Title
Student, major; Mentor, department

Research Statement
To develop training simulation software to utilize motion-controller technology to teach students in medical fields basic ultrasound examination skills.

Project Goals
1. Develop an image-simulation process that can generate realistic ultrasound images in real-time.
2. Utilize motion-control technology to realistically simulate manipulation of a real ultrasound probe.

Project impact, significance, or purpose
Previously, ultrasound training typically has taken place with live subjects and real ultrasound equipment, both of which are expensive to obtain. While some simulation systems already exist, they often require expensive hardware such as dummies or proprietary motion sensing controls. By utilizing an inexpensive game controller (e.g. the PlayStation Move) and designing the software to run on a normal PC, we will ensure that our simulator is inexpensive and accessible.

Background & Related Work Ultrasound diagnosis is an important skill in the medical field and is used in a wide range of routine and emergency medical situations [2]. Because actual ultrasound units cost tens of thousand dollars [3], and it can be difficult and expensive to find human subjects to use solely for training purposes, the trend in medical education has been to supplement hands-on training with computer-based simulations to provide more comprehensive training and to improve patient safety [4]. However, some of these computer-based simulations can still be highly expensive or otherwise limited.

A number of existing commercially- and academically-developed ultrasound simulations already exist, using a variety of image generation techniques. Many of these systems have already been demonstrated to be effective in improving professional and student performance. [5, 6, 7] However, some of these systems have limitations: for example, the LUMS School of Science & Engineering developed a system that does not generate images in real-time, but relies on a library of actual ultrasound images. Because of storage and memory constraints, only a limited number of positions and orientations around a target area are available, and a significant amount of time must be spent recording ultrasound images for every possible scenario [8]. Another example is a system developed at University of Leeds, specifically for training ultrasound-guided needle insertion surgeries, uses real-time image generation based on a CT-scan dataset. However, it utilizes a highly expensive motion sensing system that is cost-prohibitive for general use [7, 9]. Figure 1 (below) contrasts the Schallware Ultrasound Simulator (a commercial system) with our simpler, less expensive setup.

To develop realistic ultrasound image simulation, it is important to have an understanding of the underlying physical processes behind ultrasound technology. An ultrasound probe functions by transmitting and detecting ultrasound pulses using an array of piezoelectric transducers. Tissues absorb or reflect the pulses, and an image is generated based on the amplitude of detected reflections as a function of the depth (time delay) of each reflection. In a two-dimensional scan, a linear array of transducers is used so that the sound can be transmitted along an arc of angles, where the data collected from each angle makes up a "scanline" [1].

Fig. 1
Left: The Schallware Ultrasound Simulator, an expensive commercial system utilizing a dummy.
Right: A concept image for what our simulator would look like.

Project Design
The simulator will be built in the Unity3D game engine. Unity3D, although designed for game development, is perfect for our purposes because it includes a variety of libraries for handling mesh models, collision detection, vector math, and visual effects such as alpha blending and noise generation. Unity3D also has the advantage of being very platform-agnostic between Mac OS and Windows. A virtual human body (made of 3D mesh models obtained from the BodyParts3D database [14]) can be "scanned" by a virtual probe to create an appropriate realistic ultrasound image. The virtual body and probe and the generated images will all be visible at the same time. The simulator's primary software components will be the *image generation* and the *motion controller*.

Ultrasound Image Generation: The interactions between tissue and the ultrasound pulses is a highly complex three-dimensional physical process, and it is difficult (in terms of mathematical complexity and computational cost) to simulate wave behavior in any heterogeneous medium [10]. Even highly optimized algorithms require expensive processing hardware to run in a reasonable amount of time, and may still not feasibly be able to run in real-time. [11, 12, 13] For our purposes, it will make sense to directly generate the "ideal" end result of an ultrasound image (i.e. a 2D cross-section), rather than devote computational resources to modelling a complex physical process. Volumetric raycasting, a graphical method using vector mathematics to directly generate a 2D projection of a 3D object, can be readily implemented using Unity3D's built-in collision-detection and vector math libraries. There are some other artefacts that characterize ultrasound images, including speckle (noise), acoustic shadowing, motion blur, and texturing [1]. These artefacts can be added to a cross section in post-processing steps to generate a realistic composite image. Other ultrasound imaging systems have documented successful implementations of these post-processing features in real-time [9]. We will use anatomically-accurate 3D mesh models from the BodyParts3D database [14].

Motion Controller: A motion controller will be used to move a virtual probe in 3D space. We will need to establish one-to-one motion and rotation between the physical controller and the virtual probe. From previous research testing several different game controllers (the Wii MotionPlus Remote, the XBox 360 Kinect, and the PlayStation Move) we determined that the PlayStation Move is best suited for our simulator as it supports high-fidelity tracking of both rotation (via gyroscope) and position (via computer vision). The Unity3D plug-in *Unimove* allows us to interface with the PlayStation Move controllers via Bluetooth to read gyroscope data [15]. Some sort of computer vision implementation will be needed to track the 3D position of the controller via webcam. The MoveOnPC Google Summer of Code project has shown promising results utilizing the OpenCV library [16].

In summary, we will need to implement both the image simulation procedure and the motion controller input into a Unity3D application. The user will use the PlayStation Move to control a virtual ultrasound probe, which generates ultrasound images in real time of a virtual human body made of anatomically accurate 3D mesh models.

Expected Project Timeline

Months	Jan	Feb	March	April
Develop Ultrasound Image Generation	X	X	X	
Implement Motion Controller			X	
Article & Presentation Preparation				X

The two components (image generation and PlayStation Move motion control) can essentially be developed completely independently as they function as separate modules. However, I anticipate that the ultrasound image generation will be more difficult to implement as I will be building the image generation process nearly from the ground up; whereas the motion controller input will be managed by Unimove and OpenCV, which are both existing libraries. For this reason, I have dedicated more time to the image generation step and plan to start with this part of the project.

Anticipated Results

By the end of next spring, I expect to have developed a functional image simulation process and the PlayStation Move motion controller implemented, using the BodyParts3D human body as a base "healthy human" scenario. By comparing generated images with actual ultrasound images, we can qualitatively gauge the validity of our simulation. In the long term, I hope that the medical ultrasound training simulator can be tested by actual medical students, and the degree to which it improves their confidence and performance can be used to validate the overall effectiveness of the simulator. In addition to a presentation at Discover USC, I anticipate writing a paper with the intent of being published in a computer science or medical journal. After next spring, if an acceptable prototype is complete, I also hope to partner with nursing or pre-med students to test the effectiveness of the simulator as a training and teaching tool.

Personal statement

Over the summer, as part of an NSF REU program, I had the opportunity to work with [mentor] to begin development on the ultrasound training simulation. I have considerable interest in both medical technology and educational software development, and I am passionate that this project can make some contribution to improving medical education. Having both practical software development experience and academic research experience will also help me develop as I prepare to pursue internships and graduate school. A Magellan Grant would grant me some financial leeway in deciding to dedicate time to pursuing research.

References

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Magellan Scholar BUDGET FORM

Student's Name:

Student salary	Hours Enter the estimated number of hours student will work	Rate Enter the hourly wage	Subtotal
Taking classes	150	10	$1,500.00
Not taking classes	0	10	$0.00
Fringe: Student salary * student fringe rate[1]			
Taking classes	$1,500.00	0.45%	$6.75
Not taking classes	$0.00	8.35%	$0.00
Materials/Supplies	Enter sub-total from below:		$0.00
Travel	Enter sub-total from below:		$0.00

TOTAL:	**$1,506.75**

Amount requested for MGS award:	**$1,500.00**

Budget Justification

Student Salary: Indicate estimated number of student work hours per week during academic year and summer and hourly rate.

Plan to start on or before Jan 14th and finish by May 3rd. This encompasses 16 weeks. I am

(conservatively) estimating that I will work at least 10 hours a week, perhaps taking Spring break off for

15 weeks * 10 hours/week = 150 hours total.

Materials/Supplies: Indicate items, quantity, and estimated price

None necessary - CSE Department already owns all necessary equipment (Mac Mini in lab, PlayStation

Move and other controllers).

Travel: Indicate location, purpose of travel, estimate itemized costs (transportation, lodging, registration, etc).