Motion Enhanced Visualization in Support of Information Fusion

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Abstract ***The process known as information fusion faces the extraction and combination of information from multiple, heterogeneous sources to derive information of a new quality or abstraction level. Though parts of this process can be automated it is heavily influenced by user interaction. New approaches in visualization are required to support the user in interacting with constructed information spaces. This paper presents a brief analysis of the possibilities and potentials of enhancing visualization with motion for this task. The reflections are supported by a survey of the requirements and an overview of the general framework of a workbench for information fusion.***

Keywords: Motion, Visualization, Interaction, Information Fusion

1 Introduction

Given the current state of the art in database technology and modern communication networks large volumes of data cannot only be stored and managed but are subject to the providence of world-wide distribution and access. The resulting increase in the number of available information sources leads to what users perceive as information overload. Information providers often represent their data in a heterogeneous fashion regarding structure and semantics. The task of presenting deduced information can be derived. Attempts have been made to access varying data sources via a uniform user interface, thereby hiding the heterogenous nature of the underlying data [3, 5]. These efforts are restricted to specific application domains and are not generally applicable. In addition, they do not answer the open question of limited expression capabilities provided by the set of classic presentation variables like color, shape, transparency, and position of an object.

The objective of information fusion results in important requirements of methods and techniques for interactive information exploration and manipulation. Some of these are already addressed by current research in interactive systems [12, 13]. Others, like limited expression capabilities of classic presentation variables, have been mentioned in the literature [2] but not yet been considered in depth.

This paper is organized as follows. Section 2 outlines general requirements of information fusion. Ongoing research of the authors in the field of motion enhanced visualization to support user interaction is expressed in Section 3 and 4. In Section 5 a framework is shown that establishes the software basis for the presented work. Section 6 finally summarizes the key aspects of the paper.

2 Requirements of Information Fusion

Though various potential fusion applications result in different requirements, a set of tasks can be identified which are similar for a wide range of fusion applications.

Data access: At first, we have to support a uniform access to different sources. This involves the usage of database gateways in order to hide the heterogeneity, to access Web sources via the appropriated protocols, and extracting semistructured data from these sources, as well as query translation, optimization, and processing.

Data integration: An integrated view should represent data from the different sources in a homogeneous model. This involves mending conflicts at schema or instance level and dealing with aspects of data quality. In addition, inter-source relationships have to be represented and managed at the global layer.

Analysis and abstraction: Filtering or condensing data and extracting dependencies or abstractions offers the opportunity to yield information of a new quality. The notion of new quality depends on the concrete application.

Presentation and processing: The discovered information has to be presented according to the problem domain or be prepared for further processing. The visualization needs to be enhanced to allow a user exploration of the information space and offer ways of interactive manipulation of the fusion process as well as of the fusioned data.

Representation of meta-information: An important prerequisite for fusion is the existence of information about the sources, the fusion objects, and the problem domain. Such meta-information should be managed by the system and updated or extended during the fusion process, e.g. for optimization and interactive exploration purposes.

This paper concentrates on the presentation and processing stage. Of interest are aspects of visualization and its specific characteristics in the fusion process.

3 Motivating interaction support by motion

Information fusion is a process which is heavily influenced by user interaction. On the one hand, users need to decide on the kind of fusion operations to apply, on the other hand, the process of fusion needs to be presented in a comprehensible manner. After all, a possibility is needed to modify single aspects of the fusion process.

Therefore, techniques and tools need to be developed which provide the user with the capability of interacting with data to be used in the process of fusion as well as data that comes out of it. A tight correlation exists between interaction and visualization: illuminating visualization is a prerequisite for enabling the user's access to the underlying data. In addition interaction requires that the visualization allows to trace back visual characteristics to their raw data source or intermediate results of the fusion process. Therefore special data structures are needed to enrich the visualization in a way that provides the user with the capability to access the characteristics seen in the data directly. This in turn requires the provision of suitable data already at the information fusion.

Navigation techniques for exploring complex information spaces are outlined in [14]. Special emphasis is put on various zooming methods, including fish-eye views, distortions, and displacements. We expand this catalog by adding motion to visualization for the purpose of easier exploration and interpretation of information spaces.

Object movements are seen as a peculiar characteristic attribute of the information fusion in regard to visualization. On the one hand, an additional set of presentation variables is needed because the visualization of data to be fusioned often uses conventional variables such as color, shape, position, and transparency for itself [14]. On the other hand, it is expected that good correspondents exist for processes of the fusion which can be expressed by object movements. Such object movements are in need of specific interaction techniques to provide access to moving objects and movement parameters by the user. In analogy to BARTRAM, motion is thereby considered as an abstractly codable dimension in its own right [2].

To value motion as a separate display dimension results from the circumstance that it takes the design, creation, and understanding of visualization to a new quality. Perception of information encoded in motion is more efficient than perception of statically expressed information [1]. Motion provides an extensive interpretation scope. Complex psychological impressions can be produced by simple actions that are relatively inexpensive to compute [9]. This allows to make information accessible which is not directly expressed in available data but is semantically encoded therein. According to [15] motion is even a more effective method than stereo in regard to the disambiguation of three-dimensional graphs.

4 Techniques for motion

A common technique for mapping visualization data onto graphical representations are glyphs. These are graphical objects whose display variables are bound to data characteristics. Various techniques exist for constructing glyphs [4, 6, 7, 10, 11, 17]. In this work the classical set of their display variables is expanded by motion. A variety of techniques can be employed for applying motion to emphasize specific glyphs:

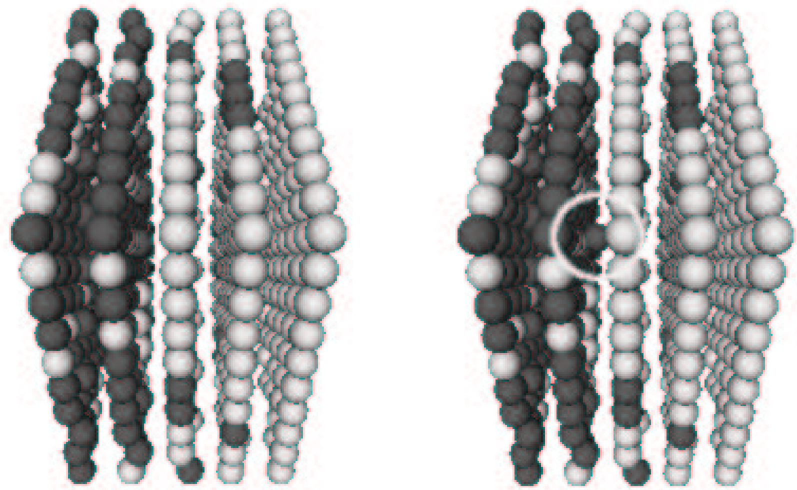
Translation The glyph's position is constantly changed. Thereby, care should be taken to ensure that the object's location does not change significantly in relation to the remaining scene. An appropriate way to conform to this restriction is oscillation.

Rotation Hereby, the glyph is usually rotated around its central point. The advantage is that the scene's coherence is not considerably invalidated. However, spotting this motion might require an intense cognitive approach by the user. To avoid this, the rotation center might vary from the object's center. It does not necessarily need to be a point inside the volume of the glyph. This flexibility is of course paid for by the potential of invalidating the scene coherence.

Distortion Steady changes of a glyph's shape provide a means of motion without manipulating the overall scene construction. Changes in shape can be done either by repetitive scaling or switching the shape's kind. While each object might be manipulated individually, its spatial correlation to other objects is not affected. This technique is therefore to be used preferably when the frame coherence of a specific object is of minor importance compared to its influence on the scene context.

These techniques can of course be combined to create sophisticated motion patterns. In addition, multiple methods can be used simultaneously in a scene to express different data characteristics by means of different motion application. Of special interest is thereby grouping of motions. Psychological study leads to the insight that groups of semantically connected data are more easily recognized if they are expressed in multiple similar motions instead of static display [8].

To provide an exemplary motion application, a financial data set is constructed where one scalar (solvency) depends on three influencing attributes (income, age, education). For the purpose of glyph construction these attributes are mapped onto spheres that are arranged along three coordinate axes. Color is used to show the degree of influence on the scalar for each attribute. The whole data set is shown in bright color, whereas the dimmed glyphs represent the data set scaled according to solvency. Figure 1(a) shows a resulting image. The result is very valuable in determining five income classes regarding solvency. What the image not reveals are single elements not contained in any of the classes. As the position



(a) Glyphs without motion applied. (b) Snapshot while applying motion.

Figure 1: Applying oscillation to selected glyphs for emphasizing almost hidden glyphs.

of the glyphs representing them does not vary considerably compared to their neighbors, they are almost hidden. Emphasizing these glyphs by oscillating motion reveals them. Figure 1(b) shows a snapshot with a moving glyph being pointed out.

As the human visual system is sensible regarding motion and changes over time, special care needs to be taken in regard to motion enhanced visualization. For easy recognition moving objects are displayed in high contrast compared to the scene's background. The scene's volume in the given example is rather moderate and easily perceivable on the whole. An exploring user does not get lost because of single, distracting object movements. When the exploration space grows, static reference points are needed for moving parts of the scene. This leads to the restriction that we cannot express a specific characteristic of *every* displayed object by means of motion. When the whole scene consists exclusively of movements without static references, the spatial perception of the user is perturbed and the visualization is more distracting rather than explaining. A possible solution for that restriction is to map parts of the motion that is to be displayed onto textures. Thereby, the whole catalog of motion techniques can be applied to enrich the visualization. The navigation support provided by static scene elements would still be retained. This aspect of applying object motion onto textures has not yet been researched in depth and remains an open challenge for future work.

5 Component based framework

As shown in Section 2 information fusion is a compound of several different activities. From an application point of view they are brought together in a so called workbench. Therein, a *fusion engine* realizes the tasks of data access and integration as well as managing fusion components for automatic analysis and abstraction. These components are dynamically loadable when required by the system. The user interacts with the system via a graphical user interface that is implemented as a separate application. Communication between this front-end and the fusion engine is done by a CORBA interface. In parallel to the engine, the front-end works component based by implementing a plugin mechanism. Visual interaction and exploration capabilities—such as the motion enhanced visualization shown in this work—are dynamically loadable into and out of the system at runtime.

Dynamic extensibility is considered a worthwhile key feature for the fusion workbench. As shown in [16] for virtual environments this vastly increases the overall application quality as it is not necessary to shut down any execution just because it becomes necessary to load a component into or out of the system. In addition, this flexibility provides the user with an additional option of configuring the workstation setup to include sophisticated visualization hardware or just act as a primitive fusion management workplace.

6 Conclusions

Information fusion is characterised as a multimodal process with heavy user interaction. Visualization using only classical presentation variables comes to its limits regarding the support of user navigation, understanding, and interaction in constructed information spaces. This paper discussed motion as a valuable enhancement to visualization. Possible techniques were shown and their advantages and possible misuses addressed.

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