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Augmented Reality Based Brain Tumor 3D Visualization

Qian Shan[a], Thomas E. Doyle[b], Reza Samavi[a,*], Mona Al-Rei[c]

[a]*Department of Computing and Software, McMaster University, 1280 Main St. W, Hamilton, ON, L8S 4L8, Canada*
[b]*Department of Electrical and Computer Engineering, School of Biomedical Engineering, McMaster University, 1280 Main St. W, Hamilton, ON, L8S 4L8, Canada*
[c]*eHealth Graduate Program, McMaster University, 1280 Main St. W, Hamilton, ON, L8S 4L8, Canada*

Abstract

In this paper we present an augmented reality system for mobile devices that facilitates 3D brain tumor visualization in real time. The system uses facial features to track the subject in the scene. The system performs camera calibration based on the face size of the subject, instead of the common approach of using a number of chessboard images to calibrate the camera every time the application is installed on a new device. Camera 3D pose estimation is performed by finding its position and orientation based on a set of 3D points and their corresponding 2D projections. According to the estimated camera pose, a reconstructed brain tumor model is displayed at the same location as the subject's real anatomy. The results of our experiment show the system was successful in performing the brain tumor augmentation in real time with a reprojection accuracy of 97%.

Keywords: Augmented reality; 3D visualization; Tumor visualization; Markerless tracking; Mobile device

1. Introduction

Augmented reality (AR) is a type of Mixed Reality (MR) which enhances the physical world by superimposing computer generated images onto it[1]. Such a system allows the user to interact with mixed surroundings of both virtual and physical objects in a natural way. Typically, 2D images are used to exhibit the anatomical structures. In this case, mental mapping is required to match the anatomy with the physical body[2]. Additionally, the left and right orientation are reversed in anatomical images, and the mapping can become confused. However, AR accepts the mental mapping task by overlaying a pre-reconstructed anatomical model directly onto an individual's physical body. This AR system provides a more intuitive approach to visualize the human anatomy and the individual's physical body concurrently. Furthermore, the 3D model provides a potential option to allow the user to view anatomical structures from different directions.

In order to superimpose a computer generated image on its corresponding anatomy, feature tracking is applied to determine the location of the subject. Feature-based tracking techniques can be classified into two groups: marker-

* Corresponding author. Tel.: +1-905-525-9140, ext. 24895
E-mail address: samavir@mcmaster.ca

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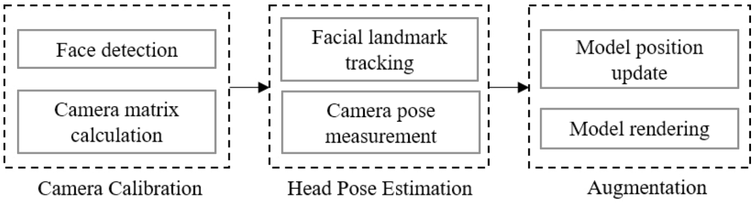

Fig. 1: The proposed system architecture for the AR 3D visualization system

based and markerless tracking[3]. Marker-based tracking uses fiducial markers[4] such as colored dots and QR code, as reference points to assist the system in calculating the camera pose. In markerless tracking, the camera pose is determined from naturally occurring features, such as edges and textures of an anatomical object (e.g. eye corners, nose tip)[5]. A number of medical AR systems reviewed in this paper require excessive preparation to perform marker placement[6] and additional optical tracking systems to track the camera pose[7,8]. Although these systems support a precise accuracy in tracking and overlaying the virtual anatomical model on the patient, placing markers on a patient can be disturbing and the hardware requirements for tracking the markers can be too expensive.

To address the gap in current medical AR systems, we propose a system to augment a pre-reconstructed brain tumor model onto the patient's anatomy using markerless tracking. The system tracks the subject in the scene by using a face detection algorithm. The camera is calibrated based on the face size of the subject. The camera pose is estimated by finding its position and orientation using a collection of facial landmarks and their corresponding 3D points. The model is then rendered at the location of the subject's head according to the estimated camera pose. The system requires no additional tracking devices and can be executed in a more flexible situation as there is no designated environmental setup for running the system. To support portability we prototype our AR system for mobile devices. Our preliminary results show that the system achieved a real-time performance with a reprojection accuracy of 97% and the augmentation manifests no apparent jitter.

The paper is structured as follows: In Section 2 we first describe the system requirements for general AR systems. We then provide an overview of our proposed system and the specifications of its three main components. In Section 3 we describe the experimental procedure and discuss the results of our AR system evaluation on mobile devices. Section 4 describes the related research. We conclude the paper in Section 5 by providing a number of future directions for this research.

2. AR System for Tumor Visualization

In this section, we first describe the requirements for a general AR system and based on these requirements we present our proposed AR system (Section 2.1). Three components of our proposed system architecture are Camera Calibration, Head Pose Estimation, and Augmentation as shown in Fig. 1. In the camera calibration component (Section 2.2), face detection is first applied to find the subject in the scene, and the camera matrix is calculated based on the face size of the subject. Head pose estimation component (Section 2.3) tracks five facial landmarks and their corresponding 3D points to estimate the head pose. The augmentation component (Section 2.4) is responsible for rendering the brain tumor model onto the scene with regard to the position and orientation of subject's head pose.

2.1. Requirements

According to Azuma's survey[9], any AR system should have three major characteristics. First, the system should be able to merge both real and virtual factors. For example, the user should be able to view both the virtual and real objects in the scene through an AR system at the same time. Second, the system must be interactive in real time. For instance, if the user places an object closer to the camera in the real world, the virtual model must respond to the position change simultaneously to match the new scene. Third, the system must provide three-dimensional registration such that the user is able to view the augmented object from more than one direction.

Considering these three characteristics, Zhou *et al.* suggested that a typical augmented reality system is composed of three components which are features tracking, camera pose estimation, and virtual objects rendering and registration[3].