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The Utilization of Machine-Learning Algorithm for Generating Interactive 3-Dimensional Holographic Images from Standard Computer-Tomographic and Magnetic Resonance Imaging Modalities: The Future of Intra-Operative Navigation Modules

Jang Yoon; Robert Chen; Louis Kang; Esther Kim; Tay Kim; Benjamin Brown; Robert Wharen; Alfredo Quiñones-Hinojosa

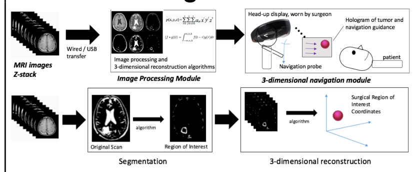
Introduction

We developed a fully integrated medical imaging system that performs 3D reconstructions of pre- and intra-operative images, translates these reconstructed images into holograms, projects holograms onto the surgical field via wearable head-up display, and provides feedback to the surgeon (via the head-up display) in real time.

Methods

We built a fully integrated system that performs 3D reconstruction of CT and MRI images from 2D z-stacks and relays these into holograms that a surgeon sees with a head-up display. We leveraged deep learning to extract surgical regions of interest (e.g., brain tumors, anatomical landmarks) from pre-operative MRI scans, and perform 3-dimensional reconstructions of them into holograms that are projected onto the surgical field (Figure 1). Specifically, a deep convolutional neural network was used for the segmentation process. The architecture of this deep learning algorithm included embedding layer and 4 convolutional layers with dropout between each of the first two, and softmax layer to classify each individual pixel in the image. After segmentation and post-image processing, we trained our software to recognize certain signals within images (i.e. contrast enhancing portion of brain tumors) to automate the reconstruction process. The training is done on a large training set of past MRI images from the Mayo Clinic. Next, we implemented the software on a wearable that projects holographic images, and built interaction software to let the surgeon interact with the 3D holographic images.

Figure 1



The image processing module will leverage machine learning and deep learning based approaches to extract surgical regions of interest (e.g., brain tumors, anatomical landmarks) from pre-operative MRI scans, and perform 3-dimensional reconstructions of them into holograms that can be projected onto the surgical field.

Results

The feedback loop is a connection between the head-up display, the navigation probe, the navigation registration receiver, and the navigation module. All communications are performed wirelessly through Bluetooth and WiFi and tested in real-time on a phantom head (Figure 2).

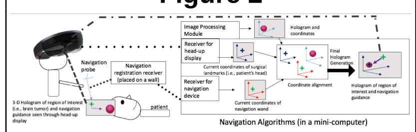
Conclusions

This study lays the groundwork and the next phase will be the expansion to surgeries involving spine, extremities and skull base. This can also improve pre-operative surgical simulation and resident education.

Learning Objectives

By the conclusion of this session, participants should be able to: 1) Describe the current unmet needs in pre- and intra-operative imaging modality, 2) Discuss, in small groups the importance of more intuitive and seamless visualization of key anatomic landmarks, 3) Identify areas of improvements needed to transform image-guided surgeries

Figure 2



The feedback loop is a connection between the head-up display (worn by the surgeon), the navigation probe (held by the surgeon), the navigation registration receiver (placed either on a stand next to the patient, or on a wall), and the navigation module (housed inside a mini-computer). All communications between the head-up display, the mini-computer and the navigation registration receiver, are performed wirelessly through Bluetooth and WiFi connections. This feedback loop is executed in real time during surgery.

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