VolumeShop: Interactive Direct Volume Illustration

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1 Introduction

Illustrations play a major role in the education process. Whether used to teach a surgical or radiologic procedure, to illustrate normal or aberrant anatomy, or to explain the functioning of a technical device, illustration significantly impacts learning. Many specimen are readily available as volumetric data sets, particular in medicine. Illustrations, however, are commonly produced manually as static images in a time-consuming process. Our goal is to create a fully dynamic three-dimensional illustration environment which directly operates on volume data. Single images have the aesthetic appeal of traditional illustrations, but can be interactively altered and explored. We present methods to realize such a system which combines artistic visual styles and expressive visualization techniques. Our implementation exploits the latest generation of GPUs and, thus, is capable of handling commonly sized data sets at interactive frame rates.

2 Multi-Object Volume Rendering

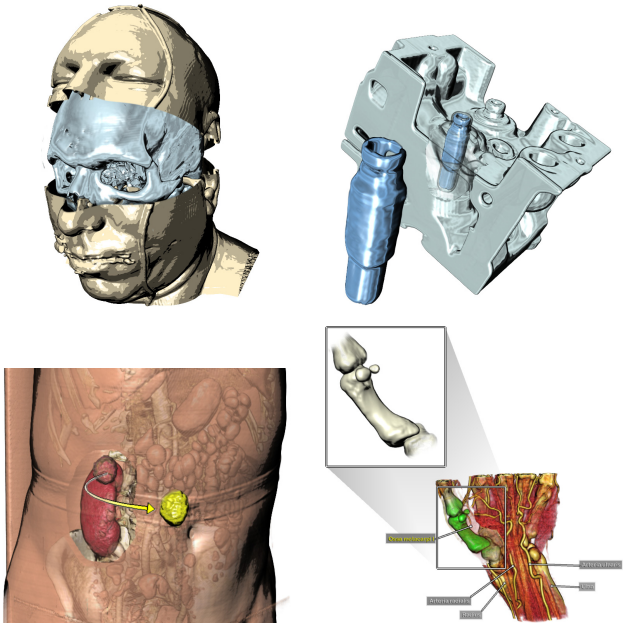
Our approach identifies three different objects for the interaction with a volumetric data set: a *selection* is a user-defined focus region, the *ghost* corresponds to the original location of the selection, and the *background* is the remaining volumetric object. A transformation can be applied to the *selection*, e.g. the user can move, rotate, or scale this object. We use fuzzy set theory to define compositing rules for intersecting objects. Selections are defined using a volumetric painting approach - the user draws on visible structures using a smooth three-dimensional brush.

3 Illustrative Enhancement

Illustration is closely related to non-photorealistic rendering methods, most of which attempt to mimic styles and techniques of traditional illustration. We employ two-dimensional lighting transfer functions to efficiently integrate many existing non-photorealistic models. A lighting transfer function consists of ambient, diffuse, and specular illumination contributions and an opacity-enhancement factor. Its arguments are the dot products between light vector and normal and half-way vector and normal. The generality of this approach allows for different shading models such as contour enhancement, cartoon shading, or metal shading to be integrated at constant costs.

4 Selective Illustration

Selective illustration techniques are methods which aim to emphasize specific user-defined features in a data set using visual conventions commonly employed by human illustrators. Cut-away views suppress occluding structures to reveal the structure of interest. Ghosting refers to a common technique which is frequently used in conjunction with cut-away views. Instead of removing the occluding regions completely, opacity is selectively reduced in a way which tends to preserve features such as edges. These methods can be applied to *ghost* and *selection* independently. Different visual enhancements can be used to indicate the relation of *selection*, *ghost*, and *background*. For example, arrows normally suggest that an object actually has been moved during the illustrated process (e.g., in the context of a surgical procedure) or that an object needs to be inserted at a certain location (e.g., in assembly instructions). A "fan" (a connected pair of shapes, such as rectangles or circles) is used to indicate a more detailed or alternative depiction of a structure. Additionally, annotations can be displayed which are automatically arranged using a force-directed placement approach.



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