An Ontology for the Conceptual Modeling of Visualization and Presentation in Management Information Systems

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Abstract: A commonly agreed language between business units and computer departments for the specification of management views is one attempt to bridge the communication gap during the development of information warehouses and management information systems. As today, there is no generally accepted standard for the conceptual modeling of management information systems, although several methods have been proposed so far. What has been largely neglected in all these approaches is the conceptual modeling of presentation and visualization. Since management information systems aim to inform managers and business users about significant facts, the visual representation of these facts is of great importance. In this paper, we develop a framework for the conceptual modeling of management information systems which takes presentation issues into account. Following this framework, we extend the meta-model of an existing modeling approach for the specification of management views with concepts for presentation modeling. We draw on existing taxonomies in order to construct a simple ontology for visualization in the domain of management information systems.

1 Introduction

The central purpose of management information systems (MIS) is to provide information for the management activities carried out within an organization [CC05]. Thus, MIS are systems that assist management in decision making. In our approach, both executive information systems (EIS) and decision support systems (DSS) that allow ad hoc queries and analytical reporting are regarded as MIS. Consequently, MIS are among one of the most prominent subjects in information systems research [CGL00].

Considerable work regarding the technical architecture and the conceptual development of MIS has been carried out in research papers. It is general consensus that state-of-the-art MIS are based on data warehouses and online analytical processing (OLAP) [De97], and can be described as 'information warehouses' [Ho03]. Data warehouses support the management perspective on business processes technically, but their implementation is extremely costly [Va00]. Therefore, a clean design and specification of the system is of great importance. The involvement of management users and management's support are deemed key factors for MIS quality and success [WW01]. One of the major issues in research on the conceptual specification of management views relates to the bridging of the so-called communication gap that originates from differences in semantic understanding [Mc96]. This gap exists between business units using a MIS and computer departments designing and implementing the MIS [Pe01]. As Alter puts it, "Of course most IT professionals know more about computer hardware and software, but the communication gap is about the difficulty business and IT professionals have in establishing mutual understanding that helps them communicate in both directions about their views and concerns" [Al01].

A commonly agreed language between business units and computer departments for the specification of management views is one attempt for bridging this gap. As today, there is no generally accepted standard for the conceptual modeling of management views. The existing approaches mainly focus on the conceptual modeling of management's information demand and the phase of requirements engineering [WS04]. Since MIS inform managers and business users about significant facts, the visual representation of these facts is of great importance. The visualization of information in either MIS-based or paper-based management reporting is usually achieved by using illustrations and graphical metaphors in order to simplify the identification of relationships among the facts (e. g. diagrams, charts, spreadsheets, management cockpits, or scorecards).

Usually an ontology provides a vocabulary and taxonomy by which both users and information systems can communicate about such concepts [DBD04]. Recent work on taxonomies and ontologies in visualization tries to distinguish between different types of visualization more rigorously, e. g. based on models [TM04a]. However, as Duke et al. [Du05] point out, the task of exploring what an ontology for visualization might be has only just begun. But every ontology is only useful as long as it reflects the consensus of a community [DBD04]. To our understanding, there has not been put forward an ontology for visualization yet that has been accepted by the majority and that we could use as a starting point. Therefore, we make use of existing taxonomies that reflect a consensual understanding in the literature and try to incorporate these into a simple ontology, focusing on visualization in the context of MIS. As a result, by combining concepts from the fields of visualization and the specification of management views, we provide a first proposal for a visualization ontology tailored to the domain of MIS.

In this paper, we first give an overview of related work in the research disciplines that contribute to our topic. Afterwards, we propose a framework for the conceptual specification of MIS which serves as a general guideline for our work.

With reference to this framework, we show how the meta-model of an existing conceptual modeling approach for the specification of management views can be enhanced with language constructs for the modeling of presentation and visualization. By taking into account an existing taxonomy for these components, we create a simple ontology for visualization in the domain of MIS.

2 Literature Review

In the field of information systems research, human computer interaction (HCI) studies focus on the ways humans interact with information, technologies, and tasks [Zh02]. This includes especially managerial and organizational issues. HCI includes a variety of research issues, e. g. human cognition or the social context of the interaction.

In database research and data warehousing, one of the central issues is the visualization of content as well, as the 'Lowell Report' points out: "It has been a common lament throughout the years that the database community does too little about user interfaces. There is now the horsepower on the desktop to run very sophisticated visualization systems. However, for a given type of information coming from a DBMS, it is not clear how best to render it visually." [Ab03]. Eick proposes possible applications of different visualization techniques for multi-dimensional data in OLAP and data warehousing [Ei00]. Additionally, several approaches have been put forward for the visual modeling and conceptualization of OLAP data [Ma05; RGR99]. Likewise, several graphical notations for the conceptual modeling of information warehouses have been proposed (e. g. [BU99; Bu96; GMR98]). What has been largely neglected is the conceptual modeling of presentation issues. Related to these works are similar modeling methods for web-based information systems and hypermedia applications that focus on structural, navigational and presentational aspects as well [Br06; Ce04; GC03; SPM99].

According to Card, Mackinlay and Shneiderman, visualization is "the use of computer-supported, interactive, visual representations of data to amplify cognition." [CMS99]. This includes both scientific visualization and information visualization for physical and abstract data respectively. The application of different visualization techniques has been especially used during the knowledge discovery process in data mining [FGW01; Ke02]. While most of the 'classical' research focuses on graphical presentations using common business charts, the developments in the field of advanced visualization techniques have encouraged a discussion about the adoption of these techniques for 'business information visualization' as an independent field of visualization [Te99; Zh01]. In addition, a wide range of authors have conducted research on identifying principles for the design of effective graphs [Cl85; Di97; Ko89; Ma86; Tu83].

But what is the best presentation technique? "A consensus is that the literature is in disarray" [CC93]. The central criterion for any successful presentation is how accurately and how fast a spectator can extract data or relationships between data from its visual presentation. As Tufte describes this, "The simple things belong in tables or in the text; graphics can give a sense of large and complex data sets that cannot be managed in any other way." [Tu83].

Vessey provides an explanation by applying cognitive fit theory, whereby the problem representation must match the problem solving task [Ve91]. Despite cognitive fit theory and new approaches to present information using different technologies or visualization techniques, the central question still remains: what type of visualization is best for what situation? Tory and Möller point out that the focus of most visualization research is on creating new and faster techniques for displaying data, rather than focusing on the users who must view and manipulate the data [TM04b].

However, user requirements are usually more important than techniques, especially in the domain of MIS [WW01]. Since the sole purpose of MIS is to help business users in the decision-making process, good presentation of information is of great importance: "The size of the information set which users can coherently bring together on the display of an interactive computer system limits the complexity of problems that can be addressed." [RC94]. Taking into account the importance of users in MIS, we do not intend to develop new visualization techniques usable in business situations, or to conduct empirical research on the choosing of a specific visualization technique for a certain management task. Instead, we follow a more pragmatic approach related to design science [He04]: we let the developer decide during the specification of management views what type of visualization he or she deems appropriate for a specific audience, type of information, or task. Consequently, if the MIS developer only knows *what information* to include into an MIS and not *how to display* it, he or she misses a crucial point.

Information modeling (the representation of an information system or organization in a specific modeling language) as well as meta-modeling (the description of a specific modeling language through another modeling language) are considered as instruments in the information systems domain for solving these design issues [St96]. The analysis of a modeling language and a meta-language leads to the concept of an ontology. Campbell and Shapiro explain that an ontology "consists of a representational vocabulary with precise definitions of the meanings of the terms of this vocabulary plus a set of formal axioms that constrain the interpretation and well-formed use of these terms." [CS95]. From our point of view, an ontology structures the object of the ontological question ("What is reality?") and defines elements of it and relationships between these elements. This procedure can be observed in several ontology construction approaches [Bu77; GR00; Us98; WW90].

We argue that linguistic research can help to deal with situations where new concepts are required. Especially the language perspective of Kamlah's and Lorenzen's language critique approach [KL84] can be used to create an ontology. According to this approach, language to communicate about an IS domain needs to be reconstructed using linguistic actions. The task of creating an ontology is then to be understood as creating a common understanding of a system of symbols. Therefore, we take into account Wedekind's "object type method" (Objekttypenmethode) [We81] and the approach for method engineering presented in [HDB05]. We pursue two goals: as a first step, we introduce our understanding on how to discuss the design of different possible visualization techniques in MIS (i. e. 'visualize the visualization' by using graphical conceptual models).

Consequently, we present a framework for the classification of presentation modeling as a phase of conceptual modeling in MIS design. As a second step, we apply this framework to an existing approach for the specification of management views. We adopt this approach and create a basic ontology for the conceptual modeling of visualization in the context of MIS.

3 A Framework for Conceptual Modeling Layers for MIS

Most approaches for the specification of management views have been developed with regard to conceptual modeling of information demand. Their language constructs span an information space for management views that is constituted by the content of the MIS' domain. In order to enhance such a language with concepts for visualization and presentation, related areas of research are of special interest.

It has been proposed that MIS are a subset of web-based information systems: although MIS usually have some characteristics that are different from web-based information systems (e. g. the degree of structuring, the granularity, the aggregation, or the level of hierarchy of the information objects), MIS can be implemented with web-based technology and share characteristics of those systems concerning navigation and presentation [Be04; Br06; JBH05]. The field of web engineering and hypermedia usually separates the modeling process into different abstraction layers [SPM99].

Therefore, we draw on this analogy, and with reference to the Dexter Hypertext Reference Model [HS94], we separate conceptual models of MIS into three layers: *content layer*, *structure layer*, and *presentation layer*. In Figure 1, these layers are shown in relation to the elements of a reference model for information visualization [CMS99].

This reference model summarizes the flow of raw data on the left hand side of Figure 1 to the task-specific views on the data on the right hand side. Data transformations convert raw data into data tables that are in general relational descriptions of data and based on mathematical relations. Afterwards, visual mappings transform data tables into visual structures that encode the data by using spatial substrates and graphical properties that can be effectively processed by human perception. Lastly, view transformations specify graphical parameters (e. g. position) for interactively modifying visual structures (e. g. slicing, clipping, panning, zooming). The whole process is controlled by human interaction which restricts and changes the underlying information for some tasks. We argue that this flow of data is related to our three layers, which constitute phases for the conceptual modeling of management views.

The information objects that represent reports inside a MIS are specified on the *content layer*. The focus lies on the modeling of content and information demands that are collected during requirements analysis. The intention is to transform these information demands into a semi-formal conceptual model. The model spans the information space of the MIS' domain, using different dimensions and facts. This is where the 'classical' modeling approaches for conceptual modeling of information warehouses are used.

The resulting models serve as a foundation for both the following layers and the data schema that is created during the implementation. Consequently, the content layer is closely related to the information stored in the data tables and for which specific visualizations need to be chosen (here in the context of management views).

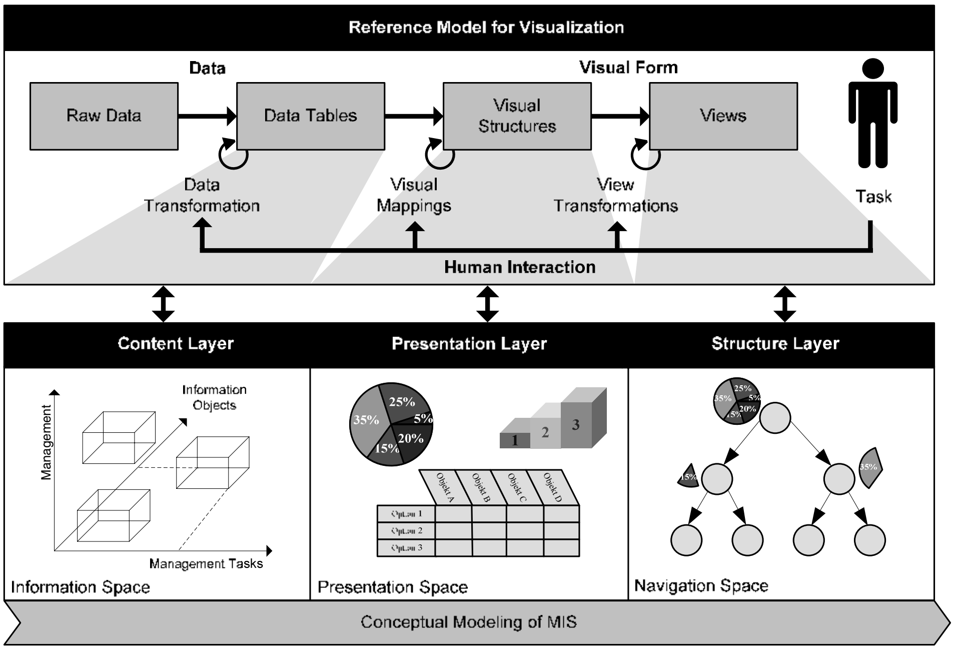

Figure 1: Layers of Conceptual Modeling for MIS

The *structure layer* separates the content into nodes and links. The resulting structure spans the navigation space and specifies possible navigation paths through the MIS' content. Thus, the navigation possibilities for users within the MIS are defined with reference to the dimensions and facts specified on the content layer. In MIS, the structure is usually embedded within the pre-defined hierarchies and aggregation levels of the used data schema, thus offering a high degree of structuring. By using OLAP operations (e. g. drill-down, roll-up, slicing, dicing et cetera) the user is able to follow the navigation paths defined by the hierarchies of the dimensions. Specific views are needed to model the needed information and navigation paths in an appropriate way to a specific management user. Therefore, the structure layer is directly linked to the views of the reference model for visualization.

Another central requirement for MIS is the presentation of content in a specific type and manner. Maniatis precisely coins this problem in the context of OLAP: "[...] since OLAP is a technology facilitating decision-making, the presentation of data is of obvious importance" [Ma03a]. Consequently, the *presentation layer* is introduced. MIS need visualization functions for the graphical presentation and visual analysis of information objects that are customized for decision makers and management users. The content needs to be represented by using specific visualizations.

Although the structure of an information object is restricted through hierarchies and navigation paths, the information object may be presented as a table, as a bar chart et cetera. Presentation modeling is grounded in the language concepts of content layer and structure layer: "The representation model serves the transformation of the conceptual schema on a lower-level representation and basically contains the information necessary for graphic representation" [WZ03]. If presentation issues are important, as in MIS, they should be modeled, but not necessarily as an integral part of the logical model [Co99].

4 A Conceptual Modeling Approach for Presentation Modeling

4.1 The MetaMIS Approach for the Conceptual Modeling of Management Views

The MetaMIS approach has been originally developed for the specification of management views on business processes [Ho03; HDB05]. By using a semantic model based on Riebel's enterprise theory [Ri79], the MetaMIS approach is an ontology-driven method which aims to bridge the communication gap between computer departments and business units. The approach is adaptable and has been significantly enhanced (e. g. [Be05; Br06]).

MetaMIS initially consists of a simple non-technical language, a formalism to represent this language, and guidelines for the modeling of information spaces based on this language. At first, overall master data of management views are modeled with respect to company-spanning concepts. These master data form the dimensions which span the space in which management views exist. After that, report master data are modeled in order to design task-specific management views.

The resulting conceptual models can be used to create a logical data warehouse schema [Ho03]. Since a full description is out of the scope of this paper, we summarize the main concepts in Table 1 (cf. [Ho03; HDB05] for a more detailed descriptions).

Concept	**Description**
Dimension	Dimensions are used to create and organize the space the management's view is composed of. Dimensions consist of levels of hierarchy and dimension objects are assigned to these hierarchy levels. A dimension requires a set of dimension objects for its definition.
Dimension object	Dimension objects are entities relevant for management's arrangements and examinations and part of the definition of dimensions in the sense that they have strong relationships to each other from the management's point of view.
Dimension scope	Dimension scopes are used to define scopes of dimensions relevant for a specific management view. Any dimension scope is composed of one or more dimension objects.
Dimension scope combination	Dimension scope combinations are used to identify combinations of dimension scopes while defining management views. Any dimension scope combination may contain one or many dimension scopes.

Reference object	Reference objects are defined by Riebel as all "measures, processes and states of affairs which can be object to arrangements or examinations on their own" [Riebel (1979)]. Dimension objects are used as coordinates to specify combined reference objects.
Aspect / aspect system	Aspects are the instruments to measure management relevant characteristics of the value of an enterprise, the business performance and the financial situation. They include qualitative and quantitative ratios. An aspect system is a set of aspects which enables the analysis of meaningful aspects of a business situation.
Fact	A fact is a relationship between the concepts reference object and aspect. Any reference object can be combined with zero or many aspects and vice versa.
Information object	An information object is formed by a relationship between concepts aspect system and dimension scope combination. They form a set of facts relevant for a management user.

Table 1: Basic Language Concepts of MetaMIS

The concept 'information object' spans the information space relevant for specific management views. The information space can be represented by using an n-dimensional hypercube (Figure 2). In this example, the four dimensions "Projects", "Time", "Business Units" and "Scenario" span the information space and the hypercube of the information object accordingly. Due to the fact that only three dimensions can be easily visually perceived by humans, we ablate the fourth dimension "Scenario" inside each subcube. It consists of different quantitation scenarios (e. g. "Actual", "Planned" et cetera).

Each combination of dimension objects relates to a point inside the information space, thus forming a specific reference object. Only the reference objects of a dimension that are restricted through a dimension scope are significant for a specific management view or report respectively. Thus only the dimension objects selected by the dimension scope are of relevance for the report. For example, of the dimension "Scenario" only the dimension object "Actual" is of importance. The parts of the hypercube that are of relevance for the report thus can be identified through projections of the grids of the hypercube.

With the MetaMIS approach, content can be modeled explicitly using the language concepts introduced above. MetaMIS implicitly spans the navigation space together with the information space. However, MetaMIS does not include language concepts for presentation modeling (cf. [Be06]).

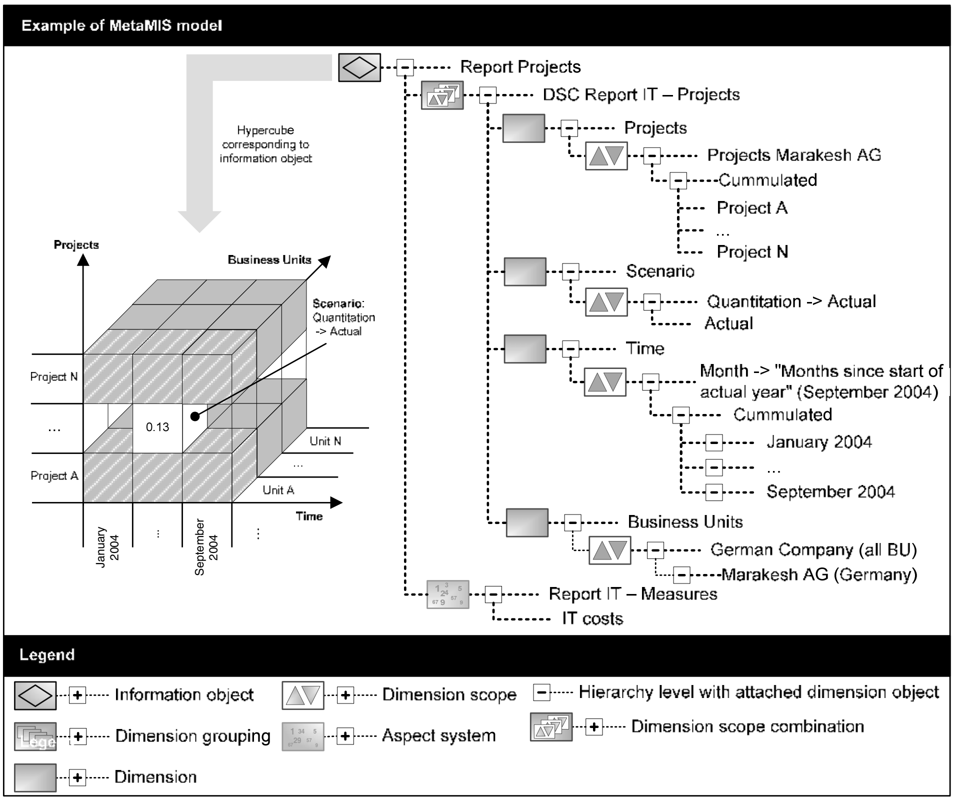

Figure 2: Representation of Information Space as a Hypercube

4.2 Specification of Language Concepts for Presentation Modeling

Since to the best of our knowledge no sufficient ontology for visualization has been put forward so far, we construct our enhanced meta-model by making use of a consensual taxonomy that is used within the visualization literature instead. As a result, in terms of the language critique approach, we reconstruct a simple ontology. Most visualizations are made from a basic set of components which was identified by Bertin [Be81] and expanded, amongst others, by Card, Mackinlay and Shneiderman [CMS99]. We presume that all kinds of presentation are based on this simple geometric set of components.

- *Marks*: marks are visible objects that occur in space. Four elementary types can be identified: points (zero-dimensional), lines (one-dimensional), areas (two-dimensional), and volumes (three-dimensional).

- *Spatial substrate*: the spatial substrate describes how a visualization structure makes use of the information space. For example, the space is best described in terms of axes and their properties if it has a metric structure. Thus, axes are an important building block for visual structures. The composition of axes creates a two-dimensional (2D) metric space.

- *Graphical properties*: graphical properties can describe position, size, orientation, the use of colours, texture, shape et cetera as possibilities to encode information. This group is usually called "retinal properties" because the retina of the eye is sensitive to them [Be81].

Based on these components, Table 2 summarizes the resulting concepts of MetaMIS for presentation modeling. They are described in more detail in the following paragraphs.

Concept	**Description**
Visualization expression	Visualization expressions are elements for the representation of dimension objects in a report in a predefined form perceivable by humans. The concept is specialized by concepts such as 2D-Table or bar chart. The definition of these concepts requires algebraic and logical expressions, based on an axis operator. Each visualization expression is constructed by one or more axes (normally not more than three on the uppermost hierarchical level due to the fact that human perception cannot handle more dimensions).
Axis	An axis is a set of *axis points*. An axis includes dimension objects from different dimensions and dimension scopes respectively. In a 2D space, an axis represents a column or row. Axes are the building blocks for visualization expressions.
Axis operator	An axis operator defines logical and algebraic expressions needed for the computation of visual expressions. Each axis has exactly one axis operator.
Presentation object	In a visual expression perceivable by humans there is a need to show more than one dimension per axis. Presentation objects represent these dimension objects which form an axis point. A presentation object is unequivocally and totally specialized by the concepts dimension object, calculation expression, or dimension scope in order to determine the dimension objects which are needed for display. The presentation objects form a hierarchy, and are organized hierarchically within a visualization expression. Each axis point is constructed by combining a set of dimension objects from a presentation object hierarchy. It is basically defined by the Cartesian product of these dimension objects.
Cross-join	A cross-join is a set of n axis points and forms a combination of axes accordingly. Each combination of axes has a corresponding fact attached to it. Each of the facts is defined by a combination of dimension objects, to which each of the axis points corresponds.
Report structure	The concept report structure defines a set of visualization expressions relevant for the same purpose.

Table 2: Language Concepts of MetaMIS for Presentation

The concept *visualization expression* (VE, representation: rectangle with colored bars) is used for the specification of representation types. A VE is a collection of content that is based on reference objects and facts. Thus, VE are closely related to marks as described above.

Pragmatically, we generalize VE for business graphics into two-dimensional *tables*, three-dimensional *cubes*, *circle diagram*s, *bar charts*, *bar graphs*, *scatter diagrams*, and *curve diagrams* [Ze01]. These concepts are among the basic types for the representation of information objects in a business environment that can be perceived by humans on a 2D screen. The representation is restricted on the one hand due to the skills of humans to process information, on the other hand due to hardware and software restrictions [Ma03b; Mi56].

For metric structures as they occur in MIS, all VE are based on the concept of an *axis* (representation: coordinate system within a rectangle). An axis is formed by a set of *axis points*. Axis points are formed by a combination of *presentation objects*. Presentation objects comprise dimension scopes and dimension objects. They can be ordered hierarchically (*presentation object hierarchy*). Each axis point is formed by a specific combination of different presentation objects that have a hierarchical relationship. Hierarchically ordered presentation objects are needed because usually more than one dimension is shown per axis in order to allow the presentation on a 2D screen.

Consequently, an axis point is basically formed by a set of dimension objects that originate in different dimensions and dimension scopes respectively. Figure 3 represents an axis and its related presentation object hierarchy. It shows a typical representation of an axis in a tabular form, e. g. a spreadsheet, using rows to represent the axis points.

The axis points are formed as the Cartesian product of all presentation objects of an axis. Literally, the presentation objects on a higher hierarchical order are 'clipped down' to the coordinate system, and each is combined with the hierarchical subordinate presentation objects.

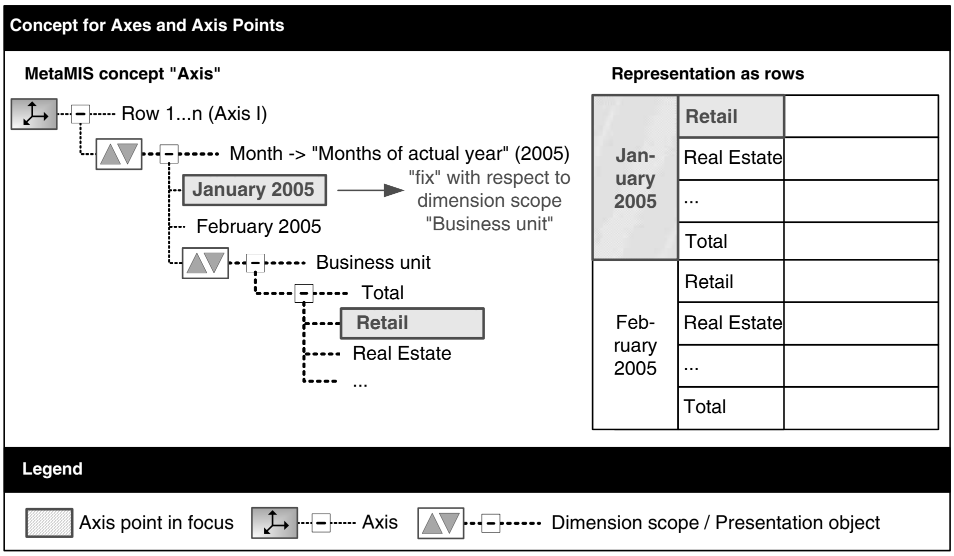

Figure 3: Example of an Axis and related Presentation Object Hierarchy

For example, in Figure 3, the top level presentation object (dimension scope “Month -> “Months of actual year” (2005)”) is pinned down to the axis through the dimension object “January 2005”. Axis points are formed by combinating this dimension object with the dimension objects of the subordinate presentation objects (dimension scope “Business unit”), e. g. (“January 2005”,”Retail”), (“January 2005”,” Real Estate”) et cetera. Thus, for each dimension object of the subordinate presentation object “Business unit”, a specific month is clipped down and fixed to an axis.

Axis points are created by any number of hierarchically ordered presentation objects. In the case of a table, this creates a nesting pattern, e. g. a pivot table as found in Microsoft Excel and other spreadsheet tools. The operator of a pivot table transposes a spreadsheet, typically aggregating cells based on values in the cells, and creates columns based on subsets of column values. Thereby the table becomes ordered by different perspectives (e. g. calculation of dimension objects by months, by business unit, or by total revenues et cetera). The presentation objects are arranged on the axis in order of their nesting, thus forming the axis points. Using axes and axis points as elementary building blocks instead of merely rows and columns, we are able to distinguish multi-dimensional VE as 2D representations more rigorously.

Tables, charts and cubes are all formed based on axes. For example, a table can be created by two axes, of which the corresponding axis points form the rows and columns, thus specifying the cells of the table.

A set of overlapping axis points on different orthogonal axes forms a *cross-join*. The set of all cross-joins produces the Cartesian product of the axis points of all axes. Intuitively, the axis points of a horizontal axis and a vertical axis create rows and columns of a table, and their intersections form the cells. A semantic relationship exists between facts and the content of a cross-join. The dimension scope combination clearly defines a reference object as an exact point in the information space on the content layer. Facts can refer to that reference object. Thus, it corresponds to the concept of cross-join formed by axis points.

On the presentation layer, the cross-join represents the reference object. In order to determine the related facts, each VE needs a relationship to the aspect system of the corresponding information object: the substance of a cross-join is clearly defined through an aspect with reference to the combination of the axis points and the combination of the dimension objects respectively.

Consequently, cross-joins bridge the gap between information space and presentation space: a cross-join connects axis points and their corresponding dimension objects on the presentation layer with the corresponding facts on the content layer [Ma03a].

An *axis operator* (representation: text) allows the specification of graphical properties by using formal logic or algebraic expressions as pseudo-code. For example, in the case of a table or spreadsheet, it can be specified if an axis is meant to represent a row or a column. Basic properties (e. g. color) or properties depending on the chosen type of VE (e. g. format of the axis as a bar or a baseline) are defined in this way. This allows flexibility in terms of the VE. Instead of representing the content as a table it is common to use visual charts in reports.

Each of these diagrams is based on a selection of axes which are chosen in the initial step (definition of data source by specification of rows and columns belonging to specific axes). Afterwards the parameters of the diagram are specified by a formal expression summarized in the axis operator (e. g. choice of diagram type, selection of color schemes et cetera).

For each VE, the information object to be visualized needs to be specified. Within the axes of the VE only these dimension objects are allowed that also appear in the dimension scope combination of this information object. The same does apply for the aspect system. Each information object on the content layer can have one or many different VE on the presentation layer. Thus, VE can be summarized by using *report structures* (representation: rectangle with document symbol). These structures order reports from a presentational point of view. Figure 4 shows an example of two presentation models for one information object, summarized by a report structure.

The presented language concepts that extend the MetaMIS approach with components for the modeling of presentation and visualization aspects are summarized as a metamodel using the Entity Relationship Model (ERM) in Figure 5. The tabular description has been excluded for reasons of space. Basically, these concepts propose an ontology for visualization in the domain of MIS.

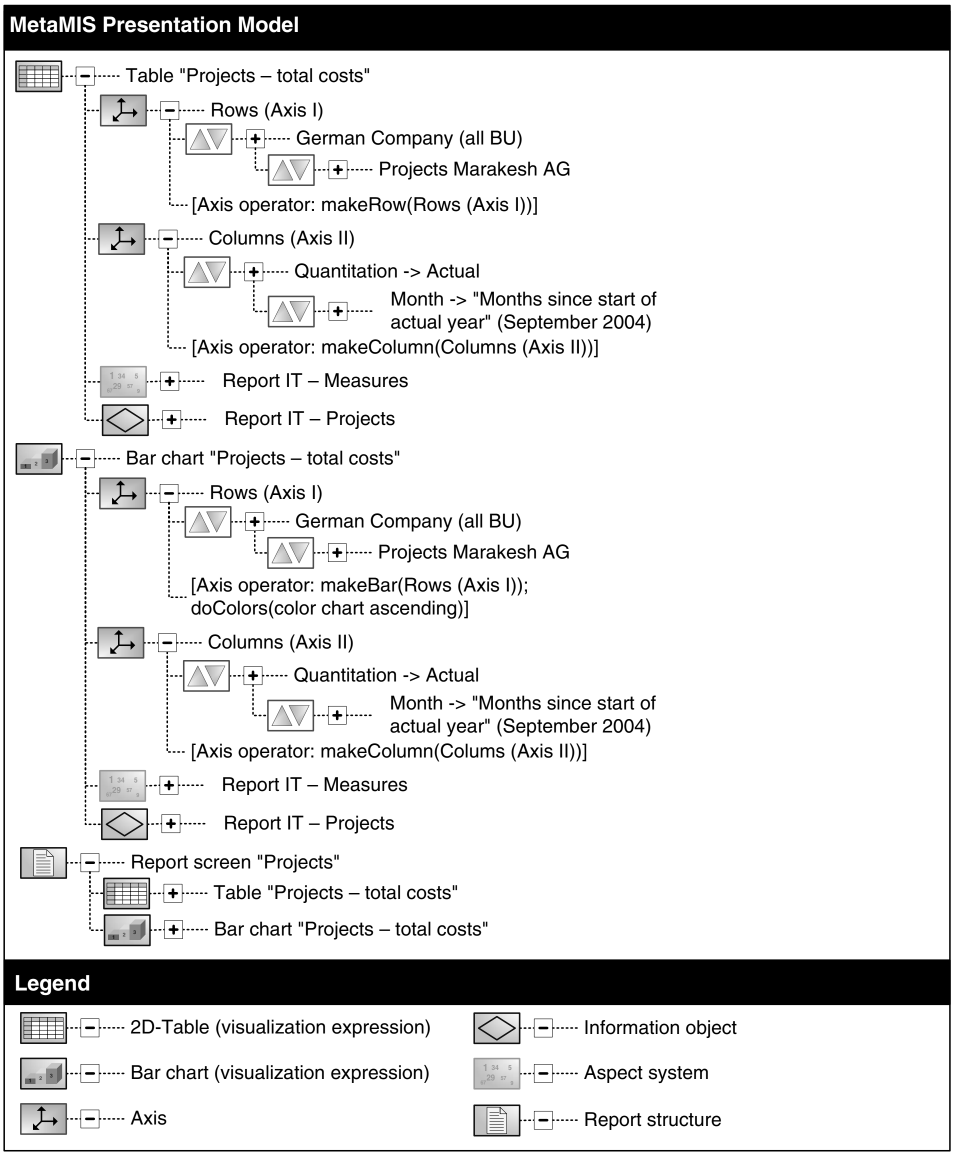

Figure 4: Example of Presentation Modeling within MetaMIS

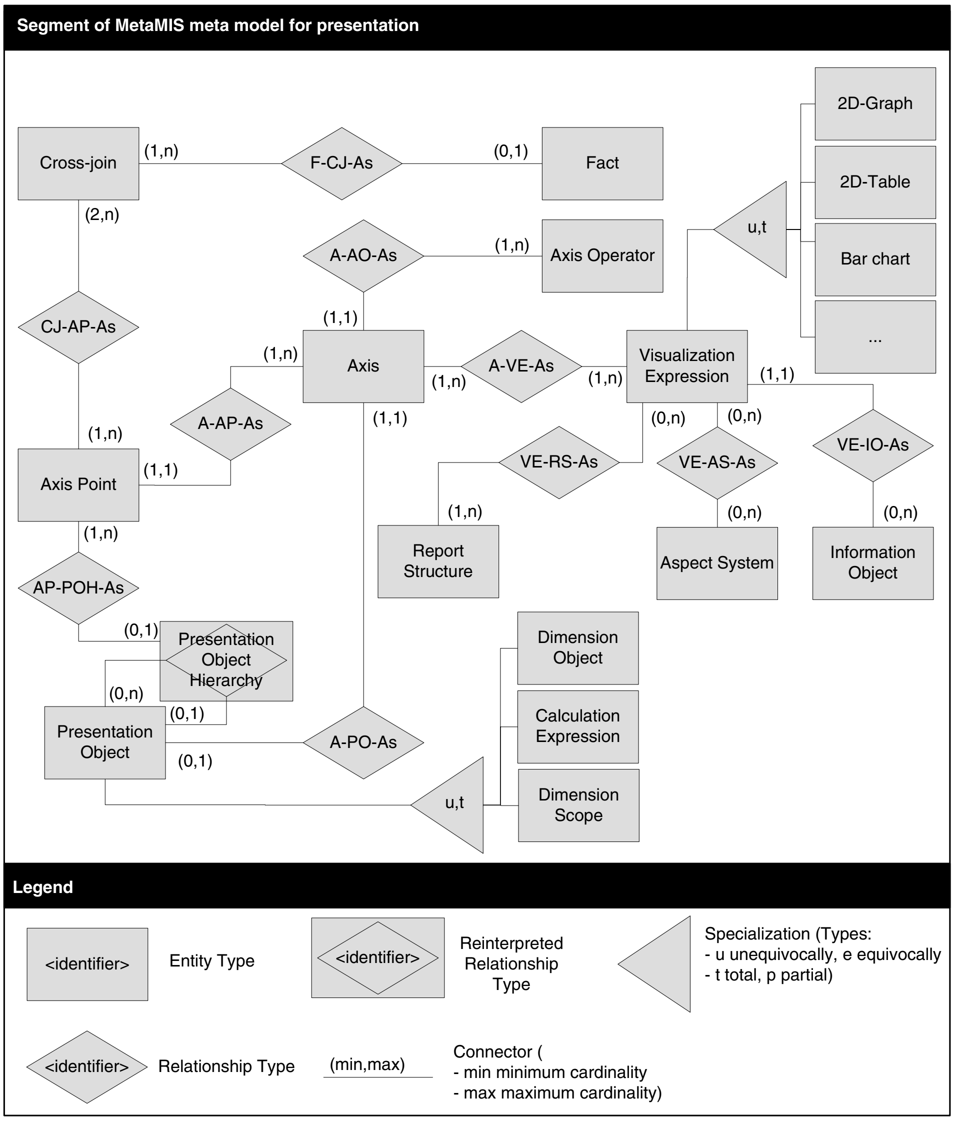

Figure 5: Meta-model of the Additional Language Constructs for Visualization

5 Discussion and Conclusion

This paper firstly presents a framework for the conceptual modeling of management views that considers presentation and visualization issues. We argue that presentation and visualization are important facets of management views and MIS respectively. By relating conceptual modeling of web-based information systems to a reference framework from visualization, we separate conceptual modeling for management views and MIS into three separate layers: content layer, structure layer, and presentation layer. Secondly, we show how an existing approach for the specification of management views can be enhanced with language concepts for the conceptual modeling of visualization issues. Since no sufficient ontology for visualization does yet exist, we use a more general and consensual set of components for building our meta-model and a first simple ontology tailored to visualization in the domain of MIS. We argue that our language-based approach is flexible enough to be adapted to any upcoming ontology (cf. [Be06]).

The MetaMIS approach has been applied in several information warehouse projects. Before our adoption, we usually encountered problems of understanding the original information objects during the discussion of the requirements specification ("How is this dimension scope going to look like on a screen? A table, or what?"). Since the presentation layer was lacking, we were always forced to picture the information objects as they were supposed to look later in the MIS, e. g. by drawing a short sketch of a report screen. Therefore, we enhanced MetaMIS with the ontology presented in this paper, in order to offer a clean separation of content, structure and presentation. We propose that this will help MIS developers during requirements specification.

There remains significant room for further research and development. First, the proposed framework is based on our understanding of concepts from both information systems and visualization research, creating a reasonable symbiosis of the two. But it must be further tested and refined before it can be considered as accepted. Second, we need to adapt existing modeling approaches and their language constructs to a more mature ontology for the domain of presentation modeling. This ontology must offer the basic building blocks for visual presentations. In order to speed things up, we will especially examine both existing taxonomies and ontologies in development from fields related to visualization. Additionally, the proposed language enhancements need to be applied to different modeling cases and field studies for gaining experiences with them, testing them, and improving them.

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