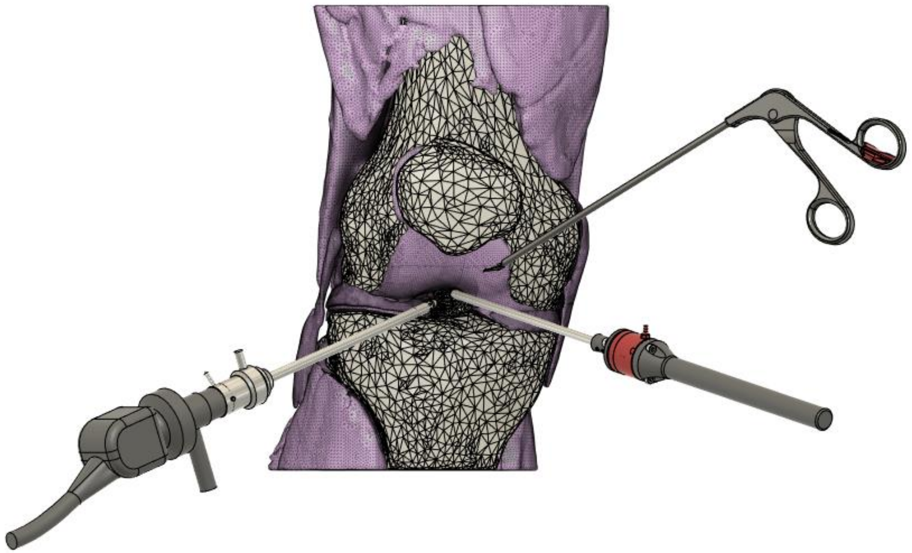
Computer-Haptic Assisted Orthopaedic Surgery (CHAOS)

Øystein Bjelland, PhD Candidate
CPS Lab / Department of ICT and Natural Sciences

Robin T. Bye, Professor
CPS Lab / Department of ICT and Natural Sciences



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Motivation

Would you be willing to become an orthopaedic surgeon's first patient?

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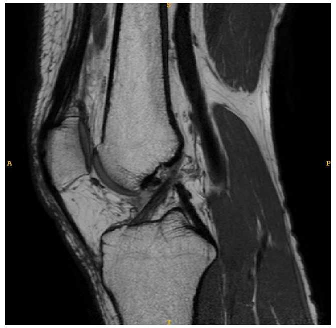
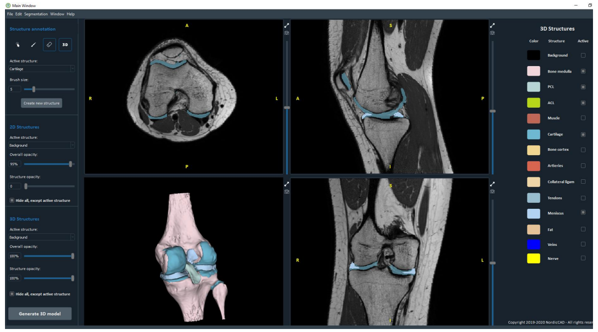
Although there exist several high-fidelity orthopaedic surgery training simulators in the market today, there is an unexplored potential for using virtual surgery simulators in pre-operative planning (Vaughan et al., 2016).

Our vision is to create a patient-specific high-fidelity arthroscopic surgery simulator – starting with knees.



(i)



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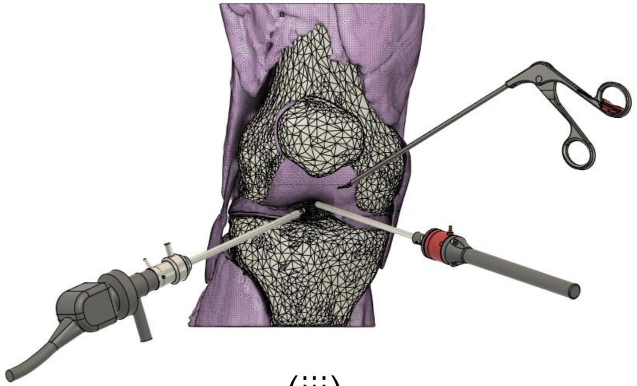


(iii)

Proposed Workflow

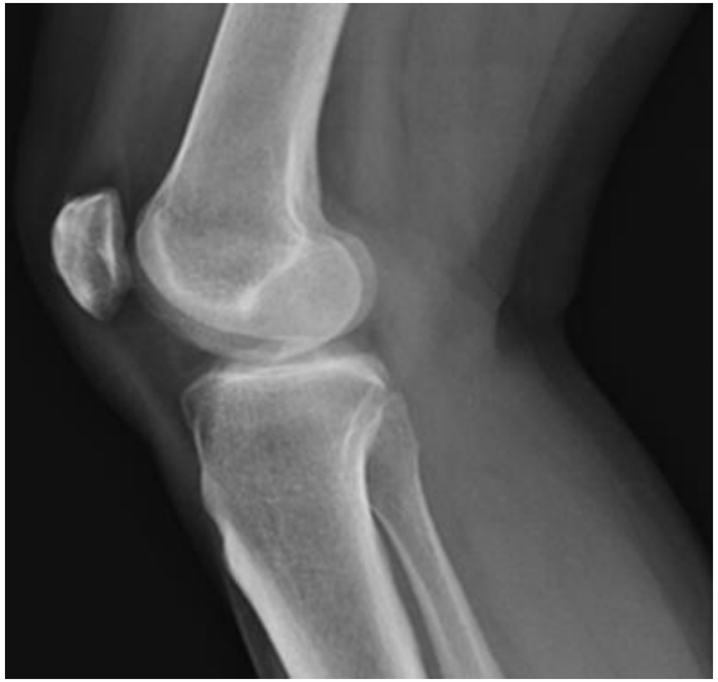
(i) Perform **MRI scan** of patient

(ii) Automatically segment MRI-image into individual anatomy using **deep learning**

(iii) Import **patient specific 3D-anatomy** into the surgery simulator and let surgeon practice **specific procedure**, with realistic **force feedback**

Computer-Haptic Assisted Orthopaedic Surgery

- Segmentation of MRI-images using machine learning
- Characterization of force-feedback during arthroscopic surgery
- Simulation strategies using Simulation Open Framework Architecture (SOFA)



X-Ray

Computer Tomography (CT)

Magnetic Resonance Imaging (MRI)

Gjesdal et al. (2020)

Challenge: manual segmentation is very time consuming (3-4 days).

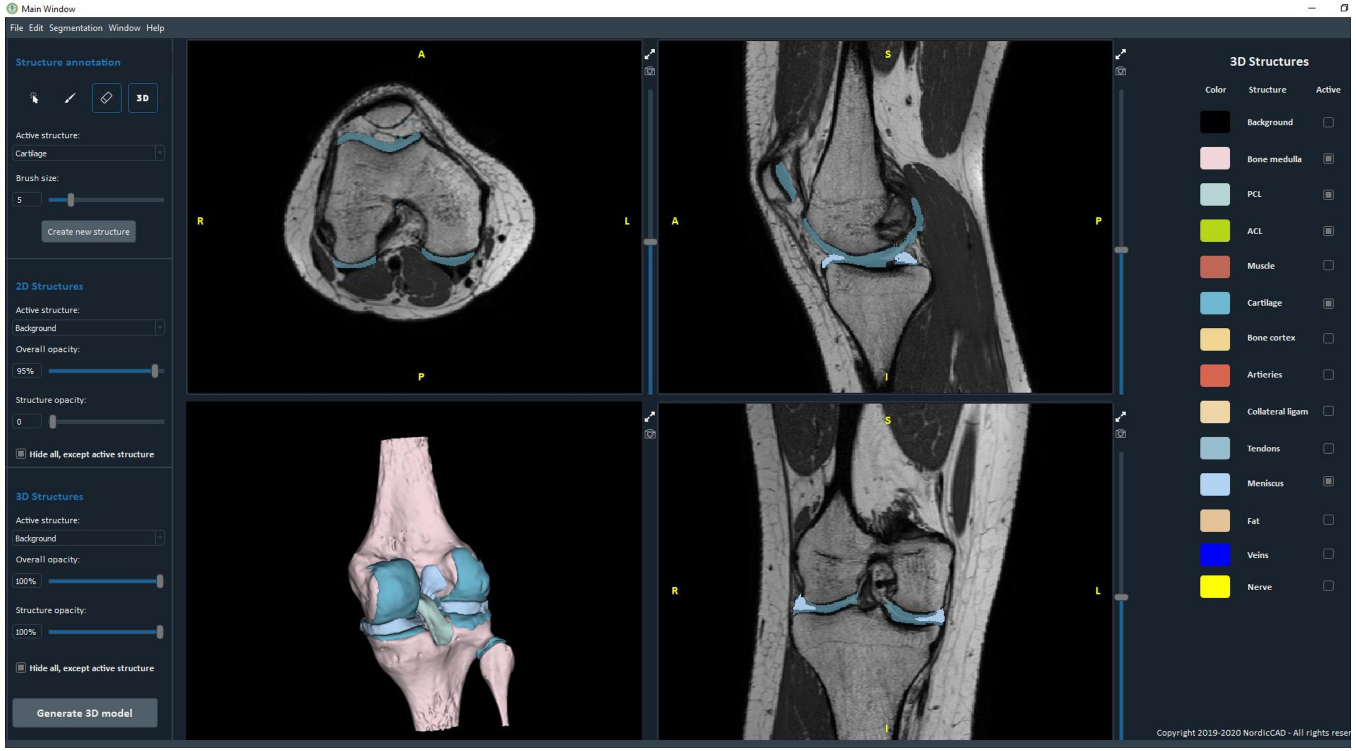
NordicCAD software developed by Gjesdal et al (2020).

Using deep convolutional neural networks with U-net architecture to automatically segment MRI images.

Based on data set of **15 knees**.

Status: Can currently segment healthy knees in **90 seconds** on a regular computer.

Future improvements: Expand to other limbs and injuries.



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Computer-Haptic Assisted Orthopaedic Surgery

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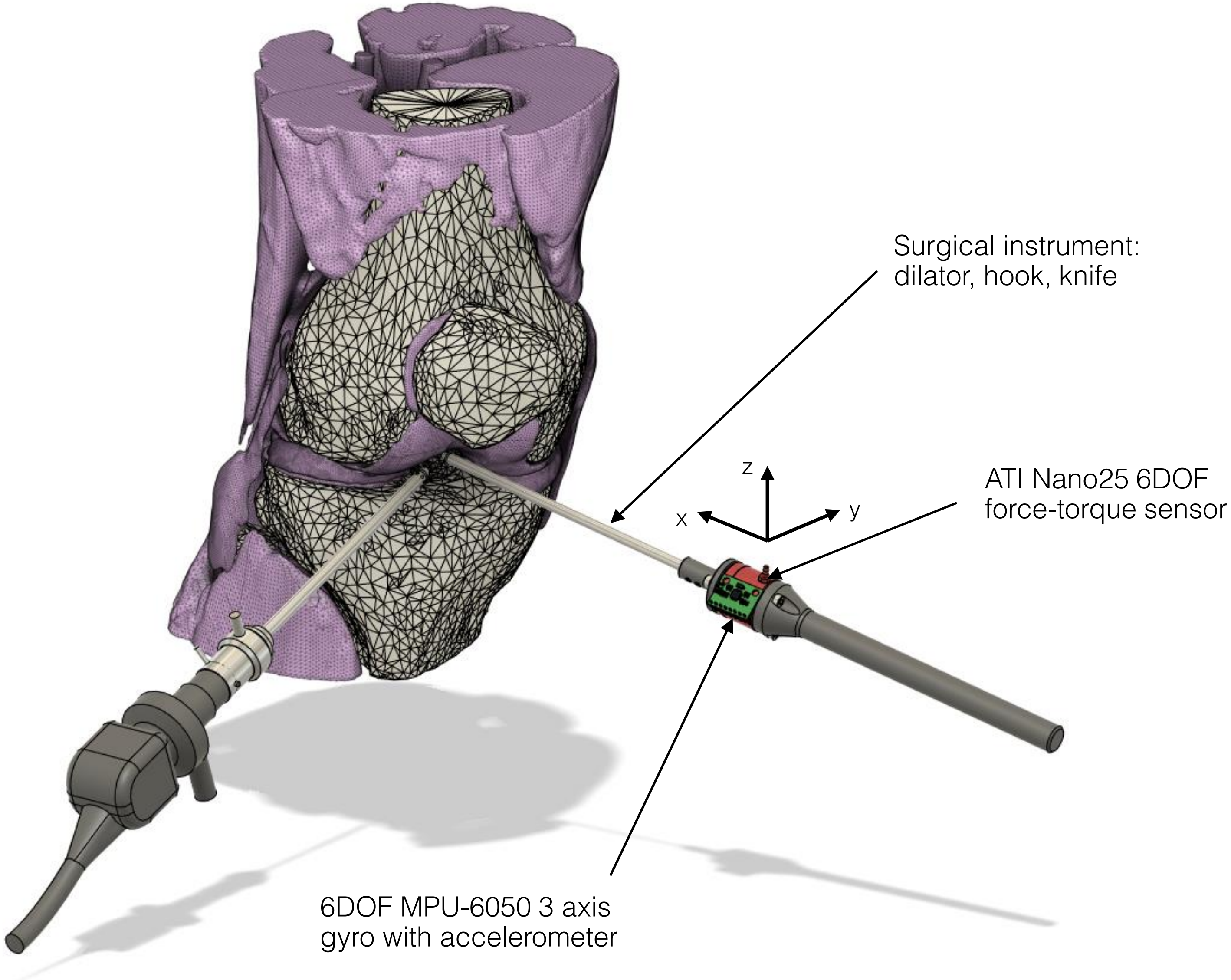
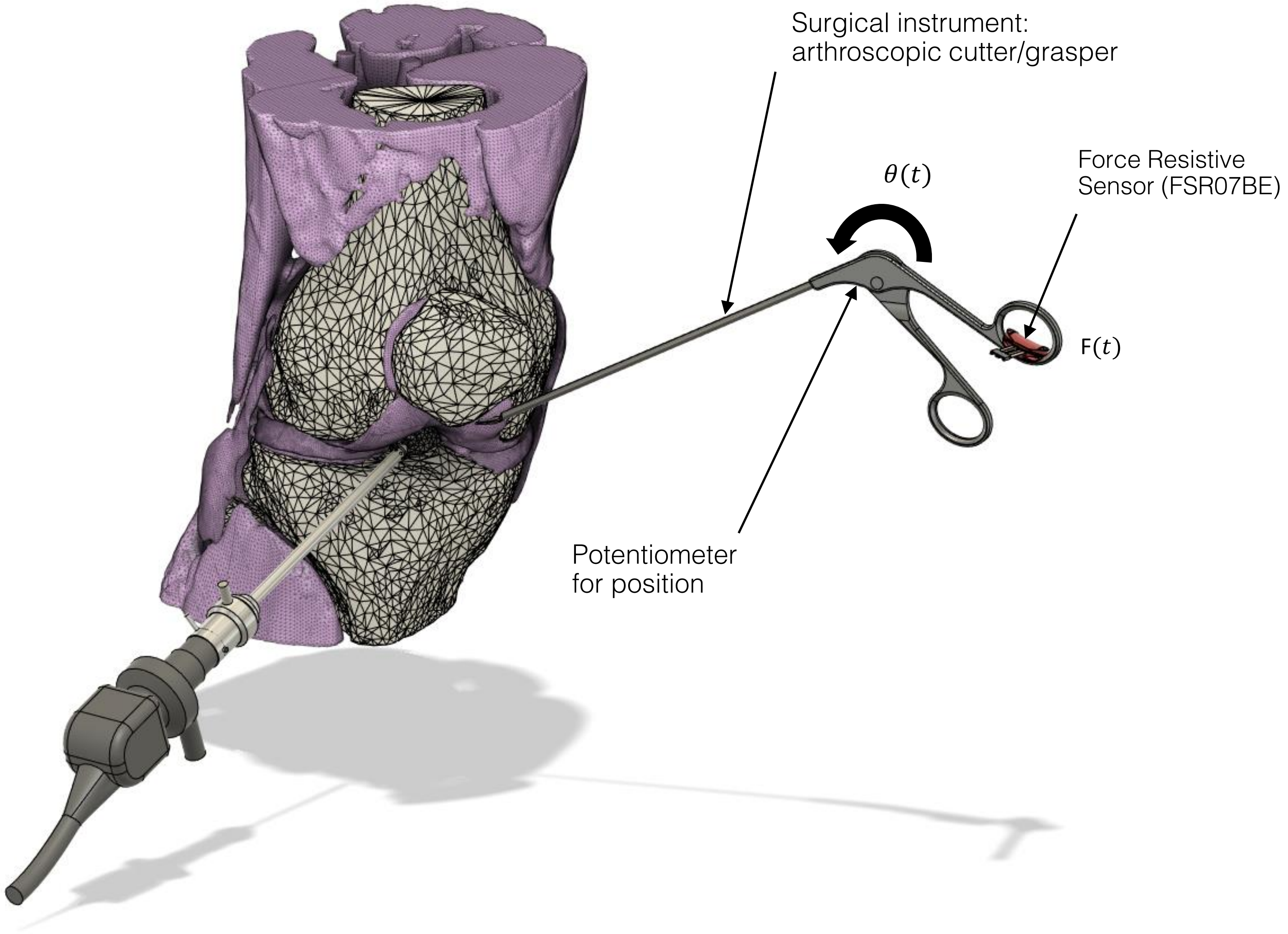
We argue that realistic haptic feedback is a **critical functionality** in a high-fidelity surgical simulator, and aim to quantify force-feedback during selected operations on cadaveric specimens.

#	Operation	Surgical Instrument
1	Establish portal	Knife / introducer
2	Orient scope (camera)	Arthroscope
3	Examine ligament integrity	Dilator / hook
4	Examine cartilage	Dilator / hook
5	Shave soft tissue	Surgical shaver
6	Cut ligament	Surgical plier / scissor
7	Suture	Arthroscopic suture kit

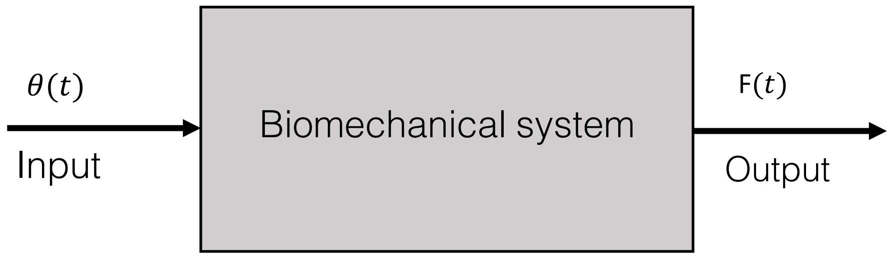
Experimental setup for characterization of **hand/wrist forces** during arthroscopic surgery



Experimental setup for characterization of **finger forces** during arthroscopic surgery



We aim to establish a **transfer function** for each of the identified operations, using input position and output force response.



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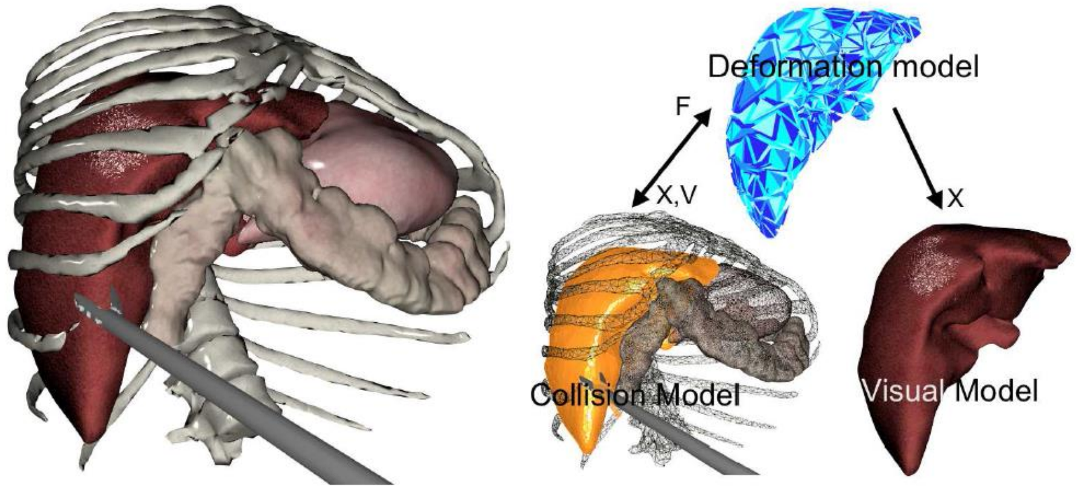
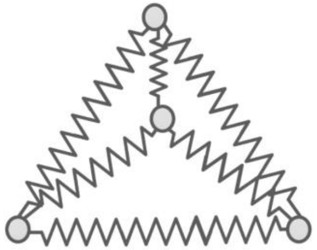
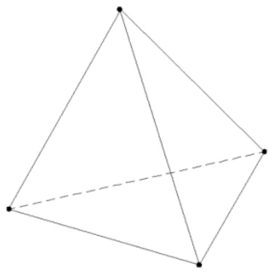
CHAOS-simulator will be based on **Simulation Open Framework Architecture (SOFA),** an open source real-time physics simulation platform with multi-model representation for surgery simulation (Faure et al., 2012).



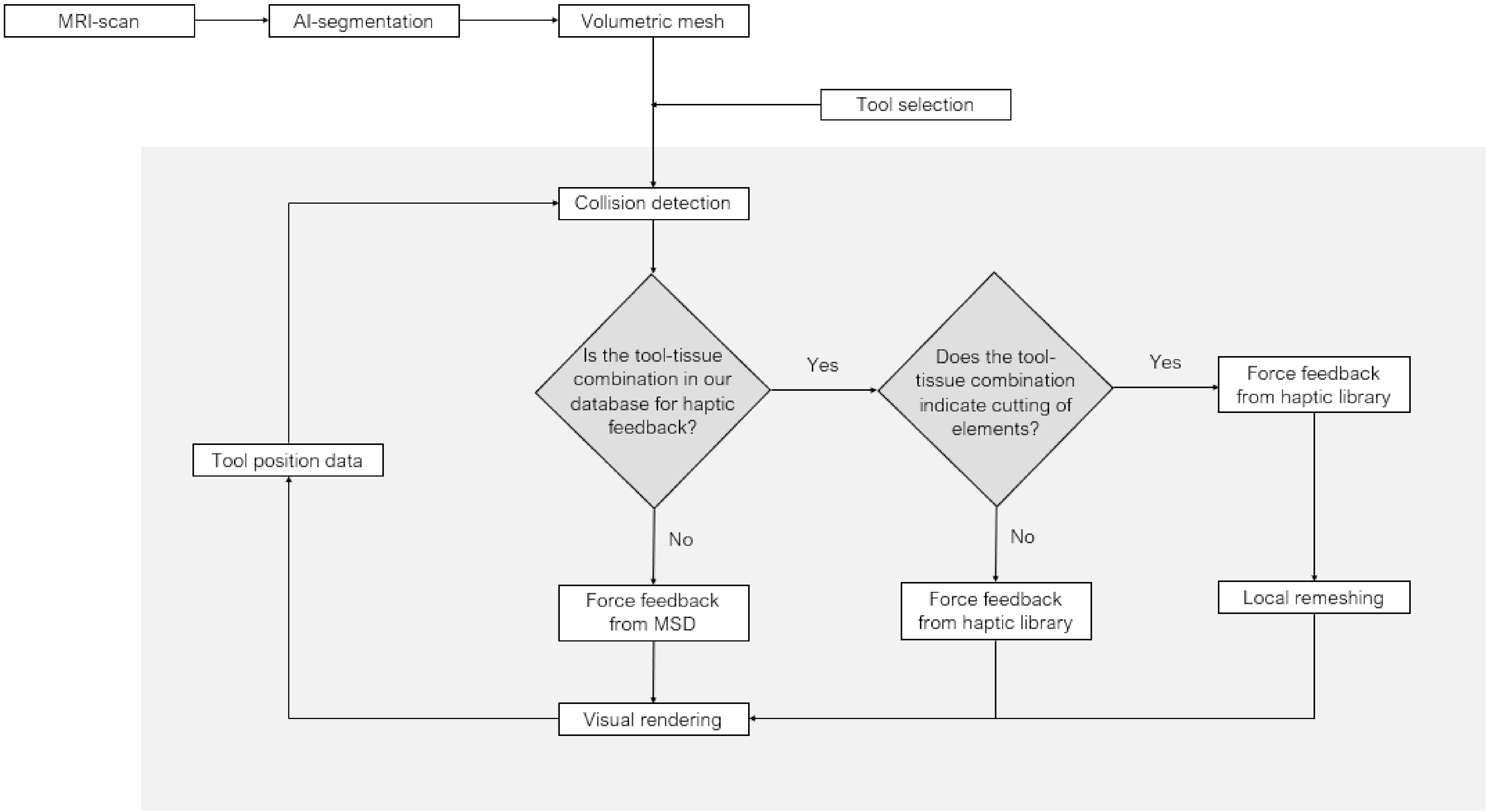




Two main simulation methods for medical training simulators (Sandholm et al., 2006).

Mass-spring-damper models. Point masses connected with springs and dampers. Are quick, but less accurate.

Finite element models. Element stiffness defined by material model. Are accurate, but computationally expensive.


MRI-scan
AI-segmentation
Volumetric mesh
Tool selection
Collision detection
Is the tool-tissue combination in our database for haptic feedback?
Yes
Does the tool-tissue combination indicate cutting of elements?
Yes
Force feedback from haptic library
Tool position data
No
No
Force feedback from MSD
Force feedback from haptic library
Local remeshing
Visual rendering

Further work

Some challenges are mesh-cutting and local remeshing, refresh rate for haptic rendering and recreating tactile feedback.

Thank you!

Øystein Bjelland, PhD Candidate
oystein.bjelland@ntnu.no

Robin T. Bye, Professor
robin.t.bye@ntnu.no