Basic Considerations of Semantics in Visual Models

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Abstract: In several applications of legal visualizations visual models are used as an aid for communication and as a basis for subsequent analyses and implementations. The following contribution is concerned with the expression of semantics in these graphical models. The aim is to gain insights and derive a first conceptualization for describing the semantics that are explicitly and implicitly expressed by the modelers.

1. Introduction

One common technique in the area of legal visualization is the usage of visual models. They can be used among several other purposes to represent mind maps that depict legal relationships, process flows in e-government or technical implementations of legal information systems. In the context of this article models shall be defined as being described by a modeling language that is composed of a syntax, semantics and notation (Fill et al., 2007). The notation that is of interest here is a graphical notation that allows a user to define models based on the syntax and semantics of the modeling language. The goal of this approach is to create visualizations that can be both used as an aid for communication, e.g. to discuss the implementation of legal regulations in a business process, as well as to allow for IT-based analyses of the created models based on an underlying formal or semi-formal description of the syntax and semantics of the modeling language. In the following it shall be investigated which semantics are explicitly represented by the models and which are only implicitly available and could be used for further investigation. For this purpose the investigation will be restricted to process modeling languages.

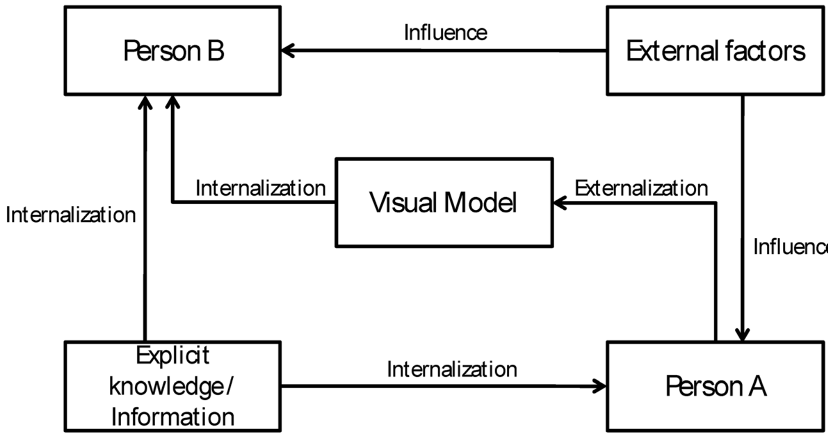

Figure 1: Internalization and Externalization of Information in Visual Models

2. Model creation

When visual models in general are created by human actors to represent some type of legal information, they typically engage in an internalization / externalization process as depicted in Figure 1. Thereby the individual perception of a person A of some information is partly made explicit through the visual model. Involved in this is not only the background knowledge that the person possesses, including cultural or social aspects, but also potential external factors, such as the global context in which the creation process takes place. A second person B who investigates the visual model may also have access to the original information and may be influenced by the same external factors but may still have a different perception of the visual model. For the purpose of communication these differences in perception need not be of a disadvantage but may even assist in gaining a mutual understanding of the other person's view.

However, from the perspective of IT based analysis and execution of visual process models it is unfavorable to deal with ambiguous representations. This concerns in particular the treatment of the semantics of these models where a machine would not understand what the human actor intended to express and could thus not act appropriately. Therefore the syntactic and semantic descriptions underlying the visualization have to be sufficiently expressive and mathematically formal. The reason for the mathematical formalization is that formal models do not leave any scope for ambiguity and increase the potential for analysis (Van der Aalst et al., 2003). In the literature a number of approaches can be found that are concerned with formalizations of process modeling languages (e.g. Mendling et al., 2007). Despite their high mathematical precision in defining the modeling languages these approaches are mainly concerned with the formal definition of the elements and relations between the elements of the modeling languages. They usually neither focus on the formalization of additional knowledge that the user may wish to express nor on the formal definition of the resulting visualization.

When using the modeling languages in practice it can, however, be observed that the users creating the models establish something that is referred to as a "mental map" (cf. Misue, 1995). This means that a user of a visual model keeps the model in mind and thereby memorizes the overall structure and location of certain activities in the model. A direct consequence of these mental maps is that, for example, a layout algorithm that automatically arranges the elements of the model according to some predefined rules may violate this memory of the user. The consequence would be that the user would have great difficulty in understanding the re-arranged model – although the formal definitions according to the syntax and semantics of the modeling language have not been altered. Additionally, the user may associate additional information with the model that cannot be expressed in the process modeling language but that influences the understanding of the content of the model.

To make use of the semantics that can be expressed by using visual process models it thus seems necessary to go beyond the formalization of the semantics of the modeling language and investigate the "semantic space" of these models. By semantic space we denote here the range of possibilities that a user has for expressing meaning, given that the syntactic and formal semantic constraints of the modeling language are met.

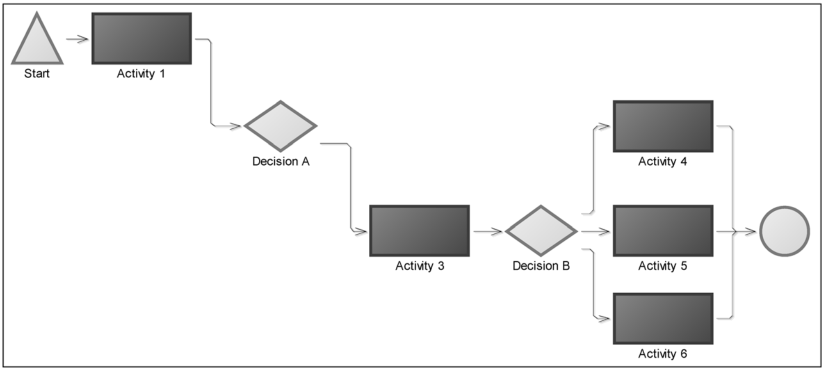

Figure 2: Typical process model[1]

3. Visualizing analysis

As the starting point for the investigation we consider a typical process model (see Figure 2) by the tuple *PM = (S, D, E, A, REL)*. This way of describing process models corresponds to a simplified version as shown e.g. in (Rinderle et al., 2006). It contains control elements such as the triangle for depicting the start *S*, the rhomb for defining a decision *D* and the circle for defining the end *E* as well as activity elements *A* represented by the rectangles and relations *REL* between the elements. It is assumed – although not made explicit here – that the model has been created based on a well-defined syntax and semantics of the modeling language. These may define for example which elements may follow each other (syntax) and how a valid path through the process is interpreted as sequences of computational steps (operational semantics). For a further formalization we refer to (Rinderle et al., 2006).

The technique that is applied in the following for investigating the semantic space shall be denoted as "Visualizing analysis". Its goal is to highlight the possible parts of the process visualization that a user may associate meaning with. It has to be mentioned that the analysis here is not based on a psychological theory where e.g. the findings in Gestalt theory and visual perception would be appropriate (cf. Ware, 2000). Rather, it is a

1 Generated with ADONIS Community Edition http://www.adonis-community.com.

first step towards the decomposition of the formal description *PM = (S, D, E, A, REL)* by directly visualizing the stages during the decomposition. For this purpose eight patterns have been defined that consist of one or more visual objects (see Figure 3).

Pattern (1): The first pattern takes into account the overall view of the process model *PM*. It corresponds to a blurred view of a process model as it might appear when viewing it from a greater distance. Although the details of the model are not visible it is still possible to identify two different visual objects in the model that can be used to associate meaning with.

Pattern (2): In the second stage the structure of the model becomes clearer. It is now obvious that the model is a directed graph, i.e. a mathematical construct that consists of nodes and edges with a direction. Thereby it is determined that the meaning associated with these elements has to correspond to some type of sequence.

Pattern (3): For the third pattern the nodes of the graph are complemented with a textual attribute as shown by the letters inside the nodes. Mathematically this is described as a named graph where nodes are assigned a name. From the viewpoint of semantics it is now possible to assign arbitrary text to the nodes.

Pattern (4): At this stage it becomes apparent that the positioning of the elements has so far not been considered. From a mathematical point of view the structure of the graph does not change. It is however necessary to introduce attributes for capturing the coordinates of the nodes and edges to enable a processing of this information. In terms of semantics the positioning can be used to make several additional statements, e.g. about the grouping of elements based on their proximity.

Pattern (5): In pattern five the nodes of the graph are further detailed by grouping them based on common characteristics. This is visually shown by introducing four different visual objects to represent the nodes. Mathematically this corresponds to a typed graph. Semantically it can now be differentiated between the aforementioned process elements, e.g. activities, decisions etc.

Pattern (6): The different elements of the graph structure can be further detailed by assigning additional attributes to the nodes and edges. For a business process model this could be e.g. cost, time or organizational responsibility attributes for the activities. This step is illustrated by using different colors for the representation of the nodes[2]. The meaning that can thus be associated with the nodes is thereby only limited by the types of the

2 On a color printout of figure 3 the nodes of patterns 6–8 will appear in different colors.

attributes and the possibilities for visualizing these attributes appropriately, e.g. due to limited number of distinguishable colors.

Pattern (7): In the last two patterns something is added that is also currently discussed in the context of using explicit semantics in business process management (Höfferer, 2007). To take into account additional semantics of process models the elements of the model can be annotated by concepts of a semantic schema. This is done by adding a controlled vocabulary that is used to further detail the elements in the graph structure by using free text. Despite the semantic freedom in this pattern it certainly lacks the possibility of formally describing the content of the vocabulary.

Pattern (8): The formal drawback of the previous pattern is resolved here by introducing a formal semantic schema for the description of the model elements, e.g. in the form of an ontology. The additional gain is that these relations can now also be visually depicted.

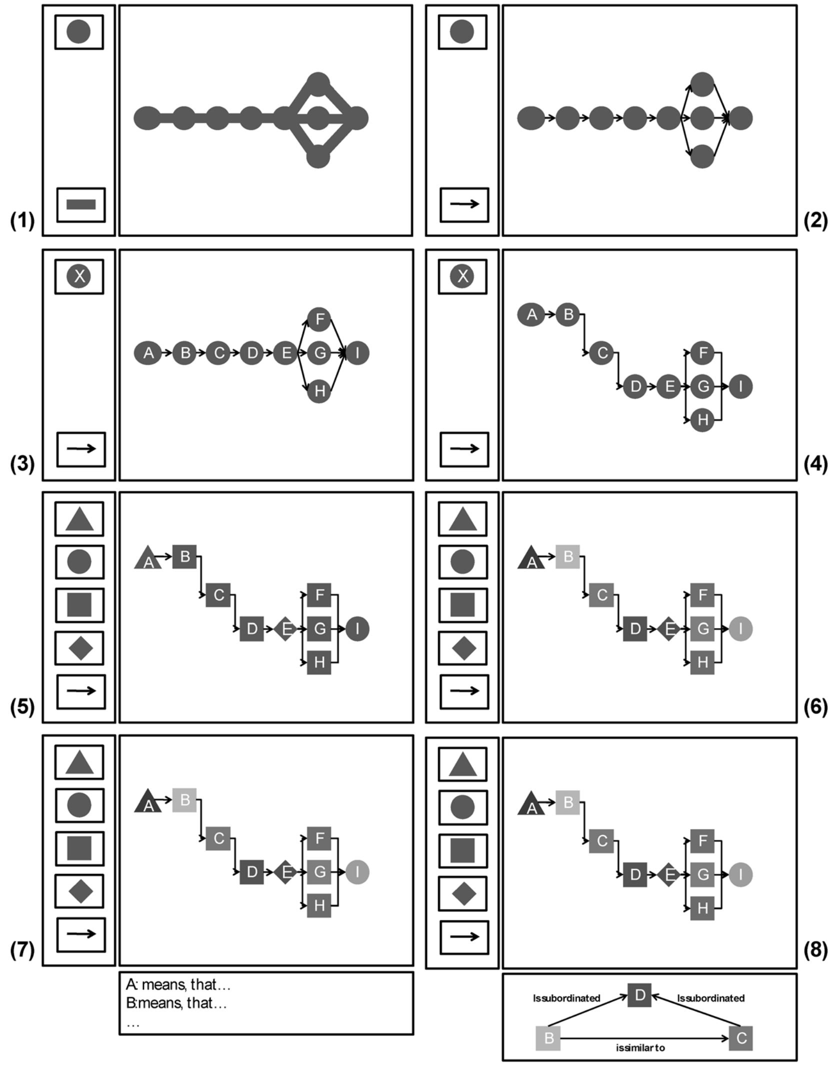

Figure 3: Patterns for Visualizing Analysis

4. Summary and Further Work

In this article it has been discussed how the semantic space that can be expressed by using visual process models can be analyzed. The analysis was based on a decomposition of a formal description of a process model. It was shown in visual form which steps of the decomposition can be identified. Further work will include the elaboration of the details of the presented patterns and their formal description. The perceived outcome is that on the one hand more insights into the semantics of the patterns and also of the visual modeling methods themselves will be gained. This could, for example, bring up semantic information that has not yet been formally considered. On the other hand the patterns may also be used entirely from their visual perspective. Thereby it could be investigated which semantic phenomena can be visually perceived without having to strive for a total formalization of all the information related to the model. This may not only open up new possibilities for model analyses by humans but may also lead to new conceptions of machine learning techniques for processing semantics, e.g. by artificial neural networks.

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