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Visual Enhancements of Enterprise Models

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Abstract. Enterprise models are used in a number of business areas today. Spanning from strategic management, business process management to workflow, IT service and infrastructure models they constitute a way to graphically represent domain-specific knowledge, either based on user-defined meta-models or according to pre-defined modelling languages. It is examined which possibilities are feasible to visually enhance these models for achieving a better understanding of the models and thereby improving the knowledge transfer between individuals. Two examples for such enhancements are presented that have been implemented prototypically on the ADONIS® meta-modelling platform.

1 Introduction

The business world today is characterized by the effects of open markets and the thus limited economic barriers: The global distribution of business activities and the resulting world-wide competition influence the way of doing business to a great extent [1]. At the same time Internet technologies such as World Wide Web, HTML, XML and web-services have led to an increase in the amount of available information over the past years [2] and offer opportunities for improving the decision base for management in the fast changing and information dependent environment.

The information relevant for the successful performance of enterprises comes from different resources: These can be operational systems that inform about the current state and condition of physical goods and facilities (eg in production and logistics), internal information systems that deliver financial data (eg in accounting) or external sources that provide information about delivered components (eg suppliers). All these types of information are usually well documented and easily accessible. However, they only give a static impression of the current state of a business. Another form of information that is as vital to a business as for instance financial figures or deliver dates is *how* the business actually generates products and services.

Still very often this information is not made explicit but persists in the head of the people executing the various activities in an enterprise. From the viewpoint of knowledge management this would be termed as tacit procedural knowledge [2](p. 82). To be effective it is necessary for the management and the workforce of an enterprise to be able to access and transfer the knowledge how the business processes are performed, how they relate to strategic objectives and what kinds of technology are required for their successful accomplishment [3]. This allows for a qualitative analysis of the causes and effects that influence the performance of the business.

2 Enterprise modelling

One of the key success factors in this regard is the provision of appropriate methods to represent this procedural knowledge to allow for its documentation respectively externalisation [4]. By *enterprise modelling* we understand an IT-based management approach to represent this organisational knowledge in the form of (graphical) models that are based either on a user-defined or standardised schema (cf [5]). Included in this definition would be models of cause-effect relationships of strategic goals as used in balanced scorecards [6, 7], business process and workflow models [8–10] as well as models of IT services and their implementation [11, 12]. They span from strategic to operational issues of an enterprise and abstract from the real world in varying degrees.

To specify a model of an application domain by using information technology an adequate modelling language has to be defined. Two approaches that can be used for this purpose are meta-modelling techniques and ontologies. Meta-models define elements and possible relations between these elements within a certain domain. The elements may contain attributes and can represent abstract or concrete parts of the real-world. A meta-model describes a modelling language and is itself specified by a meta-modelling language with a modelling syntax, semantics and notation (eg graph-based) [13, 14].

Ontologies in contrast have a slightly different objective: They have originally been proposed in computer science as a specification mechanism to enhance knowledge sharing and reuse across different applications with the aim of enabling machines to make automatic interpretations (inferences) of given facts [15]. They define "the basic terms and relations comprising the vocabulary of a topic area as well as the rules for combining terms and relations to define extensions to the vocabulary" [16](p. 40). Ontologies are currently widely discussed in relation to the Semantic Web that aims to extend today's methods of representing information on the Internet by annotating the information semantically. A typical ontology language available is OWL [17] which uses the basic constructs of resources, properties, and values to describe the objects in a domain.

One of the advantages of meta-modelling is the abstraction of a part of the real world to allow for an easier understanding of complex relationships. Furthermore, typical meta-modelling approaches such as the meta-object-facility [18] or ADONIS[1] [9] allow for arbitrary, not necessarily formally specified elements and

[1] ADONIS is a registered trademark and commercial product of BOC GmbH.

relations (cf [19]), which eases the definition of individual meta-models. Nevertheless, this higher degree of freedom also limits the usage of the models: Inferencing and consistency checking methods require additional (semantic) information[2]. Ontologies in general do not abstract from the original terms but are usually used for representing a highly detailed view on concepts of the real world. Whereas the elements of a meta-model are usually limited to a manageable number, the quality of an ontology increases with the multitude of its items and relations. To combine the advantages of both approaches recent attempts strive for an integration of meta-modelling and Semantic Web technologies [21].

An essential characteristic of enterprise modelling is the visualisation of the elements and relations. It enables users to easily understand a model and to interact with it as well as it supports the knowledge transfer between individuals. Therefore we see visualised enterprise models as one of the key technologies to explicate knowledge in a business environment.

In the following it is outlined how the visualisation of enterprise models can be formally described and in which way visual enhancements can be made to further increase their usability.

3 Visual enhancements based on object attributes

Before possible enhancements of visualisations of enterprise models can be examined some theoretical foundations of the visual aspects shall be presented. A great number of visual enterprise models rely on graph representations, ie representations that consist of a number of nodes and edges between these nodes. With regard to meta-models and ontologies the nodes are commonly used to stand for the objects or elements and the edges for the relations between these objects. Although also other forms of visual representations might be used we will focus in the scope of this article on graph representations and put a special emphasis on the visualisation of business process models to exemplarily show the highlighted implications. Nevertheless, it is claimed to provide a theoretical foundation for these remarks to allow for an applicability in other parts of enterprise modelling.

3.1 Theoretical foundations

A way to formally describe visualisations of enterprise models is to revert to the research field of the theory of visual languages [22, 23]. The approach taken here follows a formalisation put up by [24] that is very similar to approaches taken in meta-modelling and ontologies.

We start by regarding an application domain (AD) for a visual language. The AD contains objects O, attributes A and relationships R^n to describe the state S of a domain, ie $S = \{O, A, R^n\}$. This directly corresponds to approaches

[2] Similar functionalities can be achieved via the use of the Object Constraint Language in the UML 2.0 specification [20] or the ADONIS scripting language AdoScript.

in meta-modelling: The meta object facility specification by OMG for example defines as basic entities classes (metaobjects) with attributes, associations, data types and packages (see [18](p.2-6)).

A visual language (VL) is defined to be composed of a set of visual sentences (VS). The vocabulary V of the visual sentences consists of a set P of visual primitives, that have visual dimensions D, and a set of visual relations V^n that can exist between two or more primitives, ie $V = \{P, D, V^n\}$. The visual dimensions directly lead to the field of semiotics that deals with the meaning of signs and visual expressions and how they convey information. Bertin [25] lists eight visual dimensions that can be used to transcribe similarity, ordinal relations and proportionality in a two dimensional space[3]: The position, given by the two dimensions of a plane (X,Y), size, brightness, texture, colour, orientation, and shape.

The sentences of the visual language can be mapped to a state of the domain AD thereby specifying the semantics of the language. The mapping takes place eg by $O \leftrightarrow P$, $A \leftrightarrow D$ and $R^n \leftrightarrow V^n$ or a combination of these.

A practical example from business process modelling based on the ADONIS standard method would be as follows: The application domain is business process modelling (BP) consisting of exactly one start object (S), at least one or more activities (AC), zero ore more decisions (DEC), zero or more start points of parallel flows ($SPAR$), zero or more unions of parallel flows ($EPAR$), exactly one end object (E) and successor relations SR^n between the objects. $AD = \{S^1, AC^+, DEC^*, SPAR^*, EPAR^*, E^1, SR^n\}$[4]. All objects have a name as an attribute, activities also have a range of attributes including costs, duration, actors, input and output documents etc.

A graph based visual language for business processes as eg used for the ADONIS BPMS notation[5] (denoted by VL^{ADONIS}) would be as follows: The visual primitives used are the symbols *SYM1*, *SYM2*, *SYM3*, *SYM4*, *SYM5*, and *SYM6*, the visual relation is *ARR*.

The actual size φ, brightness λ, texture τ, colour χ, orientation ω, and shape σ of the primitives is given as shown in figure 1 - we denote this as a given set of dimensions for each visual primitive or relation: $SET(P \vee V^n) = \{\varphi, \lambda, \tau, \chi, \omega, \sigma\}$. The position dimensions are not taken into consideration as the position is determined by the layout of the graph of which the visual primitive is a part of.

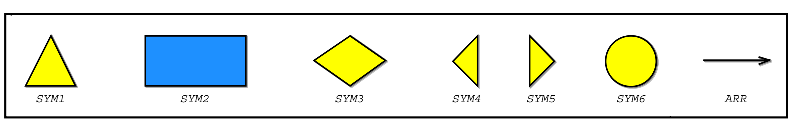

Fig. 1. Visual primitives and relation for the visual language of ADONIS BPMS

[3] Extensions of enterprise models in three dimensional space have been elaborated eg in [26].
[4] Cardinalities are denoted by uppercase letters.
[5] ADONIS Business Process Management Systems (BPMS) notation.

The semantic mapping between BP and VL then takes place as follows: $S \leftrightarrow SYM1$, $AC \leftrightarrow SYM2$, $DEC \leftrightarrow SYM3$, $SPAR \leftrightarrow SYM4$, $EPAR \leftrightarrow SYM5$, $E \leftrightarrow SYM6$ and $SR^n \leftrightarrow ARR$.

In the visual language of ADONIS for business processes the attributes of the activities are currently not mapped to visual dimensions. The ADONIS metamodelling platform nevertheless provides functionalities for linking object attributes to the graphical representation (which have for example been applied to UML [27]). This fact seems to provide an additional possibility for a visual analysis of the models. Nevertheless, at first the semiotic aspects of such a linkage have to be described so that the visual dimensions that can be used are identified.

Formally put, the question arises whether a change in $SET(SYM6)$ for example would be equivalent to a change in the relation $E \leftrightarrow SYM6$, ie whether for example the colour could be altered without affecting the core semantics of the visual language. Based on the formalisations developed so far it would be obvious that any change in the dimensions of a primitive or a relation changes its nature and therefore has a direct influence on the semantic mapping. Or based on the formalisations: $SET_A(SYM6) \neq SET_B(SYM6) \longrightarrow SYM6_A \neq SYM6_B \longrightarrow \{E \leftrightarrow SYM6_A\} \dot{\vee} \{E \leftrightarrow SYM6_B\}$.

It is hypothesised that not all types of changes in a SET directly lead to a change in the semantic mapping but that the semantic mapping is also influenced by its context. There might exist a dominant dimension in a visual language that is relevant for distinguishing the primitives whereas other dimensions can be used to code additional information. A mapping of $A \leftrightarrow D$, which implies a relationship between the attributes of the objects in the application domain and visual dimensions would increase the expressiveness without changing the core semantics of the language[6].

To further investigate these assumptions the visual dimensions of the visual primitives and relations of VL^{ADONIS} are discussed and their possible contribution to a change in the semantic mapping is highlighted.

3.2 Dimensions of visual primitives in ADONIS

The *size* dimension is constant for all primitives in ADONIS and does not present a differentiating characteristic which would permit to use it for presenting extra information. The *brightness* dimension is also constant for all primitives in ADONIS and does not contribute to the distinctiveness of the symbols. It would therefore be a candidate for integrating additional information, too. The *texture* of the primitives is a constant fill for all primitives and is neither responsible for distinguishing the elements. When examining the *colour* of the primitives the two contrary colours blue and yellow are used to code information: Yellow primitives stand for control elements (start, end, decision, start of parallelity,

[6] Psychological foundations for the perception of distinctiveness in visualisations are given by [28], [25] elaborates the details for transcribing values to the visual dimensions.

union), the blue primitive stands for an operation (activity). However, because the differentation between control and operational elements is not part of the described application domain the colour does not affect the semantic mapping as outlined above. The *orientation* dimension plays a role for the distinction of the primitive used for symbolizing the start of a process *SYM1* and the primitives for the marking of parallel flows *SYM4* and *SYM5*. It is therefore critical for a separation of elements and can not be altered. The *shape* dimension is one of the two dominating dimensions in VL^{ADONIS}. It is exclusively responsable for the separability of *SYM1*, *SYM3*, and *SYM6* and can therefore not be used for integrating other information.

	Relevant for Distinction in ADONIS	*Number of Elements affected*
Size	☒	0
Brightness	☒	0
Texture	☒	0
Colour	☒	0
Orientation	☑	3
Shape	☑	3

Fig. 2. Influence of visual dimensions on distinctiveness in ADONIS

Based on these findings two visual enhancements for business process models in ADONIS have been designed. From the four possible visual dimensions that could be used (see figure 2 for an overview) the size, brightness and colour dimension have been selected to represent additional information of the costs of activities in a business process. The choice for a linkage to the cost attribute seems appropriate in a business environment where efficiency considerations always play an important role to sustain competitive advantage. From a technical viewpoint also other attributes (eg duration, latency, average participation rate etc) could be drawn on.

4 Prototypical implementations

The visual enhancements of the process models have been implemented on the ADONIS meta-modelling platform that provides a wide range of customisation facilities for adapting the visual representations [27]. Two new model types have been created that are based on the ADONIS BPMS notation:

- A colour coded process model and
- a size coded process model.

The *colour coded process model* (see figure 3) contains the standard elements for representing business processes as described in section 3.1. The visual enhancements have been applied to the activity objects by linking the fill colour of the rectangles to the cost attribute that is defined for every activity. The base colour of the activities has been changed to red and the intensity respectively brightness increases with a raise in the costs of the specific activity. Furthermore a configuration object has been added to the process model that enables a user to specify the lower and upper bound of the cost-colour-scale and the number of shadings that are used to colour the activities. By applying the colour codes to the model of the process a user can quickly identify the relative height of costs by visual means.

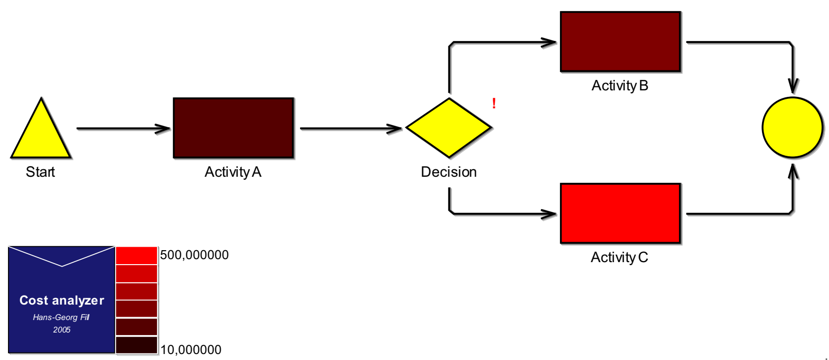

Fig. 3. Example for a colour coded process model in ADONIS

The same approach has been taken by making use of the size dimension. The *size coded process model* as shown in figure 4 is also based on the ADONIS BPMS notation elements. The implementation of the activity elements has been changed in such a way that their size is automatically adjusted according to the level of the cost attribute of each activity. Three pre-defined sizes are available and are dynamically assigned upon a change in a cost attribute.

5 Related work

The theorectical foundations that are presented in section 3.1 are related to the field of visual language theory that discusses the formal principles for visual languages [23]. Similar approaches for formalisations have been elaborated by [29, 30].

The field of information visualisation [28, 31] which is characterized by Card et al. as "the use of computer-supported, interactive, visual representations of abstract data to amplify cognition" [31](p. 7) provides a wide range of methods to visualise data. However, in this article we see the human beings, ie the actors of

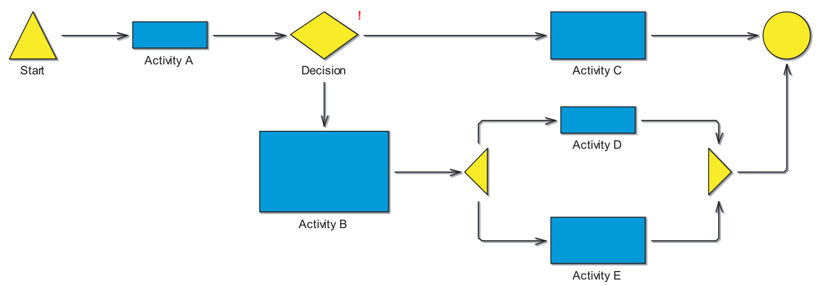

Fig. 4. Example for a size-coded process model in ADONIS

an enterprise, as the first element of the visualisation 'pipeline' and not abstract data. Despite this fundamental difference related approaches to enhance visual models can be found in information visualisation, eg the UML geon diagrams [32, 28].

Another visualisation field that is more closely related to our approach is the comparatively new area of knowledge visualisation [33, 34]. It is intended to be an extension of information visualisation in the way that it "examines the use of visual representations to improve the transfer of knowledge between at least two persons or group of persons." [33]. This aspect can be directly applied to our view of enterprise models that allow for a visual representation of knowledge in a chosen domain of discourse for the purpose of knowledge transfer between individuals.

6 Conclusion and outlook

In this paper it has been elaborated that enterprise models can be regarded as a mean to represent procedural knowledge and how the visualisations of these models can be formally described using constructs from visual language theory. It has been shown how the visual dimensions of enterprise models can be identified and how additional information can be integrated in the models to achieve a better understanding of the model characteristics. Two examples have been shown as prototypical implementations to give a visual impression of these theoretical findings.

Further work includes the empirical testing of the proposed visual enhancements to justify their use in practice as well as extensions to the implementation to allow for an arbitrary choice of attributes and corresponding visual dimensions when attempting to analyse enterprise models.

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