A Shared Haptic Virtual Environment for Dental Surgical Skill Training

Maximilian Kaluschke[1], Myat Su Yin[2], Peter Haddawy[2],
Natchalee Srimaneekarn[3], Pipop Saikaew[3], Gabriel Zachmann[1]

[1] Computer Graphics & Virtual Reality, University of Bremen

[2] Faculty of ICT, Mahidol University

[3] Faculty of Dentistry, Mahidol University

Contact: mxkl@uni-bremen.de

Introduction

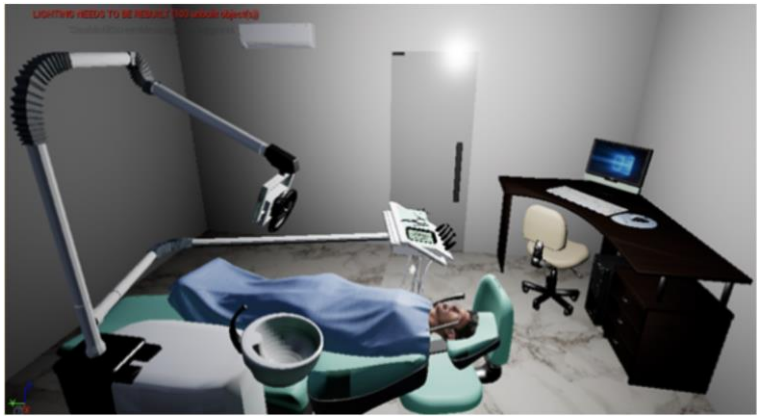
- Dentistry is difficult to learn
  - Training costs $352,184 [Segal et al., 2017]
  - Training facilities are scarce
- Remote learning is more relevant than ever
  - Currently limited to knowledge & cognitive skills
- Dentistry requires fine motor skills
- VR can help motor skill transfer
  - High immersion, natural interaction
  - Low operating cost

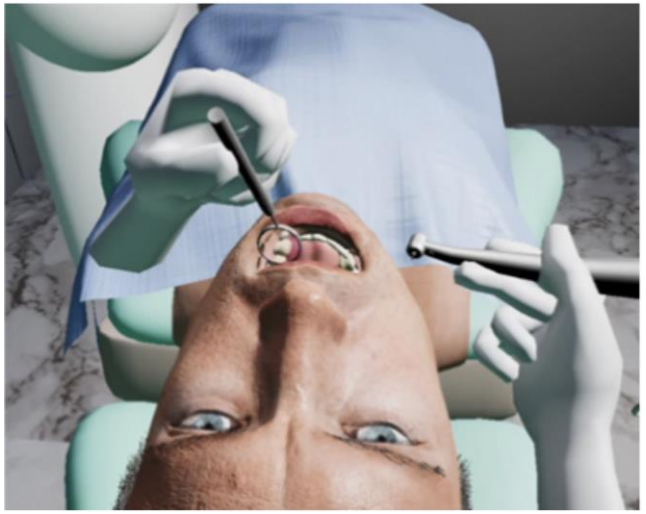
- *Our Contribution*: Shared VR environment with haptic feedback

Related Work

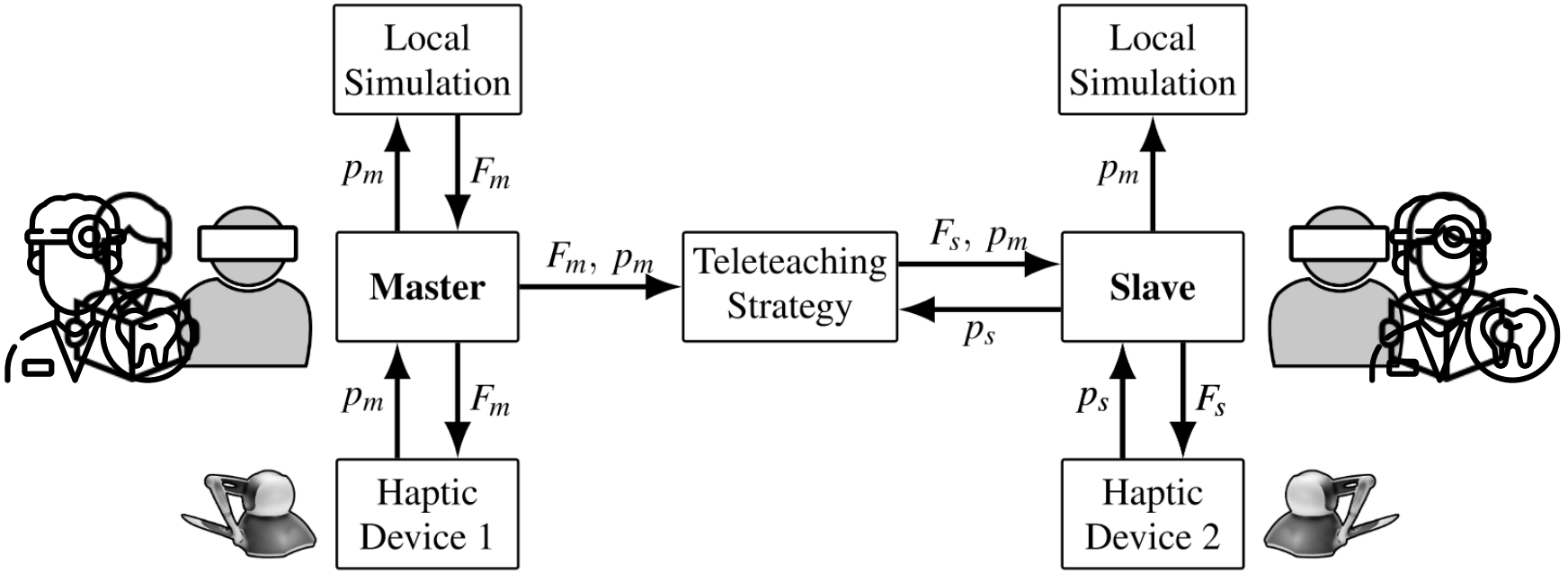
- Several VR dental simulators exist
- Commerical products
  - Simodont: +haptic feedback, +3D, -no head tracking, -no collaboration
  - VirTeaSy: +haptic feedback, stationary AR, -no 3D, -no collaboration
- Research projects
  - DenTeach: physical teeth, -only video
  - Morris et al.: same force, -no evaluation
  - Rhienmora et al., Su Yin et al.: opposite force, force recording
  - Kuchenbeker et al.: vibrotactile recording

Design – Simulator



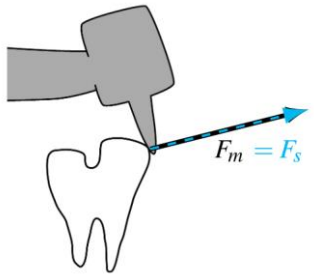


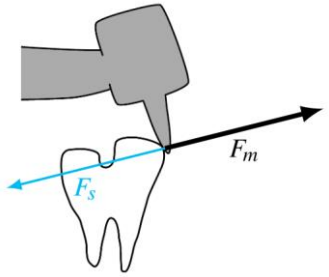
Design – Collaboration

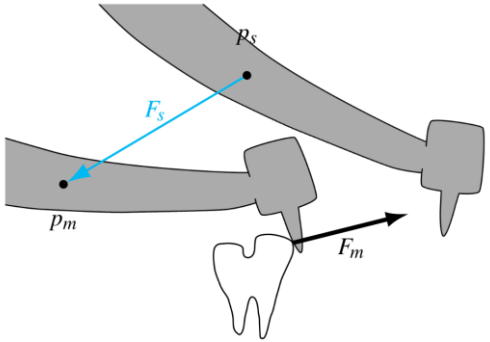


Teleteaching Strategies

1. “Same Force” $F_s = F_m$
   - User forces handle near center
   - Defines a force
2. “Opposite Force” $F_s = -F_m$
   - Same user behaviour
3. “Delta Force” $F_s = (p_m - p_s)k$
   - User gives in to force
   - Defines a position

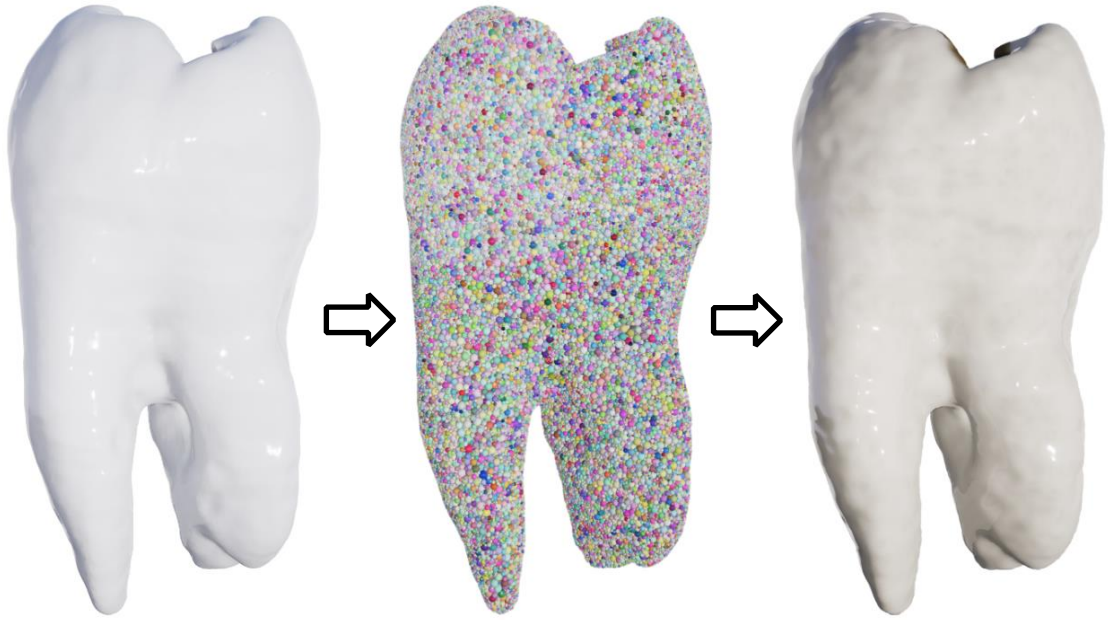






Methods – Simulation

- Sphere packing volumetric representation [Weller et al.]
  - Constraint-based haptic feedback @ 1 kHz
  - Drilling simulation @ 1 kHz



Original mesh Sphere packing Runtime generated mesh

Methods – Visualization

- Dynamic material visualization
  - At interactive rates
  - Vertex colors to visualize cariousity
- CPU+GPU algorithm with 3 stages:
  1. Distance- & Normal Field Generation (CPU)
  2. Bilateral Smoothing Kernel (GPU)
  3. Marching Cubes (GPU)
- runs @ 10 Hz (resolution 200^3)

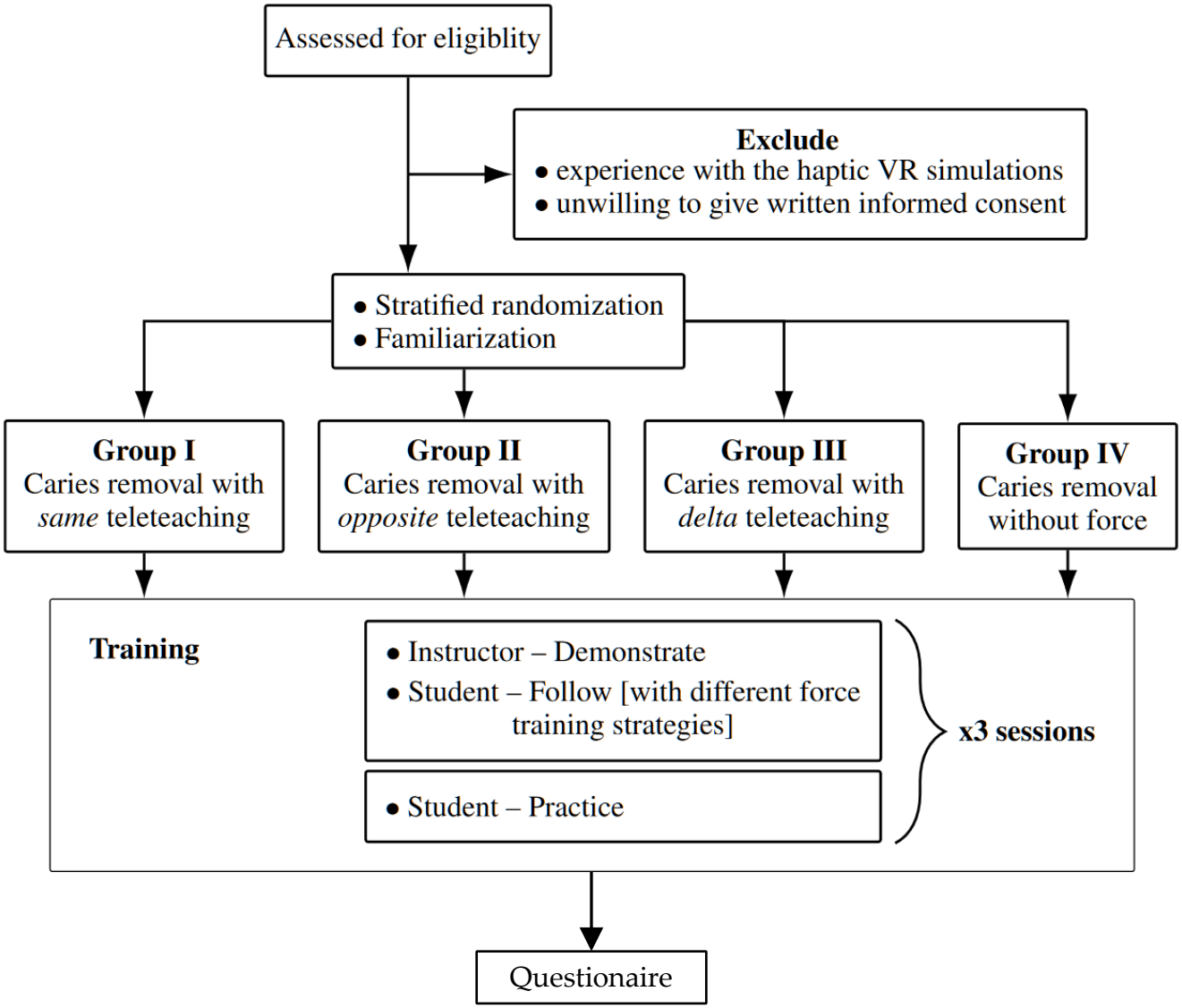
Methods – Scoring

- Metric to compare drilling results
- Ideal result as reference for comparison
  - Easy to determine: remove caries
  - Root canal treatment reference done by expert
- Set comparison metric: DICE coefficient

$$s = \frac{2*TP}{2*TP+FP+FN}$$

  - True Positive TP: unremoved non-carious tissue
  - False Negative FN: unremoved carious tissue
  - False Positive FP: removed non-carious tissue

Evaluation


Assessed for eligiblity
Exclude
• experience with the haptic VR simulations
• unwilling to give written informed consent
• Stratified randomization
• Familiarization
Group I
Caries removal with
same teleteaching
Group II
Caries removal with
opposite teleteaching
Group III
Caries removal with
delta teleteaching
Group IV
Caries removal
without force
Training
• Instructor – Demonstrate
• Student – Follow [with different force training strategies]
• Student – Practice
x3 sessions
Questionaire

Conclusion

- Novel collaborative system for motor skill training
- 3 strategies for teleteaching of drill force & trajectory
- Simulation design tailored for application domain
  - General enough for multiple use-cases
- Several optimizations
  - High fidelity haptic rendering @ 1000 Hz
  - Interactive drillable material @ 10 Hz
- Completely planned out evaluation

Future Work

- Complete the evaluation
- Replicate with 6DOF haptic devices
- Experiment with new teleteaching strategies
- Further optimization of visualization
  - Field generation on GPU (currently on CPU)
  - Data hazard needs to be resolved

Thank you for your attention!