Prostate Tumor Palpation Simulator Based on Pneumatic and Augmented Haptics

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Abstract. In this project, we focus on building a prostate palpation simulator where a practitioner teaches his/herself a process called Digital Rectal Examination (DRE). While conventional mock-up-based training simulators can only provide a fixed number of abnormal conditions, our simulator is capable of creating various prostate abnormalities ranged from a single small tumor to multiple larger tumors, with comparable fidelity and realism. For this, we have developed a new prostate-shaped end-effector that systematically changes the its shape and stiffness using pneumatic and particle jamming techniques with embedded balloon. At current stage, seven pores are embedded in the silicone prostate mock-up, so a medical practitioner can perceive tumors with wide range of stiffness, position, and number.

Keywords: augmented haptic· medical simulator· palpation· pneumatic · particle jamming

1 Introduction

Medical simulators play an important role in training of the medical students, by providing various medical case that cannot be easily experienced. The medical simulator is useful tool in determining a physician understanding and management of patient complications.

Palpation is one of the clinical diagnosis skills, where medical professionals identify abnormalities by touching and feeling haptic difference between an affected and normal tissue. In particular, the process of the analysis of prostate abnormalities using an index finger palpation through human rectal region is known as Digital Rectal Examination (DRE).

It is reported that, DRE are intimate physical examinations. The prostate cancer is most common cancer and second leading reason of death because of cancer in the United State. There are two kinds of prostate abnormalities: lumpy and hard tissues (tumors). In addition, tumor could be of any shape and size. In this project, we develop a simulator to practice the DRE technique.

2 Methodology

The goal of the work is to develop a haptic interface and rendering algorithm specialized for the training of DRE. Since the main interaction in the DRE process is to insert doctors index finger into the rectal area, a simulator for DRE should provide, for realism, full area contact feedback between the finger and the inner tissue surface of the rectal. On the other hand, the feedback of interest, which is subject to change for flexible simulation of various abnormalities, mainly occurs in very small area, at the doctors fingertip and is generally very subtle. Thus, conventional point-contact-based force feedback haptic interfaces are not suitable for this scenario. As an alternative, this paper presents

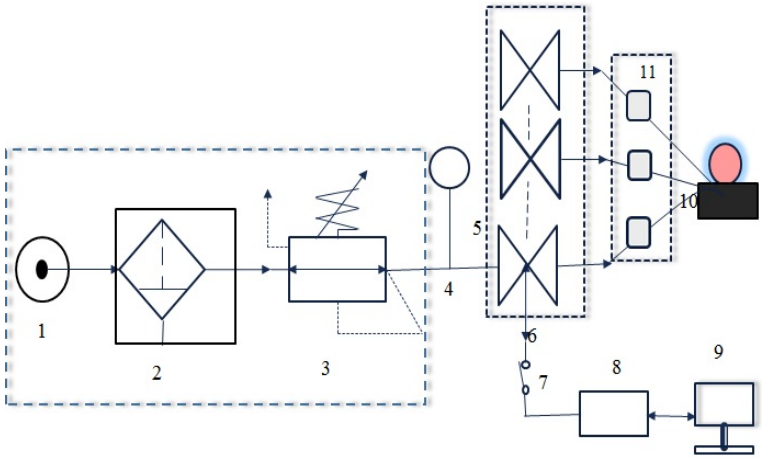

Fig. 1. Illustration of System Architecture for the prostate haptic medical simulator. 1 Air Source 2 Filter 3 Regulator 4 Gauge 5 Array of Valves 6 Two-way lines 7 Switch 8 DAQ/PLC 9 Computer 10 Membrane/prostate with flexible lines 11 Array of Vacuum generator

a haptic augmented reality-based approach empowered by a pneumatic actuation. The peripheral haptic feedback that is not subject to change is supplied by real mannequin mock-up, and the feedback of interest at the trainees fingertip is synthetically generated by a variable haptic property end-effector made of a silicone and embedded pneumatically actuated pores. It has proven that pneumatic approach has the capability to produce natural force feedback [1] [2], and actuator balloons, made up of silicon, can produce the natural skin feeling. In order to independently control the stiffness and size of the pores, we combine the pneumatic pressure control with particle jamming technique where small particle alters the stiffness of the pores when vacuumed. With capability of controlling the size of the pores with pneumatic pressure control and controlling the stiffness of the pores with particle jamming techniques [3], the system can

produce lumpy tissues and hard tissues effects. Moreover, a mannequin of the body part presents a physical medium that is similar to a typical patient case and it makes the simulation more realistic [4].

2.1 System Architecture

To achieve above mentioned control, we have designed and developed an architectural model comprising standard pneumatic active and passive components in specialized arrangement as shown in fig. 1.

2.2 End Effector

The core part of our implementation is on the end effector. We developed a new prostate-shaped end effector that systematically changes its shape and stiffness using pneumatic and particle jamming techniques with embedded balloon. The end effector is casted using Eco-Flex 0030 (Smooth-On). The overall layout of the silicon end effector is shown in Fig. 2.

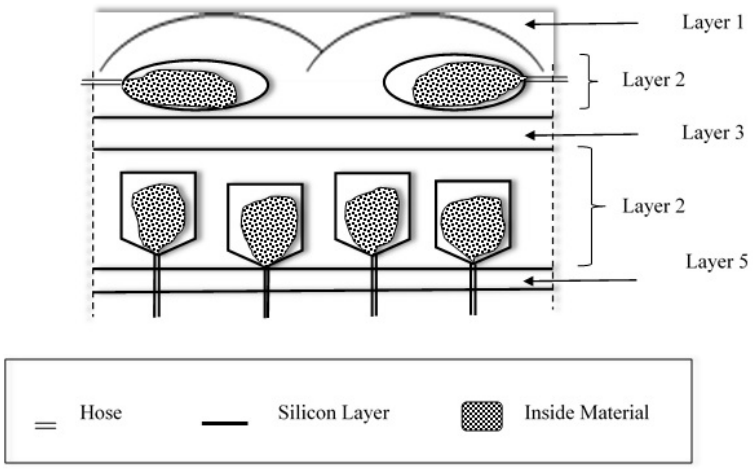

Fig. 2. Illustration of side-view layout of the silicon end effector.

Two layers of pores are arranged, which simulates different depth of the tumors. Upper layer and lower layer has multiple pores that localize the tumor. As mentioned, the stiffness and the size of the tumor are controlled by pneumatic control of each pores.

3 Demonstration

Currently, the silicon prostate mold is designed with seven pores inside. Each of pores is able to provide different seven level of inflation and deflation. In this

demonstration, we provide augmented haptic simulator to educate the medical practitioner with better perception of multiple, reconfigurable, and classified scenarios (such as prostatitis, BPH, and cancer) of abnormal conditions with lump, stiff, and deep tumor, of the prostate by performing DRE examination.

The setup of demonstration is shown in fig. 3. With this setup, participants can experience real-like practice of DRE process with various different symptoms, such as deep stiff tumor or swallow and different sized multiple tumors.

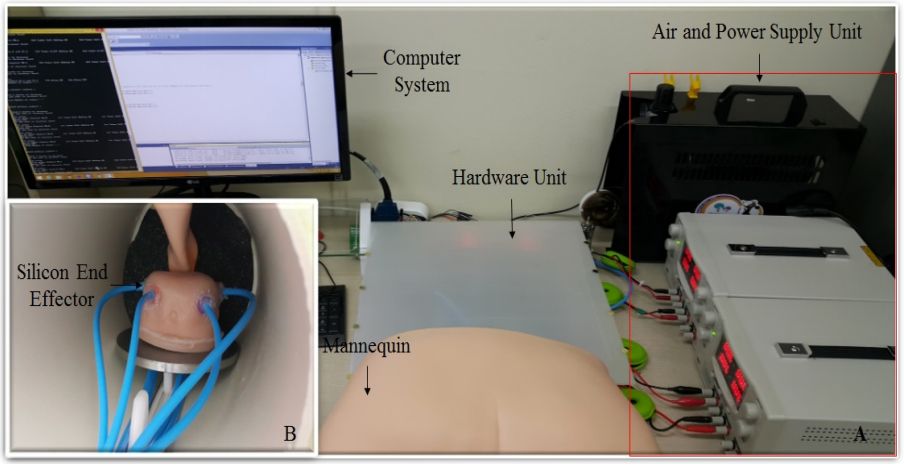

Fig. 3. A. Illustration of the overall set-up of the system, B. Assembly of end effector within mannequin.

4 Future Work

In this paper, we are intent to demonstrate preliminary study of the prostate tumor palpation simulator. However, in near future we will evaluate the system effectiveness to train the medical practitioner.

5 Acknowledgement

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