MEDICAL SIMULATIONS

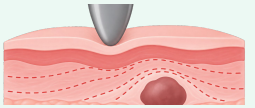
Training | Planning | Guidance | Diagnosis



Selected scenario:
Visuo-haptic palpation

REQUIREMENTS

Deformation | Interaction force | Heterogeneity | Real-time | Geometry & stiffness variation | Toward patient-specific

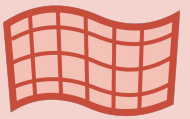


Surface interaction reveals subsurface structure

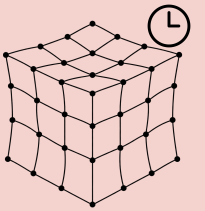




CHALLENGE



Soft tissue is deformable and difficult to simulate



Conventional simulation is accurate but computationally expensive and requires complex biomechenical modeling

APPROACH

OFFLINE (data generation and training)

measured data | MSM / FEM | material calibration | training data

train GNN surrogate

ONLINE (inference)

surface points + interaction + tissue information → GNN surrogate → deformation, force

THESIS PROGRESSION

CHAPTER 5	CHAPTER 6	CHAPTER 7
Feasibility	**Heterogeneity & Robustness**	**Generalization**
homogeneous silicone phantom	*silicone phantom & rigid inclusion*	*11 geometries x 3 stiffness levels*
cGNN with MSM pre-training + sim-to-real transfer learning	*cEGCL with FEM pre-training + sim-to-real transfer*	*calibrated hyperelastic models + continuous stiffness encoding*
56 ms	15 ms	10 ms

AIM

Fast deformation and force model for soft, heterogeneous tissue

sub-mm deformation accuracy | 10 ms inference | generalizes across stiffness & geometry

Computational core for future visuo-haptic palpation simulator