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Knowledge- and Context-sensitive Visualization Techniques for Immersive Environments

Abstract

Today, the amount of unstructured, multidimensional information is becoming more and more complex and overwhelming. One promising approach to face these problems is the efficient use of large displays. Their immersive effect is even stronger when using a stereoscopic, three-dimensional representation of information. However, especially when working with textual information, there are a lot of interactions that are intrinsically two-dimensional, like reading and editing of documents. Using mixed-dimensional visualization, interaction should be adapted to complement visualization dimensionality in order not to sacrifice task performance. We use the concept of **dimensional congruence** to find best matches for the dimensionality of interaction techniques with the demands of visualizations and tasks. Darken and Durost [1] have defined dimensional congruence as: "[...] a condition whereby the spatial demands of a task are matched directly by the interaction technique that is used to execute it." Therefore we use a combined 2D + 3D visualization and interaction interface. Interaction is adapted to complement visualization dimensionality in order not to sacrifice task performance. This results in a superior user interface, being more intuitive and natural to use.

When using a 3D environment, e.g., a PowerWall, the technical limitations of such 3D projective systems result in a loss of detail and sharpness of the visualized information. This usually makes stereoscopic visualization unfavorable when displaying fine details or textual information. To accommodate these problems, we have developed a **focus+context screen for large virtual environments**. The concept is implemented by enhancing a common 3D projective system with a third seamlessly integrated (high-resolution) projector. This projector is used for displaying an additional high-resolution 2D focus area. Users start working with the system in the default, pure 3D mode. Here, they are able to get a fast, immersive overview of the available information. After requesting detailed (meta-) information of an object, the 3D space is transformed and the visual focus is set on the selected item, while simultaneously preserving the 3D contextual relationship. A 2D overlay is then projected onto the focus area, providing users with high-resolution, high-contrast detail information. Baudisch et al. [2] have defined that "focus plus context screens implement regions of different resolution by combining multiple display units of different resolution". Our 2D+3D focus+context metaphor extends this definition by "different resolution and different dimension". The concept scales to every application environment, where objects can be organized in 3D context space and users usually request detail information about them. It is even applicable in common VR scenarios. Here, the context usually is defined by a geometric object (e.g., a CAD model of a car). The focus can be any detail information that is available for that object (e.g., measurement data for parts of it, selection-related paragraphs of service manuals, etc.)

Beside the problem of dimensional congruence, monitoring and tuning such visualization scenarios is a complex challenge. Because of the continually changing conditions and vast variety of parameters, even experts with infinite experience have problems dealing these circumstances. In order to improve this unsatisfying situation, we have extended the design of our visualization system by **incorporating multi agent technology**. Our approach makes use of two types of agents (deliberative and reactive agents). Reactive agents can only execute simple tasks but they can be easily integrated

into dynamic environments. Regarding the architecture of a visualization system, a module or a group of modules always performs one fixed task; this means that terms of regulation (e.g. frame rate and rendering quality) can be described by straightforward static rules. Thus, a reactive agent is always assigned to either a module or a group of modules and it controls the modules' parameters on demand. Since a reactive agent only needs the knowledge in the module specific context it acts similar to a control loop. In contrast, a deliberative agent has the ability to handle complex problems, but in general it is not able to process such jobs in real time on his own because of the applied sophisticated calculation methods. The supervision of the reactive agents, as well as the analysis of information generated by them, is done by such a deliberative agent, called Controlling Agent. Based on the overall knowledge about the involved visualization components and with respect to the user specific demands it automatically responds to changes in the environment (e.g. the system load) by modifying the desired values of the subordinated reactive agents.

Office environments, where specialists are seeking for best possible information assistance for improved processes and decision-making, serve as one powerful demonstration environment. In the last decades the paradigm of document management and storage has radically changed. In daily working this has led to electronic, non-tangible document processing and virtual instead of physical storage. As a result, the spatial clues of document filing and storage are lost. When documents are stored in a computer they become invisible for human beings. To retrieve them, they have to use search engines, which usually tend to produce a vast number of hits. Here, our perceptual user interface serves as a complementary working environment for document filing and retrieval. The use of 3D display technology provides a spatial media for document interaction and stimulates the strengths of visual processing. The approach supports explorative search and active navigation in document collections.

A second field of application is problem solving in **Urban Planning.** It is based on a very broad range of data and data structures. This varies from statistical and geographical data to semantic values like historical descriptions of areas. All the data is used to present solutions for different specific problems. To explain problems and to visualize results in this application area two-dimensional techniques like charts, tables and text or photorealistic three-dimensional views are used. But all the data has to be analyzed to get results.

Two main aspects affect the area of interest, the planning process, the increasing number of actors and different interests and the ongoing enlargement of the need for information and analysis. In this case urban planners have to redesign certain areas. These areas are left behind by the military or by civilian users. In the first step they analyze the current situation by collecting all information (geographical data, traffic requirements, water management, pollution, statistics, natural constraints...). From this point they start to develop different planning alternatives which fulfil all requirements based on the needs of multiple actors. Therefore they have to figure out the effective usable data and to analyze this data. This work is actually done by producing hand-made plans. If they wish to change these planning alternatives, they have to redraw the plans. As part of our work these hand-made plans should be replaced by an automatically generated plan based on the input given by the actors. As add-on semantic values as the users' point of view and their interests are part of the analysis.

The basic considerations concerning the deeper analysis of the involved actors are i.e. some parameters of general interest, as well as actor-specific parameters and the different interests of the actors differing in dependence of country and situation. Each actor has a personal point of view on the various parameters to be considered. Based on these facts a dynamic system that allows a globalization of the decisions is built up. Apart from these points the system handles large and unstructured data sets and the corresponding analysis displays the parameters and their correlations. Final goal is the consolidation of the interests of the individual actors and the development of the actor-specific planning alternative. Starting point is a data collecting tool. The required data can be collected on-site by a hand-held palm. This data together with the already existing data like statistics can be stored in the data base. In the next step the actors define all necessary parameters in the special reuse process. All replanning processes are unique and require special parameters but the planning process itself is a standardized procedure. The actors also define parts of the area for desired usage like housing, business and production areas. Afterwards the actors weight the parameters by defining the influence with regard to the whole area and the importance of a parameter from their point of view. All these input information can be analyzed by generalized area voronoi diagrams. As part of that voronoi diagram the new developed metric is used. This metric combines the semantic value of the collected information and the spatial distance between areas. Following the analysis the results have to be visualized by using a multilayer technique. With this technique each actors' result is displayed. They can overlay the results to get a basis for ongoing discussions. As additional requirement not only the analysis results have to be visualized but also the incoming basic data must be displayed to make the decision making process transparent. Therefore a new developed information visualization technique called pie tree is used. This technique is an extension of existing information visualization techniques.

[1] Darken, R.P. and Durost, R. Mixed-dimension interaction in virtual environments. *Proceedings of VRST 2005*, ACM Press (2005), 38-45.

[2] Baudisch, P., Good, N., Stewart, P. Focus plus context screens: combining display technology with visualization techniques. *Proceedings of the 14th annual ACM Symposium on User Interface Software and Technology*, ACM Press (2001), 31-40.