# Towards Data-Driven Patient-Specific Haptic Rendering in SOFA

Øystein Bjelland[1]

## I. Introduction

Patient-specific surgical simulations with kinesthetic feedback can help surgeons in pre-operative planning and for studying difficult surgical cases. For haptic rendering of patient-specific interactions, two approaches are considered: (i) interpolation in pre-recorded force-position data [1], and (ii) identification of material properties for finite element (FE) simulations. Interpolation methods can accurately reproduce haptic force profiles, but are limited to modelling only the haptic interactions. FE-based frameworks that computes haptic interaction forces using Lagrange multipliers provide an holistic approach for surgical simulations with kinesthetic feedback [2]. However, to satisfy real-time constraints, simplifications such as linear material models and large FE-mesh element size sacrifice fidelity [3].

## II. Method

This work-in-progress study presents a method that can enrich haptic interactions by combining haptic force signals from pre-recorded patient-specific instrument-tissue interactions with FE-based force signals using a Kalman filter (KF) for signal fusion. The KF-method assumes a state-space formulation in the three-dimensional space domain with force and stiffness selected as states. The pre-recorded force signals are rendered only during selected combinations of instrument-tissue interactions, and is therefore event-based. The method has previously been tested on a 1D proof-of-concept simulation setup [4], and is now expanded to 3D simulation by implementation in the Simulation Open Framework Architecture (SOFA) with a Geomagic Touch haptic device.

## III. Preliminary Results and Discussion

Arthroscopic meniscus examination is used as a case study. Interaction forces between a porcine meniscus and probe were collected using a device based on an ATI Nano25 force-torque sensor with position tracking. A simulation scene based on MRI anatomical models was implemented in SOFA, and examination simulation was conducted. The constraint forces and corresponding transformation matrix in constraint space were retrieved from the LCPConstraintSolver and tissue mechanical objects using SofaPython3. The KF force signal was simulated using MATLAB, and will later be implemented in SOFA. Preliminary results are displayed in

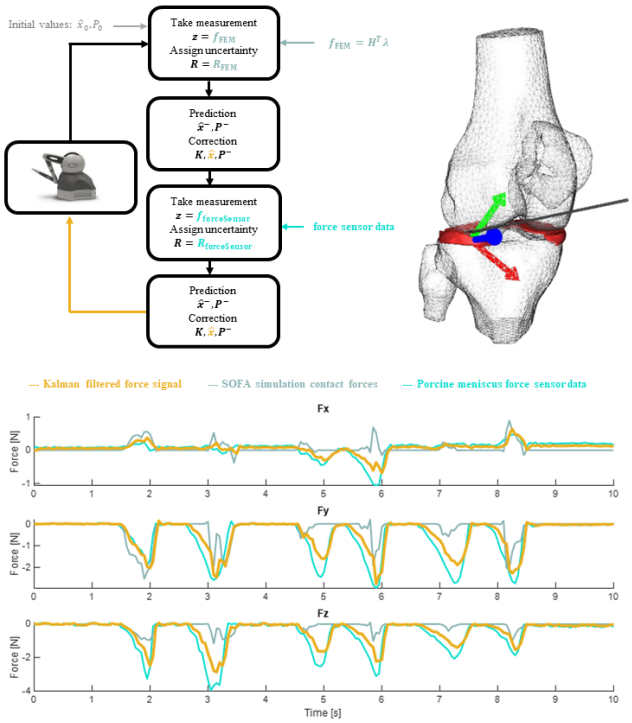


Fig. 1. Top left: Kalman filter method for combining finite element-based interaction forces and experimental force sensor data. Top right: simulation scene with arthroscopic probe, rigid bone and finite element meniscus models in SOFA. Bottom: preliminary results showing interaction force signals for two arthroscopic probes of the anterior-, mid- and posterior parts of a lateral meniscus.

Fig. 1, and shows that the KF force signal captures the main characteristics of the experimental force sensor data, while being synchronized to the FE-based force signal. The filter can be tuned to be biased toward the force sensor signal or the FE force signal. This enables patient-specific haptic response while keeping basic FE material models.

## References

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[1]Ø. Bjelland is with the Department of ICT and Natural Sciences at NTNU - Norwegian University of Science and Technology, Ålesund, Norway. e-mail:oystein.bjelland@ntnu.no

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