Realistic Haptic Feedback for Material Removal in Medical Simulations

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Motivation

- Aging society
  - Joint-related disease
- Orthopedic Surgery
  - Knee replacement
  - Hip replacement
Motivation

- Experience-based learning
  - Training only possible by practice
- Traditional methods
  - Plastic dummies
  - Cadaver donors
- VR simulation
  - Low cost
  - High realism
  - Haptic feedback
Challenge

- Requirements
  - High simulation frequency (1 kHz)
  - Volumetric representation
  - Stable & continuous 6-DOF sim.
- Traditional solution
  - Penalty-based methods
    - Often implemented with VPS
  - Force instability & discontinuity

[McNeely et al., 1999]
Our Method – Object Representation

Motivation | Challenge | Our Method | Results | Conclusion
Our Method – Simulation Algorithm

• Iterative multi-pass algorithm
  • Three algorithm passes

• Two tool instances
  1. Free moving
  2. God-object

• Coulomb friction model

Algorithm passes

1. Surface Contact
   • New god-obj. position
   • Force

2. Surface Estimation
   • Contact point
   • Contact normal
   • Contact density
   • Contact friction coeff.

3. Material Cutting
   • Modify spheres
   • New god-obj. position
Results

• Game engine plugin
  • Unity
  • Unreal
• Application: Hip Surgery
  • Acetabular Reaming
  • Industrial Robot (139 N)
• Head-Mounted Display
Results

• Acetabulum material parameters
  • Optimization against experimental data
  • Density distribution affects simulation
  • Mean error 0.9 N (0.4%)

• Performance
  • ≤1 ms for ~300,000 spheres
Conclusion

• New haptic simulation method
  • Multiple use-cases
  • Heterogeneous density
  • Material removal
  • Coulomb friction
  • Less force discontinuities
  • Parallelized on GPU (1 kHz sim. rate)

• Optimization of material parameters (0.4% error)
Thank You

Please read our paper for details!
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