Continuous 6-DOF Haptic Rendering of Dental Drilling

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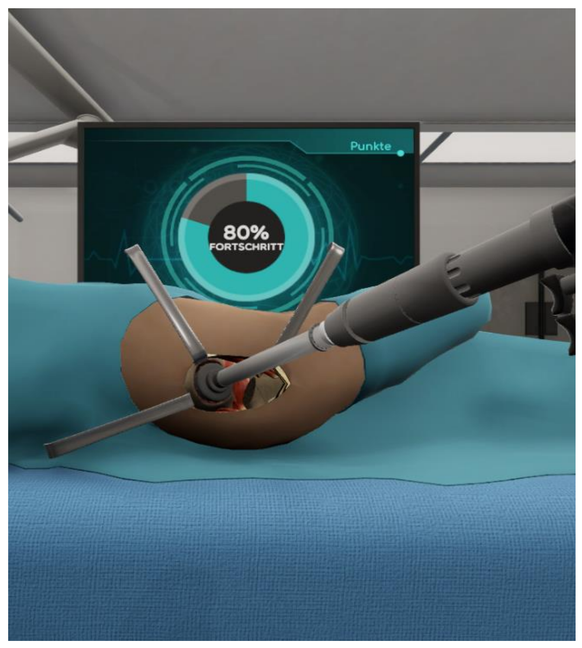
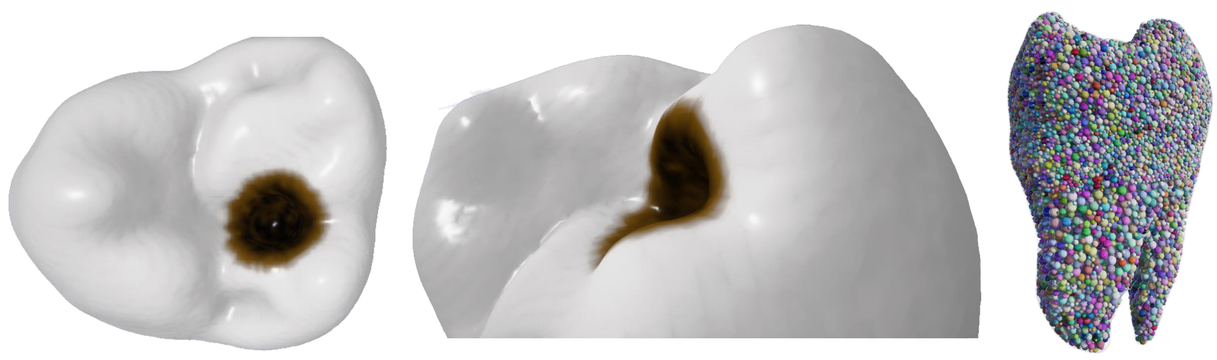
Motivation

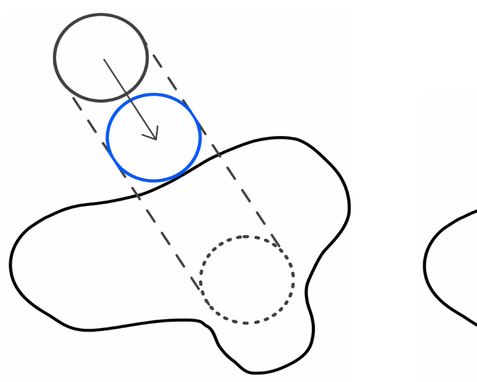
- Medical procedures depend on surgeon‘s skill
- Frequent effective skill acquisition paramount
- Cutting surgery especially difficult to simulate
- Haptic feedback enables generating authentic feeling to surgery student
- Traditional training methods are either
  - *costly*: rare organ donor parts
  - *unrealistic*: dummy organs that have different physical properties (i.e. false teeth)



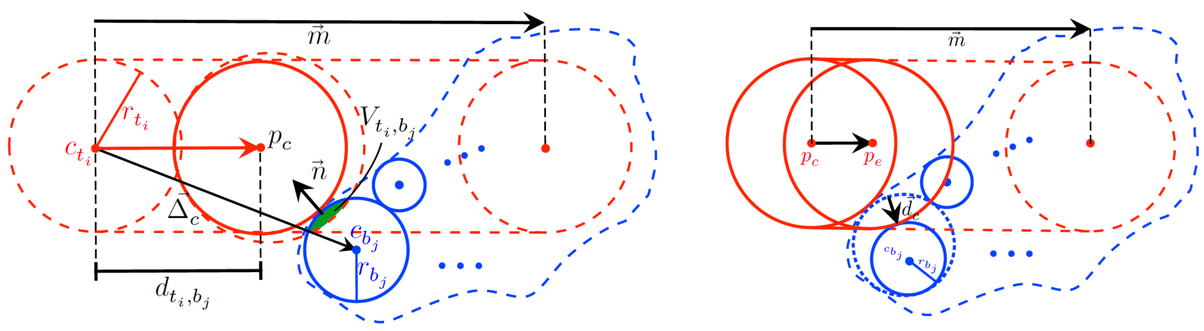
Methods

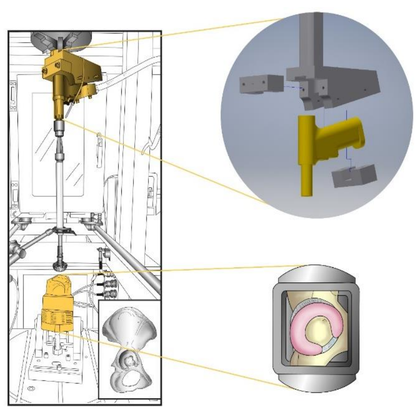
- *Precomputation*: Inner sphere representation
- Iterative multi-pass algorithm
  1. Continuous collision detection
     - Moving tool vs. removable material
  2. Neighbourhood based surface estimation
     - Surface normal
     - Material parameters (friction, density)
  3. Material removal along movement path
     - Continuous removed shape
- Constraint-based linear haptic feedback
- Penalty-based torque computation
- Coulomb friction model
- Massively-parallel GPU implementation
- Implicit metaball surface over spheres

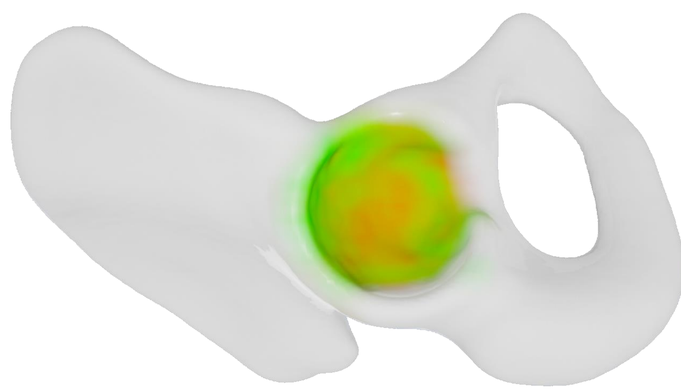




1. Surface contact
2. Surface estimation
3. Material Removal

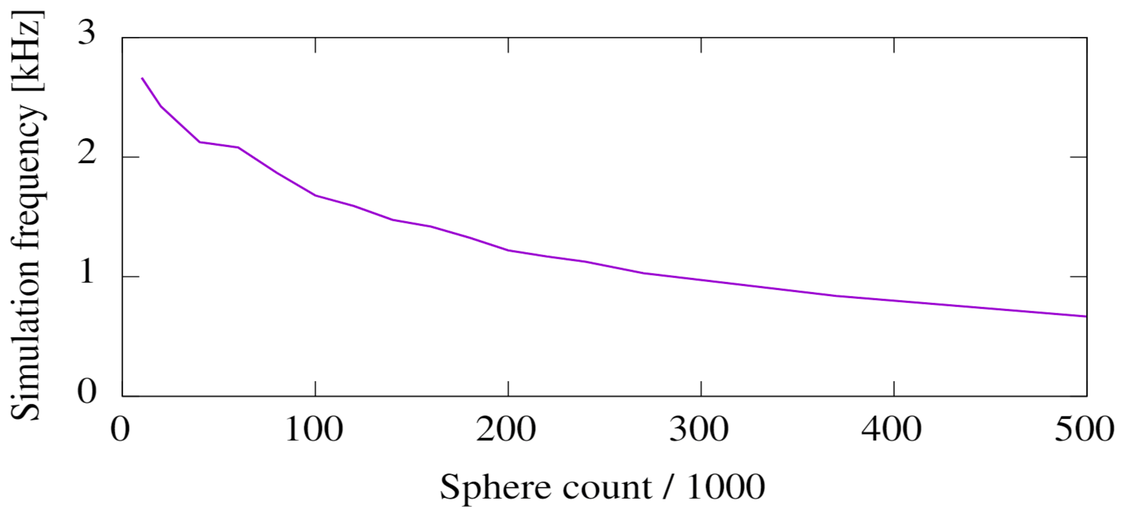






Results

- Plugin for Unreal & Unity
- Integrated in three different applications
  1. Hip replacement surgery
  2. Root canal opening
  3. Caries removal
- Optimization of material parameters by experiment
- Dynamic simulation @ 1 kHz (for <300k spheres)
- Stable forces up to 137 N with KUKA LBR iiwa robot



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ZIM Zentrales Innovationsprogramm Mittelstand