

Teleoperation of a surgical robot using force feedback

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Group 735

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- ▶ Minimally invasive surgery
- ▶ Surgical robots teleoperated by console
- ▶ Visual feedback received by surgeon



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- ▶ Surgeon has to estimate the force exerted by the tool
- ▶ Studies show haptic feedback reduces error rate





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- ▶ Force feedback teleoperation of surgical tool
- ▶ Geomagic Touch
 - ▶ 3 actuated degrees of freedom
 - ▶ Cartesian force feedback
 - ▶ Outputs up to 3 N of force
- ▶ EndoWrist

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- ▶ Communication
 - ▶ Minimize delays in communication
- ▶ Force estimation
 - ▶ Sensors too expensive for short lifetime of tools
- ▶ Control
 - ▶ Remove oscillations in force feedback

System overview

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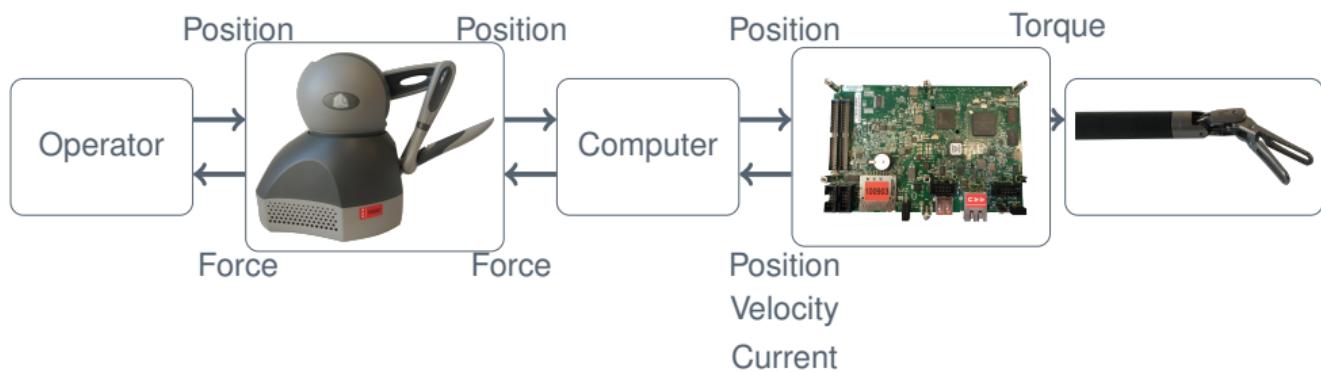
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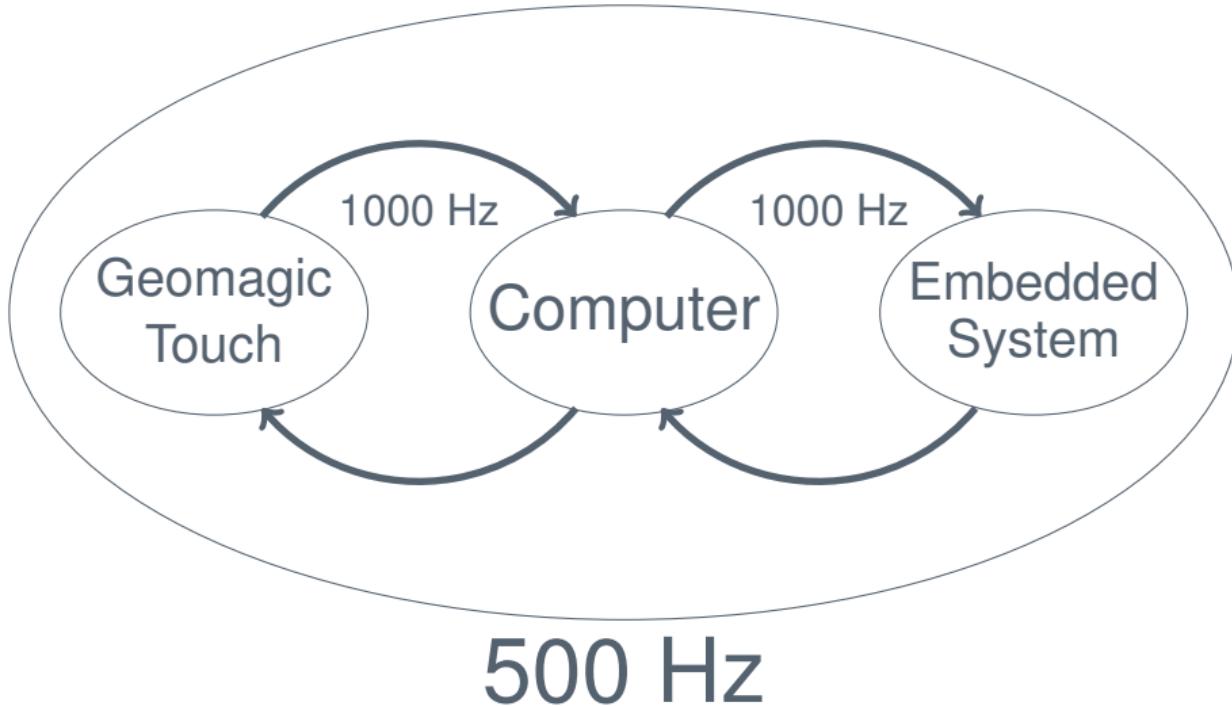
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- ▶ Maximum for the initial system: 100 Hz
- ▶ Our approach:
 - ▶ Reducing the size of exchanged data
 - ▶ Changing the transport protocol

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Reducing the size of the packet

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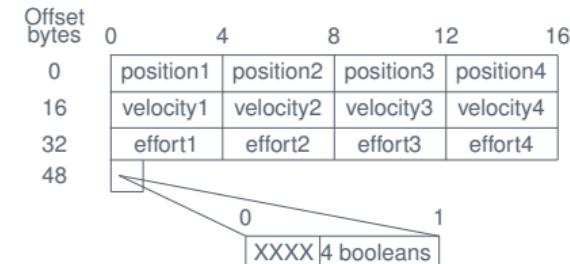
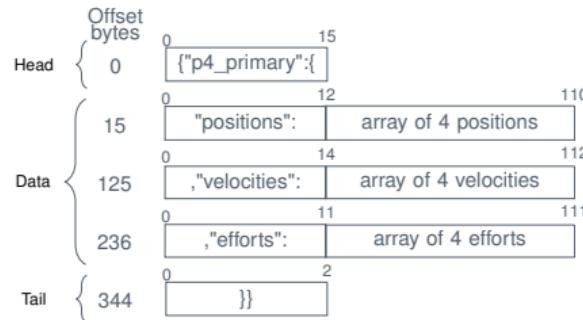


Figure : Packet built using the binary representation

Size reduced by 85%

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- ▶ Changed from TCP/IP to UDP
 - ▶ Less overhead
- ▶ Results: maximum of 638 Hz

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Forces

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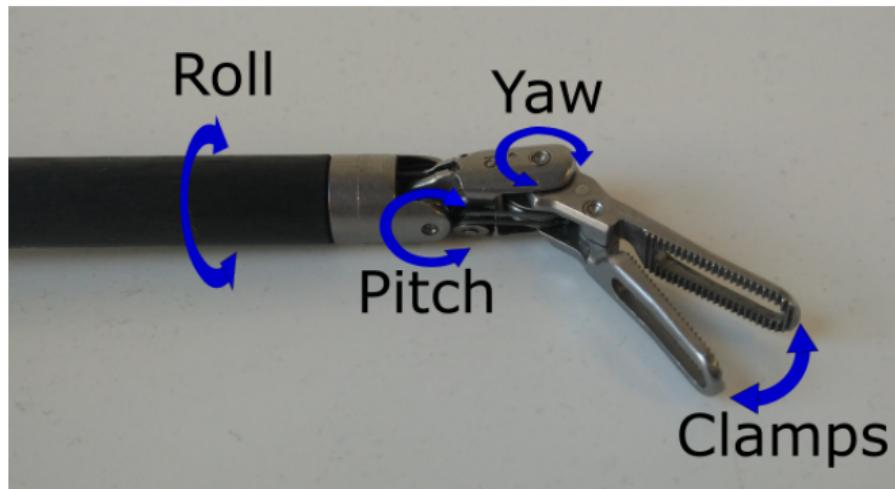
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- ▶ Roll, pitch and yaw forces



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Force estimation

Model structure

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- ▶ Nonlinearities in the EndoWrists dynamics (yaw, pitch)
- ▶ Roll force linear
- ▶ Black-box identification
 - ▶ Hammerstein-Wiener Model



Figure : Hammerstein-Wiener model.



Force estimation

Linear model

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- ▶ Linear model
 - ▶ Choice of inputs affects model quality
 - ▶ Inputs: effort, velocity
 - ▶ Outputs: force
- ▶ Black-box identification
 - ▶ Subspace identification
 - ▶ Hankel singular value analysis

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Force estimation model

Hammerstein Wiener Models

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- ▶ Nonlinearities
 - ▶ Deadzone nonlinearities on input
 - ▶ Saturation nonlinearities on output

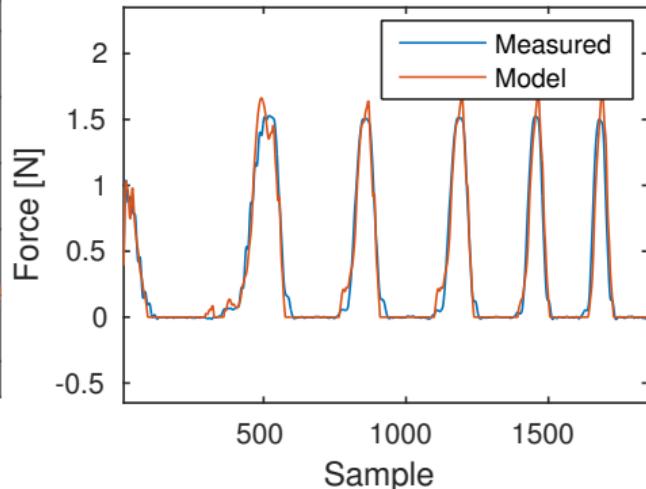
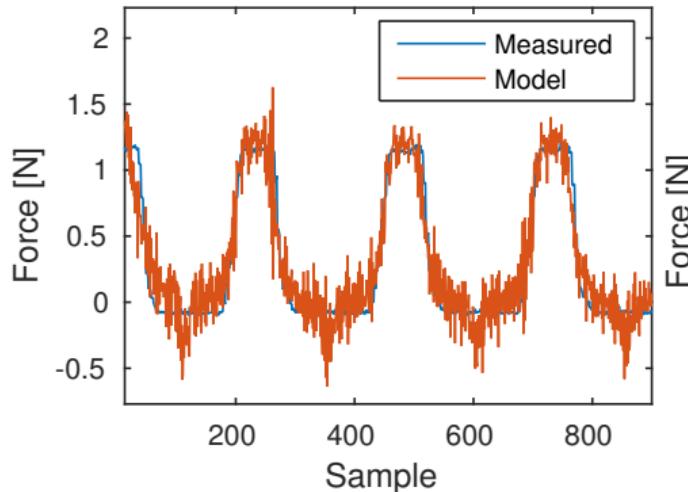


Figure : Comparison of pitch (left) and yaw (right) model to measurements.

Control Architecture

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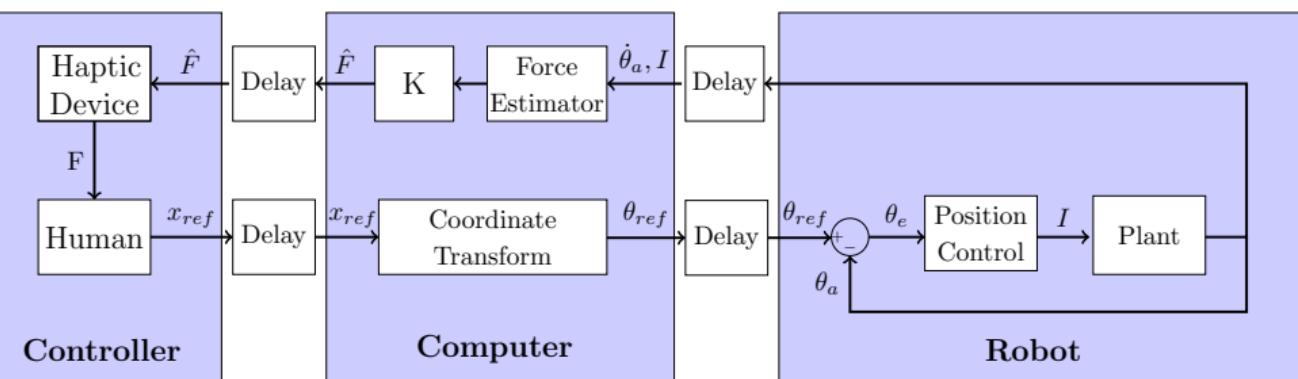
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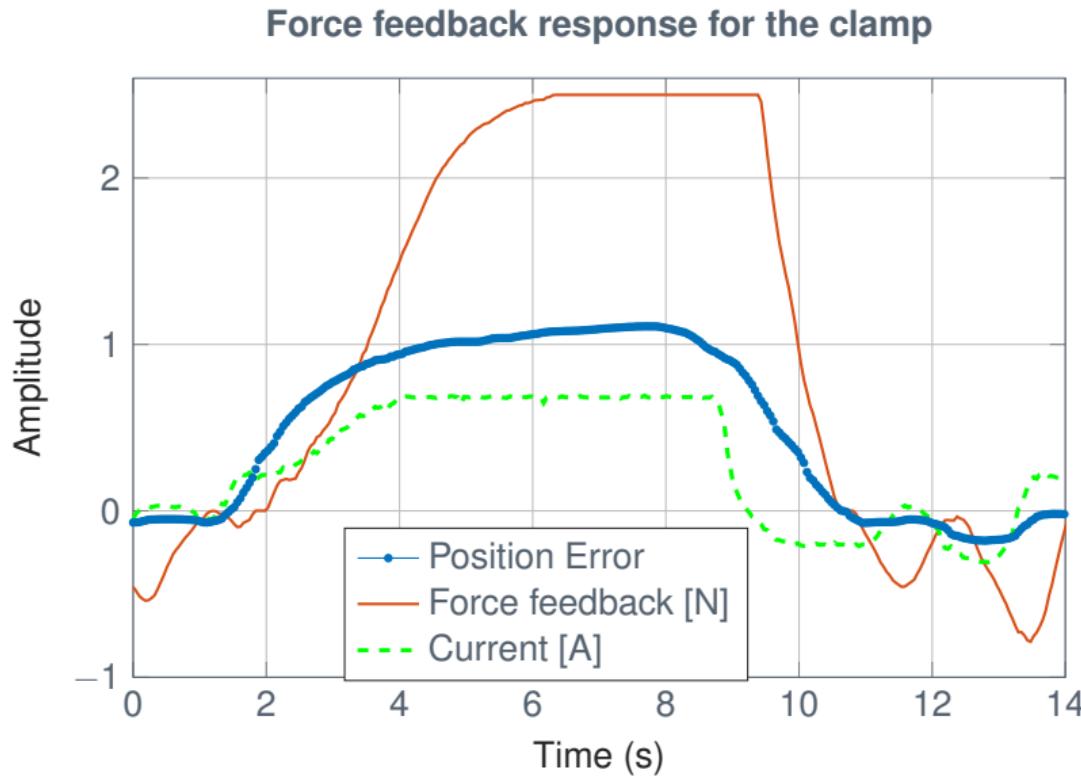
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- ▶ The maximum communication frequency of 385 Hz did not reach the 500 Hz goal.
- ▶ New encoding decreased packet size by 85%
- ▶ UDP omits unnecessary retransmission
- ▶ Compression algorithms could further improve the communication frequency

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- ▶ The EndoWrist's highly nonlinear nature made the modelling a challenge
- ▶ The yaw (grip) force model has a delay of 0.2 s
- ▶ The pitch model has a tendency to overestimate force
- ▶ An improved dynamic model could be used with a the implemented Kalman filter for state estimation and reference following

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Thank you!