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Konrad-Zuse-Zentrum  
für Informationstechnik Berlin

ZIB

Takustraße 7  
D-14195 Berlin-Dahlem  
Germany

ALEXANDER WIEBEL, FRANS M. VOS UND  
HANS-CHRISTIAN HEGE

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Takustraße 7  
D-14195 Berlin-Dahlem

Telefon: 030-84185-0  
Telefax: 030-84185-125

e-mail: [bibliothek@zib.de](mailto:bibliothek@zib.de)  
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# Perception-Oriented Picking of Structures in Direct Volumetric Renderings

Alexander Wiebel\*<sup>1</sup>, Frans M. Vos<sup>2</sup> and Hans-Christian Hege\*<sup>1</sup>

<sup>1</sup>Zuse Institute Berlin (ZIB), Germany <sup>2</sup>TU Delft & AMC Amsterdam, Netherlands

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## Abstract

Radiologists from all application areas are trained to read slice-based visualizations of 3D medical image data. Despite the numerous examples of sophisticated three-dimensional renderings, especially all variants of direct volume rendering, such methods are often considered not very useful by radiologists who prefer slice-based visualization. Just recently there have been attempts to bridge this gap between 2D and 3D renderings. These attempts include specialized techniques for volume picking that result in repositioning slices.

In this paper, we present a new volume picking technique that, in contrast to previous work, does not require pre-segmented data or metadata. The positions picked by our method are solely based on the data itself, the transfer function and, most importantly, on the way the volumetric rendering is perceived by viewers. To demonstrate the usefulness of the proposed method we apply it for automatically repositioning slices in an abdominal MRI scan, a data set from a flow simulation and a number of other volumetric scalar fields. Furthermore we discuss how the method can be implemented in combination with various different volumetric rendering techniques.

## 1 Introduction

Direct volume rendering (DVR) [Sab88] is the state-of-the-art for the display of volumetric data from medicine,

engineering and the sciences. As a flexible and versatile tool, it is adaptable to virtually all application problems dealing with 3D scalar fields. The latest developments of the power of computer hardware allow DVR to be used interactively even on consumer type systems. Although this makes it available for the analysis and inspection of data from medical imaging devices, the radiologists responsible for these tasks still mainly rely on the examination of slice-like depictions (including multi-planar reformatting, MPR). Motivated by this fact previous work has already addressed the combination of DVR and MPR representations [KBKG07, KBKG08, KBKG09, Vli08]. Providing interaction techniques (commonly called volume picking, point picking or volume pinpointing) that allow to pick in the volumetric rendering to adjust a slice, and vice versa to pick on the slice to reorient the DVR, make it possible to integrate DVR in the daily routine of the radiologists. DVR can serve as overview while the slices are still used for the detailed examination the radiologists need to perform.

Keeping this background in mind, the motivation for the technique presented in this paper is threefold: current methods either use metadata or are designed for medical data only, or provide only very basic picking techniques like *first-hit* or *opacity-threshold*. The aim of this paper is to introduce a picking technique that circumvents all these disadvantages by taking a perception-based view. Picking is probably the most intuitive interaction technique possible because it is the technical equivalent to one of the most natural actions in the real world: *pointing at something*. We present a method that enables users to intuitively select spatial positions in volumetric renderings.

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\*wiebel@zib.de

\*hege@zib.de

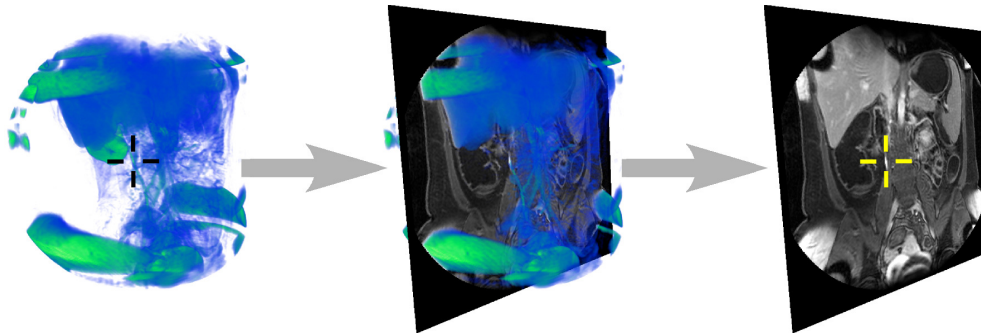


Figure 1: Perception-oriented picking in DVR applied to abdominal magnetic resonance imaging (MRI) scan. The picked position is used for selecting a slice depicting the picked feature (vessel). The position is marked with crosshairs in the left and right image.

In particular, the main contributions of this paper are

- a short summary of how picking is realized for different rendering techniques working on volumetric data,
- a new, perception-oriented technique allowing to pick positions in arbitrary direct volume rendering images,
- the method’s independence of any information apart from the volume data and the transfer function of the direct volume rendering,
- its applicability to renderings for any volumetric scalar data set and any types of transfer functions (e.g. also “foggy” looking images),
- and its usefulness for navigating (e.g. selecting slices) in the resulting visualizations.

Thereby, we intend to pave the way for further application of DVR in application areas that still are reluctant to adopt this fundamental visualization technique

## 2 Related Work

In this section we review the previous work on picking in volumetric renderings and the combination of direct volume rendering with slices. Concerning perception there has also been a lot of work in visualization research, see

e.g. [TM04, HE11]. However, this work is mainly concerned with designing visualization according to perception principles, and rather than how volumetric visualizations are perceived.

### 2.1 Picking

Direct volume rendering, has been around for over twenty years now [Sab88] and over time has developed into an interactively usable rendering technique (see e.g. [KW03, AGI\*08]), which has resulted in research that aims at facilitating the interaction with volumetric depictions. Volume picking, the interaction technique that is in the focus of this article, has been adapted from its well-known predecessor that is used for picking real geometry like surfaces. Accordingly, the first volume picking techniques mimicked the surface picking by searching for the first surface-like structure along the viewing ray passing through the picked screen position. Gobbetti et al. [GPZT98] introduced the most widely used technique. It searches along the ray using the usual compositing scheme (described in Section 4) and stops as soon as the accumulated opacity exceeds a user defined threshold. This means a surface is assumed to be at locations where the opacity threshold is exceeded. The endpoint of the search is returned as 3D position resulting from the picking. A simplified version of this approach sets the threshold to zero. This results in selecting the first not completely transparent position in the volume (*first-hit*).

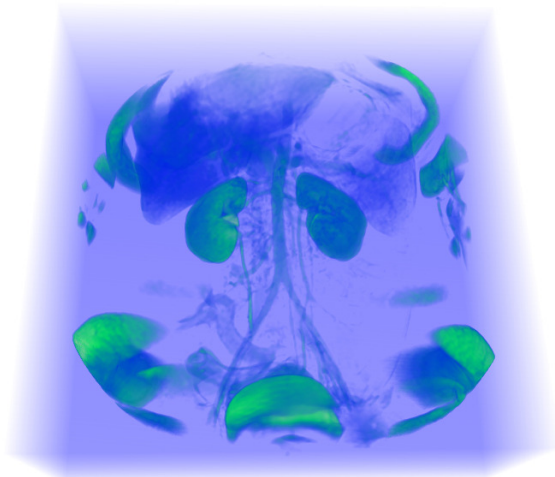


Figure 2: Problem of *first-hit* method with zero threshold and “foggy” rendered image. The resulting position will be on the bounding box instead of, e.g., the kidneys because every position in the volume has non-zero opacity.

Both variants can result in undesired results. Using a zero threshold will return positions in regions surrounding the features in “foggy” looking renderings (see Fig. 2). If, on the other hand, the threshold is non-zero some relatively transparent but still visible regions might be missed (see Fig 3).

Another widely used method selects the largest data value along the ray. While yielding perfect results in conjunction with maximum intensity projection renderings, this technique is not suitable for DVR in general. For common DVR it can result in selecting positions that are completely transparent, i.e. deliberately not shown, due to the selected transfer function. This and the above technique are described in more detail in Section 3. Toenies and Derz [TD97] present a technique that searches for user-defined data values or user-defined properties of metadata along the ray. In our setting, it suffers from the same problem as the previously described method. Bruckner et al. [BŠG\*09] select the position along the ray that contributes most to the final pixel. They report that it works nicely with the special volume rendering technique they used in their *BrainGazer* system. As the sample con-

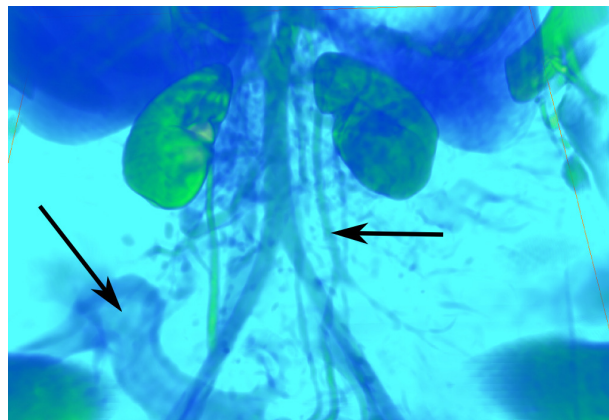


Figure 3: Problem of threshold picking method with relatively transparent regions. Such regions might be missed although they are clearly visible. Example regions (vessel, terminal ileum) are marked with arrows.

tributing most does not necessarily have to belong to the most visible *object*, i.e. the group of samples contributing most to final pixel, we use a the most contributing interval in our approach.

The following list of visualization tools and their volume picking techniques gives an impression of the use of the techniques: MeVisLab [MVL] provides a technique selecting the maximum data value as well as opacity threshold-based picking. Voreen [MSRMH09] and Avizo [Avi] use the first-hit approach. VTK [SML98] and thus ParaView [Squ08] employ the opacity threshold method [NCP].

Kohlmann et al. [KBKG09] employ a more sophisticated picking method called *contextual picking* that is especially tailored to medical data in DICOM [BH92] format. It uses the meta information given in the DICOM files to deduce which anatomical parts of the volumetric image the user intends to pick (e.g. angiography→vessels). Very few, initially user specified, ray profile samples are matched against the data curve along the viewing ray to find the intended structures. As the matching identifies the approximate extent of the picked structure, Kohlmann et al. are able to provide picking positions either on the front of the structure or in its center. Malik et al. [MMG07] use ray-profiles similarly in a different context, i.e. the division of the data into