X3D in Medical Training and Simulation
Extensible 3D (X3D) From Haptic-based Medical Training to Clinical Applications

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The Australian e-Health Research Centre
www.csiro.au
Background

Post Doctoral Fellow at CSIRO’s Australian e-Health Research Centre in Brisbane, Australia

Former PhD student of Bangor University,

Prof Nigel W John
Main Steps of Building a Medical VE

Main steps of building a medical environment.

Two examples: Craive Project and CSIRO Project

- Task analysis
  - Identify all steps
  - Identify metrics to be measured

- Virtual environment
  - Hardware
  - Interface devices
  - Software: H3D (X3D + haptics)

- Integration & Validation

- Emerging Trends

- Can it be done in X3D?
Training Issues in Medicine

Traditional Apprenticeship is Current Gold Standard:

- Practice on live patients
- Large time cost
- Increases risk to patient
- Dissemination of new techniques difficult
- Availability of training is an issue as distances increase

Are Virtual Environments the answer?
Case studies

Craive

• Training in Visceral Interventional Procedures
  • Development and validation of a virtual reality simulator for training in interventional radiological visceral needle puncture procedures
  • Simulate puncture of the liver and the kidney with a needle, incorporating tissue resistance, pathology and physiological movement of respiration

CSIRO

• Bronchoscopic procedures
Who should be involved?
Collaborators in Radiological Interventional Virtual Environments (CRaIVE)

Clinicians
Computer Scientists
Psychologists
Clinical Engineers

Manchester Royal Infirmary
Dr Nicholas Chalmers

University of Manchester
Dr Sheena Johnson
Carrie Hunt

Royal Liverpool University Hospital
Prof Derek A Gould
Amrita Sinha

University of Liverpool
Dr Thien V How
Jianhua Zhai

Bangor University
Prof Nigel W John
Dr Franck Vidal
Dr Llyr ap Cenydd

University of Leeds
Dr Andy Bulpitt
Dr Richard Holbrey

St James’s University Hospital Leeds
Dr David Kessel

University of Hull
Prof Roger Phillips
Mr James W Ward
Dr Yan Zhang
Dr Sandhya Pisharody
Dr Martin Crawshaw

Imperial College London
Dr Fernando Bello
Dr Pierre Frederic-Villard

Medic Vision
John Lineham
Who should be involved?

The Royal Brisbane and Women's Hospital - RBWH

David Fielding MD
Thoracic Department
The Royal Brisbane and Women's Hospital

Tim Coles, Hans de Visser, David Conlan, Cédric Dumas
Surgical Simulation and Planning Team
The Australian e-Health Research Centre

Prof Marcus Watson
Queensland Health's Clinical Skills Development Service
School of Psychology, University of Queensland
CRAIVE - Analyse the task

**Video procedure**

**Interview subject experts**

- Identifies critical procedure steps
- Informs simulator design

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Camera 1: Room Overview
Camera 2: Screen
Camera 3: Operator’s Hands
CRAIVE - Documented Task Analysis

Biopsy

Task Analysis for Biopsy (Freehand, Ultrasound guided)

- Preparation
- Equipment Required
- Steps
  - Task 1: Select Syringe
  - Task 2: Preparation of syringe
  - Task 3: Draw up local
  - Task 4: Ensure there are no bubbles in the syringe
  - Task 5: Cleaning incision site
  - Task 6: Sterile Sheets
  - Task 6+: Locating biopsy site
  - Task 7: Injecting local anaesthetic
  - Task 8: Incising Skin
  - Task 9: Preparing Ultrasound
  - Task 10: Preparing for Procedure
  - Task 11: Checking probe is the right way around
  - Task 12: Biopsy Procedure
  - Task 13: Uncial Biopsy Needle
  - Task 14: Coaxial Biopsy Needle
### Task 6+: Locating biopsy site (guided by Ultrasound)

<table>
<thead>
<tr>
<th>No.</th>
<th>Task Description</th>
<th>Realisation</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>6+</td>
<td>Locating biopsy site</td>
<td>Implemented</td>
<td></td>
</tr>
<tr>
<td>6+.1</td>
<td>To ensure 5ml local anaesthetic syringe is easily accessible when required. (Place on sheet covering patient, or leave it easily accessible on the trolley.)</td>
<td>As task</td>
<td></td>
</tr>
<tr>
<td>6+.2</td>
<td>Check positioning of ultrasound screen. Can you view it OK?</td>
<td>As task</td>
<td></td>
</tr>
<tr>
<td>6+.3</td>
<td>Yes - (go to step 6+.3)</td>
<td>Trainee pushes phantom button and a window for Ultrasound image appears on the screen.</td>
<td></td>
</tr>
<tr>
<td>6+.4</td>
<td>No - (ask assistant to move screen into view and go to step 6+.3)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6+.5</td>
<td>Pick up ultrasound probe.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6+.6</td>
<td>Covering the head of the probe with a thin layer of ultrasound jelly. Ensure the jelly completely covers the end of the probe.</td>
<td>Trainee palpates anatomy of mannequin. (The mannequin provides haptic feedback via the embedded haptic device???)</td>
<td>Need to know anatomical information about organs, ribcage, etc. This is patient specific (for Vn???)</td>
</tr>
<tr>
<td>6+.7</td>
<td>Palpating patient to locate an initial site for biopsy, which will be refined by ultrasound scan.</td>
<td>Trainee operates the probe phantom towards the mannequin with one hand, the other hand keeps palpating the anatomy of mannequin.</td>
<td></td>
</tr>
<tr>
<td>6+.7</td>
<td>Place probe in the region of the initial site for biopsy</td>
<td>Trainee sees a simulated Ultrasound image on the screen. Trainee adjusts the position of the probe.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Looking at the ultrasound screen, roll the probe back and forth on the incision site until the ideal biopsy site.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Bronchoscopy - Task Analysis

• Literature
  • Books
  • Guidelines

• Existing training knowledge
  • Working with educators
    • Queensland Clinical Skills Development team
    • Expert thoracic mentors

• In vivo observations
  • Synchronised video recordings
  • Practitioner Interviews

• Controlled environment measurements
  • Detailed observations of training scenarios
Satoshi Kitamura. Clinical Application of Fiberoptic Bronchoscopy
Bronchoscopy - \textit{In vivo} Video Analysis

Bronchoscopy - Self-Confrontation Interview
Bronchoscopy - 3D Tracking
Craive
Implementation and Validation
CRAIVE – Components of ImaGIne-S

Needle puncture of liver and kidney

**Input**
- DICOM Data;
- 3D Geometry, e.g. surgical tools, needles

**H3D**
- Segmentation
- 3D Reconstruction
- Collision detection
- Soft tissue deformation
- Force models
- Respiration

**Computer**

**Interaction**
- X3D + haptics
- Stereoscopy
- Haptics
- Physical Model
CRAIVE – Components of ImaGINe-S
CRAIVE - Fluoroscopy Images on the GPU

- The X-ray simulation uses the OpenGL pipeline to compute the cumulative attenuation from the Beer-Lambert law
- Works in conjunction with simulation of movement due to respiration
Ultrasound-like images are generated by:

- First extracting MPR image from the voxel data, or segmented mesh data, based on the position and orientation of the transducer
- Acoustic shadowing effects and noise are added using multi-texturing.
CRAIVE - Haptic Model

Reproducing the same trend as shown by the experimental data, *i.e.* higher force before the penetration followed by a plateau phase.


CRAIVE - Simulated Ultrasound Guidance using H3D
ImaGINe-S Prototype
CRAIVE - Validation

Performance on the simulator is indicative of real life experience.

Our results indicate that ImaGINe-S plays a useful role for training skills for liver biopsy.

Improvements were made as a result of face and content validation.

Study Details

41 Participants
Liverpool = 13, Leeds = 15, Manchester = 13
Male = 31, Female = 10

Experience

- 0 years = 8
- 1-2 years = 13
- 3+ years = 10
- (missing = 10)

ImaGINe-S at the Cardiovascular and Interventional Radiological Society of Europe (CIRSE), Copenhagen 2008
CRAIVE - Years of Experience Comparison

Face, content and construct validity has been demonstrated

Prototype is ready for commercialisation

Years of experience comparison:

ANOVA, 0 years & 1-2 years & 3 and over years

Significant Differences found on CPS areas:

• **No go area touched** (F = 5.218, p = 0.012)
• **Targeting** (F = 4.258, p = 0.025)
• **Session times** (F = 4.277, p = 0.024)
• **Probe usage time** (4.209, p = 0.025)
• **Total needle distance moved** (F = 3.691, p = 0.038)
• **Number skin contacts** (F = 10.792, p < 0.000)
• **Total time in no go area** (F = 5.812, p = 0.008)

All in the predicted direction
Emerging Trends
New Trends – Augmented Reality
PalpSim
Exchangeable Anatomy Descriptions
New Trends - Accessible Solutions

- Basic skills training
- Basic skills training
- Basic skills training

- Part task simulator
- Full scale simulator

Decreasing Cost

Increasing Availability
New Trends - Tiered Training

Web

Desktop keyboard and mouse

Desktop procedural interface

Simulation centre
New Trends - 3D Tracking & Automatic Feedback
Emerging Trends

Multi tiered solutions

Part task
- Mobile solutions
- Desktop, not simulation centre training

Ubiquitous tracking

Markerless tracking
Posture and movement feedback
Automated Feedback

New Visualisation Methods
Augmented reality displays
Software for Surgical Simulation

Modelling
- Segmented / illustrated meshes ✓
- Parametric models

Physical based simulation ✓

Haptic interaction ✓

User tracking ✓

Visualisation
- 2D visualisation ✓
- Volume Visualisation ✓
- Stereo viewing ✓
- Augmented reality ✓

Portable solutions ✓
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