

Realistic Haptic Feedback for Material Removal in Medical Simulations

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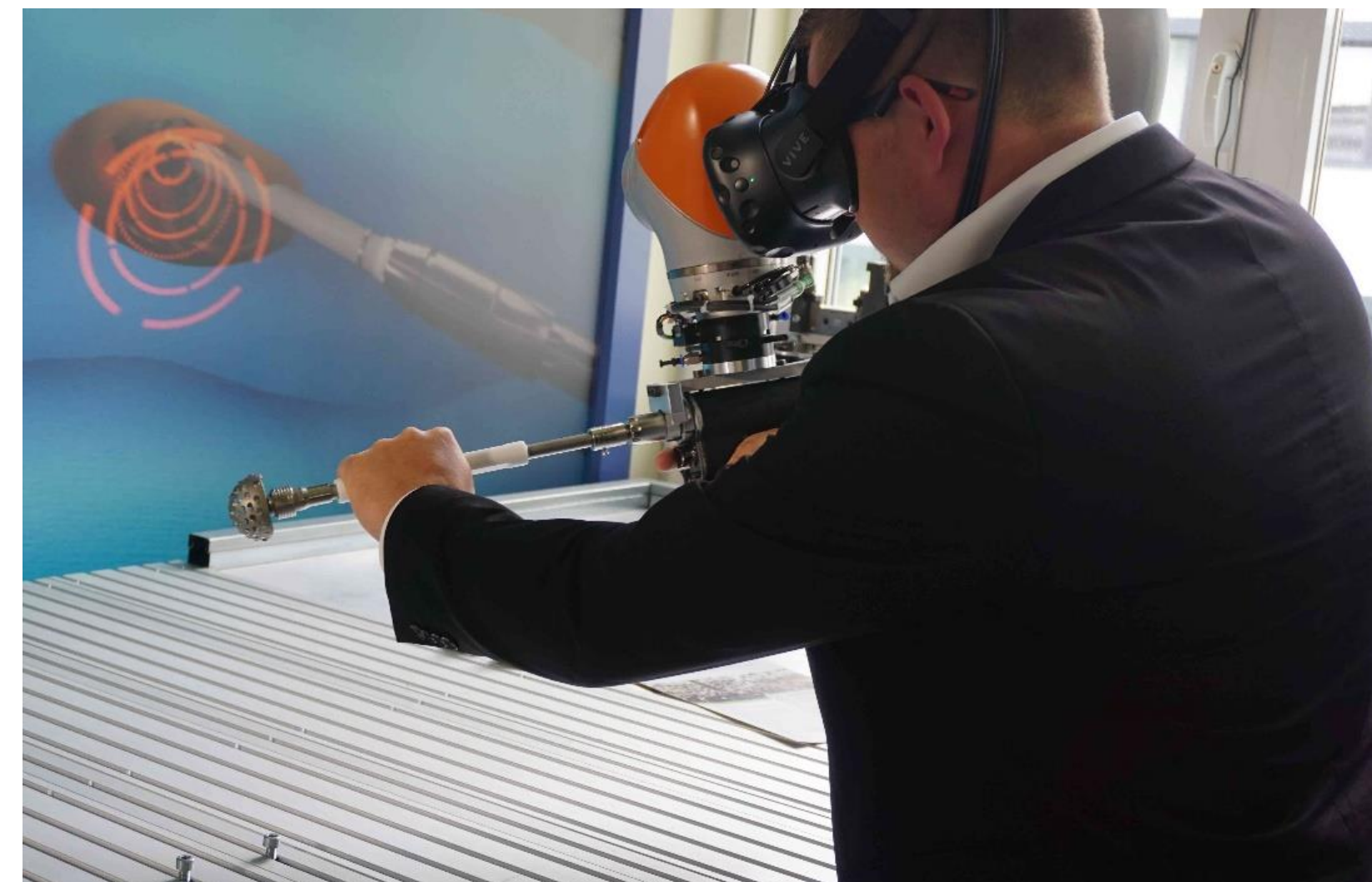
Motivation

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



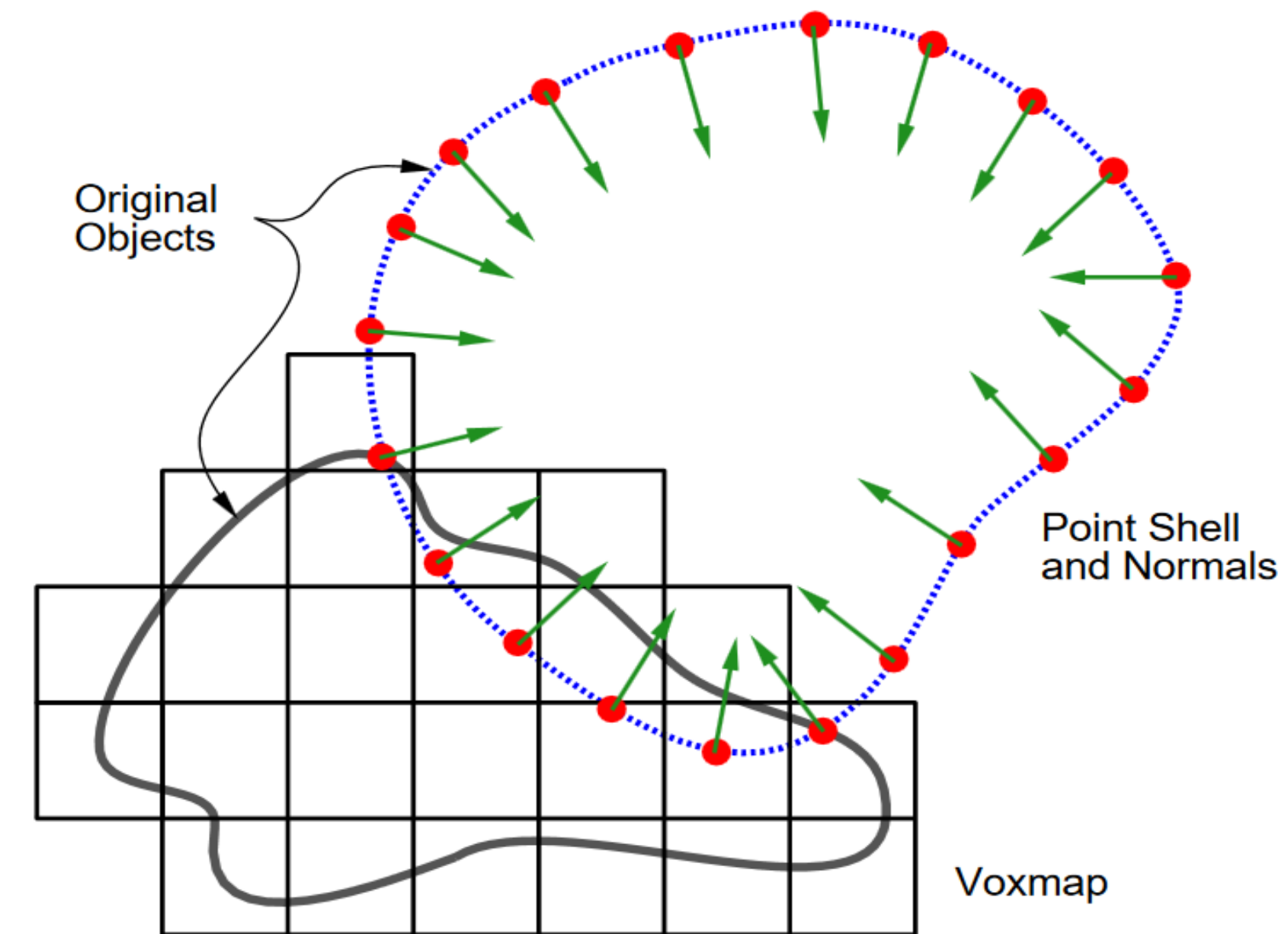
Motivation

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



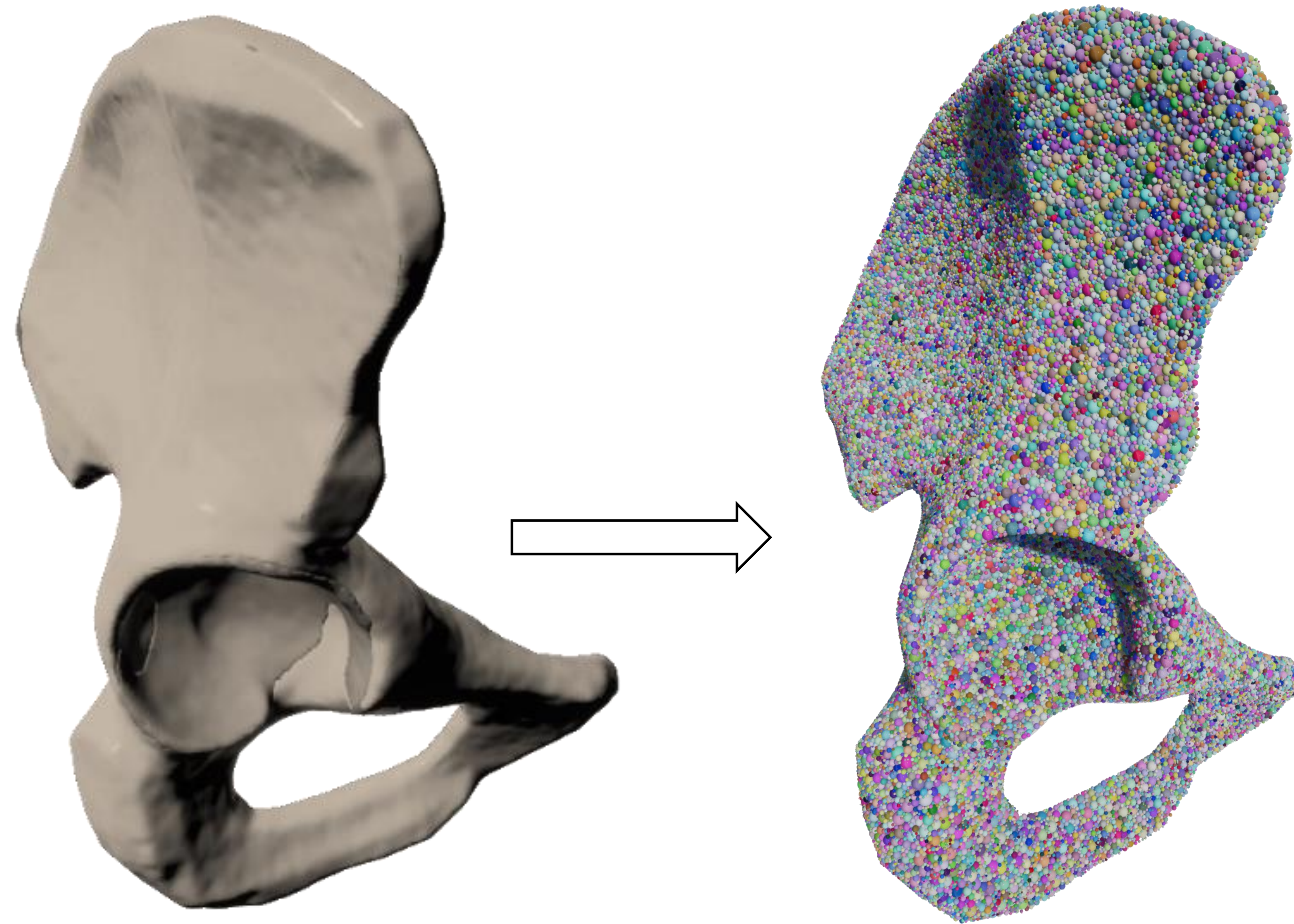
Challenge

- 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



Our Method – Simulation Algorithm

- Iterative multi-pass algorithm

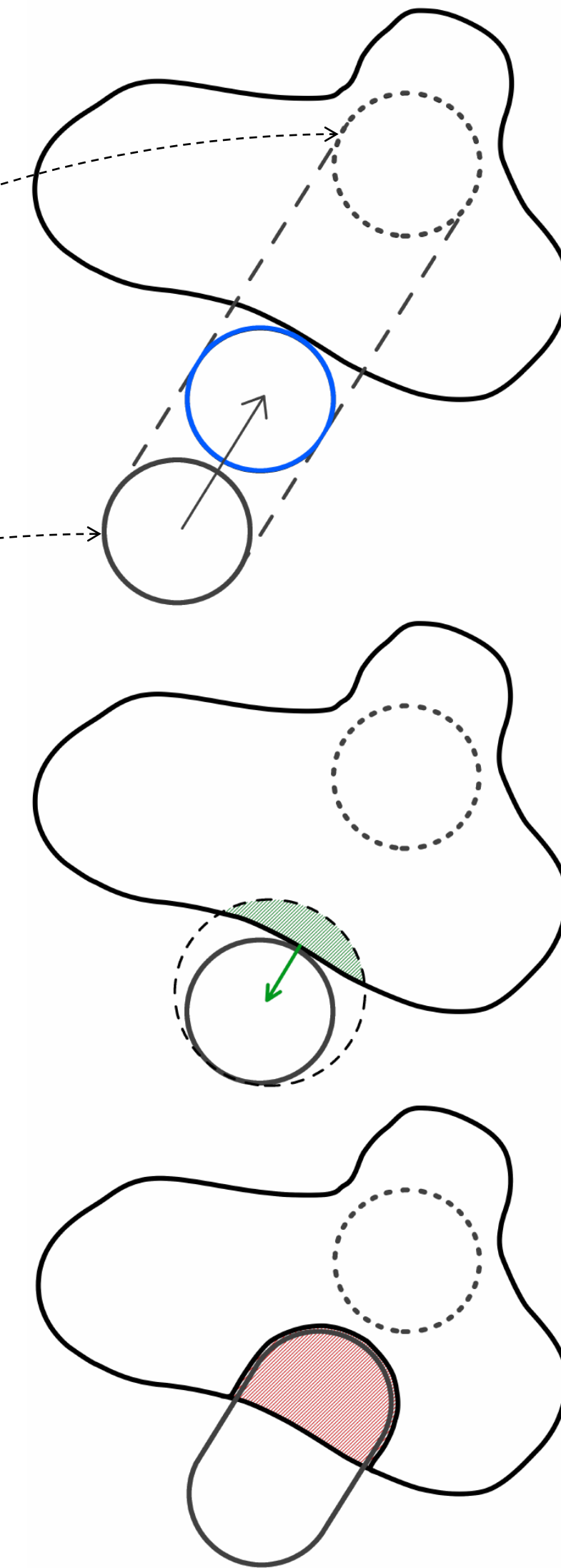
- Three algorithm passes

- Two tool instances

1. Free moving

2. God-object

- Coulomb friction model



Algorithm passes

1. **Surface Contact**

- New god-obj. position
- Force

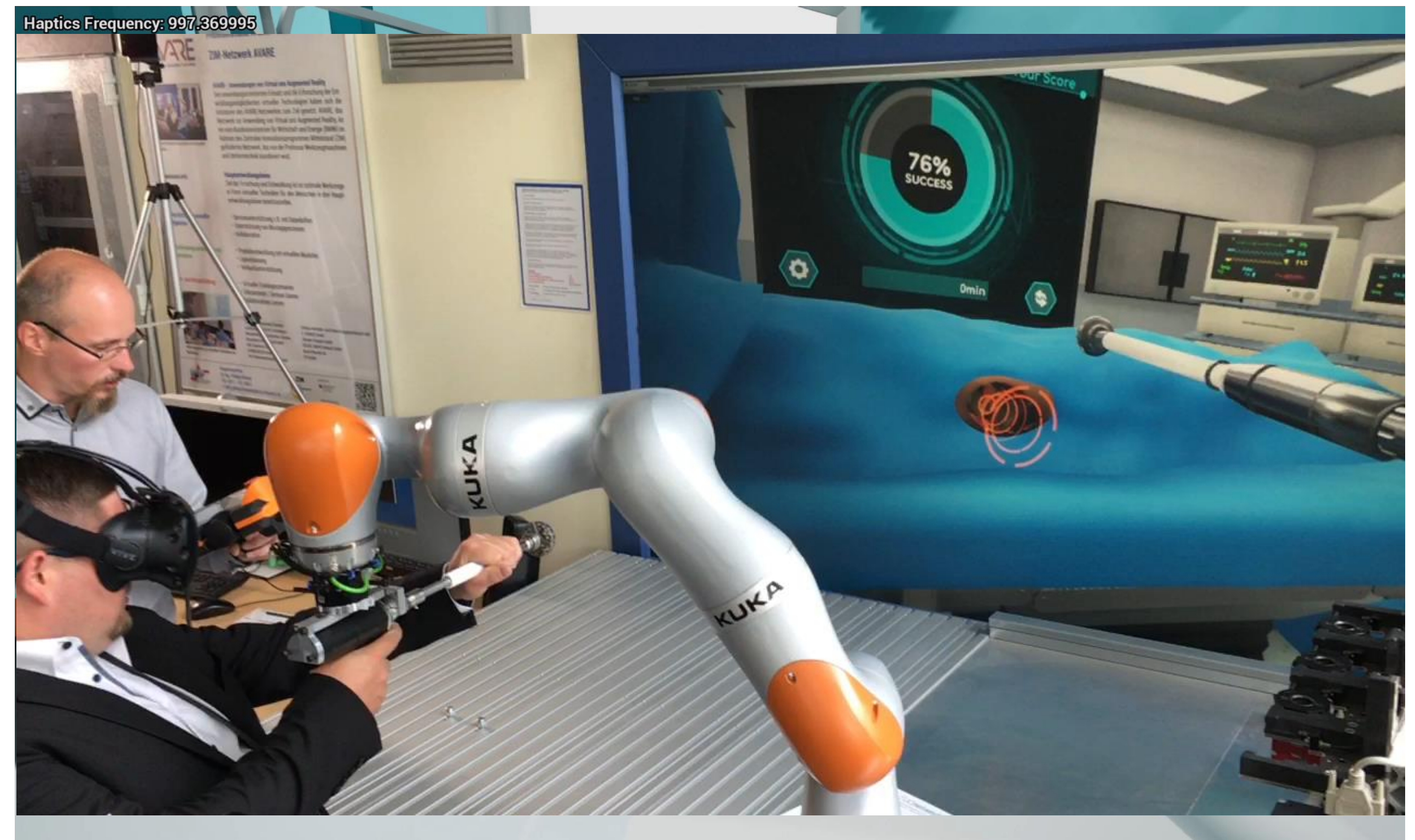
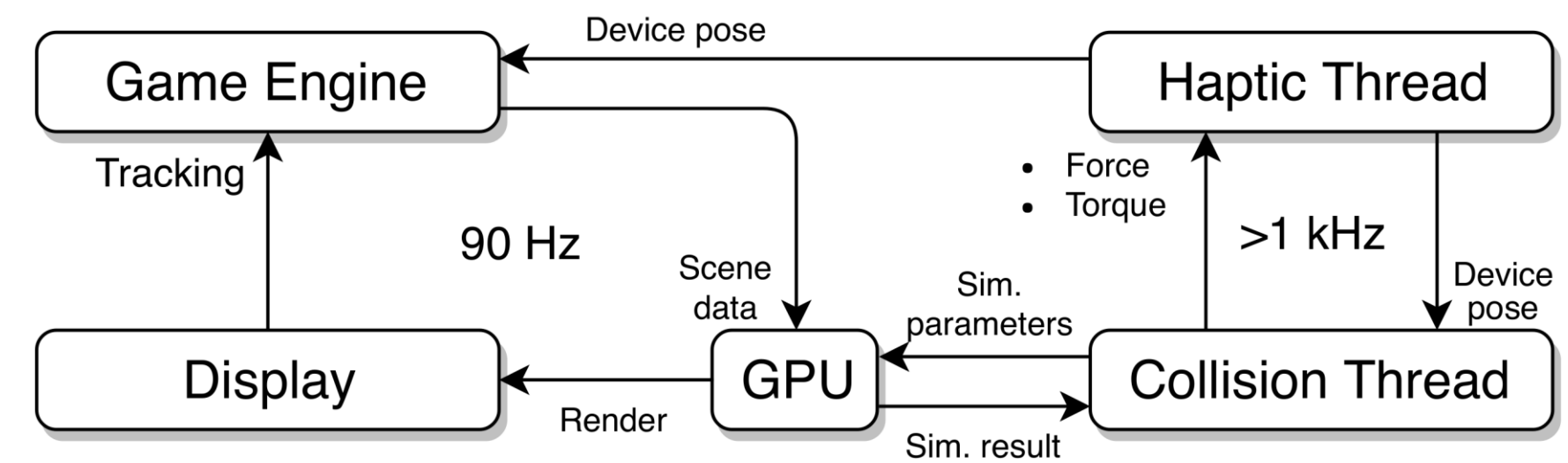
2. **Surface Estimation**

- Contact point
- Contact normal
- Contact density
- Contact friction coeff.

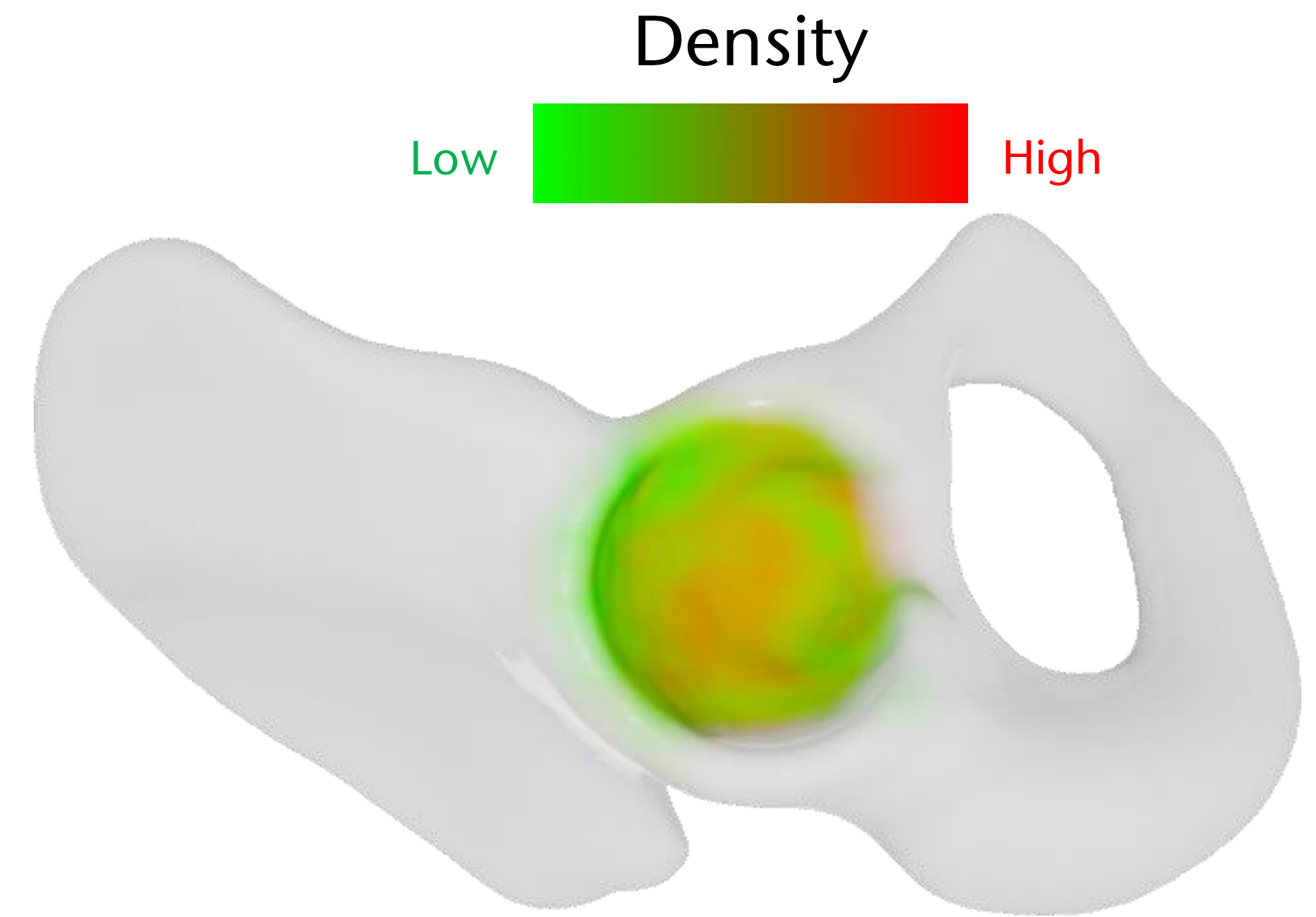
3. **Material Cutting**

- Modify spheres
- New god-obj. position

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



- 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



- 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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