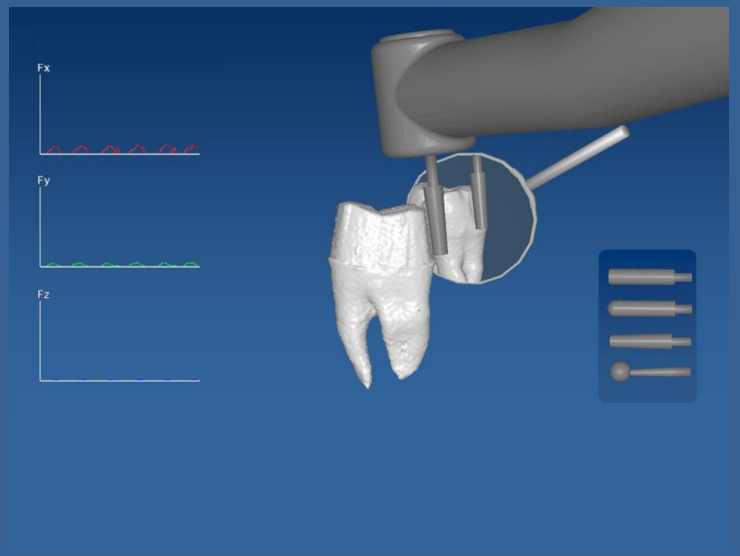
MAHIDOL UNIVERSITY
Wisdom of the Land

Intelligent Virtual Environments for Surgical Training



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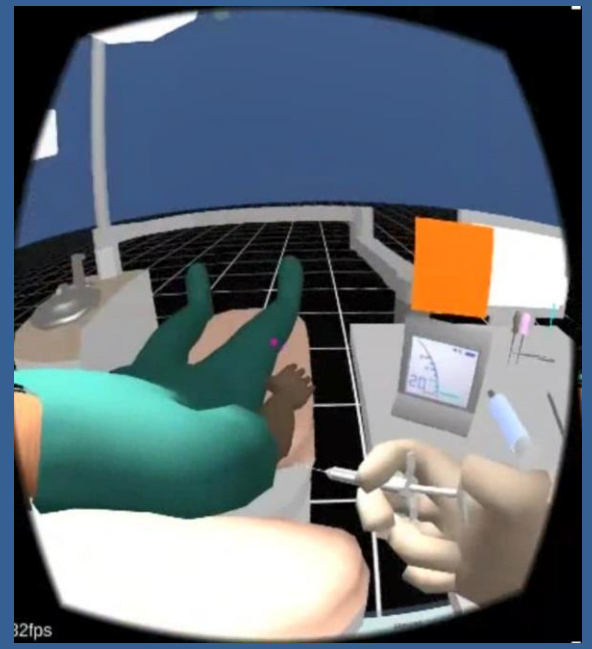
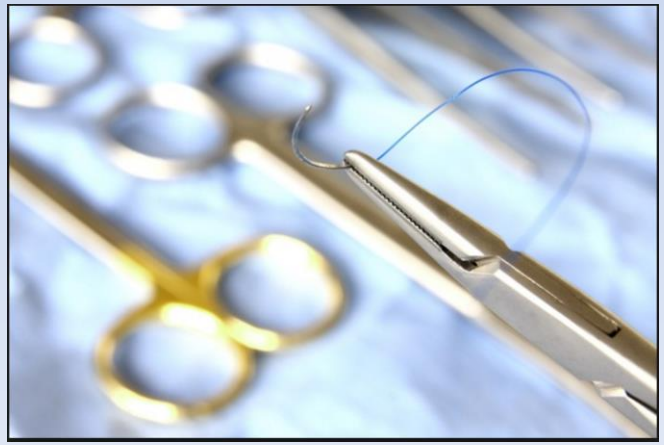
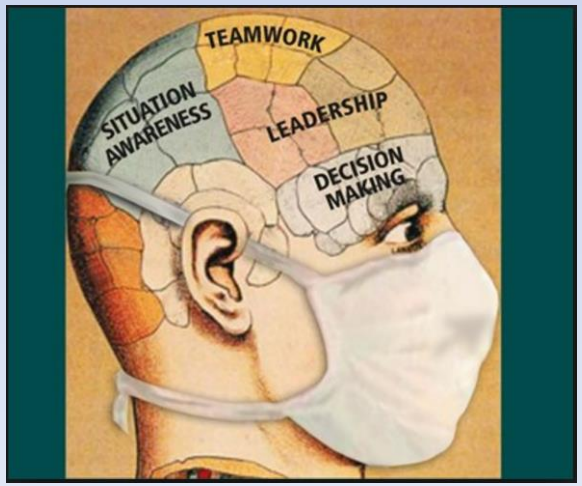


Surgical Skills

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

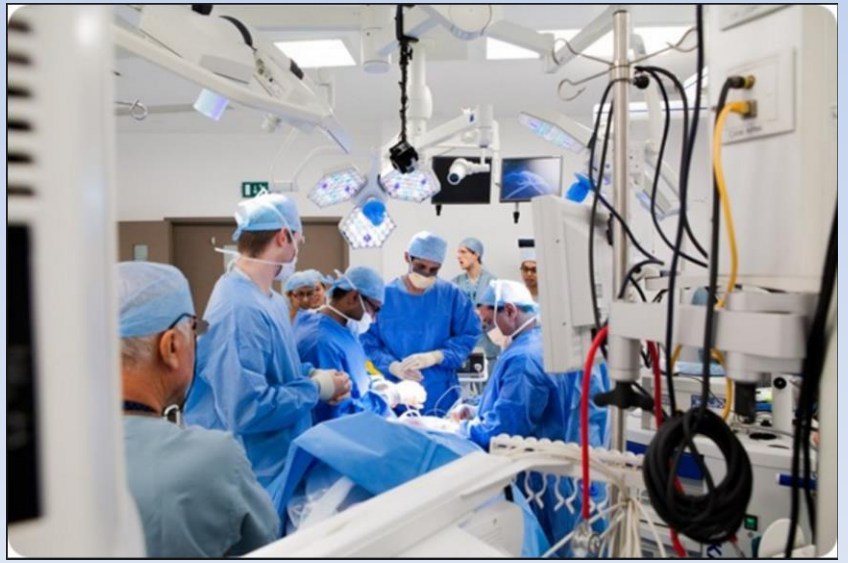


- Non-Technical
  - Communication
  - Teamwork
  - Leadership
  - Decision Making



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

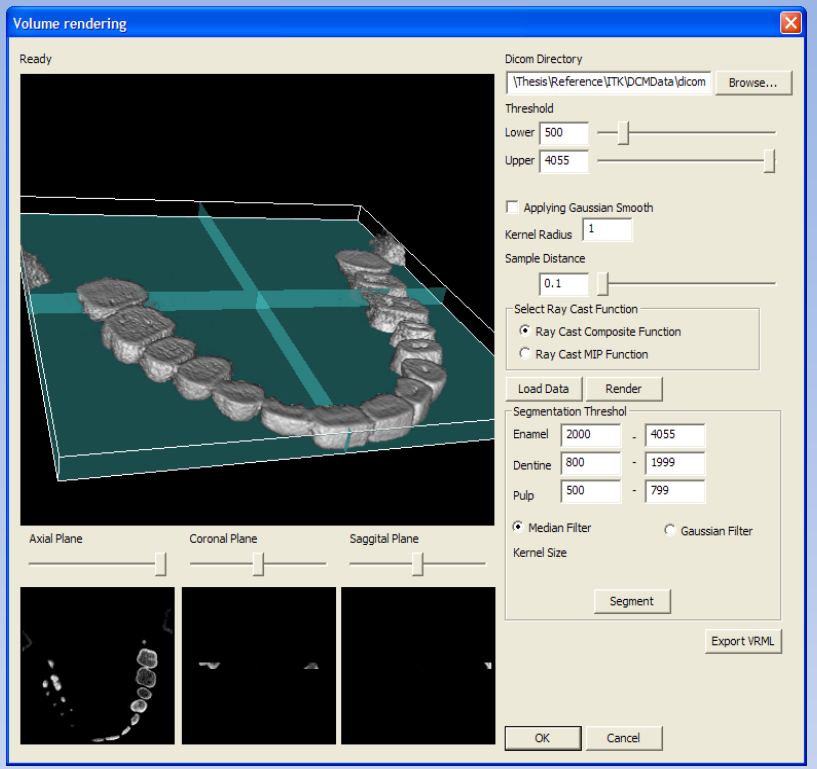
- Increased training time at little or no incremental cost
- Rare and dangerous scenarios
- Encourages experimentation and learning from mistakes

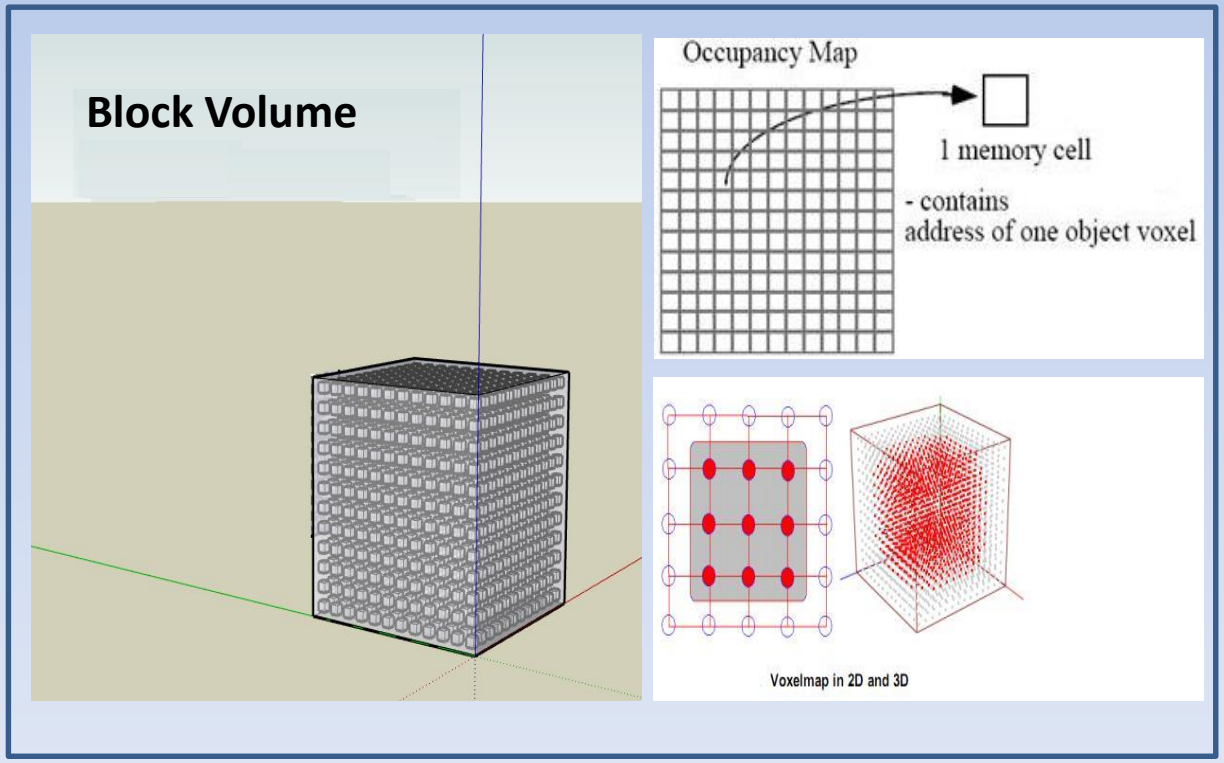
- Assessment of not just outcome but also process
- Provide causal explanations
- New modalities for feedback and guidance not possible in the physical world

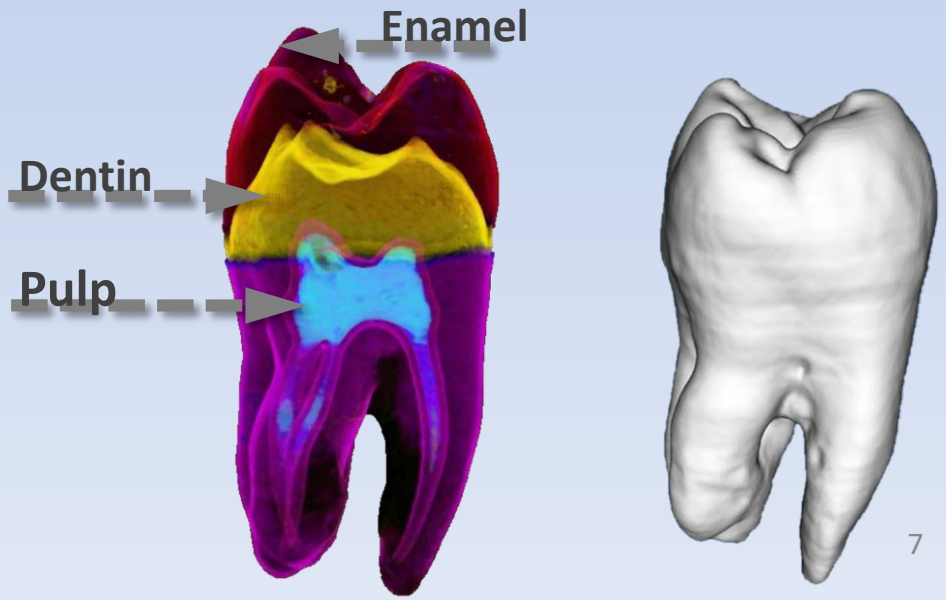
Dental VR Simulator

Data Acquisition

- Acquire tooth data using 3D micro CT
- Segment into tissue types and densities
- Represent as 3D occupancy map = voxels

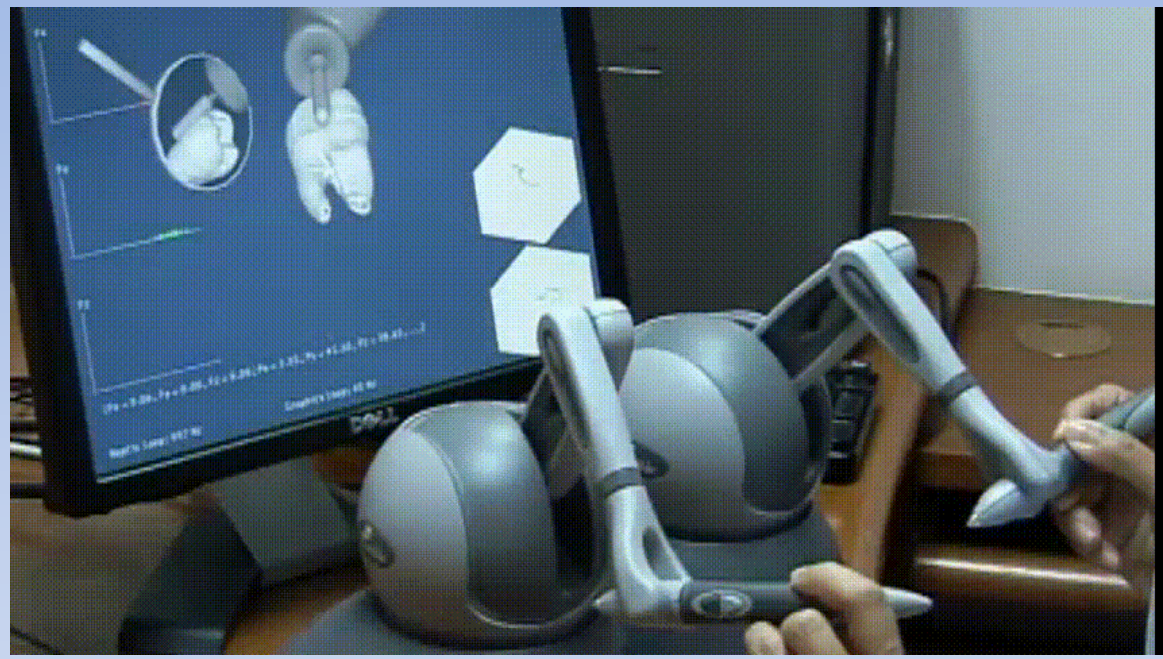


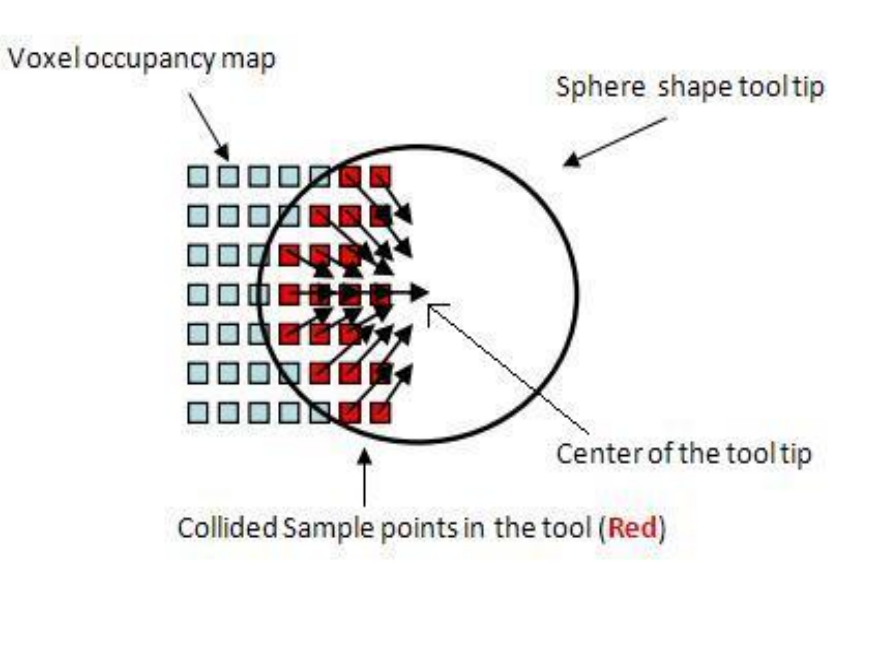


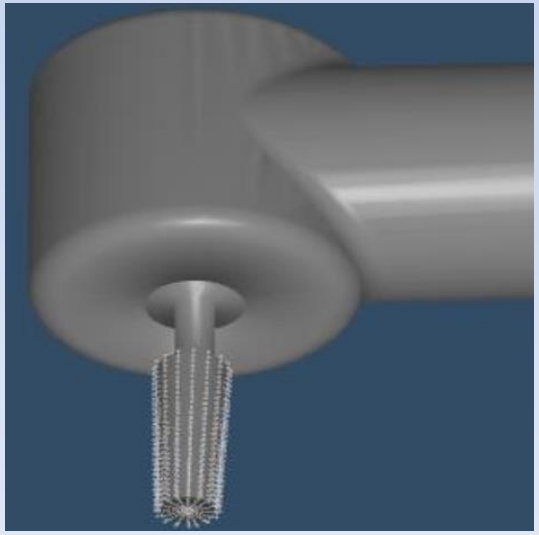


Haptic VR Dental Simulator

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

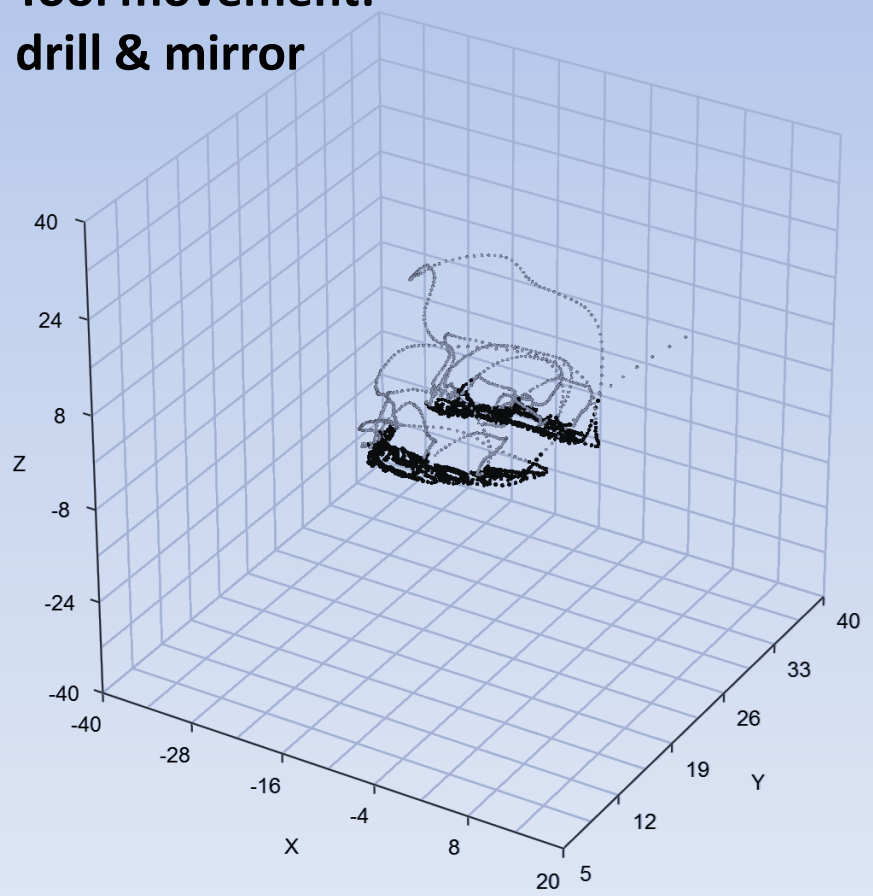




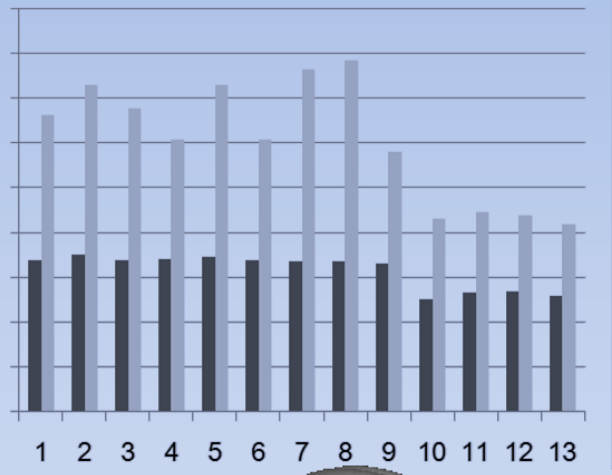


Kinematic Variables

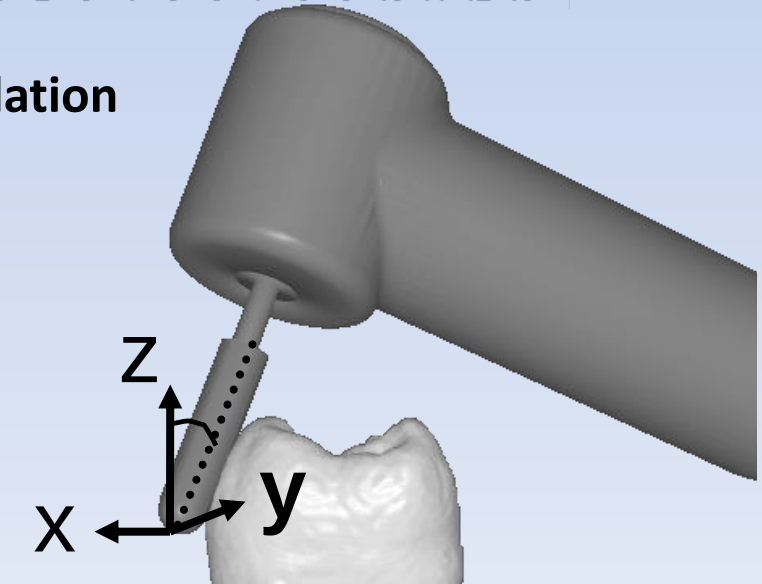
Tool movement: drill & mirror



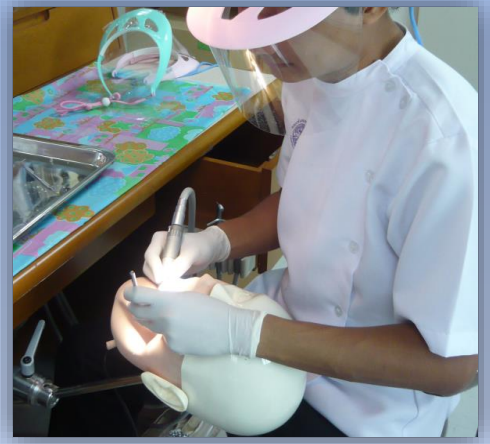
Applied force



Angulation



Transferability of Learned Skills



32 4th year dental students

Group 1 – Experimental (*n* = 16)

Root canal access opening using **VR simulator**

Group 2 – Control (*n* = 16)

Root canal access opening using **phantom head**

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

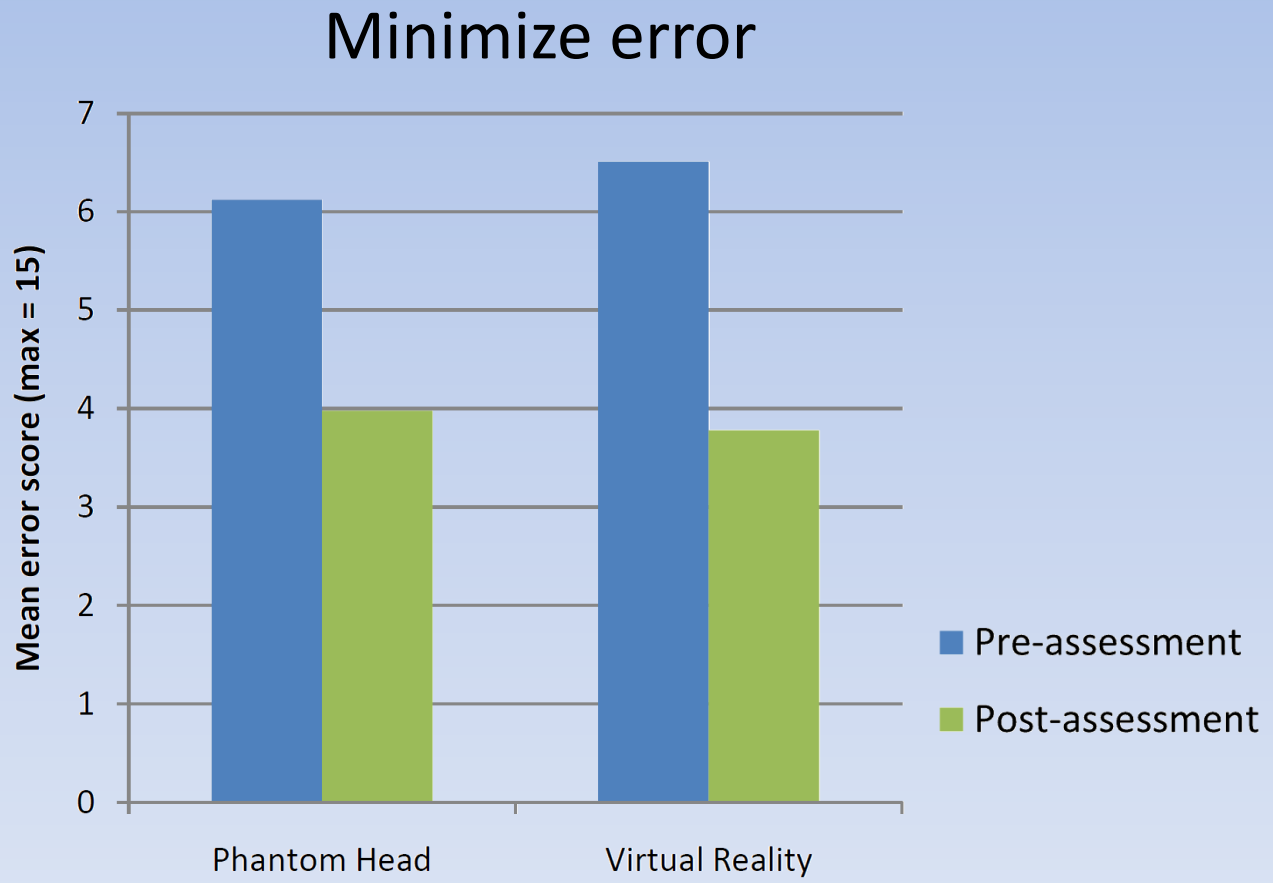
3 days of 2h training

3 days of 2h training

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

Transferability of Skills

- Post-test performance significantly improved over pre-test performance in both groups.
- Difference in error score reduction was not significant.

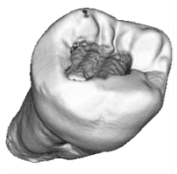


How can we use the simulator to provide enhanced feedback?

Intelligent Formative Feedback

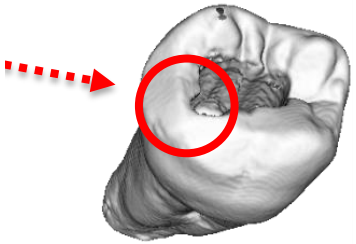
1 Assessment of outcome

- **Four axial walls**
- **Pulp floor**
- **Overall outcome**



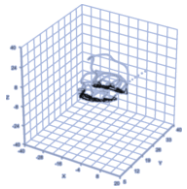
3 Analysis of relation between procedure and outcome

- **Force**
- **Orientation**
- **Movement patterns**

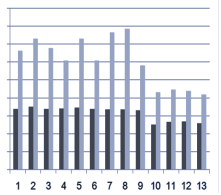


2 Analysis of procedure

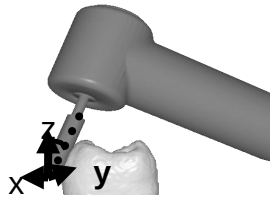
Hand movement



Applied force



Orientation

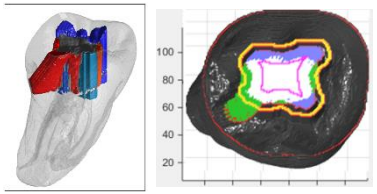


Time taken

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.*



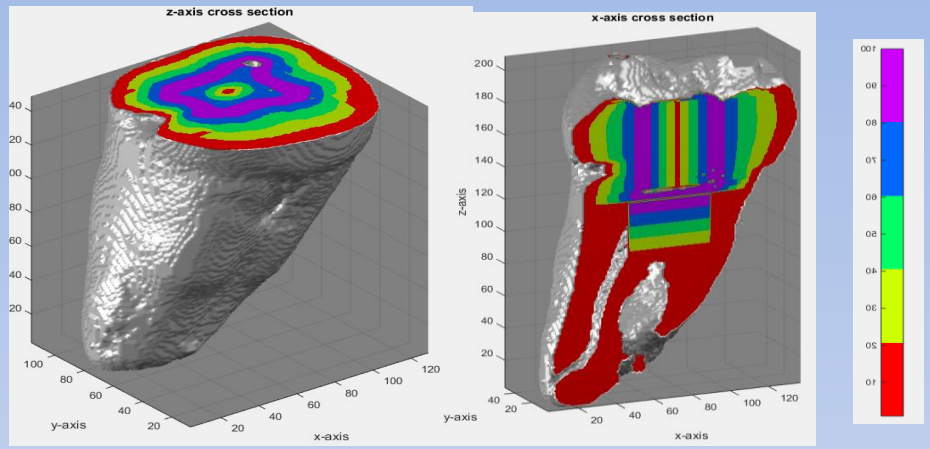
Graphics

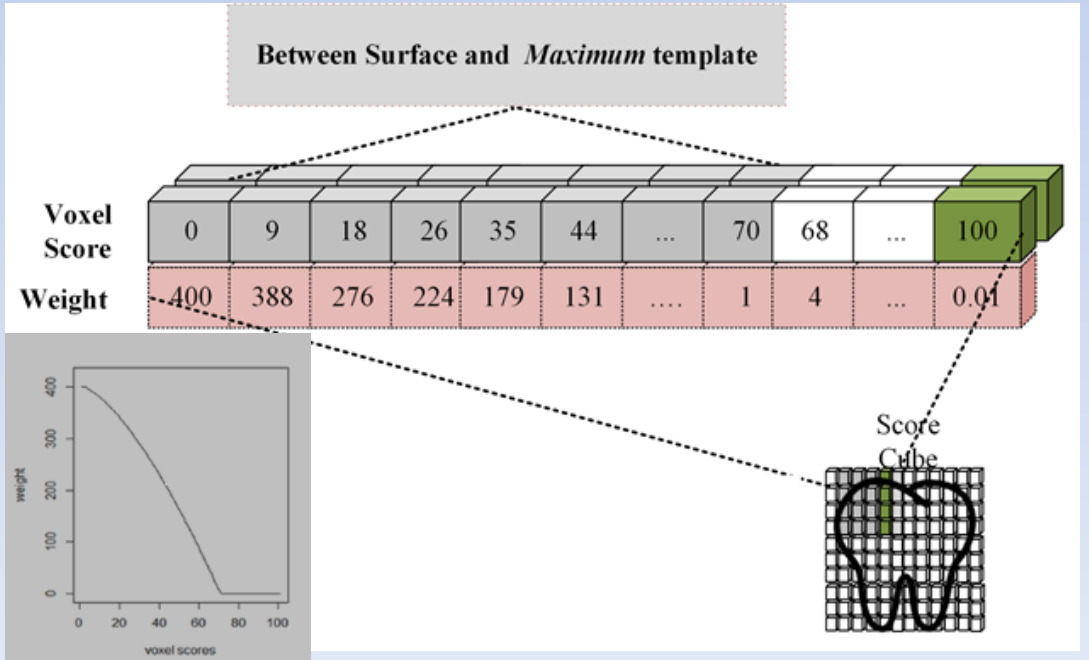
Video

Haptics

Assessment of Outcome

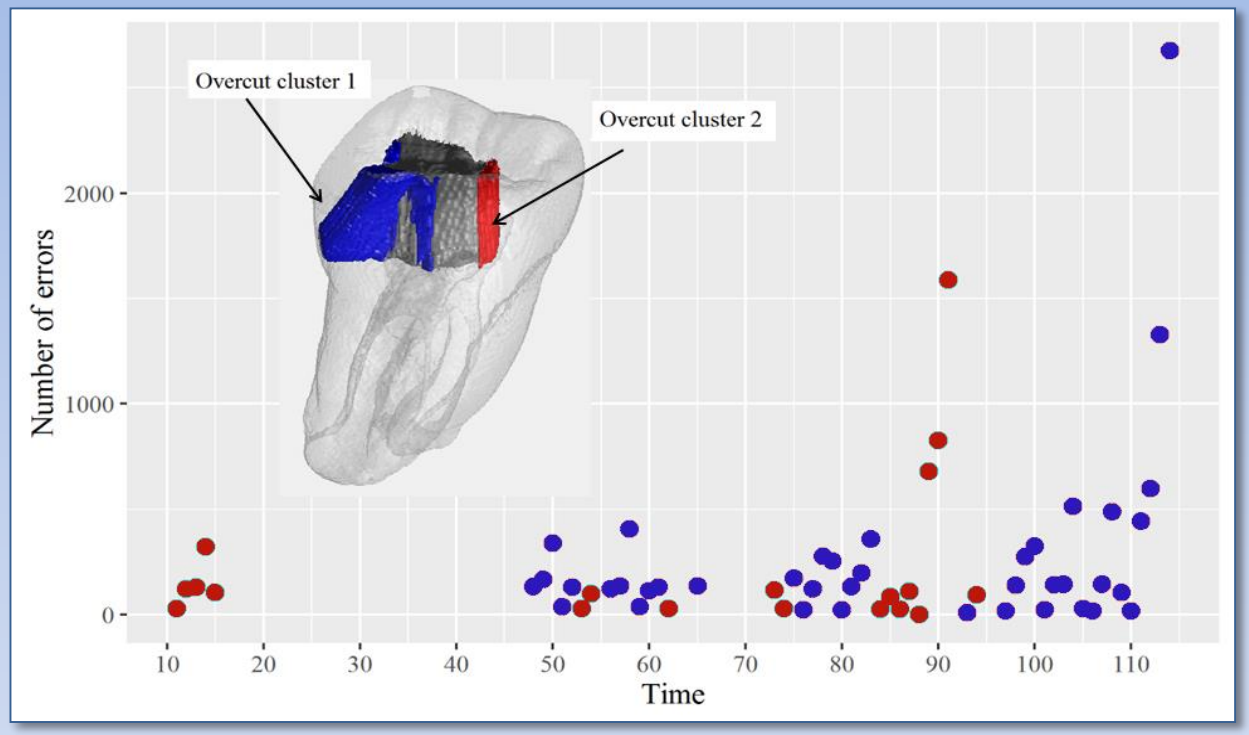
- Max, Min, Optimal templates generated based on tooth anatomy
- Interpolate scores between templates and template to surface
- Detailed score information for entire tooth
- Translation into language commonly used in dental surgery
- High agreement with expert scores



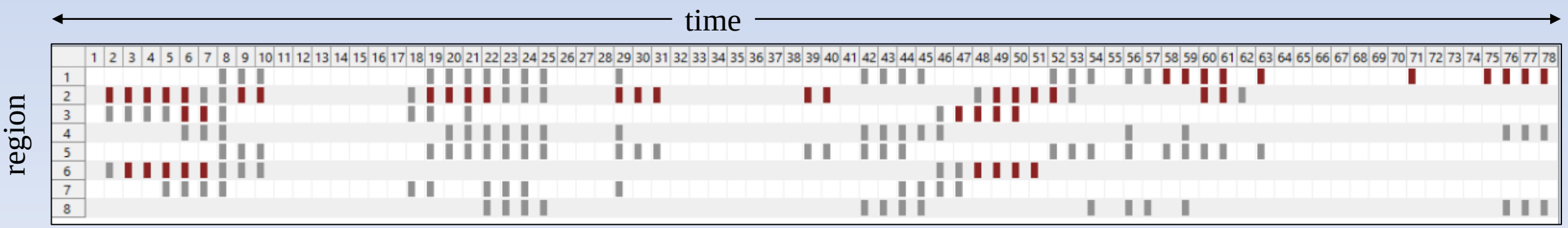


M. Su Yin, P. Haddawy, S. Suebnukarn, P. Rhienmora, Automated Outcome Scoring in a Virtual Reality Simulator for Endodontic Surgery, *Computer Methods and Programs in Biomedicine*, 153, pp 53-59, 2018.

Correlating Procedure and Outcome



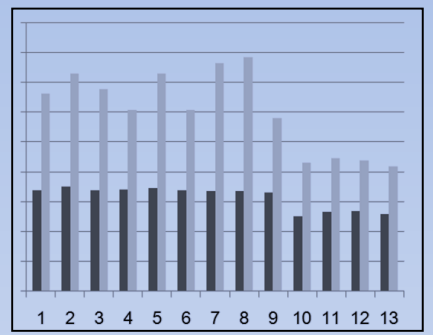
Region	
1	Mesial wall
2	Lingual wall
3	Distal wall
4	Buccal wall
5	Mesiolingual border
6	Distolingual border
7	Distobucco border
8	Mesiobucco border

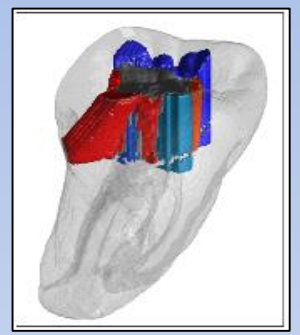


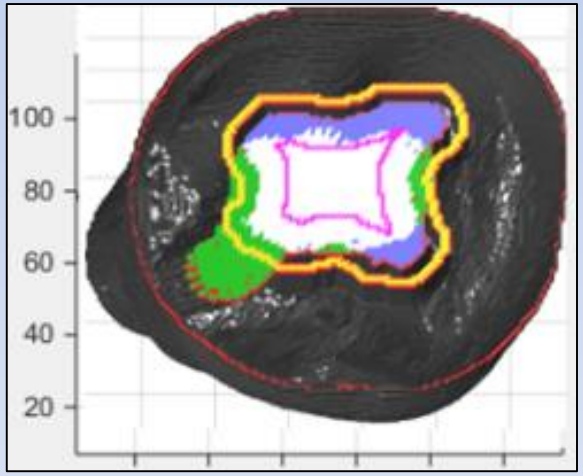
Error voxel collision

Multimodal feedback

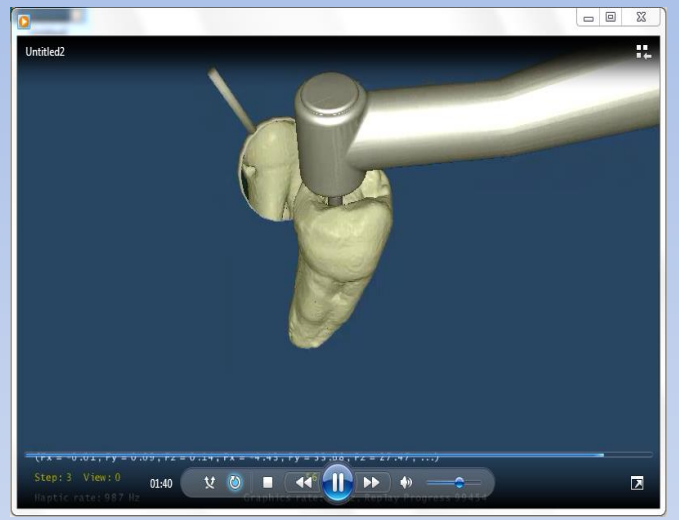
Visual + Textual

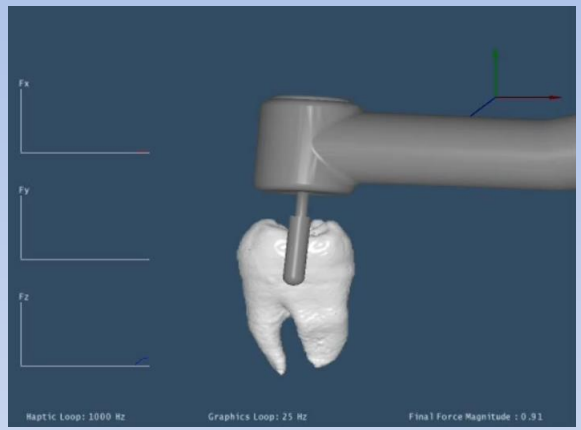




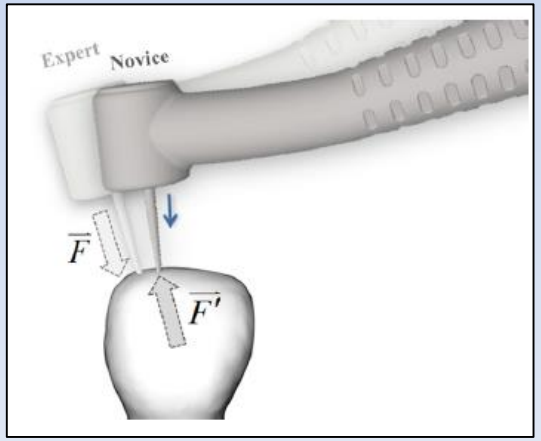


Enhanced Replay



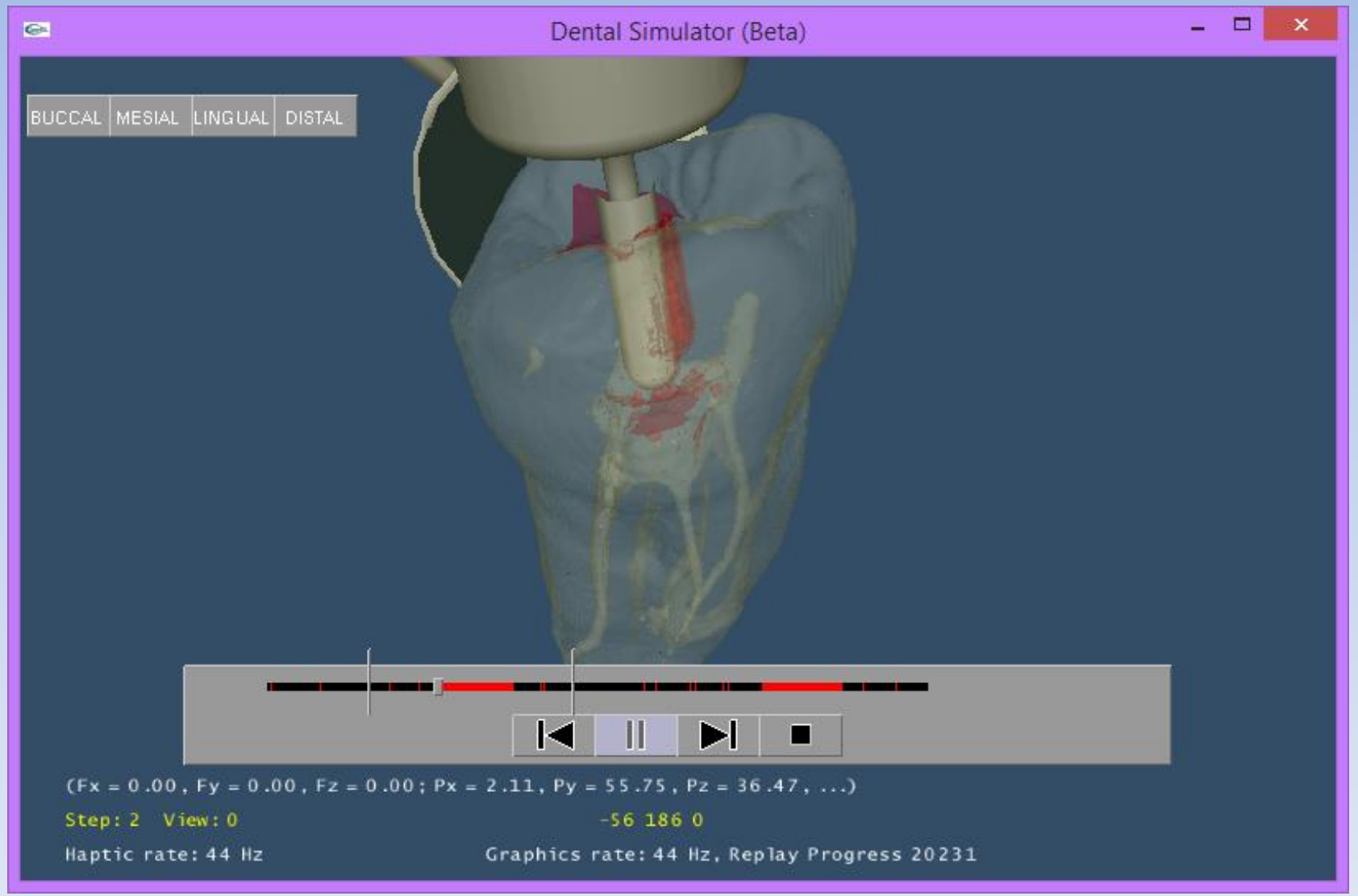


Haptic

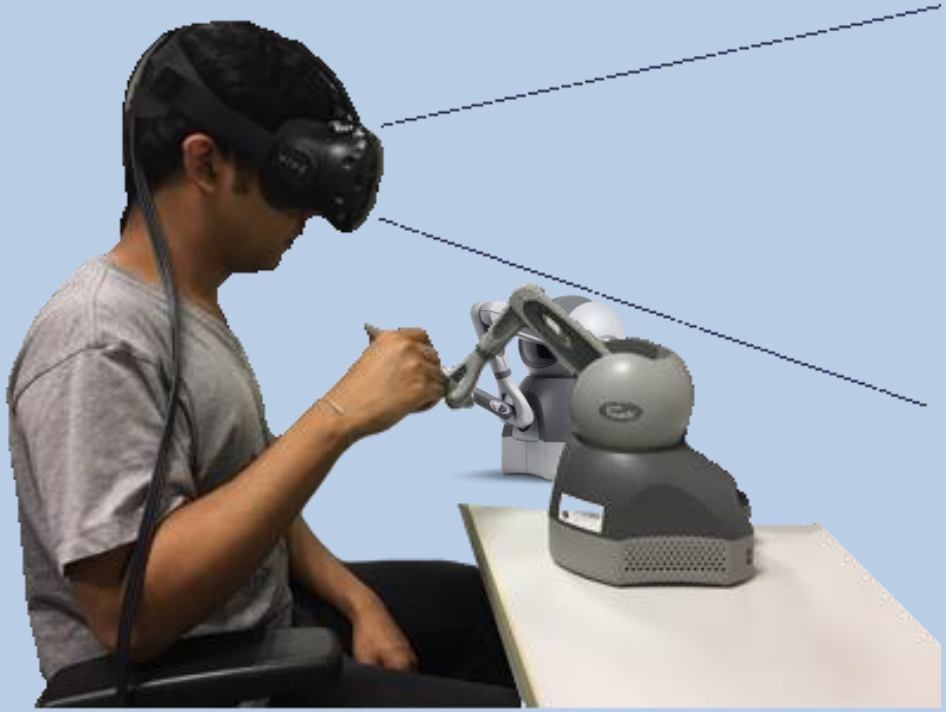


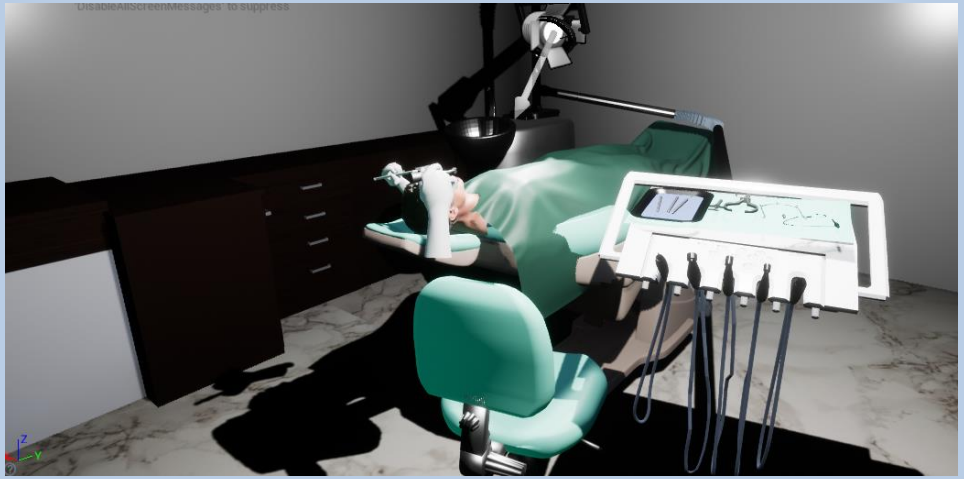
M. Su Yin, P. Haddawy, S. Suebnukarn, H. Schultheis, Use of Haptic Feedback to Train Correct Application of Force in Endodontic Surgery, *Proc. 22nd ACM Int'l Conf. on Intelligent User Interfaces* (IUI 2017), Limassol, March 2017.

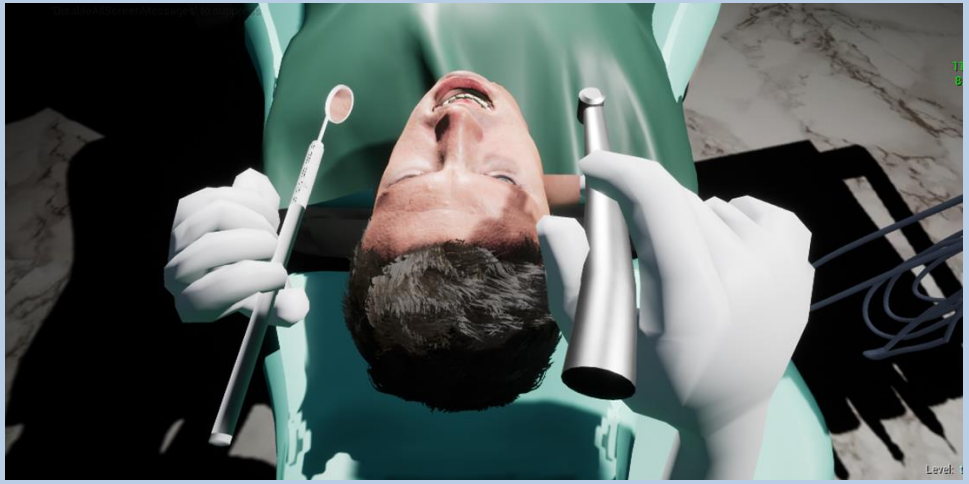
Enhanced Visual Replay Formative Feedback



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

Thanks to

Collaborators and Grad Students

- Prof. Siriwan Suebnukarn
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