Towards An Autonomous Neuro-Navigation System For Robotic Neurosurgery

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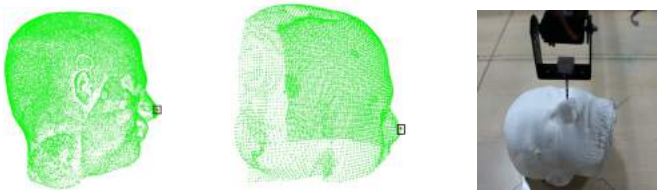
***Abstract*— Cranial neuro-navigation has become an integral part of contemporary neurosurgery, and is often practised as an intensive manual process with the available clinical information. The neurosurgeons decide the craniotomy path referring to a non real time radiographic images, often leading to an impromptu deviation in the surgical plan. Hence an alternate and effective method to autonomously guide a path with minimum medical risk is proposed for practising neurosurgical craniotomy procedures.**

I. Proposed workflow

Image guided surgery (IGS) is reported to improve the outcome of the surgery, and offers real time anatomical information to the surgeon, which allows them to refine the plan towards surgery [1], [2]. Traditionally, in an IGS procedures, fiducial markers or stereotactic head frames are employed to aid in registration. However there is an associated pain and discomfort with the insertion of the pins associated with head frame that penetrate the scalp and secure the frame to the skull [3]. The idea of utilizing natural anatomical landmarks or key points of the head is regarded as an efficient strategy in arriving towards a patient comfort solution. In this work, the two dimensional information in the image space and real time operative space are acquired in multiple orientations and reconstructed into 3D point clouds which are then registered for the successful operation of navigation system, by feature matching between the two point clouds. Feature matching could offer an improved initial state which is then refined to achieve the intended accuracy. The novel workflow consists of four major methods: Point cloud acquisition, Keypoint detection, feature description, and registration method.

The proposed 3D navigation guidance system is verified and validated using an experimental setup aimed towards robotic neurosurgery. The experimental setup included a portable IR scanner and a physical drilling head movable system. The physical positioning of the drilling head in the operative space with respect to the annotated points in the 3D reconstructed MRI images is then validated with the setup. For validating reference less IGS system, a 3D human head model of the available MRI slices was printed and the model was employed in the drilling setup for IR scanning. In the operative field, the 3D information of the printed skull is acquired with the help of a hand held IR camera. The facial region till the nose is utilized for registration as the other regions are prone to occlusions in the surgical environment. In the experiment, the transformation of annotated point marked in the MRI based 3D point cloud to the physical positioning of the drilling setup was investigated, and one such positioning is shown in the Figure 1. The experiments were also repeated at various anatomical landmarks such as lowest point in the lobule of the right, and left ear, and tragus point of the ear to report an error of less than 2 mm, that is attributed to the registration error and the navigation error of the experimental drilling setup.



(a) (b) (c)

Fig. 1: Experimental validation showing (a) point cloud reconstructed from MRI slices with marked point at the apex of nose, (b) point cloud reconstructed from IR scan showing transformed landmark post registration, and (c) drilling setup with needle pointing at the selected landmark.

II. CONCLUSION

The registration of the image space with the surgical scene with reliable accuracy, is considered a valuable contribution in modern day neurosurgery. An efficient and robust local descriptors offer essential cues about geometry for analyzing and registering 3D objects, which is highly useful in the operative space of neurosurgery. The objective of the platform is to provide the robotic system a method to navigate in relation to patient anatomy. The proposed platform was integrated and demonstrated with the developed prototype level navigation system and accuracy of the overall system was reported.

References

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