The Challenge of Visualizing Three-dimensional Data

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Abstract

Computer graphics has become an integral part of everyday life and work. As one part of computer graphics, visualization plays an important role when data from various sources should be presented or investigated. One example is the visualization of 3D data, which originates in computer tomography or similar acquisition modalities. Here, the special challenge of visualization is to make meaningful images of data which densely populates the 3D domain. The problem to deal with is occlusion, of course. 2D images just do not provide sufficient space for all data to be visualized. Quite some solutions have been presented up to now to nevertheless generate useful images. Direct volume rendering on the basis of compositing, maximum-intensity projection, rendering of boundary-structures like iso-surfaces, etc., are just the most important techniques to be mentioned here. This talk tries to demonstrate the challenge of 3D visualization by giving an intuitive visualization of the problems first, as well as by showing solutions, which have been established over the last years.

1 The Challenge

One reason, why visualization has become very popular during the past decades, is that human observers usually make effective use of their powerful visual system when investigating their environment. Especially the analysis of images, which have been perceived through the human visual system, is very effective. Features are quickly detected, even without the need for serial search [11]. And that is exactly the point where visualization hooks in – instead of listing large amounts of numbers as a direct representation of data visual depictions are used to effectively convey information. However, the bandwidth of the human visual system also is limited, and therefore the amount of information which can concurrently be provided to the human observer is limited also.

The bandwidth of the human perception can be measured in different terms such as resolution, extension, and dimension. The latter will be of most impact for the following considerations. From the spatial placement and orientation of both human eyes, we can derive that human vision only is of a little more than 2D. All human 3D vision amounts to the perception of planar data which is only enhanced by depth information. Human observers usually see boundary surfaces of solid 3D objects which surround them. From internal and automatic correlation analysis between the images of both eyes as well as from shading of surfaces the 3D shape of such surfaces is derived.

The challenge of visualizing 3D data now is to effectively communicate 3D information as such which is provided by 3D scanning modalities in medical applications while at the same time dealing with the limited bandwidth of the human visual system. As the above described limitation does not allow to directly present 3D data to visualization users – which in this case would degrade visualization to a trivial job – indirect methods are required to support the investigation of 3D data.

Either subsets of the data are shown, or aggregations thereof. Also the use of indirect representation through boundary surfaces is often used.

2 Visualizing 3D Data

Many approaches have been presented in the past which were tailored to effectively convey 3D information, more specifically to gain useful insight about the interior of 3D objects. In this talk a few of them are discussed together with their advantages and disadvantages. Surface-based methods as, for example, those which are based on the Marching Cubes algorithm [9] are compared to direct volume rendering (DVR) as initiated by Kajiya and Levoy [6, 8]. For DVR, the special problem of how to intuitively specify a transfer function is presented together with a couple of solutions [4, 1, 10, 7]. The problem of stacking isosurfaces is addressed as discussed by Interrante [5] as well as focus-plus-context approaches for volume rendering are discussed as, for example, two-level volume rendering [3]. Also, non-photorealistic rendering of volumetric data as described by Ebert and Rheingans [2] is compared to other approaches such as maximum-intensity projection [12] or simple data-integration.

Finally, this talk will conclude with the observation that the choice of the most appropriate visualization technique – as there is no best available which would allow to trivially show all the data – heavily depends on the data given, its internal structure, as well as the goal of the visualization user.

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