Exploring Hybrid User Interfaces for Surgery Planning

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Figure 1: A sketch of a possible hybrid user interface: left – a surgeon reading up on the patient file and documenting the surgery planning; right – two surgeons discussing a patient, the left one manipulates a 3D view with a physical object and the right one inspecting radiological images using a tablet.

Abstract

Hybrid user interfaces are a great opportunity to combine complementary interfaces to make use of the best interface for specific steps in a workflow. This position paper outlines one diverse application field: surgery planning. Planning a surgery is a complex task as the surgical team has to get an overview and understanding of a patient's medical history and the internal anatomical structures of the organ or region of interest. In this position paper, we outline how different hardware (e.g., mixed reality head-worn devices and physical objects) and interaction concepts (e.g., gesture-based interaction or keyboard and mouse) can create an optimal workflow for surgery planning.

Index Terms: Hardware—Haptic Devices; Human-centered computing—Mixed / augmented reality; Human-centered computing—Virtual Reality; Human-centered computing—Gestural Input; Human-centered computing—Health care information systems; Human-centered computing—Human computer interaction (HCI)

1 Introduction

When Feiner and Shamash [2] proposed the term *hybrid user interfaces* in 1991, they aimed at combining "relatively high-resolution" 2D interfaces with the "relatively low-resolution and coarse" 3D interfaces of that time. With devices such as Valve's Index[1], Meta's Quest Pro[2] or the recently announced Vision Pro by Apple[3] 3D head-worn devices (HWDs) provide high-resolution output as well. The Valve Index has two 1440 x 1600 LCDs, which probably exceeds every display resolution from the 90s. Even though the original reasons for combining different displays and interfaces might be outdated, the combination can still be valuable due to the distinct benefits of each technology.

One application area which can benefit from hybrid user interfaces is surgery planning, as surgeons have to work with 3D content from medical imaging and traditional text documents. The 3D representations need an adequate visualisation system, whereas documents are preferably accessed on a desktop computer. In this position paper, we motivate the topic of surgery planning as a potential use case for hybrid user interfaces. In the remainder of this paper, we outline the process of surgery planning, describe an application scenario that combines surgery planning with hybrid user interfaces, and conclude with an outlook on future research.

2 Background: Surgery Planning

Surgery planning is a standard process for surgeons in all medical fields, especially when they aim to remove tumours. The anatomical structures of individuals deviate, and tumours can occur in different places and extents, emphasizing the need for individual surgery planning for each patient. Additionally, grasping the spatial relationships between blood vessels and tumour tissue is essential to a surgery's success. The distance between these two can be crucial for the decision on how to approach the operation and, more importantly, if the tumour can be removed at all. Therefore, planning the intervention is a critical stage in the decision-making on how to treat the patient [11].

The surgical planning is based on magnetic resonance imaging

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[1]https://www.valvesoftware.com/en/index/headset

[2]https://www.meta.com/de/en/quest/quest-pro/

[3]https://www.apple.com/apple-vision-pro/

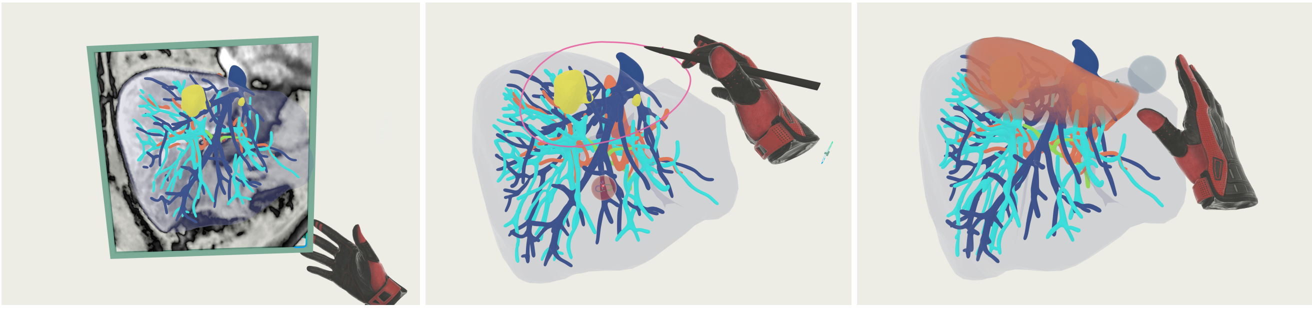

Figure 2: Visualisation of the MRI overlay, line drawing, clips and volume marking functionality - left: the frame showing an overlay of the MRI images at the given intersection of the model; middle: one clip and a line are added to the model; right: using the ball-shaped tool at the hand the red volume was marked. The images are from [14].

(MRI) or computed tomography (CT) images representing the 3D anatomical structures as a stack of 2D greyscale images. Conventional 2D displays are generally used to view MRI and CT images. Interpreting these images to determine where tumours are located and how they are positioned in relation to other anatomical structures requires years of experience, and an inherent uncertainty remains. In addition, surgeons use the stack of 2D images to reconstruct the actual 3D representation mentally, allowing them to understand the anatomical structures and their relations. This process requires extensive training and is often challenging, even for experienced surgeons. Furthermore, as each surgeon builds a 3D representation in their own mind, agreements between surgeons are mainly discussed without a shared visual image of the 3D structures.

Many (research) tools combine these 2D images into 3D visualisations (cf. [9, 15–17]). To achieve a 3D visualisation, one could use a semi-automated segmentation, often resulting in 3D polygonal models – as used, for example, in [12, 14] – or based on a set of (predefined) transfer functions creating a volume rendering, for example, see [8]. HWDs are excellent in viewing this kind of 3D content, as they can lead to a better spatial understanding of the anatomical structures and their relations [10] as reported in [14]. Other tasks, such as writing reports or documentation, and checking a patient's medical history, are better and more conveniently done on a conventional display connected to a desktop computer. And despite the efforts to create suitable solutions for typing in a virtual environment, such as [7], typing on a conventional keyboard is still faster and easier.

Figure 3: A surgeon interacting with a virtual organ model displayed in virtual reality by an organ-shaped object. Figure from [13].

3 Application Scenario

The scenario of a surgeon preparing for surgery could benefit from a multi-device setup consisting of a desktop computer with a keyboard, mouse and display, a mixed reality HWD, and potentially even handheld devices such as tablets – each component complementing each other to support surgeons in various stages of their workflow [18]. Recent research has shown the general applicability of this approach of meaningful combinations of such immersive and non-immersive components, e.g., [4–6, 18]. To familiarise themselves with the patient's medical history and current results from blood work, biopsies, and other diagnostic procedures, the desktop computer or the tablet is most convenient as this data is generally stored as plain text. Following this, the results from medical imaging (MRI & CT) – represented in 3D as volumetric renderings or as models by segmentation – can be investigated from different perspectives using the stereoscopic viewing capabilities of mixed reality HWD. Surgeons can manipulate the 3D renderings using controllers, gestures, or a proxy. The proxy could be a tracked object that resembles the actual organ (see Fig. 3), such as proposed by [1, 12], and others, or a basic shape (e.g., [3]). This helps the understanding of spatial relationships and is more memorable. Using dedicated planning tools, such as annotation, clipping, cutting, combining the underlying 2D images or measuring (see Fig. 2 or [14]), different approaches to tumour removal can be evaluated.

Having a virtual environment also enables collaboration. A second person can join the planning session, and both surgeons can discuss, e.g., the surgery procedure based on the same visualisation. In an optimal setting, the surgeon could annotate the 3D model and add a screenshot to the documentation they write on the computer. The final planning and annotations would also be available on a tablet. A tablet is handy and easy to carry around, so the lead surgeon can use it during the surgical team briefing or to explain the procedure and approach to the patient. The tablet application would provide a handheld augmented reality view to show the 3D model from different perspectives for improved spatial viewing. In the hybrid user interface setup, the tablet device could also be used to view the 2D MRI or CT slices on the tablet itself using a standard scrolling motion on the display. Another potential use could be the replacement of the frame in Fig. 2 on the left side, which is used to inspect the radiological images and thereby provide a physical input to manipulate this view. Furthermore, the tablet could also work as a viewing frame to adjust the screenshot to put into the documentation on the desktop computer.

Using an HWD additionally allows for extending the screen space of the desktop computer – which can provide a better overview of the available data. For a patient case with multiple tumours and lesions, it would be easy to have multiple screenshots, e.g., with measurements of the regions of interest, from the organ placed around the screen to have direct access when noting the details to the patient file. As most diseases progress over time, different stages could be allocated at different places in the virtual space – enabling the surgeon to compare different time points and document the essential aspects.

4 Conclusion & Outlook

Surgery planning is a complex task, especially as surgeons have to get an overview and understanding of the patient's medical history and current physical state based on measurements taken. Additionally, they must grasp the spatial relationships between vital structures, such as blood vessels, nerves, or organ boundaries, and their goal, e.g. a tumour. To achieve this, different hardware and interaction concepts are required for optimal workflow. Mixed reality HWD provide the best view and natural interaction for 3D representations to grasp spatial relationships. The medical history and lab results are the easiest to read on a desktop computer screen. Additionally, with the variety of information needing to be processed, a standard desktop screen is often insufficient. This calls for a solution integrating them as complementary interfaces to allow for an optimal and time-efficient preparation, which ultimately can increase patient safety. When designing such a hybrid user interface, it is important to keep an eye on the cognitive demand to not exhaust the surgeons as well as the ease of use. With respect to the transferability of the interaction concepts, it is important to look into different surgical domains, as different types of surgery – open surgery or keyhole surgery – and different anatomical structures – solid structures like bones vs. soft tissue like the liver or bowel – pose different challenges. Furthermore, researchers should take into account that many systems in the health or medical domain are proprietary, which limits the interaction possibilities between existing systems and even though there are standards for imaging, they still might vary.

Acknowledgments

This research was funded by the *Deutsche Forschungsgemeinschaft* (DFG, German Research Foundation) – Project-ID 251654672 – TRR 161. This project has received funding from the *German Federal Ministry of Education and Research (BMBF)* in the grant program "Gesundes Leben" (healthy living), grant number 16SV8077.

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