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3D Reconstruction Methods Purporting 3D Visualization and Volume Estimation of Brain Tumors

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ABSTRACT

This work proposes the Crust algorithm for 3D reconstruction of brain tumor, an effective mechanism in the visualization of tumors for presurgical planning, radiation dose calculation. Despite the promising performance of Crust algorithm in reconstruction of Stanford models, it has not yet been considered in 3D reconstruction of brain tumor. Validation of the results is done using the comparison of the 3D models from two cutting-edge techniques, namely the Marching Cube and the Alpha shape algorithm. The obtained result shows that Crust algorithm provides the brain tumor model with an average quality of triangle meshes ranging from 0.85 to 0.95. Concerning the visual realism, the quality of Crust algorithm models is higher on comparison to the other models. Precision of tumor volume measurement by convex hull method is analysed by repeatability and reproducibility. The standard deviations of repeatability were between 2.03% and 3.97%. The experimental results show that Linear Crust algorithm produces high quality meshes with average quality of equilateral triangles close to 1.

KEYWORDS

Alpha Shape, Brain Tumour, Convex Hull, Crust, Marching Cubes, MRI, Reconstruction, Visualization, Volume Estimation

INTRODUCTION

Brain tumors are one of the common causes of death in cancer patients and can strike a human at any age. Brain tumor is a devastating disease that requires fast and accurate diagnosis as well as treatment. It can be primary brain tumor or metastatic. Primary tumors are divided into malignant or benign depending on the presence of active cancer cells. Malignant tumors are identified with the presence of active cancer cells while benign tumor contains inactive cancer cells. According to the Central Brain Tumor Registry of the United States, CBTRUS, a major portion (69.1%)of the tumor are non-malignant which can be well treatable, usually controllable and curable. The survival of a patient depends on the location of the tumor and the early diagnosis for treatment. Magnetic Resonance Imaging (MRI) is an energy-based sensor technique for acquiring the brain images for the diagnosis of brain tumor. MRI is the most proficient imaging modality in which radio frequency waves penetrate the skull without degradation and provides the information. MRI helps in discriminating tumor from cerebral abscess by providing noticeable contrast to different brain tissues. The images provided by MRI is in 2D form which lack depth information and demands good visualization capabilities acquired by long term experience, to interpret the complex interrelationship between anatomical, spatial structures.

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These 2D scans can be converted into 3D models which are closer to reality through the process of three-dimensional reconstruction.

3D reconstruction of medical images deals with the transformation and visualization of multidimensional image datasets and finds extensive application in facilitating qualitative diagnosis, prompt detection, pre-surgical planning and medical education. Surgery is one of the major treatments for brain tumor that harness opportunities in prolongation of patient's life while taking account of the risks. 3D reconstruction and visualization of tumors accompanied by the anatomical structures replicate the actual surgical field (Neyaz et al., 2017), providing foundations to the neurosurgeons for surgical intervention. Preoperative planning using 3D reconstruction techniques reduces the procedure related complications and improves the success rates. When compared to conventional 2D imaging, 3D reconstruction system allows human-computer interaction that helps in understanding the specific details and selection of best therapeutic methods for treatment. Moreover, it improves the doctor patient communication.

Most of the existing algorithms in the field of geometrical illustration and graphical visualization have been used for 3D surface reconstruction of models such as Stanford Bunny, Dragon, Armadillo etc. Crust algorithm is efficient and accurate for dense data. Since medical data is dense and rich in information, this work proposes Crust algorithm as an approach in the three -dimensional brain tumor reconstruction. To the extent of our knowledge, Crust algorithm has not been employed in the 3D reconstruction of brain tumor. Volume measurement of tumor helps the radiologists and surgeons in further follow up and exploring the outcome of therapy. This work proposes Convex hull approach for volume measurement of tumor from the reconstructed model. The requisite of robust patient specific visual models that aid in pre-operative planning as well as automated brain tumor volume measurement is the motivation of this work.

The rest of the paper is organised as follows. The background section provides an overview of the existing related works in the literature. The methodology section provides the details of dataset, explains the Crust algorithm for reconstruction and volume calculation by Convex hull. The result and analysis section describes the results obtained in segmentation, 3D reconstruction and volume calculation of brain tumor. Further the analysis of Crust algorithm on the basis of visual realism, processing time and quality of mesh is carried out. The discussion section highlights the power of Crust algorithm on comparison with existing methods and performance of Convex hull in volume estimation. The conclusions are provided in the final section.

BACKGROUND

Three-dimensional reconstructed models are being utilized in diagnostic and prognostic decision making by medical practitioners. The patient specific reconstructed model helps in the investigation and analysis studies (Lamata et al., 2010) ,surgical management by improving the confidence of surgeons while handling complex cases (Lamadé et al., 2000) and radiation dose calculations (Jiang et al., 2005). The survival rate of a brain tumor patient is determined by the successful surgery which is influenced by the position, shape and size of the tumor. Patient survival can be appreciably improved by removing the tumor as much as possible for which surgical approach can be planned with the 3D reconstructed model of the tumor. Although numerous methods exist for 3D reconstruction of organs, various approaches that have been put forth for the 3D reconstruction of brain and brain tumor in the literature are discussed in this section.

Support Vector Machine (SVM) concept was used for 3D reconstruction of brain tissues by Wang et al.(2007). The characteristics of One Class Support Vector Machine (OCSVM) is utilized to contrive a tight hypersphere that encloses the target objects. The encephalic tissues were reconstructed three-dimensionally using this technique. Sphere-shaped SVMs (SSSVM) was used for the 3D reconstruction of encephalic tissues by Guo et al. (2010). The advantage of this method is that arbitrarily irregular surfaces can be reconstructed since no precedent knowledge regarding

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