A Step Towards An Automated Drilling Device For Neurosurgical Applications

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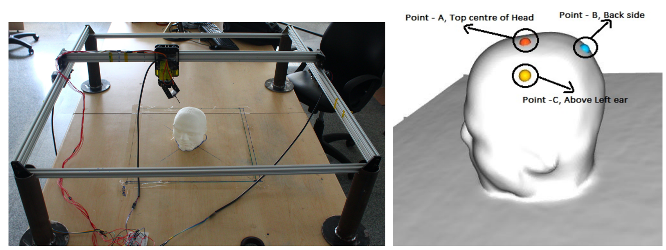
Abstract— **Mechanical drilling and perforation of bone is one of the most standard practices followed in neurosurgery, but is considered as a highly specialized task and is especially performed by skilled neurosurgeons. The paper proposes a design towards achieving the first step in building an autonomous neurosurgical tool for craniotomy practices. The proposed device caters towards reaching to a specified target location of human head in the surgical space and orient the drilling tool system perpendicular to the target point on the surface to perform needle insertion or deep drilling. The developed autonomous drilling system is integrated to an image-guided system installed in surgical space. The autonomous drill positioning system is validated experimentally on a 3D printed human head, and its placement and orientation errors with accuracies are reported.**

I. System Design and Experimental Results

The current drilling systems [1] are not robust enough to follow the drilling path, guided from a frameless software reconstructed model, that is derived from patient's imaging in surgical space [2]. Additionally, neurosurgeons have to deal with a specific problem to hold drilling tool perpendicular along all the drilling points in the path so that it has a minimum effect on the underlying dura [3]. Hence an automated path planning module that guides the physical drilling system, with drilling tool setup oriented perpendicular to any specified point on the guided path is desired. The paper proposes a novel surgical automated guidance system which relies on minimal manual intervention, and aims for precise positioning, orientation of drill head for a predetermined path, as a first step towards an autonomous craniotomy system. The positioning system is designed as a closed rectangular-shaped setup by employing four rails, and an additional fifth rail is placed perpendicular to the two parallel rails as shown in Figure 1 (a). The fifth rail along with the drilling head is configured to move along two parallel rails in either direction via two stepper motors, thereby enabling 2 degrees of freedom (DoF) for the drill head in X-Y directions. The drill head consists of 2 servo motors connected in pan-tilt orientation, thereby providing two more DOFs in the form of tilt and rotate angular actions. Thus the system is able to point to any point on the patient's brain that is placed inside the positioning system. 3D point cloud image of the patient's brain along with the system is constructed in the surgical environment using 3D Primesense 1.08 sensor. For experimental validation, the 3-D printed head is placed inside the system and geometric lines, and curves of varying lengths were annotated on the MRI reconstructed 3D image. Three extreme positions were selected on the modelled head, to determine the minimum and maximum orientation errors conceded by the system, as shown in the table I.



(a) (b)

Fig. 1. (a) Picture of the designed automated drilling setup and (b)Schematic showing three marked points in the 3D reconstructed human head model, considered for guided drilling.

TABLE I

Angular orientation errors conceded by the drilling system.

Points	Orientation error
Point - A	0.4° ± 0.86°
Point - B	4.9° ± 0.96°
Point - C	5.7° ± 0.87°

II. CONCLUSIONS

The proposed design presents a positioning error of less than 0.1 mm, orientation error of maximum 5.7°, accuracy of more than 99 % in following straight line drilling path, and accuracy of 91 % to 93 % for angular and curvilinear paths. The demonstration of normalised drill path is an attempt to model the environment required for deep skull base drilling.

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