Volumetric Data Interaction in AR and VR Using a Handheld Touch-Sensitive Device

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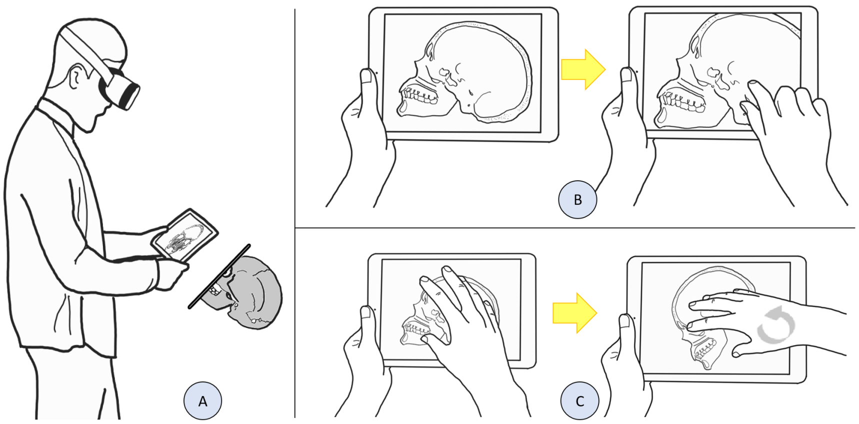

Fig. 1. A) A Head-Mounted Display is used to display an iso-surface model (here: grey coloured scull) in an Mixed Reality environment while the handheld device displays a snapshot, which was taken by the user. B) The size of the model and snapshots can be resized using a pinch gesture. C) The orientation of the model and snapshots can be changed by rotating all fingers on the touch-sensitive display.

This position paper introduces the idea of utilising a mobile touch-sensitive device for interacting with volumetric data in Mixed Reality environments, such as Virtual Reality and Augmented Reality. The interaction techniques include spatial transformations, data slicing, as well as the creation of snapshots. These actions are executed with the help of the device's touch-sensitive interface or by handling the device as a tangible interface.

CCS Concepts: • **Information systems** → **Users and interactive retrieval**; • **Human-centered computing** → **Interaction design process and methods**; **User studies**.

Additional Key Words and Phrases: Spatial Transformation, Slicing, Snapshot

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1 INTRODUCTION

The interaction with volumetric data visualisations using conventional user input with keyboard and mouse on a monitor is less intuitive and cumbersome. In recent years, the number of available devices for displaying Virtual Reality

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(VR) and Augmented Reality (AR) has increased significantly. This allows to break the two-dimensional monoscopic visualisation barrier by displaying three-dimensional stereoscopic models in a Mixed Reality (MR) [11] environment using a Head-Mounted Display (HMD), and enables novel interaction techniques with multiple degrees of freedom. There have been various attempts to make the handling of three-dimensional data in VR and AR more intuitive. However, no standard has been established yet. In this paper we suggest the use of common two-dimensional techniques using a touch-sensitive handheld Device (HHD) in combination with spatial interaction, to allow the user to manipulate and analyse volumetric data sets.

2 RELATED WORK

Opposed to a conventional Desktop interaction, there is a broad variety of possibilities to interact with volumetric data in 3D space. The choice of input device has a great influence on the design of the interaction technique. Our work is therefore positioned in the context of two areas of related work: Input devices and interaction techniques, both with the focus on manipulating three-dimensional data.

2.1 3D Input Devices

The designs of handheld 3D input devices range from cube-shaped boxes, such as the Cubic Mouse [8], to devices containing a tracked sphere [7], or even a combination of two 6-Degrees of freedom (DOF) controllers [7]. Due to the integration of two-dimensional data, a planar interface offers advantages, such as haptic feedback [15], enabling more intuitive interactions for users. Second, HHDs can be used to attach virtual elements, allowing the user to move these elements out of the users field of view, by moving the HHD out of users' viewing frustum. This helps to avoid the cluttering of the users view, but also allows the user to bring the elements back by looking at the HHD [2].

Such planar devices can be differentiated by their capabilities into *simple* and *smart* HHD. *Simple* panels do not hold any computing power themselves. They are used to provide haptic feedback, and can be handled as a tangible interface. Devices of this type work by data being displayed onto a panel by means of projectors or AR [2, 4, 5, 13, 18, 21]. The usage of *smart* handheld devices has started with simple palmtop PCs. They enabled the usage of intelligent technology [6], which obviated an overflow of information in the main scene [1], and reduced cognitive overload [14]. Apart from own computing power, *smart* devices, such as mobile phones and tablets, also come with a touch-sensitive interface, which can display data and can be used for the interaction. In contrast to previously introduced input devices, mobile phones and tables are off-the-shelf hardware and therefore easily accessible and common [9].

2.2 3D Interaction Techniques

A pioneer in the use of panels for interaction with volumetric data in AR is the *Studierstube* project [19], where an HMD displays buttons and images onto the tracked panel while a tracked pen allows supplementary input [18]. With this set-up the user was enabled to create objects, scale and rotate them. Additionally, the combination of panel and pen allows the positioning of a model and detailed views or the handling of the panel as a cutting plane [18].

In 1992, the *pool of water* metaphor was used to define cutting planes when working with 3D models [12]. This inspection technique is more tangible in MR environments where the flat displays can be used as cutting planes. Multiple publications have utilised panels for the slicing of volumetric data models [5, 15–18].

The slicing of models can be extended by features like the freezing of the cutting plane within the model [21]. This allows the user to place multiple cutting planes or make use of a volumetric cutting plane [20], which enables a different perspective on the inner structure of the used 3D model. Beside the tangible aspect of using a *smart* tablet as a cutting plane [9], Song et al., showed how the tilt of mobile devices can be used to move and tilt a cutting plane directly or remotely on an external screen [16]. Further, the touchscreen of such a device can be used to annotate volume data [16], and to search content in these annotations.

In contrast to the papers discussed, we propose to utilise a smart touch device in combination with a 3D visualisation. This combination enables manual slicing, as well as established touch gestures such as swipe, pinch, and textual input.

3 CONCEPTUAL DESIGN

The planar shape of an HHD is perfect for touch interactions such as swipes additional to force feedback (vibrations) or accelerometer. This section proposes to use these actions to apply spatial transformations, create annotations, apply slicing and take snapshots of volumetric data models.

When interacting with volumetric data in MR, the computational effort can be extensive. Therefore, a marching cubes algorithm [10] or similar needs to be applied to convert the volumetric data model into an easier displayable iso-surface model. The triangular property of iso-surfaces is better for the real-time calculation and therefore more suitable to be displayed using a video-based HMD (see A in Figure 1). Depending on the HMD, the problem could occur that the resolution is not sufficient for the AR mode and it is therefore necessary to render the content of the mobile device onto the display in AR as well. To acquire the exact position of the input device for rendering onto the display, trackers associated with the used HMD should be used.

3.1 Spatial Transformation

The spatial transformations includes the positioning, rotating, and resizing of the rendered model. Positioning and rotating can be implemented by mapping the tablet motion and orientation to the model. The touch input allows the usage of a common pinch gesture for the zoom (see B in Figure 1) or a hand rotation using all fingers on the screen for changing the model's or snapshot's orientation (see C in Figure 1). The rotation is dependent on the perspective of the HHD to the model when using the suggested hand gesture. If the tablet is held horizontally the model can be yawed (rotated around the z-axis) while it can be rolled or pitched (rotated around the x- or y-axis) when held vertically depending on the orientation of the tablet to the model.

3.2 Slicing

The planar interface of the HHD is ideal to act as a cutting plane by moving the panel through the model which is rendered in AR or VR. While the HMD visualises the surface of the iso-surface model in the MR environment, the slicing plane displayed on the HHD is calculated from the original volumetric data. The cutting plane is placed in short distance before the surface of the HHD so that there is a small distance left displaying the outlines of the iso-surface model (see A in Figure 2). This way the user has a better understanding for the model even without the cropped part of the model. The HHD is used as a reference point for the clipping plane when slicing the model, and in case of AR for the visualisation of the sliced part of the volumetric data set. The rendering of the displayed cut is done on a workstation and either transmitted to the HHD or visualised by using the HMD to render the slice on the HHD.

The position of the cutting plane can be frozen within the model by pressing a button on the tablet. This way the model stays cropped with a volumetric image rendered in place of the cut. This enables the user to utilise multi-planar slicing by placing additional frozen planes within the model as seen in B of Figure 2. The idea of multi-planar slicing was inspired by the three cutting planes of the cubic mouse [8]. In addition, the user can use volumetric slicing by placing a form (e.g. a cube or cylinder) within the model and remove everything within this form. By inverting this effect the user has only the form and data within its boundaries left [20]. These boundaries are also calculated from the original volumetric data set.

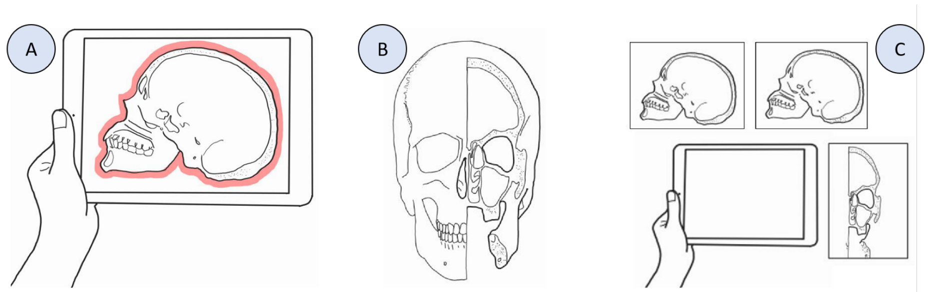

Fig. 2. A) The outline in red shows the iso-surfaces located between the display and the cutting plane. B) The model shows the result of multi-planar slicing. C) Taken snapshots can be displayed in the MR environment and attached to the HHD.

3.3 Snapshots

When slicing a model, displayed cutting planes can be saved by taking a snapshot. This can be triggered via a button on the touch display or a swipe gesture. The swipe gesture can be used to indicate the planned position where the snapshot should be placed within the user's environment. Further, they can be mapped to and aligned around the HHD (see image C in Figure 2). Positioned snapshots can be removed from the environment by performing a grab gesture on the touch interface.

The selection can be implemented by a ray cast or a simple gallery on the HHD which is used to save all snapshots. The user can choose between multiple displayed shots by tilting the device into the direction of the chosen item. Boring et al. proposed to use snapping behaviour to avoid errors due to speed or inaccuracy [3]. A taken snapshot is saved with a connection to the exact position of the cutting plane where it was taken. This connection can be visualised with a line connecting a placed snapshot and a visualised slicing plane. When interacting with a specific slice, the user has the option to inspect neighbouring slices by tilting the tablet.

3.4 Annotations and Search

The tactile touch input can be used to position annotations within the model while it also allows to search such. Also, the user can add a video or audio recording when creating a snapshot to provide context information.

4 CONCLUSION

The usage of a planar touch-sensitive HHD allows the combination of intuitive tangible interactions with touch input which is familiar from the everyday use of mobile devices. This paper proposes to integrate the existing touch surface more into the interaction with three-dimensional data and thus to allow simple touch manipulations in addition to manual positioning in space. This implementation would improve the handling and inspection of volumetric data in AR and VR and make the exploration of a model more intuitive.

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