Visualizing the Shadows of Information

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Abstract: Three-dimensional visualization facilitates human perception, imagination, and reasoning based on computer-represented knowledge. Since human imagination and reasoning is based on 3D-shapes, the presentation and validation of knowledge is most efficiently performed with the aid of geometric shapes. Thus, we propose the use of visualization methods in knowledge management, supporting qualitative information by quantitative data that is simpler to explore. We support our thesis by a case study modeling the ontology of a human heart. This work connects the areas of human knowledge as philosophical ontology and knowledge management as ontology in artificial intelligence.

1 Introduction

When Plato presented his allegory of the cave, he had in mind the perception of reality by human observers. Knowledge management considers a digital version of reality, necessarily assuming that "what exists" coincides only with "what can be represented" [1]. However, often human perception does not match with the digital knowledge representation. We propose the use of visualization methods to improve computer-represented knowledge to reach human minds.

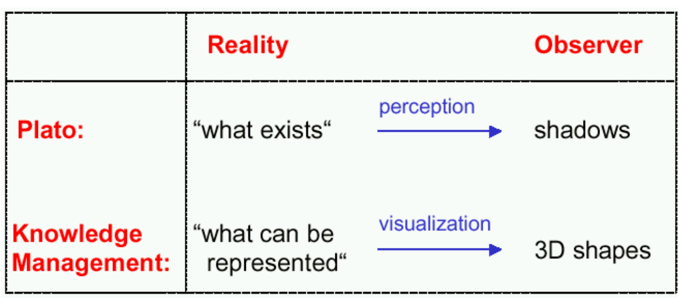

Figure 1: Plato's allegory of the cave applied to knowledge management.

A human observer who is trained to perceive objects by observing their shadows would be reluctant to look at the real objects, so Plato argued. A reason for this might be that real objects are too difficult to handle and that two-dimensional shadows showing only the essential contours are optimal for efficient recognition and assimilation by an observer. Analogously, we can optimize the perception of computer-based knowledge representations by transforming them into "shadows". Three-dimensional visualization methods are most effective for this, since human observers are well trained to reason in three dimensions, see figure 1. Thus, visualization is a "knowledge technique" coming close to human reasoning.

Peirce already proposed to "make exact experiments upon uniform diagrams" as a means of replacing "experiments upon real things that one performs in chemical and physical research." [7]. Consequently, visualization –if only viewed as a generalization of diagrams– allows to experiment with knowledge and elicit new and implicit knowledge.

Experimenting with entities in a three-dimensional representation could be transferred to the visual verification of reasonable shapes, their intersections or connections, and their spatial relations to each other. This supports our assumption that it is useful to perform experiments in the areas of knowledge management and philosophy with the help of interactive visualization.

Certainly, visualization raises new issues, mainly because the visualization machinery requires to make commitments. There is also the potential of inconsistencies. Another issue is that visualized models bypass certain senses of suspicion of human viewers. Humans simply tend to believe what they see. Validation of perceived and represented knowledge is necessary.

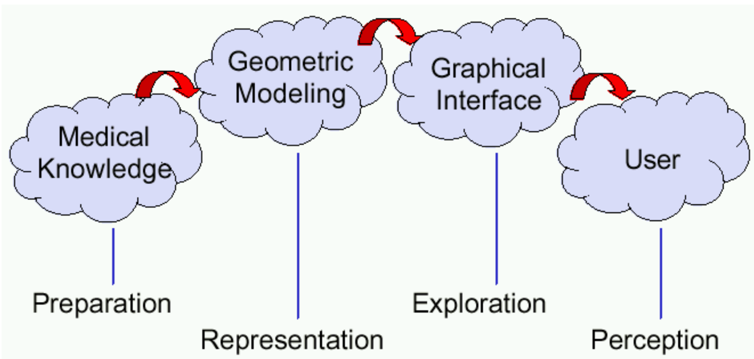

Figure 2: Perception of knowledge using visualization as man/machine interface

On the other hand, visualization is very often an extremely useful instrument for the verification of the results of model constructions, like ontologies. For our case-study below, we needed to model the human heart, the result of which is sometimes hard to evaluate as long as it is formally described. Having the model visualized immediately reveals its validity.

Visualization simplifies and accelerates the transformation of digital data into knowledge, see figure 2. A major challenge is the visual display of quantitive information [6] widely used in knowledge management systems with ontological structures [5]. We propose the semi-automatic generation of three-dimensional geometric models from qualitative and quantitive data. The next section shortly describes the representation of knowledge. The construction of a 3D-model is dealt with in the third section. We support this approach by a case study of a virtual echocardiography tutoring system in section four, followed by some concluding remarks.

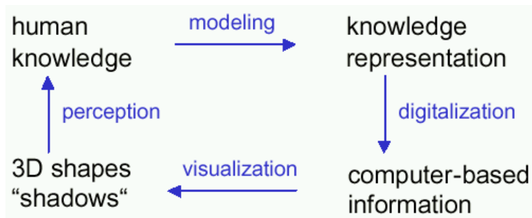

Figure 3: Visualization reverses the process of modeling knowledge.

2 Data, Information, and Knowledge

The most important task of knowledge management is to allow a human user to gain knowledge and to draw conclusions. Visualization techniques provide the important interface between man and machine in this process. This holds especially for the querying of specific information out of a large data sources. Presenting requested bits of information to a user requires to construct a three-dimensional geometric model. The geometry, which carries the information, can be interactively explored by the user, tuned to his cognitive excellence.

In a sense, we reverse the process of constructing models from nature, constructing “shadows” of nature from models, see figure 3. This has an impact on the modeling and representation of information, since the direction of this process must be reversed.

In the following, we use the term “knowledge” exclusively associated with human intelligence. A computer system can only produce knowledge by interaction with humans. The data stored in such a system, intended to spend knowledge is called “information”.

Data acquisition is the process of gathering information, digitizing it and storing it in some kind of data base. There may exist many different, unstructured data segments originating from different sources associated with different applications. In particular, we distinguish between data of qualitative and quantitive type.

Qualitative data can be described by a set of classes and instances thereof with certain attributes and relationships. The latter are described by one or multiple graphs connecting the individual nodes (classes or instances).

Quantitive data sets mostly describe mathematical functions mapping a domain **D** into a range **R**. The simplest type of qualitative data is a real or integer number. Continuous functions can only be represented on a digital system by using a finite set of coefficients with associated smooth basis functions, for example polynomials.

When querying information from a knowledge management system, the first challenge is to obtain the “right” pieces of information automatically from a vast amount of data. Unstructured data originating from different sources needs to be filtered and combined into a

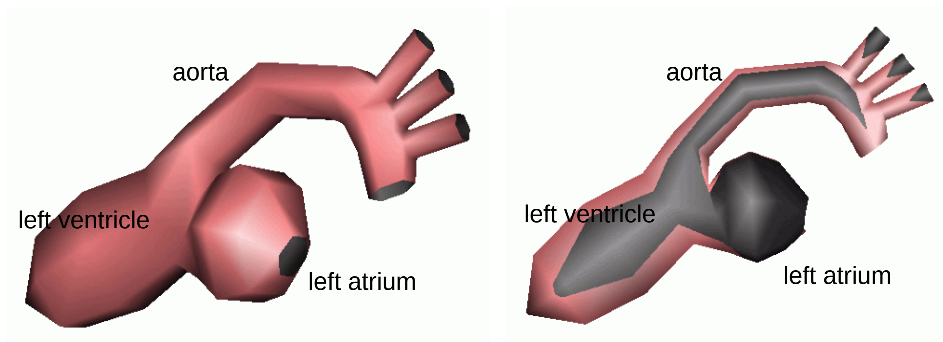

Figure 4: Visualization of left ventricle, atrium, and aorta of a human heart based on a triangulated surface representation (left). The interior can be explored by slicing through the geometry (right).

representation satisfying the requirements given by the query. The second challenge is to construct a mathematical (geometric) model for the visualization. For this process, qualitative data needs to be transformed into numerical data representing three-dimensional geometry. This is an important step, since we want to transform the results into a human-perceptible form by casting three-dimensional 'shadows' of the combined data.

3 Geometric Modeling and Visualization

The crucial part of the visualization process is the automatic generation of geometry in form of a mathematical model. This model, tagged with the corresponding textual information, is then examined by the user employing standard interaction and visualization tools, like slicing, see figure 4.

In many cases, the underlying data has not been prepared for visualization applications and qualitative information needs to be re-defined in mathematical terms. For example, a possible ontology of a human heart may contain the primitives "left ventricle" and "left atrium" with a qualitative "are connected" relationship. Even if we know that the atrium is located "on top of" the ventricle, we need a lot more information for constructing a mathematical model. If we assume that both primitives are shaped like ellipsoids with prescribed locations, radii, and orientations, then we can easily derive a surface representation for both primitives. By intersecting both ellipsoids we could even validate that the associated primitives are connected.

The required numerical information that is not present in the data must be "guessed" that all qualitative relationships derived from it remain valid. Additionally, the visualization system should be transparent enough that the user can easily recognize which parts of the model are supported by data and which parts are based on default settings. In principle, it is possible to derive numerical data from qualitative constraints. For example, an arrangement of objects (like organs in a human body) can be estimated iteratively from qualitative definitions like spatial relations, relative size, and coarse shape. Such an estimate is not unique in general and depends on a certain "residual" that is minimized by the construction.

A different approach is to supplement the given ontology by numerical information that is attached to the individual instances, see figure 5. This approach has an enormous impact on the design and implementation of knowledge management systems, but it leads to more precise mathematical models. An example for this approach is described in the next section.

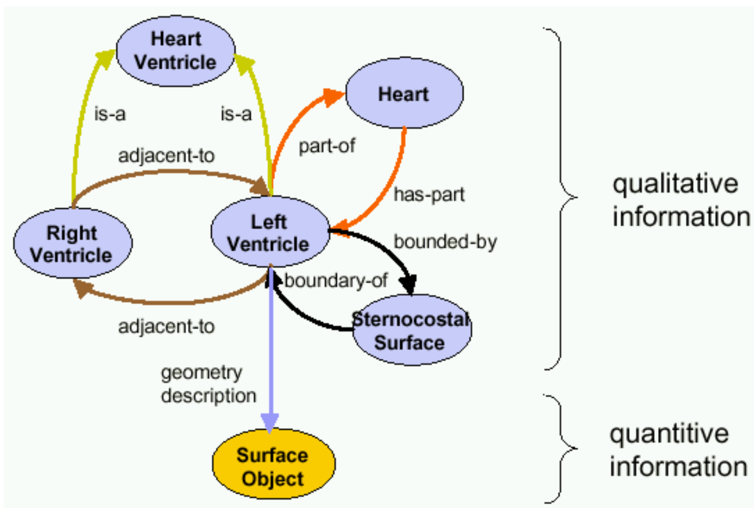

Figure 5: Different relations for left ventricle.

4 Case Study: A Virtual Echocardiography System

The objective of the virtual echocardiography system is to provide a virtual examination environment for use in education, medical documentation, surgery planning and simulation. Joining interactive visualization and artificial intelligence (AI) techniques enables us to provide a powerful tutoring system. To satisfy the requirements of such a system, it is first necessary to develop a formal representation for a healthy human heart and for an echocardiography finding. By combining the heart representation with a particular finding, we obtain a view of an individuals heart. This combination of information is used to generate a mathematical model for computer animation of the individual heart focusing on selected parts.

Both formal representations have been implemented using the ontology editor Protege-2000 [4]. While the finding ontology is mostly a collection of known finding parameters, the modeling of a heart ontology is much more complex. For this purpose, we used the anatomical structure of the Digital Anatomist [2, 3]. In addition to the anatomical hierarchy, a variety of different relations between the individual entities need to be specified

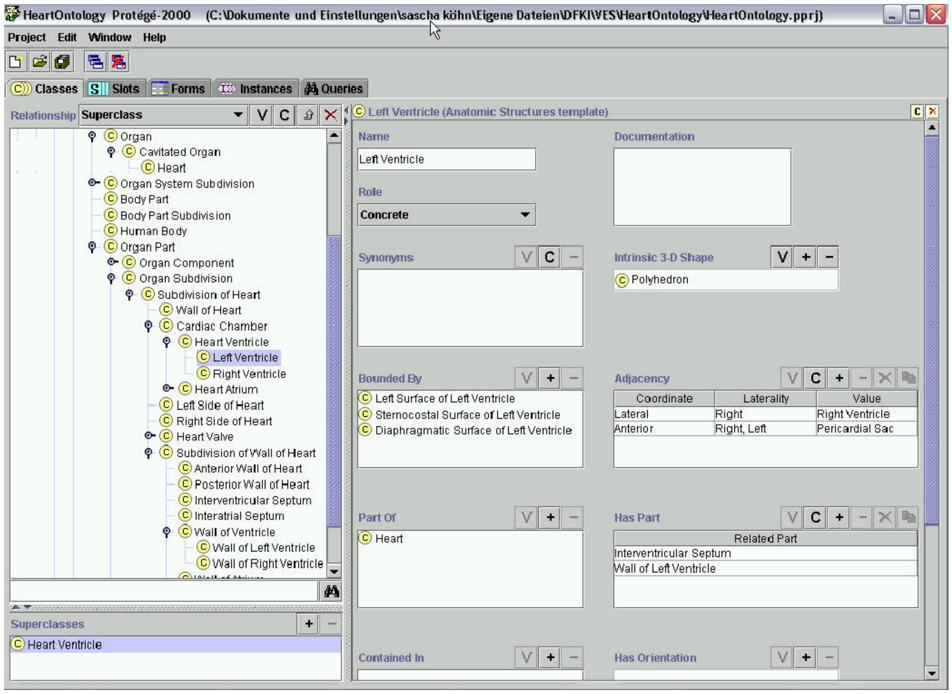

Figure 6: Modeling the ontology of a human heart using Protege 2000.

representing all geometric and functional aspects of the heart, see figure 6.

In the Digital Anatomist model, all geometric relations are restricted to qualitative information. For example, the location of adjacent organs is defined by certain quadrants or octants rather than by coordinates. This information has the advantage of generality, but it is not precise enough for constructing a geometric model. In our approach, the individual anatomical entities (representing for example “Left Ventricle”, “Left Atrium”, “Mitral Valve”, “Diaphragmatic Surface of Left Ventricle”, etc.) were coupled with numerical geometric data consistent with the quantitative relations.

The geometric representation itself is defined by an ontology containing objects of different dimensionality and topology, see figure 7, as well as spatial and functional relations. The mathematical model for the visualization is now based on the numerical attachments to the individual anatomical entities.

In our first approach, we only used qualitative information from our system to create the heart geometry. In a second step, we used a magnetic resonance image (MRI) of a human heart to approximate the heart geometry, see figures 8 and 9. The new geometric information certainly exceeds the knowledge that can be extracted form the quantitative information. However, the quantitative knowledge is more general, since our geometry is derived only from one particular heart.

Implementing both qualitative and numerical relations leads to a flexible knowledge man-

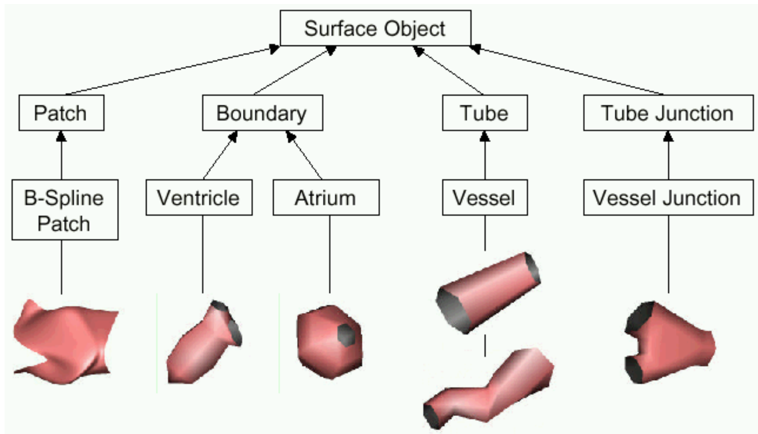

Figure 7: Hierarchy of geometric objects that can be attached to the qualitative data facilitating the visualization process.

agement system, capable of satisfying arbitrary queries about any kind of information regarding the assembly of the human heart. The vast amount of information resulting from these queries would be difficult to overlook by a human user. When coupled with interactive visualization and exploration methods, the complexity of the data is much simpler to perceive and more convenient to handle for a human user.

A disadvantage of our approach is the great amount of work for data preparation and representation. Certain operations on the data, like joining a heart ontology with a finding ontology become much more complex, since both qualitative and numerical relations need to be considered. On the other hand, the need for constructing geometric models for visualization had a significant impact on the conception and implementation of our knowledge management system. We hope that a great amount of the work used for constructing geometry from qualitative relations can be automatized in the near future.

5 Conclusions

We have motivated the need for visualization techniques in knowledge management, simplifying the perception of information by human users and allowing them to deal with abstract knowledge in a natural way. This offers not only the ability to experiment with and examine knowledge easily but also permits to gain new knowledge out of the visual presentation by reasoning e.g. on spatial relations, and shapes. It will furthermore allow to connect the areas of human knowledge (as a philosophical ontology) and knowledge management (as an AI ontology). Since it is necessary to connect human intelligence and machine intelligence, we conclude that visualization can be an important part of AI and will become even more important in the future.

We presented the design of a virtual echocardiography system as a case study pursuing

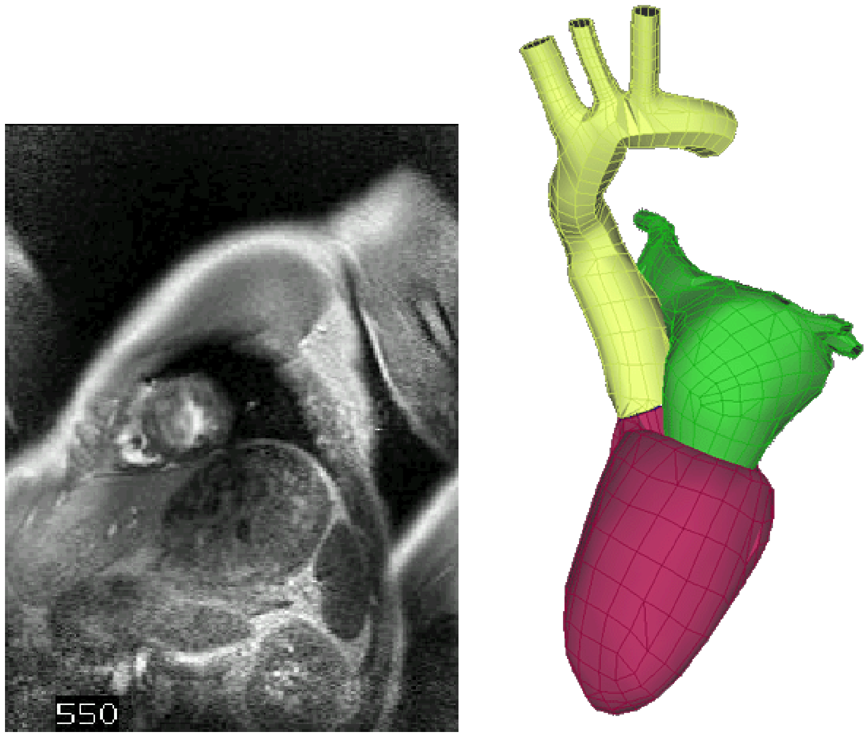

Figure 8: Enhanced geometric model by constructing surfaces from MRI data. Four-chamber view MRI (left) and geometry for left ventricle, left atrium, and aorta constructed with 3D Studio Max (right).

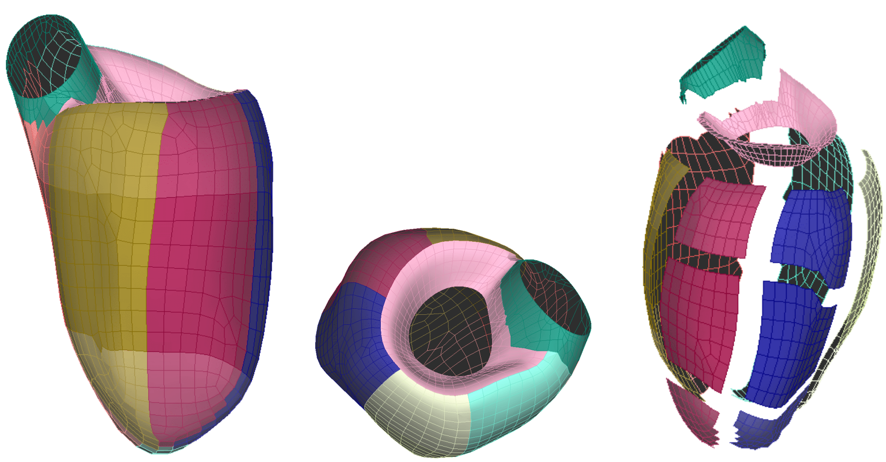

Figure 9: Exploring the model by rotating and splitting the geometry. Anterior view (left), top view (middle), lateral view with detached surface components (right).

a visualization-related ontological design. A problem of future work is the automatic generation of three-dimensional geometry form unstructured, qualitative data without the need of manually attaching numerical data to certain entities. Another very interesting question concerns the best choice of metaphors for the visualization of knowledge casting “shadows” from the machine into the user’s mind.

Acknowledgements

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