Intelligent Virtual Environments for Surgical Training

Peter Haddawy
Faculty of ICT
Mahidol University
Surgical Skills

• Technical
  – Instrument use & handling
  – Dexterity
  – Knowledge of anatomy
  – 3-D spatial reasoning

• Non-Technical
  – Communication
  – Teamwork
  – Leadership
  – Decision Making
Challenges in Surgical Training

- Increasing enrollments and lack of expert surgeons to provide sufficient level of supervised training
- Desire to include assessment of procedure quality in student portfolios
- Subjectivity of assessment
- Desire for standardization of procedures
Benefits of Simulation

- Increased training time at little or no incremental cost
- Rare and dangerous scenarios
- Encourages experimentation and learning from mistakes
- Assessment of not just outcome but also process
- Provide causal explanations
- New modalities for feedback and guidance not possible in the physical world
Dental VR Simulator
Data Acquisition

• Acquire tooth data using 3D micro CT
• Segment into tissue types and densities
• Represent as 3D occupancy map = voxels
Haptic VR Dental Simulator

- Two haptic devices: handpiece and dental mirror
- Haptic feedback computed for handpiece: tissue density, force, angle
Kinematic Variables

Tool movement: drill & mirror

Applied force

Angulation

X Y Z
Transferability of Learned Skills

Group 1 – Experimental ($n = 16$)
Root canal access opening using **VR simulator**

Pre-test - Access opening on extracted maxillary molar using phantom head

3 days of 2h training

Post-test - Access opening on extracted maxillary molar using phantom head

Group 2 – Control ($n = 16$)
Root canal access opening using **phantom head**

3 days of 2h training

32 4th year dental students
Transferability of Skills

• Post-test performance significantly improved over pre-test performance in both groups.
• Difference in error score reduction was not significant.
How can we use the simulator to provide enhanced feedback?
Intelligent Formative Feedback

1. Assessment of outcome
   - Four axial walls
   - Pulp floor
   - Overall outcome

2. Analysis of procedure
   - Hand movement
   - Applied force
   - Orientation
   - Time taken

3. Analysis of relation between procedure and outcome
   - Force
   - Orientation
   - Movement patterns

4. Deliver feedback in the language natural to the students
   - Text: There is an over-drilled area in the distal wall because the amount of force applied in this wall is the substantially higher than the expert.
   - Graphics
   - Video
   - Haptics
Assessment of Outcome

• Max, Min, Optimal templates generated based on tooth anatomy
• Interpolate scores between templates and template to surface
• Detailed score information for entire tooth
• Translation into language commonly used in dental surgery
• High agreement with expert scores

Correlating Procedure and Outcome

Region
1. Mesial wall
2. Lingual wall
3. Distal wall
4. Buccal wall
5. Mesiolinguale border
6. Distolingual border
7. Distobucco border
8. Mesiobucco border
Multimodal feedback

Enhanced Visual Replay Formative Feedback
Immersive Simulator
Conclusions & Future Work

• Virtual environments provide a new opportunity for more effective teaching
  – Detailed data on problem solving activity
  – New modalities for feedback and guidance not possible in the physical world
• Techniques shown are general and apply across a wide variety of problem domains
• Ongoing work
  – Incorporate eye tracking
  – Generate symbolic descriptions of kinematic data
  – Differentiate between cognitive and physical sources of errors
  – Simulator for training spinal surgery
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