



FROM MEDICAL IMAGING TO AUGMENTED REALITY FOR SURGICAL APPLICATIONS

Axis: Health of the future - Santé du future

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Context

This thesis project aims to propose a complete pipeline allowing to go from medical images to Augmented Reality (AR) to assist surgeons during operations. To do this, we must be able to extract 3D information from medical images to integrate it in real-time in a robust and precise way on the patient in AR during the operation while allowing the surgeon to interact with it.

There are many scientific barriers: medical images can be of several types (MRI, scanners, x-rays, etc.) and must be aligned with each other to allow the different information present in the images to be merged (e.g., organs, bones, tumors, vascularization, etc.) and integrate them within a global 3D model whose scale is consistent and where the registration has been established. This global 3D model of information extracted from medical images will be extracted semi-automatically by the GeM RPM and PIMM teams. In addition, it is essential to segment this global model according to the different natures of the information (organs, bones, vascular tissues, etc.) to allow surgeons to choose the parts to be

visualized in AR. By integrating AI technology in the analysis of medical images for the semi-automated segmentation of organs and tumors, we will be able to develop this segmentation of images in an optimized way for the creation via 3D printing of models. (Anatomical structures, surgical cutting guides, and models for 3D visualization in virtual and augmented reality). Regarding AR, there are several challenges: the first consists of being able to automatically detect organs, bones, etc., of the patient during the operation in order to be able to register the 3D model and display it robustly, quickly, and accurately in AR. In order to deal with this obstacle, the objective is to rely on deep learning methods. A second challenge concerns the use of the AR application during the operation. This challenge concerns the interaction of the surgeon with the application, but also the automatic or semi-automatic measurement of the elements to be displayed or hidden according to the surgeon's activity.

Positioning

Artificial Intelligence (IA), Augmented Reality (AR) and Virtual Reality (VR) are all transforming the practice of medicine by providing new, innovative, and effective methods for analyzing and interacting with data such as digital medical images. IA now plays a key role for the analysis of medical images (e.g. classification, 2D segmentation and identification [1], 3D volumetric images segmentation [2], 2D image reconstruction [3]) but also to automatically recreate 3D models from those images [4] (e.g. provide accurate 3D models of organs and/or of tumors [5]). AR and VR play an essential role in the current and future training of health professionals such as surgeons [6] and different actors in the medical world, including medical students [7]. AR and VR in surgical education have enhanced teaching and learning experiences and provided opportunities for distance teaching, participation, and collaboration between different surgical teams worldwide.

Information from medical imaging, such as computed tomography (CT), magnetic resonance angiography, and magnetic resonance imaging (MRI), is crucial for applying AR and VR in a medical, surgical context. Indeed, thanks to AR/VR capabilities for real-time in-situ visualizations, these technologies could be used not only for preoperative planning, surgical training, and education, but also during real surgery [6, 8, 9, 10, 11]. During operations, surgeons could benefit from the display of the information contained in medical images obtained preoperatively. In order to best assist surgeons, it is necessary to be able to present this information in situ, i.e., directly on the patient, and well localized both in terms of position and orientation: this is the role of AR. However, in order for such technology to be used in real time surgery, it must be able to recognize specific organs, tissues or other anatomical characteristics, which can be achieved by prior training of deep learning networks [1,4], and parametric models [12,13,14].

This thesis project aims to be able to extract and merge the information contained in the preoperative images and then propose solutions for the automatic detection of the organs or bones of the patients, which will serve as "anchor points" for the display of digital information to the surgeon during the operation. The assistance to the surgeon is at the center of this project and the thesis will also aim to propose innovations in the methods of interaction of surgeons in AR during operations.

In this project, our goal is to use AR to guide the user during a surgical procedure in order to enforce safety and efficacy of such procedures.

The information provided to the surgeon can be of different sorts: anatomical delineation, display of

invisible (e.g., tumorous) tissues, virtual cutting guides, etc.

To do so, we need to be able to offer an end-to-end digital pipeline, an automatic digital chain originating from medical images that need to be analyzed and processed (segmented, classified) in order to finally give rise to accurate 3D models of the organs and tumors [15]. We aim to use these 3D models in two different ways: (i) for 3D printing (organs, tumors, etc.) that can be used for medical training, and (ii) serve as reference for the tracking required for the real-time visualization in Augmented Reality [16] [17].

The objectives of this PhD thesis are as follows:

- Work on a fully automated pipeline for the processing of digital medical images to generate accurate digital twins of organs/tumors.
- Use 3D print organs/tissues to develop new or use existing CNNs models, and train them to be able to perform robust and real-time tracking required for AR visualization and interaction.
- Develop experimental scenarios and physical models with the help of surgeons to mimic a real surgical procedure in AR. Based on these scenarios, develop interaction and visualization techniques to be tested in AR experiments using AR hardware, e.g. a Microsoft HoloLens 2.



Figure 1. Interaction with a 3D model through an AR device (Microsoft HoloLens 2).

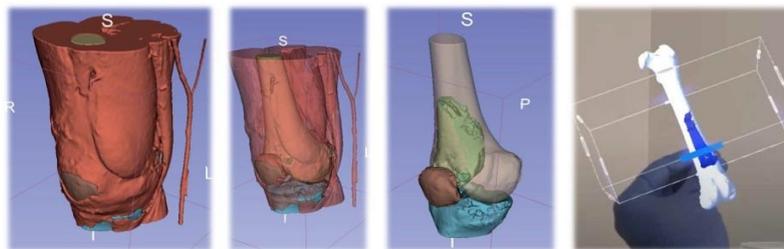


Figure 2. Bone Tumor Segmentation by an automatic digital chain. Surgical Guide VR model.

Required skills

- Development of Augmented Reality applications
- Unity
- Knowledge of Artificial Intelligence (optional)
- Interest in 3D modelling (optional)

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