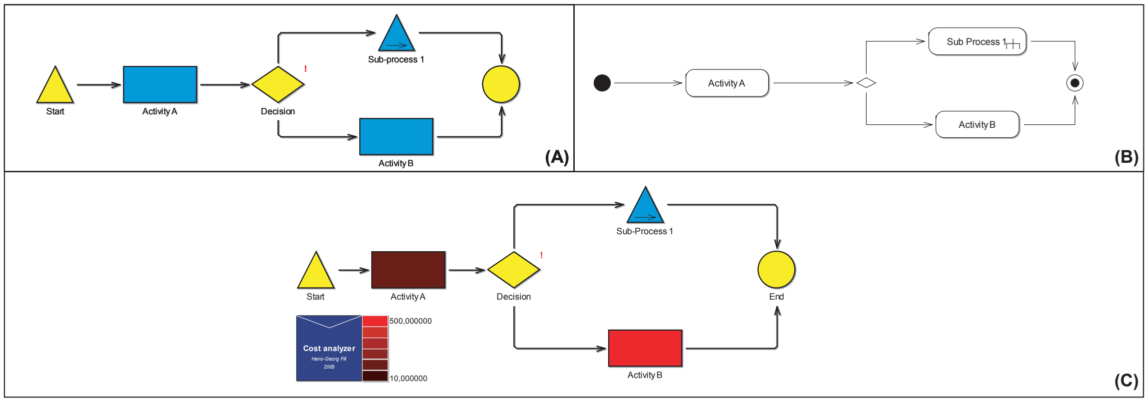

Figure 4. Different visualizations of business processes

tor is the *Organizational Embedding*, i.e. which technologies and systems are already in use in an enterprise, which security and economic constraints have to be obeyed and whether additional hardware or software components are required for a successful installation. Furthermore aspects of *Mobility* may play a role, i.e. whether the visual representations need to be web-accessible, stand-alone or available on mobile devices. A more strategic aspect of technology which is not to be underestimated is the *Relation to current paradigms*, i.e. whether the chosen technology is highly innovative for an orientation towards the future and with the chance of benefitting from first mover advantages or whether an experienced and highly reliable technology is chosen.

5. Application to Business Process Models

With these foundations it is now possible to apply the concept of Semantic Visualization to the area of business process modeling: At first appropriate Ontological Visualization Patterns have to be created that contain the required functionality based on the requirements of the modeling method and the HCI and technological aspects (e.g. for representing arrows with bendpoints for control connectors, representations that can show a cost value by a color gradient for analysis purposes, black and white representations for simple PDA displays etc.).

In detail for the needs of business process modeling such patterns have to correspond to the exact semantic requirements of the modeling method. In the case of Business Graphs this implies that there exist patterns that semantically match to the concepts in the graph as shown in figures 3 and 6, which can be achieved by reference to a common ontology that either specifies the semantics of the Ontological Visualization Pattern as well as the semantics of the concepts in the meta-model, and that there are patterns that can represent the operational semantic requirements as demanded by the control connector classes of directed graphs.

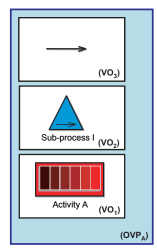

Figure 5. Ontological Visualization Pattern using a color-coding visual object for activities

Furthermore the patterns have to be in line with the requirements from HCI and satisfy the semiotic, pragmatic and physiological aspects. The advantage of Semantic Visualization is clearly visible in this respect as it allows for the definition of multiple Ontological Visualization Patterns that can fulfill different requirements and can (if the technological foundation does not restrict it) be chosen on demand based on individual user preferences (for an example of an alternative pattern that is used for an analysis case see figure 5).

As the vision of Semantic Visualization is the automatic interaction with Semantic Visualization services the aim would be to use standardized formats for the description of the Semantic Visualization Stack. However, with the currently available standards only parts of the requirements for Semantic Visualization can be met: For the specification of visual objects SVG can be partly used for the creation of templates, although it has to be extended with custom namepaces to take into account the need for externally ac-

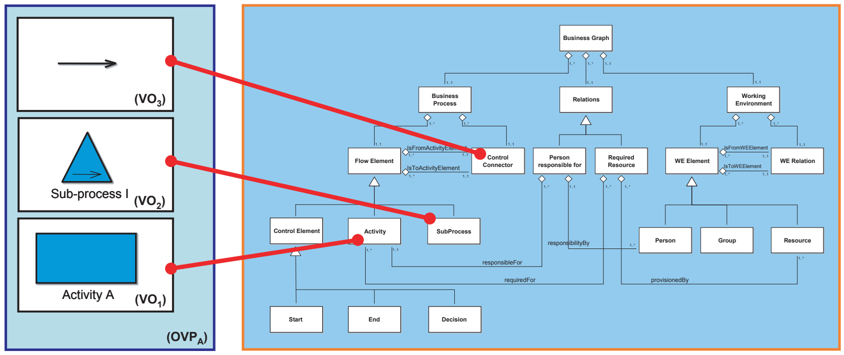

Figure 6. Mapping of an Ontological Visualisation Pattern to a Meta-Model with implicit semantics

cessible variables and control structures.

Currently a prototype for a visual object editor is available in Java. It has similar functionality as any graphic editor for vector graphics with the additional possibility of integrating variables and control structures. Visual objects can therefore be easily designed and exported as Java Swing components which allows for an easy integration in other applications as well as for achieving a first realisation of visualization web services by using them in a web application.

6. Conclusion

In this paper it has been outlined how the paradigms of service orientation and semantic service description can be applied to the area of visualization. To fully realize the vision of the proposed idea of Semantic Visualization in analogy to the Semantic Web internationally aligned open standards would be required. A student project using SVG and web service technologies is currently being conducted to evaluate the practicability of adapting common standards to the needs of Semantic Visualization.

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