DEVELOPING A SIMULATION TRAINING TOOL FOR ULTRASONOGRAPHY

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ABSTRACT

This paper discusses the methodology and development of a simulation training tool for ultrasonography. It is designed for training medical practitioners whose practice involves comprehensive and problem-specific physical examination of the patient with the use of ultrasound. Inherent in this user-dependent technology is the need to ensure user capability and appropriate usage of the ultrasound. Simulation is integral to ensuring that capability. Simulation training is able to execute training in a real-world, temporal mode; it can house large digital libraries of ultrasound images for a breadth of experiences; and it can accommodate a repetition of exercises to reinforce learning. Credibly, this simulation training tool for ultrasonography will engage instructional materials in the form of actual patient ultrasonographic images.

Keywords: ultrasonography, pathology, transducer, probe

1. INTRODUCTION

Ultrasonography is an ultrasound-based diagnostic imaging technique used for visualizing subcutaneous body structures to include tendons, muscles, joints, vessels and internal organs for possible pathology or lesions (pathology is defined as the scientific study of the nature of disease and its causes, processes, development, and consequences). It is capable of performing both diagnostic and therapeutic procedures. As such, portable bedside ultrasound devices have revolutionized the practice of medicine, and they are utilized across many sub-fields of medicine (anesthesiology, cardiology, emergency medicine, gastroenterology, gynecology and obstetrics, neurology, ophthalmology, urology, musculoskeletal). Experts in the study and use of ultrasonography recognize this point-of-care medicine is defining the future of patient – physician interaction with pathologies assessed upon examination as bedside visualization. This technology, however, is user-dependent, so ensuring user capability and appropriate usage is necessary. To fully exploit the capability of ultrasonography, medical practitioners using ultrasound must have increased and pathology-specific training to facilitate cognitive and mechanical proficiency. This paper discusses the methodology and development of a simulation training tool to meet that need.

The approach taken is outlined in the following four parts. Part 2 – *Why a Simulation Training Tool is Needed* answers why additional training is needed for point-of-care medicine, who needs this training, and how simulation is integral for this training. Part 3 – *Meeting the Needs of the Training Tool* discusses the necessary focus of the training from substance to interface. Part 4 – *Developing the Tool* discusses the development of the tool such as interface, hardware, and simulator design. Part 5 – *Results and Conclusion* provides an assessment of a prototype tool and discussion for further development of the tool.

2. WHY A SIMULATION TRAINING TOOL IS NEEDED

Medical simulation is able to execute training in a multiplicity of modes, house large digital libraries for a breadth of experiences, and accommodate a repetition of exercises to reinforce learning. Ultrasound practitioners need to understand what they are looking at – impossible to assess with present training modality.

2.1. Why this Tool

Medical students today do not always recognize pathology when they see it, and/or they understand pathology with cognitive skills, but not with the ultrasound image they have extracted. There are also cases whereby students are found to lack the dexterity and mechanical skills needed for the extraction of images. Most curriculums require cognitive examinations wherein the image is provided and the student must simply associate the name of the pathology with the supplied image. Technically, students are given instruction and hands-on training for image extraction, but they do not always recognize the pathology they have retrieve via the extracted ultrasound image due to the fact that he does not have the cognitive skill to do so or because the image is not well-retrieved or a combination of both these handicaps (Levitov 2009). In the US the standard of 20-30 most common pathologies must be obtained and recognized by the student. A gold standard of 150 procedures / images exists, but even then the student may be incompetent (Levitov 2011).

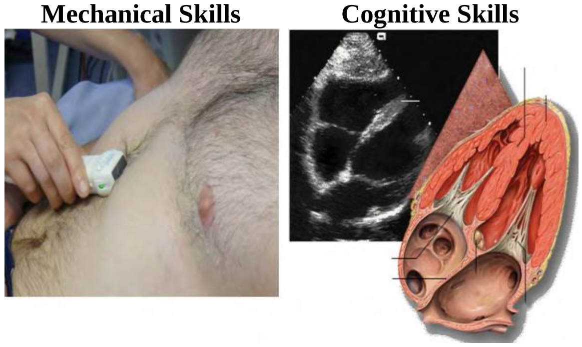

Figure 1: Bedside Ultrasonography Skills

2.2. Who to Train

Thus a simulation training tool for ultrasonography is needed to provide additional and incisive exercises medical students, residents, fellows, and practicing clinicians whose practice involves comprehensive and problem-specific physical examination of the patient. This training can benefit students and clinical practitioners by teaching them to: 1) extract images from a comprehensive library of pathologies, 2) develop of a care plan, and 3) debrief to communicate clinical skill.

2.3. Simulation – Integral for this Training

As such, a tool is need to augment current standards of ultrasonography education through immersive simulation training that includes a comprehensive library of pathological images which the students must extract, recognize, and discuss as part integrating advanced ultrasound principles for patient care.

Arguably, simulation is the ***only way to conduct this training*** because bedside ultrasonography is point-of-care medicine and as such the physician should be able to perform both diagnosis and therapeutic procedures at the bedside, using ultrasound to guide interventional procedures. Training with patient *in vivo* could prove difficult for both patient and clinician: it might be disconcerting to a patient if the physician cannot extract an image, or recognize pathology at the bedside. The immediacy of the technology could prove embarrassing for a physician if he cannot diagnosis or prescribe care through the use of ultrasound in the presence of the patient. Thus, simulation can avoid both these uncomfortable scenarios.

Simulation is the ***best way to provide this training***. Primarily because it is the most ***effective*** means to train and assess the student's knowledge and capability via a body of pre-determined pathologies that must be extracted and discussed via simulated exercises. This training experience will develop, enhance, and make expert their cognitive and technical skills. Second, simulation training is the most ***efficient*** means to exploit the capability of ultrasonography by facilitating repeat-ability of exercises, independent practice sessions. It also is an ***expedient*** means to ensure the future of bedside medicine.

The current users of ultrasonography include physicians practicing internal, critical care, obstetrics-gynecology, and cardiovascular medicine. A broad future audience of clinicians exists because ultrasonography can prove to be a defining skill for practicing physicians as it is superior over the traditional craft (Levitov 2011). Dr. Abraham Verghese of Stanford University (California) is recognized as providing the best physical examination in the US. Verghese is defining (perhaps exposing) the limitation of skills of physicians in physical examination (New York Times 2012). Ultrasonography can mitigate that limitation of skills.

3. INCORPORATING TRAINING REQUIREMENTS INTO THE TRAINING TOOL

To ensure the needs of the training are met, consultation with medical experts is necessary. Their expertise facilitates an understanding of three important concepts before tool development can proceed: the concept of *point-of-care-medicine*, the current type of training provided, and preferences for the simulation training. These first two concepts are discussed in Section Two above. The following articulates the needs of concept three: preferences for the simulation training.

3.1. Substance of the Tool Design and Interface

Experts in the use and training of ultrasonography would like to see a medical curriculum re-work that requires students to incorporating their knowledge of image acquisition with their cognitive skills of pathology recognition. In short, it means the training should consist of a means to present students with images of multiple pathologies. Essentially, this calls for incorporating images of pathologies into an environment which forces students to interrogate the patient, which can come in the form of a cadaver, mannequin, or simulated-actor. How does one do this without re-inventing the wheel? Modify a traditional instrument into a training tool with specified education and training requirements.

Current ultrasound technology engages a general-purpose sonographic machine for most imaging purposes (see Figure 2).

Figure 2: Medical Ultrasound Scanner

Most ultrasound procedures are done using a transducer on the surface of the body (see Figure 3). The probe contains multiple acoustic transducers to send pulses of sound into a material. Whenever a sound wave encounters a material with a different density (acoustical impedance), part of the sound wave is reflected back to the probe and is detected as an echo. The time it takes for the echo to travel back to the probe is measured and used to calculate the depth of the tissue interface causing the echo. The greater the difference between acoustic impedances, the larger the echo is. If the pulse hits gases or solids, the density difference is so great that most of the acoustic energy is reflected and it becomes impossible to see deeper.

Figure 3 Ultrasound Transducers

This makes clear to needs of the training tool: 1) the images to need be in real-time and, 2) the tool must be a HANDLING tool so that the students can manipulate the transducer to obtain images. As such the training tool must have a reasonable degree of technical difficulty to obtain images. This can be done in two ways: re-animate cadavers or use a simulation platform.

For purposes of this tool development, we determined to use a platform that can be dislodged, yet not completely virtual. The platform must be able to recognize how the transducer is positioned. For added training benefit, the tool must allow transducer to gradually imperfect or distort an image as a teaching experience. When developing aspects of position accuracy with the transducer, the simulation must be able to note patient size and take into account that probes can measure within centimeters for linear or angle-wise images and within 10-15 degrees for triangular or trapezoid images.

The real-world nature of this training tool is premised on using actual patient images – a library of pathologies – images that occur in reality of practice and then tying the right image in real-time.

3.2. Intended Results of Tool Development

Developers of the tool must make every effort to hold to the requirements and preferences of the physicians who have provided their expertise in the development of the tool. As such, the simulation training tool should:

- be highly interactive, diagnostic training tool
- engage user-friendly simulation technology
- developed as ultrasonography information-based
- consist of (real) patient image-based, with images occurring in reality of practice
- facilitate image extraction engaging different transducers and their varying capabilities
- require a reasonable degree of technical difficulty to obtain images for *handling* experience
- present the trainee with images in real-time via a simulated platform
- include inconsistent and inaccurate image extraction as a teaching experience
- provide retrieved and actual patient outcome as realized in the case study image
- serve as a training competency verification tool

4. DEVELOPING THE TOOL

A simulation training tool for ultrasonography must be grounded in electrical engineering and computer science software design to replicate ultrasonography training experiences that are immersive and temporal; *i.e.*, as the ultrasound probe, the transducer, is manipulated images are extracted in real-time. The simulations are drawn from actual patient images serving as the basis for a variety of training scenarios. The tool combines electronic sensing components that detect the position and orientation of the simulated transducer with software that controls proper image selection so that the user is presented with the appropriate image based on his or her skill of probe manipulation. Essentially, this tool requires developing the relationship between transducer and image to create simulator capability so the student can practice manipulating the probe to retrieve pre-set or randomly selected pathologies. In short, we are deconstructing the traditional instrument to create a simulated, real-world training experience.

It is important to note that the simulator will be built with three distinct parts that will operate in cooperation with each other: the graphical user interface (GUI), the hardware interfaces that the user will physically manipulate (such as probes and dials), and the imagery data itself, which will be displayed based on the pathology of the simulated patient and the position of the probe.

4.1. Interface Design

The GUI will be a fairly straight-forward windows based program allowing the trainee to start up the program, select a patient case-study and then initialize the probe. The GUI will read the data coming off the hardware dials, buttons, and the probes providing the user with the appropriate responses to their manipulation of the probe and controls.

4.2. Hardware Design

Once the trainee has selected a patient, he or she will need to select the correct probe to use based on the patient's pathology. The trainee will have to manipulate the probe into the correct position on the mannequin or standardized patient to see the recorded images. If an incorrect probe is used, the simulator may not show the correct image. As some of the probes are meant to be inserted into the patient's body, the simulator will have to include a mannequin that can accept a probe in the correct locations. In addition to the probe, the trainee will have to manipulate some dials and buttons to alter the field of view and strength of the transducers as would be the case on an actual Ultrasound Scanner. These buttons and dials can be interfaced with the GUI using a standard off the shelf USB input/output (IO) board, such as an Arduino or other similar devise (Arduino 2012).

4.3. Simulator Design

The images that will be displayed on the simulator's screen will be stored in a large database containing information about the pathology, age, and sex of the patient. In addition, the angle of view and location on the patient will be stored so that the simulator will know where on the mannequin the probe will have to be located in order to display the appropriate images.

4.4. Hardware Probe Design

Developing the probe and tracking its movement is the most critical part of the simulator design, and will require an Inertial Magnetic Unit (IMU) to track the movement of the probe. An IMU uses the earth's magnetic field and an inertia sensor to tell the software in which direction the device is pointed, and the direction it has been moving. Unfortunately, the accuracy of these devices is compromised as they have a tendency to drift over time (Florida Conference 2002). However, while it will be possible to reduce this drift through the use of a Kalman filter algorithm, it may be useful to implement another method of tracking the probe as well to improve its accuracy (SIGGRAPH 2001). This can be accomplished by complimenting the IMU with the use of a Microsoft Kinnect to provide visual tracking of the users hand or a Wiimote using its IR camera to track IR emitters on the probe.

The use of a Microsoft Kinnect, along with an IMU may provide the best methodology for tracking the probe's position and orientation. This system is relatively cheap, comes with an easy to use API, and does not necessarily require an unblocked line of sight to the probe. In fact, it should be possible to track the trainee's hand as well as the probe, as the Kinnect software is setup to do just that. However, this system must be tested against its intended use, as the mannequin, which looks just like a human, may potentially interfere with the tracking of the trainee's hand by the Kinnect. Optionally, a wiimote can be pointed at the mannequin and IR emitters fitted to the probe so that the wiimote can track the location and orientation of the probe, as long as the line of sight to the probe from the wiimote is kept clear.

Technically the accuracy of the probe's location with respect to the virtual model and the mannequin or standardized patient is required to have a high level of fidelity in order for it to be effective. This means that the more accurately the probe and the location of the mannequin can be monitored the higher fidelity the virtual image can potentially display. However, the accuracy of the probe's relative position is not the only factor in ensuring the validity of the technical aspects of this simulator. The Virtual model must also show deformation of internal organs as the probe is pressed up against the subject's body, and to verify this, a subject matter expert such as a practitioner of Ultrasonography is required to provide feedback (Gerovichev 2004).

5. SUMMARY

The need for developing simulation medical training tools is quite obvious – technology outstrips educational products *i.e.,* the technology and devices are readily available, but the training is lacking. It has been said that the patient-doctor interface has not changed since 1860s. Yet as this is written, bedside ultrasonography is taking hold of that problem and turning it around. Ultrasonography is the first serious attempt to advance bringing medicine, vis-à-vis the patient-doctor interface, into the 21st century, although some medical experts place these advances to about the 1980s (Levitov 2011).

Developing medical simulation training tools requires close cooperation with the users, the clinicians, determine precise educational content. Simulation engineers and those in the modeling and simulation community simply do not have the expertise nor the materials needed to ensure that the training materials are appropriate. As shown in this discussion of ultrasonography education, those training-specific materials are the patient images – a library of pathologies – images that occur in reality of practice to populate the tool. With the requirements and images in hand, actual development of the tool can begin. The engineering expertise comes in the form of tying the right image in real-time – programming, simulation, and interface design.

This methodology paper outlines how to develop a simulation training tool for ultrasonography. And although this is not the only effort in existence, a cursory review of what is available indicates that many training products are too costly and some have been criticized as not well-thought out. If the expert users of ultrasonography are correct, that the use of ultrasound will change the future of bedside medicine, then it is fair to conclude the U.S medical curriculum will adjust to include ultrasonography education and training as an integral part of its curriculum.

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