

Teleoperation of a surgical robot using force feedback

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Gruppe 633

Daniel Bähner Andersen

Nicolaj Vinkel Christensen

Ralf Victor Lømand Ravgård Christiansen

Simon Bjerre Krogh

Thomas Holm Pilgaard

Institut for elektroniske systemer

Aalborg Universitet

Danmark



AALBORG UNIVERSITY
DENMARK



Agenda

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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

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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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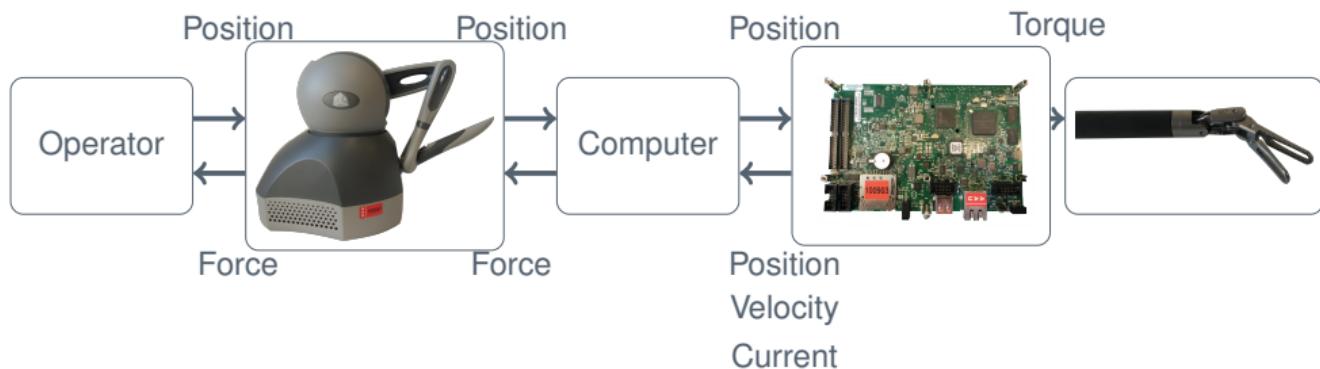
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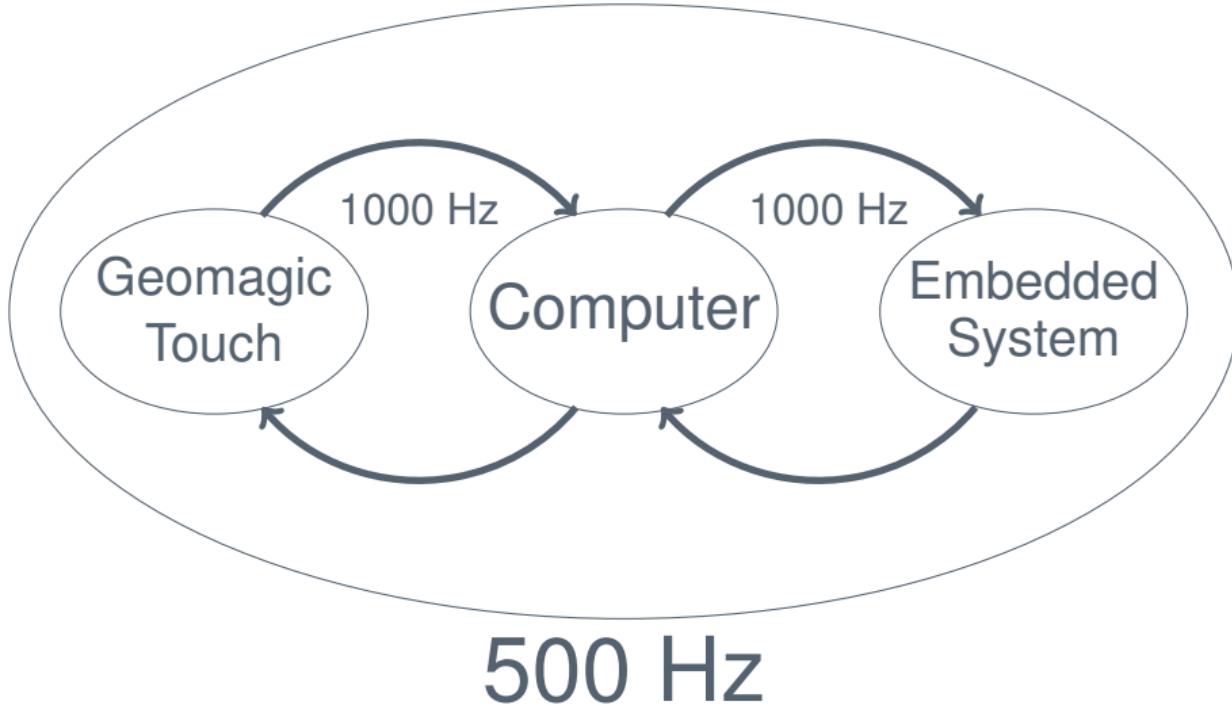
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Communication

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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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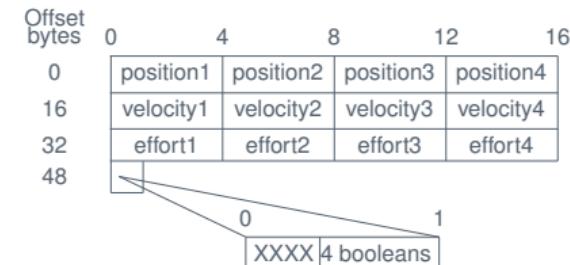
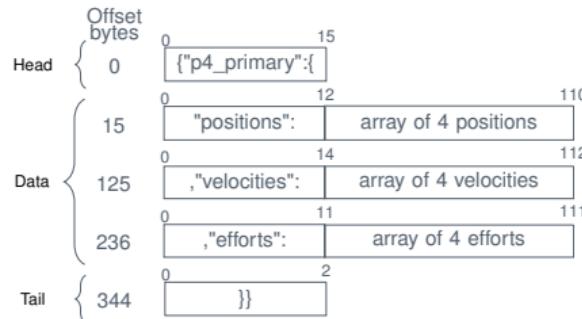


Figure : Packet built using the binary representation

Size reduced by 85%



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Results: maximum of 638 Hz

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Filip Maric

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Force estimation model

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- ▶ Model approach
- ▶ Nonlinearities in the EndoWrist dynamics
 - ▶ Hammerstein Wiener Models



Figure : Hammerstein-Wiener model.



Force estimation model

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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► Input and output nonlinearities

- Effort
- Force

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Force estimation model

Hammerstein Wiener Models

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- ▶ Nonlinearities
 - ▶ Deadzone nonlinearities
 - ▶ Input/Output -saturation

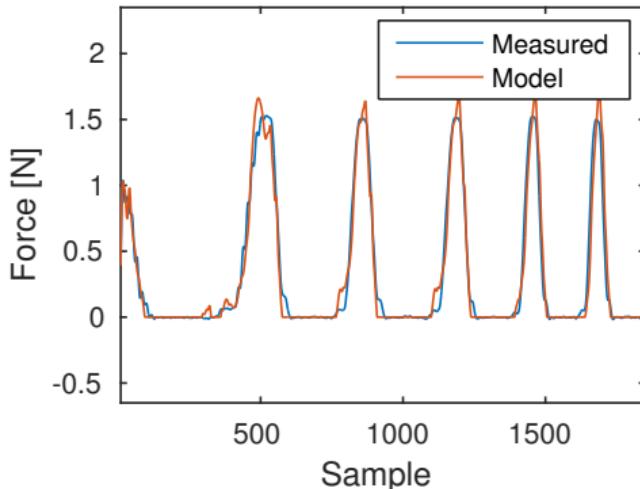
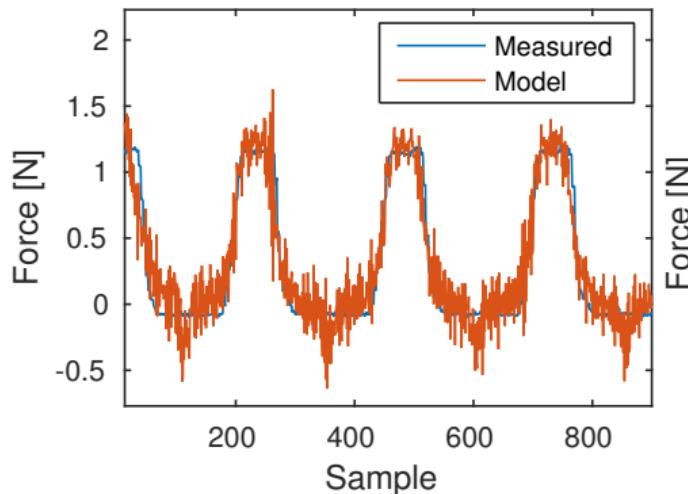


Figure : Comparison of pitch (left) and yaw (right) model to measurements.



State estimation

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- ▶ Modeling for additional outputs allows correction of the model using an estimator
- ▶ A multiple output model that adequately captures the dynamics of the system could be used in a Kalman filter to create a state estimate
- ▶ The state estimates can be used in a state feedback loop to change system dynamics
- ▶ Reference following capabilities can be added to the system, despite the nonlinear characteristics of the dynamics



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- ▶ The hypothesis was tested in simulation
- ▶ Simulation results show that full reference following is possible despite the input nonlinearities in the system
- ▶ While the transient behaviour of the reference value is replicated, offsets and parasitic gains need to be compensated
- ▶ Could be implemented with improved model, doesn't improve estimate of current one.



Filip Maric

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Discussion I.

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- ▶ The maximum communication frequency of 385 Hz did not reach the 550 Hz goal.
- ▶ New encoding decreased packet size by 85%
- ▶ Compression algorithms could further improve the communication frequency
- ▶ UDP omits unnecessary retransmission
- ▶ Emergency shutdown in case of communication error
- ▶ Safety should be implemented against cyber attacks.

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Discussion II.

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- ▶ The EndoWrist's highly nonlinear nature made the modelling a challenge
- ▶ The imperfection of the data acquisition corrupts the models
- ▶ The models underestimate the force
- ▶ The grip force model has a delay of 0.2 s.
- ▶ The communication delay is negligible compared to the delay of the model
- ▶ The improvements caused by the Kalman filter proved to be minimal

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Simon Bjerre Krogh

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Don't call this conclusion??

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- ▶ Communication
 - ▶ Data representation changed
 - ▶ Communication protocol change
 - ▶ 64 % of communication speed reached
- ▶ Hammerstein Wiener modeling
 - ▶ Improvement on nonlinearities of the force feedback
 - ▶ Estimates the trend of the force