A method for planning interventions in the brain with straight access paths

N. Navkar[1], Z. Deng[1], J. Stafford[2], J. Weinberg[3], and N. V. Tsekos[1]
[1]Computer Science, University fo Houston, Houston, Texas, United States, [2]Imaging Physics, MD Anderson, United States, [3]Neurosurgery, MD Anderson, United States

INTRODUCTION:

Image-guided interventions and certain surgical procedures utilize radiologic imaging for identifying the most appropriate path for accessing a targeted structure. Often, such preoperative planning entail the use of multi-contrast or multi-modal imaging [1,2] for assessing different aspects of patients' pathophysiology related to the procedure. A major challenge either at the preoperative or the intraoperative stage of an image-guided neurosurgical interventional procedure [e.g. 3,4] is the visualization, comprehension and manipulation of the large volume of three-dimensional (3D) brain data. In this work, we propose an efficient visualization method for generation of access maps on the surface of the skin of the patient that can guide the neurosurgeon in selecting an entrance point for accessing a specific targeted anatomical structure with a straight tubular tool. The operator can conveniently inspect these access maps and determine the most appropriate path of access by avoiding vital structures and minimizing potential trauma to healthy tissue.

METHODS:

An interventional procedure with a straight tool, such as a biopsy needle or an applicator, maybe approached as a two-point access practice. The first point i.e. the target is well known from the original inspection of images, and to select second insertion point, it would be helpful to visualize the outer surface of the patient that could incorporate the information about the underlying tissue. This is achieved by generating three maps of corresponding information. (1) *Direct Impact Map*: Shows the projection of the vital structures. It is calculated by assuming the target to be a light source and using concept of ray casting to project vital structures on the skin. Rays of light, which is obstructed by a vital structure such as a vessel, would cast a shadow on the skin. This shadow region corresponds to direct impact map. If any insertion is made through a point on the map it would directly impact the vital tissue. (2) *Proximity Map*: Properties of intervention tool such as deflection, thickness also needs to be considered during planning. The aforementioned properties may bring the tool to very close proximity and even puncture a vital tissue. To address this, we incorporate a safe 3D buffer region that encloses the vital structures. This buffer region is projected in form of proximity map on skin. It shows the distance on the interventional tool from nearest vital structure through various insertion points. (3) *Path Length Map*: It shows the depth of the target from the skin and is based on the concept that shorter the distance travel by interventional tool, the less is the risk of trauma even to non-vital structures.

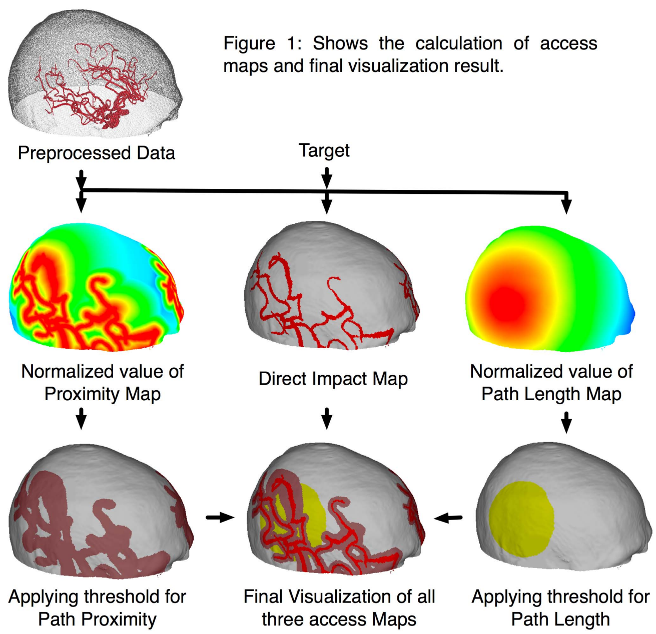

Figure 1: Shows the calculation of access maps and final visualization result.

The whole approach (Shown in Figure 1) was evaluated using data from healthy volunteers. A high-resolution T2 weighted 3D spin-echo multislice set was used for extracting the surface of the head. A time-of-flight MRA from the same subject were used for extraction of the brain vasculature and assign them as vital tissue. Thus, the preprocessing step involved MR data acquisition, followed by image segmentation, 3D mesh models generation and finally co-registration. After the preprocessing step, the three access maps were generated which projects the information (necessary for safe intervention) of underlying tissue type between the point of entrance and the target.

RESULTS:

For a given neurosurgical procedure, the set of feasible insertion points on the surface of the patients' skin can be easily analyzed on the final visualization generated by the method. Suitable thresholds as per the procedure were applied to normalize value of proximity map and path length map (Shown in Figure 1). In final visualization, the yellow region corresponding to path length map, which ensures that is any insertion is made though a point on it, the distance travel by the insertion path would be less than the given threshold. The proximity map forces the interventional tool to maintain a safe distance, specified by the threshold, from the vital tissue i.e. vessel. The direct impact map, shown in red color, avoids any direct impact of the interventional tool on the vital tissue. Thus, the method assists neurosurgeon in selecting incision points on the surface of scalp for a neurosurgical interventional procedure that entails straight access, e.g. deep brain stimulation, tumor biopsy and tumor ablation. Apart from vessels the same approach can be extended to other critical anatomical structures. It can also be used in conjunction with current existing visualization techniques. This work was supported by NSF-CNS 0932272 grant.

ACKNOELDGEMENTS: This work was supported in part by NSF CPS-0932272 and HEAF 97722.

REFERENCES:

(1) Seigneuret et al. Multimodal and multi-informational neuronavigation. In Proc of CARS, 2000, Pg 167-172.
(2) Bourbakis et al. A 3-d visualization method for image guided brain surgery. IEEE Transactions on Systems, Man, Cybernetics, 2003, Pg 766-781.
(3) Beyer et al. High-quality multimodal volume rendering for preoperative planning of neurosurgical Intervention. IEEE TVCG, 2007, Pg 1696 – 1703.
(4) E. Brunenberg at el. Automatic trajectory planning for deep brain stimulation: A feasibility study. In MICCAI 2007, Pg 584–592.