Augmented Reality System for Training Robotic Prostate Biopsy Needle Guidance

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Abstract

In this paper is presented an Augmented Reality (AR) system used for training the urologist to insert the biopsy needle using a serial robot as a case study. The AR based training set-up consists of a large screen projection system for the visualisation of the colocated environment and the software that uses one static single-camera marker tracking to colocate the virtual patient in the robot workspace and to provide guidance instructions for the urologist to perform the biopsy needle steering. The presented AR system has the potential to become a valuable education and training tool for users, helping them to acquire robotic operation skills that can be applied to robotic-assisted needle biopsy of the prostate.

Keywords: Augmented Reality, Surgery Robot, Biopsy, Robot Training

1 Introduction

A biopsy is a procedure performed to acquire a piece of tissue from a body which will be analyzed in laboratory to determine if cancer is present. During the past decade, different types of biopsy needle guiding robots where developed (Pisla et al., 2016; Plitea et al, 2015) for minimizing the risks and improving the precision of the biopsy procedure.

Surgical robots designed for biopsy procedures require pre-operative planning of trajectories prior to be used for needle guiding procedures and the urologist needs to acquire the necessary skills in order operate the robot. These skills can not be learned directly on patients.

There are few commercially available phantoms suitable for percutaneous biopsy, but their costs is high (Sekhar et al, 2014). In order to overcome this limitation, 3D simulation training can be used (Selmi et al, 2013; Villard et al, 2014; Tsuda et al, 2009). This method uses a 3D simulation of the robot environment and surgery environment and it allows to improve the familiarization with hardware equipment and to learn safe and effective techniques (Voros et al., 2013; Kwon et al, 2013; Rogula et al, 2013). 3D simulation training using virtual environments is an efficient learning method (Keshtgar et al, 2005), however require the necessity to prior reconstruct the detailed 3D virtual environments of the real environments.

The term "Augmented Reality"(AR) implies a variety of Virtual Reality (VR). In a VR system the user is completely immersed in the environment generated by the computer. An AR system will allow the user to visualize the real world, supplemented with computer-generated virtual objects coexisting with the real environment (Azuma, 1997). The main features of an AR system are: co-location of virtual objects in the real world; running interactively in real time; aligning real and virtual objects to each other. Therefore AR systems will not replace the real environment, but will add new information in order to assist the user in various applications. If the goal of VR systems is a total immersion in the virtual environment, the AR requires maintaining contact with the real world, virtual images being added over real ones. The advantage of such a system is that it
will not replace the real world with a computer generated environment, but will add new information in order to help the user, offering the ability of manipulating both real and virtual objects. AR technologies are applied in many different fields including: medicine (Chen et al., 2015), manufacturing, military, education and entertainment etc. One of the main areas in which the AR technology is applied is robotics. The main advantage in using AR against VR is removing the need to generate a 3D virtual environment that represents the workspace. Therefore, the user interacts in a natural and intuitive way with the robot situated in an authentic 3D space.

This paper present ongoing research carried out at Transilvania University of Brasov with the aim to develop an operator interface based on AR technology that enables training of robotic prostate biopsy procedure. The prototype application presented allows to control a test case serial robot using a teach pendant and simulate the robot needle guidance biopsy actions on a 3D virtual patient co-located in the real working environment.

2 Materials and methods

2.1 The hardware architecture of the AR robotic biopsy training system

The AR robotic biopsy training system was developed based on serial robot (Kinova JACO), a high-performance graphical workstation (HP), a web camera (Logitech C300), a professional video projector and frontal large projection screen (presented in Fig. 1).

For the training of the robotic biopsy procedure a serial Kinova JACO robot (www.kinovarobotics.com) was proposed to be used as case study (Fig. 1). The robot arm has six degrees of freedom and is equipped with a three fingers based gripper that can be controlled individually. The gripper fingers can grasp easily various types of the biopsy guns.

In order to colocate 3D virtual models with real images and present them to the user is used a physical display device. Many types of AR display are available: Head Mounted Displays (HMD), portable displays (like Tabled PC), monitors and projectors. HMD is a common choice for AR because enhance the immersion sensation. If a HMD device will be used for the proposed AR system, the position and orientation of the calibrated 3D virtual model will change with corresponds to the movement of user. Because of this issue, for the presented system it was used an AR large screen projection system with one static single-camera. Acording to (Fiorentino et al., 2014) large screen projection technology can be a valid alternative to other types of AR displays.

The video projector (Digital Projection Titan 1080p Dual 3D Projector) has high definition resolution 1920x1080 for performant visual rendering. The images are projected on a frontal screen with the dimension of 4000x1500 cm. A fixed position webcam featuring 1280x1024 resolution was used for the tracking of fiducially markers and grabbing video images from the real environment. The graphical workstation is equipped with 12GB RAM memory, a Intel(R) Core(TM) i7 at 3.47GHZ CPU and NVidia QuadroFX 6000 graphic card running on the Windows 7 operating system.

2.2 The software framework of the AR robotic biopsy training system

The AR robotic biopsy training system was developed under the platform of the library called Instant Player

Fig. 1 The hardware of the AR robotic biopsy training system
For the representation of the 3D models was used the Virtual Reality Modelling Language (VRML) ISO standard. Editing VRML virtual environment was realized through the application VRMLPad (www.parallelgraphics.com/products/vrmlpad/).

2.3 3D-reconstruction of virtual patient

The 3D model is obtained on the basis of the preoperative MRI data of a patient. The segmentation of the hard and soft tissue from MRI data was performed manually. For the 3D reconstruction from 2D slice images was used the 3D Slicer software (www.slicer.org). The resulted reconstructed 3D patient model was saved using the *.vtk format.

For the integration in the AR software framework, the model was converted in the VRML format separately for each anatomical entity as a set of IndexedFaceSet nodes composed by a number of vertexes and triangles. The conversion from the Slicer *.vtk 3D file format to the VRML type was done using the Paraview software. Then all the nodes where grouped in individual 3D surfaces with topological labels. Fig. 2 shows a patient with skin, bones, pelvis, bladder and prostate 3D models after the 3D-reconstruction.

![Fig. 2 The 3D reconstructed pelvis model of a patient](image)

2.4 Registration of the 3D virtual patient in the real environment

The InstantPlayer AR software allow identification of the square markers, determine 3D position and orientation of identified markers in order to align the virtual pacient onto the real one, register the 3D virtual pacient in the real environment.

![Fig. 3 The establishment of 3D patient location in AR system](image)
In order to calibrate the virtual patient’s position in relation to the robot using marker based tracking technology, the user has to carry out the following steps: (i) generate a reference marker using an image editor (Fig. 3), (ii) add marker matrix data in the *.pm file of the Instant VisionLib module, (iii) integrate the tracker data from the *.pm as a reference file into the AR application and co-locate of the 3D virtual model on the real robot workspace by modification of scale, 3D position, and orientation, relative to the camera transformation matrix.

3 Test case
In the conducted test case, the users had to set configurations of the Jaco robot using the teaching pendant in order to allow positioning of the biopsy needle tip inside of the prostate quadrant and avoid the proximity with high risk organs (Fig. 4). The robot trajectories are recorded and saved using the JACO software. The users appreciate the possibility to learn robot needle guidance for transperineal biopsy procedure using as a test case a virtual patient and a real robot. However, they point out that improvements can be made on the graphics rendering and managing occlusions between real robot and virtual patient. Also the integration of a TRUS device simulation is needed.

4 Conclusions
In this paper, it was presented a prototype AR system which has the potential for a promising tool for education and training of robotic biopsy needle guidance. It is based on the usage of augmented reality in order to introduce the virtual patient in a real environment. In this collocated environment the user can create and save robot trajectories, using reality based simulation directly available in the working environment. This approach helps inexperienced users to learn robot biopsy needle guidance in an intuitive way.

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References