SphereViz - Data Exploration in a Virtual Reality Environment

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Abstract

We present SphereViz, a novel 3D user interface for the visual exploration of multi-dimensional data sets in virtual reality environments. SphereViz builds on known visualization and search concepts like RadViz and RelevanceSphere. It combines them with 3D-interaction techniques like World in Miniature for projection in virtual environments. A prototype implementation of SphereViz allows to study, on one hand, the visualization methods of images in 3D space, and on the other hand, intuitive search methods and adequate interaction techniques.

1. The SphereViz interface

We present current work on the design of SphereViz. SphereViz is a new 3D interface for searching multi-dimensional image data sets.

The 3D interface is designed for virtual reality (VR) environments. It presents a collection of image thumbnails in a virtual sphere as outlined in Figure 1. The position of a thumbnail in the sphere is determined by a number of parameters. These parameters either describe image properties such as total intensity, color proportions, etc, or characterize the image content. Each parameter is associated with a dimension that spans the virtual space. As a result the proximity of the thumbnails gives an indication of the similarity of the images. The users can interact with the dimensions in the virtual reality environment. By modifying the way the dimensions span the space in the sphere, the user can rearrange the thumbnails and thus explore the image similarities.

VR technology has rarely been used for information visualization, although it would provide some powerful properties like stereoscopic 3D imaging in real-time, first person view, and 3D interaction [1] [2]. One reason for this is the performance restriction set by current 3D imaging hardware. Even with efficient data structures it is hard to present large data sets in VR. But, as VR-systems become more and more efficient, this should change in the near future.

SphereViz has been implemented as a prototype. It allows to experiment with using such 3D user interfaces for information visualization in general. It serves as a presentation platform and as a test bed for further development. It also gives us a first impression of the whole interface.

The prototype has been presented to various potential users at different stages of the development in order to get early user feedback. The positive reactions have motivated us to follow on with this approach.

2. SphereViz prototype implementation

The SphereViz prototype allows to visually search an arbitrary chosen image archive. The images are characterized by a multi-dimensional set of parameters. Each parameter is associated with one dimension. The main goal is to find yet undiscovered relations between
these parameters as well as to group images with similar properties.

For interaction and visualization we have chosen VR technology mainly because of the need to complement traditional visualization techniques in presentation of a larger amount of images (see Section 3.1). We gain additional value through the advanced interaction capabilities provided by VR compared to mouse and keyboard (see Section 3.2).

The visualization and the interaction concepts of SphereViz base on a combination of already known techniques that we have optimized for a VR application. For visualization we use a combination of the Relevance Sphere [3] and RadViz [4], for interaction we use the World In Miniature (WIM) technique [5]. A more detailed description of these techniques is given in Section 4.

From a visual point of view, SphereViz presents a set of 2D thumbnails inside a wire frame sphere. The thumbnails are implemented as billboards. They always turn their front side to the users viewpoint.

The algorithm to determine the place of the thumbnails in the sphere is called Spring-Embedder Model [6]. Figure 2 shows this principle. Each parameter dimension is represented as a spring connecting the thumbnail with a handle on the sphere surface. The spring applies a given force on every thumbnail. The strength of the force corresponds to the thumbnail parameter value in the associated dimension. The image is placed at the position where the equilibrium of forces is reached.

![Spring-Embedder Model applied to SphereViz.](image1)

From an interaction point of view, the user can now walk through the virtual world and inspect groups of thumbnails or magnify single thumbnails. Additionally he or she can grab the parameter handles and move them freely on the sphere surface. This will cause the thumbnails to be re-arranged in real-time. This visible movement gives valuable feedback to the user.

To ease moving handles we introduced a World In Miniature (WIM). A small copy of the world is presented right in front of the user. Like with a remote control the user can move handles in the foreground while the thumbnails will be re-arranged in the background. Thus one can avoid to walk the whole world just to grab two handles.

The photo archive mentioned above has been implemented as a proof of concept for SphereViz and serves well for illustration purposes. SphereViz has also been applied to a scientific image archive containing images of solar flares. These images have been recorded by NASA’s Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) spacecraft [7] [8]. RHESSI provides an archive of about 60000 automatically generated thumbnails of solar flares (Figure 4).

![Photo archive in SphereViz. Greenish images are placed on the left side, bluish in the front and reddish at the back](image2)
The content of thumbnails is described with additional metadata like flare duration, observing time, location on the sun, or total intensity. These parameters are used to arrange the thumbnails in SphereViz (Figure 5).

Figure 5. Thumbnails of solar flares in SphereViz

3. Information exploration in virtual reality

SphereViz benefits from the advanced spatial visualisation and interaction methods provided by Virtual Reality. Spatial visualisation allows presenting clusters of images in a very user friendly way, spatial interaction is used for evaluation and searching tasks. VR increases the legibility of large datasets and provides more intuitive techniques for browsing through the data.

3.1. Spatial visualisation

For visualisation the SphereViz prototype uses real-time stereoscopic displays. With stereopsis we have an additional visual depth cue to structure objects in space. In contrast to 21/2 D representations (in this case 3D models displayed in 2D), a set of spatially arranged thumbnails can be seen as a structured cluster, even if they fill the whole display and cover each other.

Visualized data objects are characterized by three attributes: size, scale, and distance. They play an important role for a better understanding of the displayed data in particular because the objects are perceived in «natural scale». The design of the SphereViz prototype allows to experiment with these attributes. We already learned that the optimal configuration depends on the problem domain.

3.2. Spatial interaction

For spatial interaction the SphereViz prototype uses a video-based tracking system. This allows to track the position of any reference point such as the users' head or an input device. Users can freely walk in the virtual world and interact with virtual data objects. They can control the visualization by natural actions like grabbing or moving objects. Thumbnails that are covered by an other object can be brought to the foreground just by walking around the object. Thus, the user can focus on his or her main task, without bothering about input devices.

Spatial interaction concepts are characterized by three attributes: dimension, position and orientation. These attributes depend on the users location and on the input devices. Through the use of the WIM we have added a way to experiment with these attributes. A down-scaled hand-held copy of the virtual scene can be manipulated by hand. When the user rotates or moves the WIM he or she gets a second viewpoint without changing the virtual scene. Additionally the WIM can be used to move the parameter handles on the sphere surface and thus to change search queries comfortably without loosing the visual context.

4. Used visualization and interaction techniques

SphereViz is a combination of Lyberworld’s RelevanceSphere, RadViz, and the World In Miniature (WIM) interaction technique. They will be briefly discussed in the following sections.

4.1. Lyberworld’s RelevanceSphere

In Lyberworld’s RelevanceSphere [3] a set of documents is visually presented within a sphere. Parameter objects, called terms, sit on the sphere surface and can be used to rearrange the documents. Therefore, the objects can be moved freely on the
sphere, while the clustering of the documents changes accordingly.

4.2. RadViz

In RadViz, [4] a 2D visualisation method for high dimensional data sets, every dimension is represented as a point on a circle. These dimension points are equally distributed on the circle. For the layout of the data points within the circle RadViz uses a spring embedded algorithm. Every data point is connected to a dimension point by a spring. Based on a physical calculation model, the spatial position of each data point is set to the location where the equilibrium of forces is reached. Data points with average properties are located in the centre of the circle, extremes are placed near the sphere border.

4.3. World in miniature (WIM)

The World in Miniature (WIM) is an interface technique that uses a virtual hand-held miniature copy of the immersive virtual scene for visualization and interaction tasks. In addition to the first-person perspective offered by a virtual environment, WIM offers a second dynamic perspective onto the scene. Objects can be manipulated directly in the immersive scene or through the WIM.

5. Conclusions

We presented SphereViz, a novel 3D user interface for the visual exploration of multi-dimensional data sets. It bases on well-known data visualization techniques which have been optimized for the use with VR. Combined with virtual reality interaction techniques our approach lead to a new, intuitive way to interact with scientific data archives.

We see a great potential in using VR for visual exploration of multi-dimensional data sets and in particular in SphereViz. Amongst others driven by the game industry, we expect VR technology to evolve significantly within the next 10 to 15 years. VR will allow users to look at and interact with large datasets in new ways.

Our work focused on the optimization of the visualization and interaction techniques for the search task, as opposed to high-performing backend algorithms and data structures. Taking the Visual Information-Seeking Mantra into account [9] the current application covers the zoom and filter and the details on demand part. In future versions we plan to extend the WIM to give the overview of all available data. Next to solving performance issues we expect ways to overcome the mental overload to be of great interest.

As SphereViz is work in progress, there are also several plans for further optimization of the interface concept. Springs can be adjusted to control their strength and therefore their relevance in the system. Parameter handles can be moved to predefined configurations such as being equally distributed on the sphere surface. Images can be highlighted in order to track their position while moving the assigned parameter handles. Image details can be viewed in high-resolution on a 2D-screen. Finally, SphereViz will be extended to other types of data sets to become a general 3D user interface for the exploration of non-image data archives.

6. References