Personal Training Simulator for Asynchronous Learning of Obstetric Ultrasound

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Why Ultrasound Imaging

- Medical ultrasound offers specific advantages in comparison to MRI and CT
  - Non ionizing radiation, safer to scanning subjects
  - Moderate cost, portability and wide availability
- Ultrasound highly depends on users’ competency to obtain correct diagnosis due to comparatively low image quality
- Becoming a competent ultrasound sonographer requires significant amount of training
Ultrasound Training Models

- **Clinical training**
  - Often lacking procedure- or discipline-specific standards
  - Availability limited in terms of personnel and equipment

- **Simulator-based training**
  - A cost-effective and safe alternative
  - Competency training procedure can be integrated
  - High acquisition cost and limited availability
New Personal Ultrasound Training System

- Sham Transducer
- Physical scan surface
- Virtual Torso & Transducer
- Ultrasound Image
- Landmark Calculation
- Ultrasound Console
- Instruction Window
- Data Manager

Image: Diagram of the new personal ultrasound training system, showing components such as the sham transducer, physical scan surface, virtual torso & transducer, ultrasound image, landmark calculation, ultrasound console, instruction window, and data manager.
Sequences of 2D images are acquired along N parallel scan paths, with 6 DoF tracking info (trakSTAR+Stradwin).

Individual 3D volumes created from the 2D image sequences along each linear scan path.

Calculation of N-1 stitching planes where overlapping volumes will be stitched together.

Blending of image adjacent to stitching plane to compensate for speckle pattern mismatch.

3D non-rigid registration in the vicinity of each stitching plane to remove image discontinuities.

Final Global Image Volume generated.
Simulator Tracking System

- IMU orientation data in world coordinates
- Anoto position data in Anoto surface coordinates
- Transform data to surface coordinate system at the location of the sham transducer (α', β', γ', x', y')
- Transform and scale to surface of the virtual torso

Physical Surface and Sham Transducer

Virtual Surface and Transducer

Virtual Transducer and Torso
Training Modules

- Module 1 – Basic Ultrasound Concepts and Physics (10 tasks)

- Module 2 – Orientation to the Obstetric Space (4 tasks)

- Module 3 – Fetal Landmarks and Biometry (4 tasks)
Orientation to the Obstetric Space

Task List of Module 2

- Locate bladder/lower uterine segment/cervix

- Determine fetal position

- Determine placental position

- Find amniotic fluid index (AFI), measure vertical pocket in 4 quadrants
Fetal Landmarks and Biometry

Task List of Module 3

- Measure biparietal diameter (BPD)
- Measure abdominal circumference (AC)
- Measure femur length (FL)
- Estimate fetal weight
Training Procedures

**Tutorial mode:**
Watch demonstration video, showing how to perform a given set of tasks in a given learning module.

**Practice mode:**
Perform the set of tasks in a given module on a specified number of subjects (or image volumes).

**Evaluation mode:**
Demonstrate acquired competence by performing the same set of tasks in the given module on new subjects.
Evaluate performance in each task with
- Multiple choice or
- Landmark identification
- Biometric measurement
- Combination of them

Landmarks insertion
- By offline segmentation and then model landmarks with ellipsoid, cylinder, sphere…
- By experienced sonographers assistance if hard to identify and model
Determine Fetal Position

- Fetal head is offline identified by using Iterative randomized Hough transform (IRHT) on a series of 2D images then construct 3D ellipsoid model for the fetal head based on 2D outlines

- The model parameters is loaded and used to evaluated the accuracy of fetal head identification
Determine Placenta Position

- Placenta is offline identified by using Region Growing on a series of 2D images then construct 3D model for placenta based on 2D outlines
Biparietal Diameter Measurement

Task 3a: Measure biparietal diameter (BPD)

Find transverse view of head with thalami, no posterior fossa structures, along with occipitofrontal diameter to calculate head circumference. Freeze image of correct plane and place the software calipers appropriately.

- Simulator assesses the performance by comparing the learner’s measurement with predefined BPD.
Simulator assesses the performance by comparing the learner’s measurement with predefined AC and the orthogonality of anterior-posterior and lateral abdominal diameter.
CONCLUSIONS

• Introducing a low-cost, portable obstetric ultrasound training system by using inexpensive tracking hardware, a virtual torso in place of a physical manikin and PC/laptop implementation

• Realistic scanning experience achieved by availability of extended image volume and 5 DoF scanning

• The training system is suitable for both self-paced learning and as part of a formal training curriculum

• Constructing a training simulator prototype which can be quickly modified to build new training simulators for other medical disciplines

• Future work includes the emulation of tissue deformation

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