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Cost Effective Ultrasound Imaging Training Mentor for use in Developing Countries

Llyr ap Cenydd [1], Franck P. Vidal [1], Nigel W. John [1], Derek A. Gould [2],
Elizabeth Joekes [2], Peter Littler [2]
[1] Bangor University, UK
[2] Royal Liverpool University NHS Trust, UK

Abstract

This paper reports on a low cost system for training ultrasound imaging techniques. The need for such training is particularly acute in developing countries where typically ultrasound scanners remain idle due to the lack of experienced sonographers. The system described below is aimed at a PC platform but uses interface components from the Nintendo Wii games console. The training software is being designed to support a variety of patient case studies, and also supports remote tutoring over the internet.

Keywords: ultrasound training, medical virtual environment, HCI.

1 Background/Problem

Ultrasound is a low cost, vital cross-sectional imaging tool in the developing world. Alternative imaging modalities, e.g. CT, MRI, are only found in large teaching centres, and even then the cost is prohibitive to the vast majority of patients. We have experience of working with hospitals in Western Africa, in particular Kwame Nkrumah University of Science and Technology and Komfo Anokye Teaching Hospital in Kumasi, Ghana. The latter is the fourth largest hospital in Western Africa and the second largest in Ghana. It has 1000 beds and only one radiologist. Despite this they have four ultrasound machines used by doctors from several specialties with minimal or no formal training. Outside this teaching hospital there are numerous district hospitals and clinics, equipped with ultrasound machines, but lacking appropriately trained staff to use them. An affordable Ultrasound training programme is desperately needed. This is a common situation in much of the developing world.

Intensive basic ultrasound training has been provided by staff from the Royal Liverpool Hospital in an annual four day course, aimed at doctors working in hospitals and clinics across Ghana, and who have had minimal ultrasound training. Feedback from the course in 2007 showed 4 of 7 doctors who performed up to 30 scans per week had no formal training at all. All 20 candidates on the course wanted and clearly needed further ultrasound training. For proficiency at least six months full-time scanning is required by most training programs. The current severe training limitations frequently result in diagnostic errors, adverse patient outcomes or expensive equipment remaining unused.

Whereas effective ultrasound training solutions are available on the market e.g. MedSim's UltraSim product [3], they are relatively expensive and not easy to deploy and maintain in developing countries. We require a low cost alternative for remote training of ultrasonography in countries where technology resources are limited. This paper describes work in progress to build such a system to fulfill the above requirements.

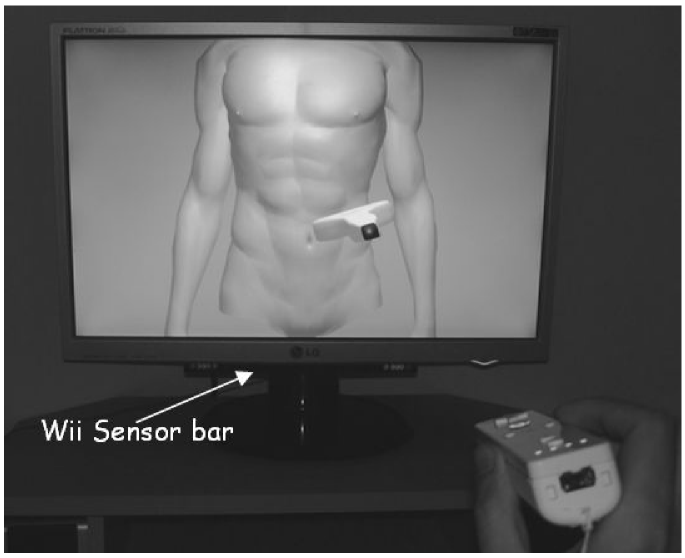

Figure 1: Using the Wii Remote as an Ultrasound Transducer.

2 Tools and Methods

The design of first prototype has been categorised into three modules: the hardware platform, the software environment, and the remote mentoring support. These are described below.

2.1 Fully Functional Low Cost, Robust Hardware Environment for the Trainee

Our initial work has confirmed the potential of using low cost components from the popular Nintendo Wii games console to provide the human computer interface to our system. In particular, we deploy:

- A Wii Remote Controller (available for £30), which we then configure to function as the dummy ultrasound transducer in the training application. The Wii Remote is a bluetooth wireless device containing a 1024x768 infrared camera with built-in hardware tracking. It can therefore be connected to any PC platform that supports the bluetooth protocol, which is standard in most laptops, and can be provided using an inexpensive USB bluetooth dongle on desktop PCs.
- The Wii Sensor Bar (available for less than £10) provides an infra red light source that is used to track the Wii Remote. Wireless sensor bars are available, powered by batteries, and so do not have to be connected to the Wii console to provide the power source.
- The Wii Nunchuck Controller (£20) - which contains an accelerometer - can be used to position and orientate the virtual patient. Use of this device is optional.

The use of the Wii peripherals for PC-based applications is commonly called “Wii-jacking”. Many examples and sample code for using and deploying these devices can be found on the internet, e.g. [2].

A PC with a good graphics card provides the application platform. The graphics card is the most expensive hardware component being used but it is necessary for real time performance. The current generation of graphics cards aimed at the games market provide sufficient processing power for our purposes. Figure 1 shows the Wii Remote in use as our ultrasound transducer. The Wii sensor bar has been located below the monitor. Tracking accuracy of the Wii Remote will be enhanced when the recently announced Wii MotionPlus accessory is available. The MotionPlus

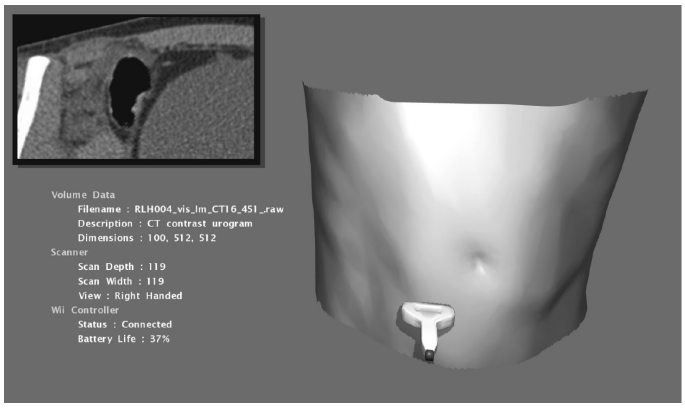

Figure 2: User Interface for Scanning Session.

contains a multi-axis gyroscope, which when combined with the Wii's existing sensor bar and accelerometer will allow true 1:1 motion to be calculated.

Other technology from the games market is also being explored. An alternative device that could act as the transducer is the Novint Falcon Force Feedback joystick (£200). This offers a haptics response but has a more restrictive work space that will be a problem for freehand ultrasound scanning.

2.2 Advanced Software Environment

An interactive, easy to use 3D graphics application is being developed. As the virtual transducer is scanned across the virtual patient, an image corresponding to the location and orientation of the probe is displayed – see Figure 2. CT provides access to a rich source of patient data covering all patient types and variations. The skin surface of the virtual patient is first segmented from an appropriate CT data set. A multi-planar reconstruction of the CT data is then calculated according to the current position of the virtual transducer – for example, the image shown in the top left of Figure 2. The next step is to display what looks like an ultrasound image of the virtual patient.

Our previous research to produce an image guided needle puncture simulator has developed an algorithm to create simulated ultrasound images from CT data on the GPU in real time [4]. This requires hard structures such as bones to totally reflect the US signal. Similarly, pixels located behind gas also appear darker. A shadow mask can be implemented to produce the desired effect. At the horizontal interface between two different materials, bright reflections can be observed in real ultrasound images. Using a high pass filter to compute the gradient direction, it is possible to detect such interfaces in real-time and add bright reflections. Image noise is also added to produce images more representative of ultrasound. Figure 3 shows an example of the ultrasound-like images that can be generated using this approach. This is typical of what the trainee will see when performing a virtual ultrasound scan.

The application also allows the trainee to change the settings of the virtual US machine so that the appearance of the rendered image can be changed as appropriate.

2.3 Remote Mentoring

The communications infrastructure in low resource settings will be variable and often of low bandwidth. The instructor's workstation will therefore need to receive the minimum amount of data possible in order to monitor the trainee. Only changes to the orientation and position of the trainee's virtual ultrasound probe are therefore transmitted. These data can be further compressed and transmitted in a light weight UDP data packet. The instructor's software uses

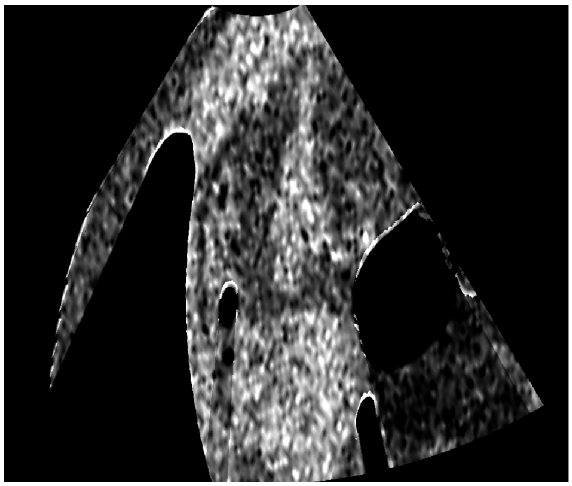

Figure 3: Generated ultrasound image corresponding to CT slice in Figure 2.

this information to display the same ultrasound image that the trainee is seeing. The same data sets need to be available at both locations.

Depending on bandwidth, text chat, audio and/or video is used to provide further support for remote mentoring.

3 Results

The Wii Remote has proved to be remarkably adept at providing a low cost "dummy" ultrasound transducer. The user can set up the position of the virtual patient and then use the Wii Remote to undertake a virtual ultrasound scan. By moving and rotating the Remote, force and torque are applied to a physically simulated on-screen scanner, mimicking the user's actions. Though also physically simulating the patient's body, accurate calculations of transducer contact position, orientation and pressure can be made.

We provide depth cues to the user on how close the transducer is to the patient by emitting an artificial light source from the transducer and making the Wii Remote vibrate when it comes into contact with the skin. Any CT data set can be used by the application to generate simulated ultrasound images and data sets have been made available that provide appropriate training scenarios.

The fidelity of the ultrasound-like images generated is being evaluated in this and in the related simulator project for ultrasound guided needle puncture. Feedback obtained through these evaluation studies confirms that the images generated sufficiently resemble real life ultrasound images. However, CT data is not always available, e.g. for a scan of a pregnant woman. An alternative is to acquire real ultrasound data together with the position of the transducer and use this to create the images seen in the trainer. This technique was first used by Barry et al [1].

A limited pilot training curriculum based on current UK curricula is now being developed. The simulation has undergone preliminary face validation studies by a radiologist subject matter expert and was considered to reflect many of the elements of the ultrasound procedure as performed in the real world.

4 Conclusions/Discussion

Low cost, simulated ultrasound training will have wide applications in a range of specialties throughout the medical community. Local benefits in training sonographers and doctors away from patients will increase and standardise the exposure to case mix. Enormous benefits to

patients are envisaged for low resource countries where ultrasound imaging provides the most straightforward, productive, and least expensive medical imaging modality available. Ultrasound training, mentored over the internet by qualified radiologists and radiographers, possibly located in other countries, is particularly applicable to settings with no local training program. In fact remote training using a system such as this will also provide new training opportunities in countries such as the UK even though a comprehensive health service is already in place.

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