movement intelligence *before* control

a story on *where* to look in biology

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biology-inspired approach to robotics #1:

movement intelligence is

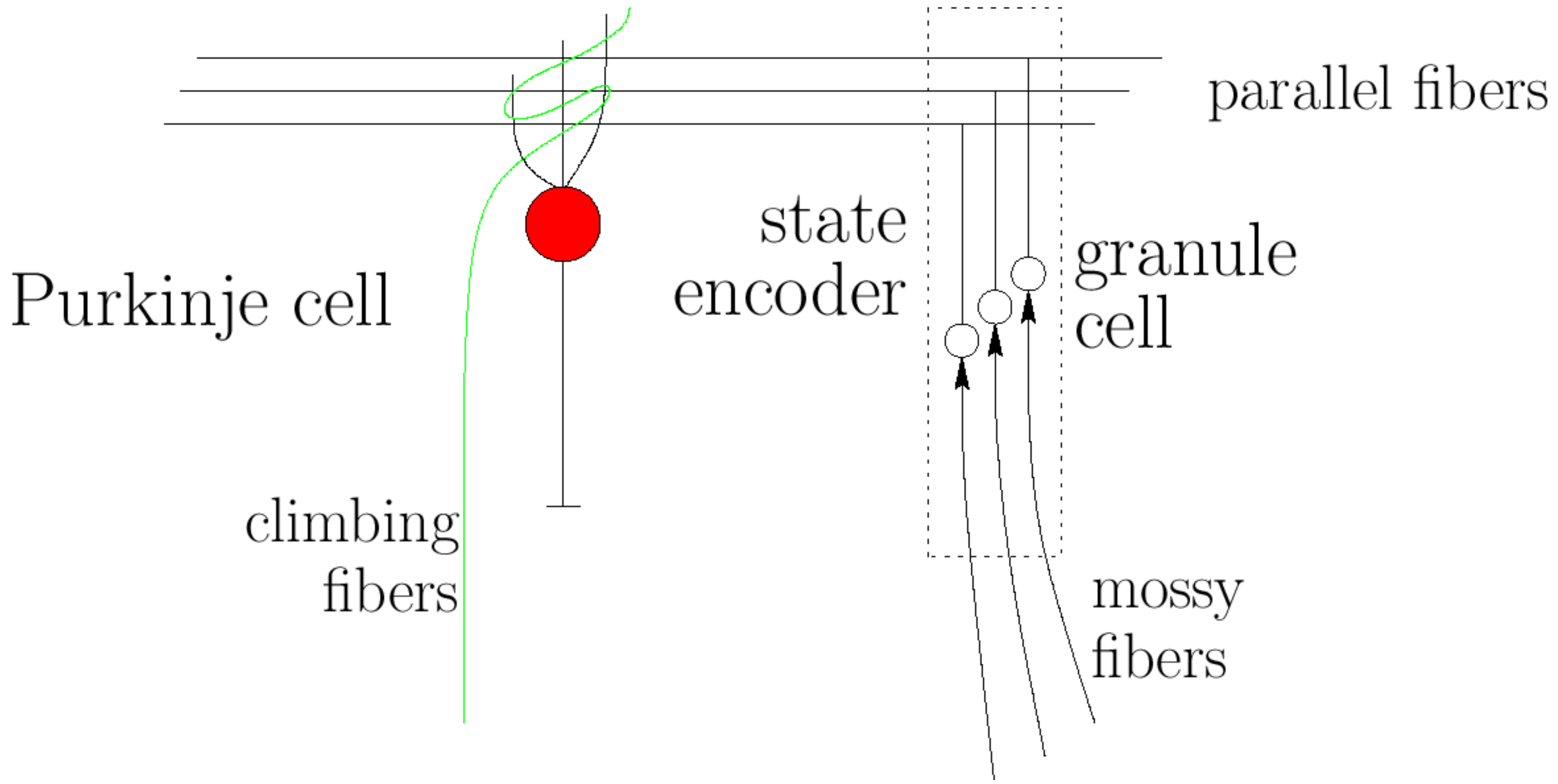
caused by

superior control

("a robot with a biological brain")

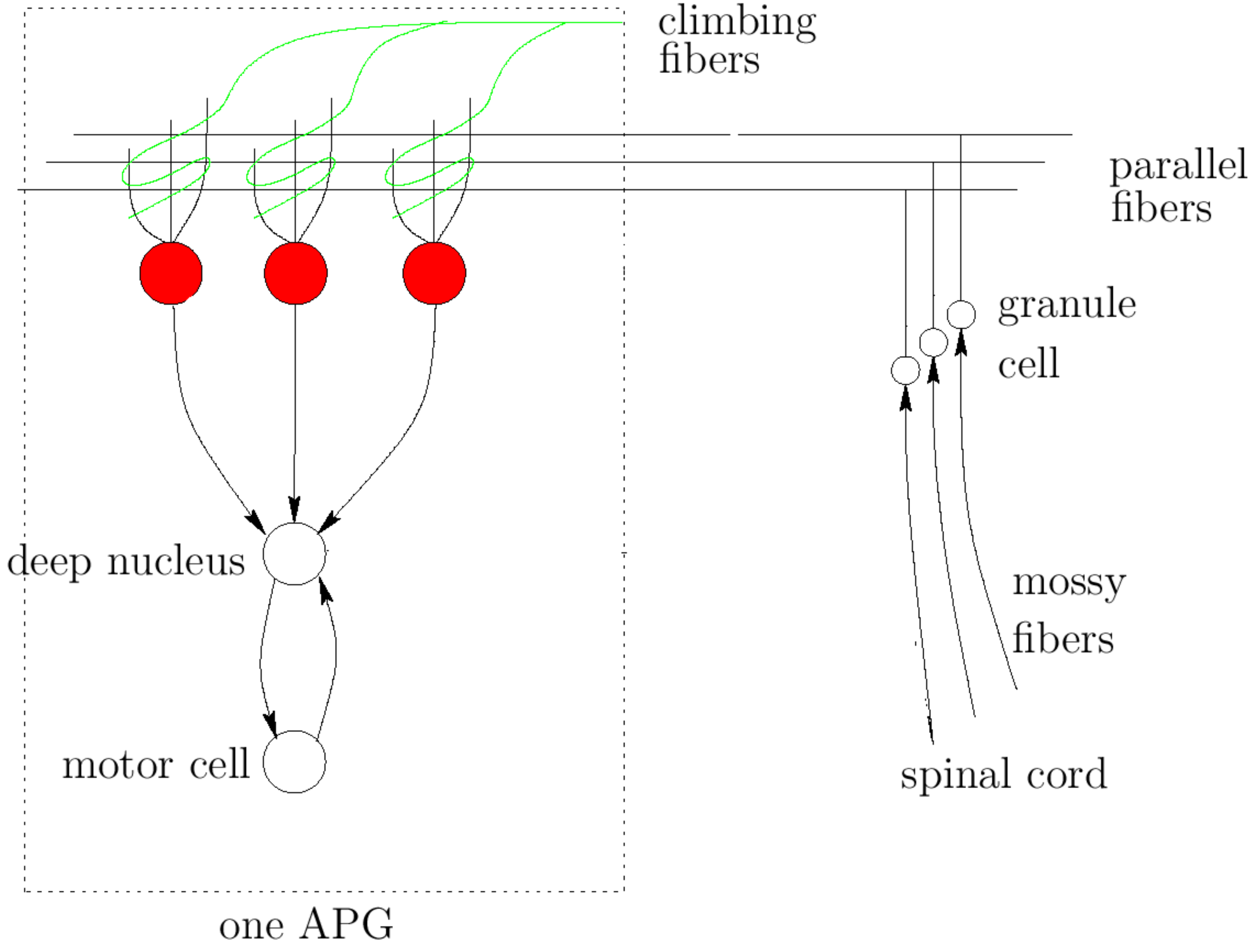
cerebellar models 1: the CMAC

- Braitenberg (1961)
- Marr (1969)
- Albus (1971)
- Albus (1975)



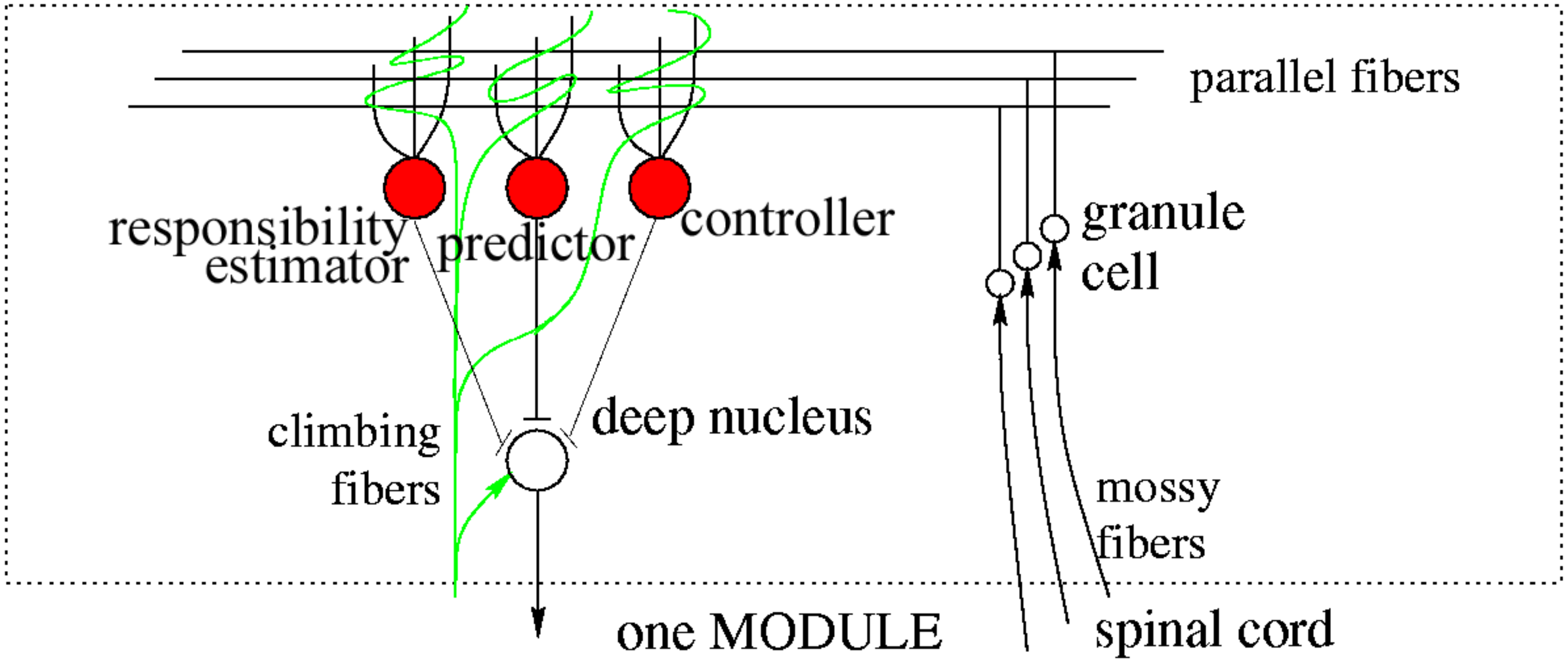
cerebellar models 2: the APG

- Houk, Barto, Fagg (1989)



cerebellar models 3: the MPFIM

- Wolpert, Kawato (1998, 2000)
- Peters, van der Smagt (2001)



and more and more...

- Smith‘s “Fairly Obvious Extension” (APG with vector-eligibility)
- Schweighofer’s model (biologically inspired)
- Hoff/Bekey Method (combined with spinal model)
- CNS-BU Model (VOR)
- Jabri et al (multi-layer Perceptron)
- 2009: Jörntell, Nilsson (high-level model “LSAM”)
- ...

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from high-level (cerebellar) views

- cerebellar lesions lead to *ataxia*, lack of order in movement---but movement is very possible

- there are *huge delays* in the PNS which prevent fast feedback loops

- recent theories see the cerebellum as a *filter* which smooths out cortical movement patterns with inertial feedback

- ...somehow the controlled system must be smarter

biology-inspired approach to robotics #2:

movement intelligence is

present **despite**

control

("a computer with a biological body")

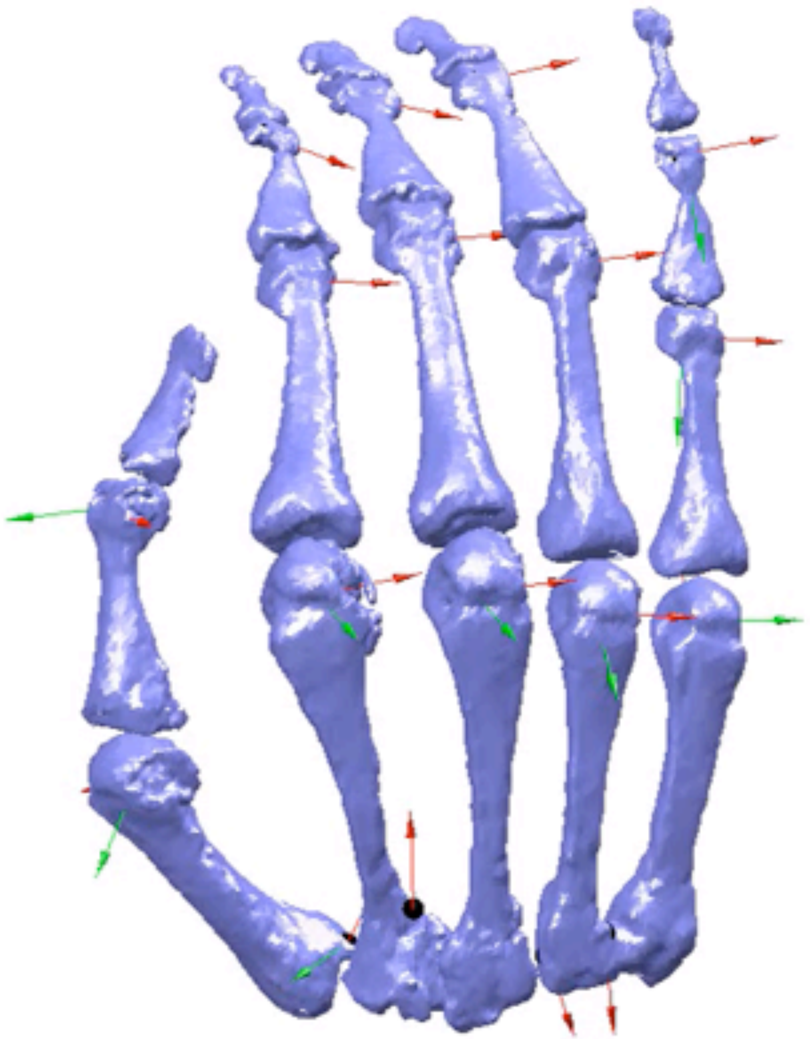
let's see how nature did all of these

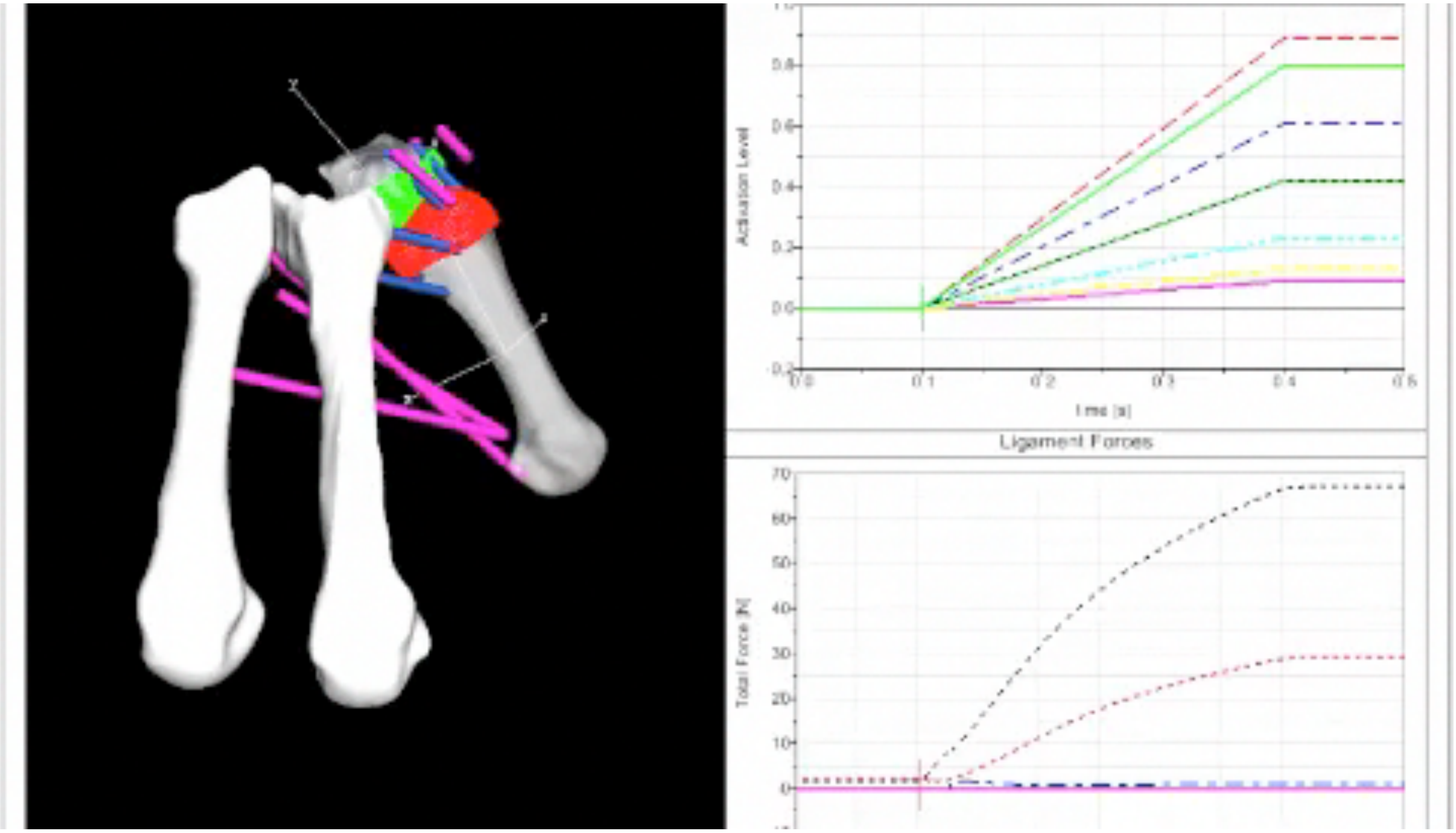
step 1: let us try to understand the human body in its

- kinematics
- statics
- dynamics

step 2: let us *then* add intelligent control

1 kinematics   problem: modelling the human hand





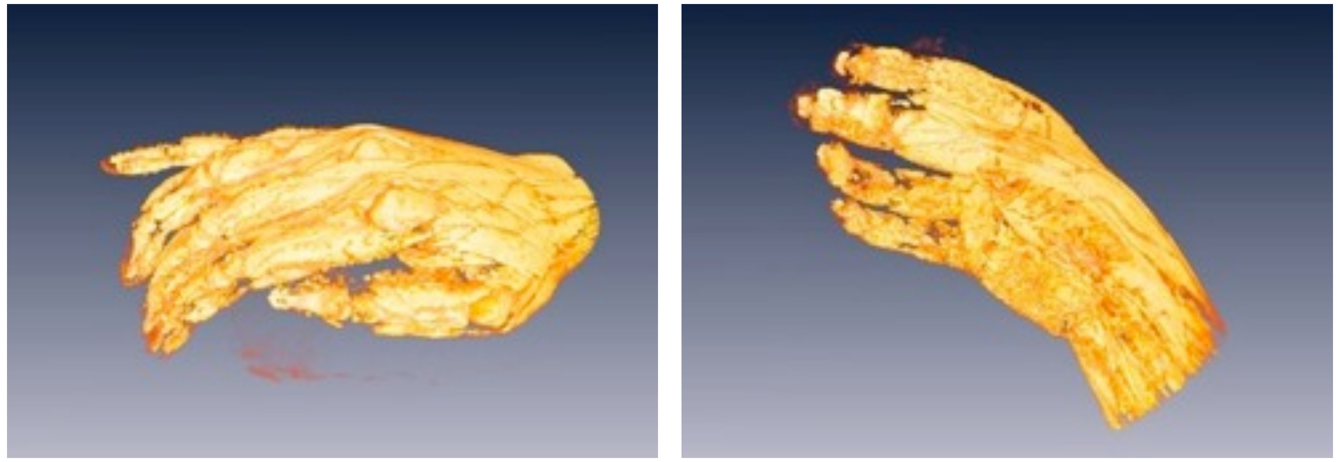
Stillfried & van der Smagt, Proc. ICABB, 2010
Stillfried & & van der Smagt, J. Biomech, 2012
Synek & Stillfried, BioRob 2012

1 kinematics problem’: tracking

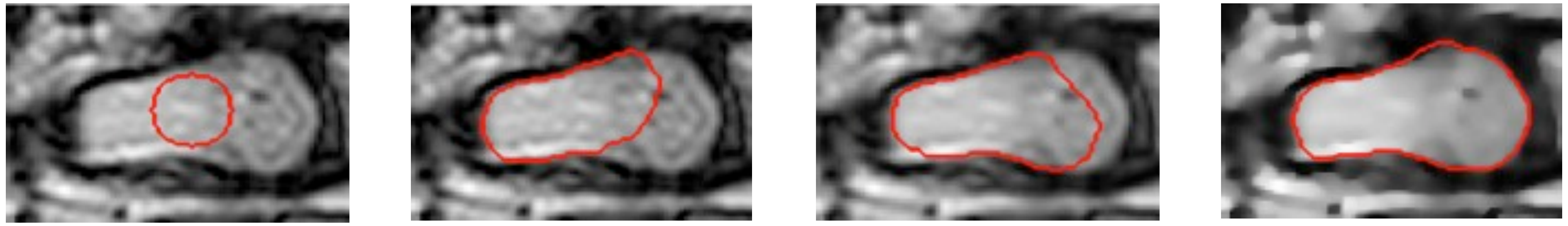
MRI

- repeatable position of rigid structure

- high costs
- costly post-processing
- single-participant only



- deformation not quantifiable



1 kinematics   problem': tracking

tracking system

- novel marker system
- "highly accurate"
- real-time

- costly
- skin deformations
- non-portable

- marker assignment done through unique markers

1 kinematics problem': tracking

Kinect

- "marker-free"
- real-time
- portable
- low accuracy

- uses particle filtering to do sequential Bayesian estimation

Cordella & & van der Smagt, BioRob 2012

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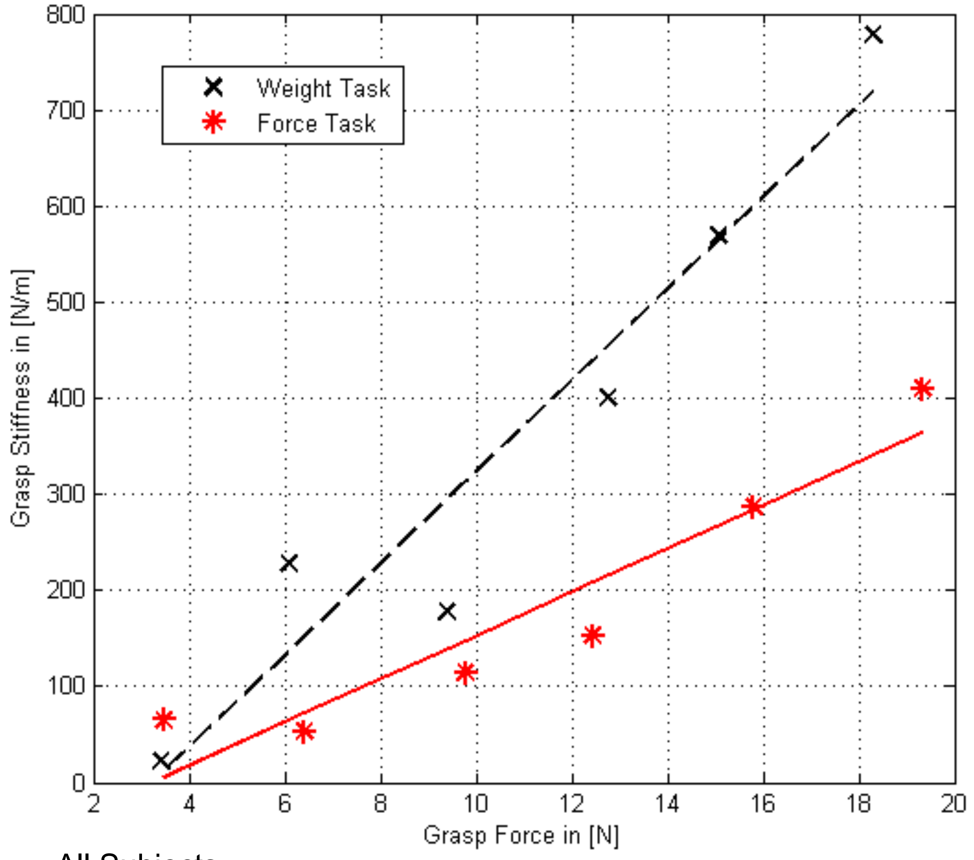
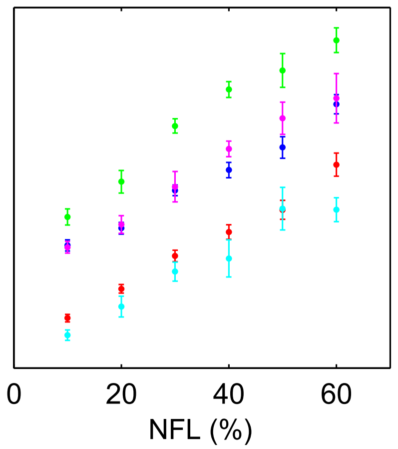
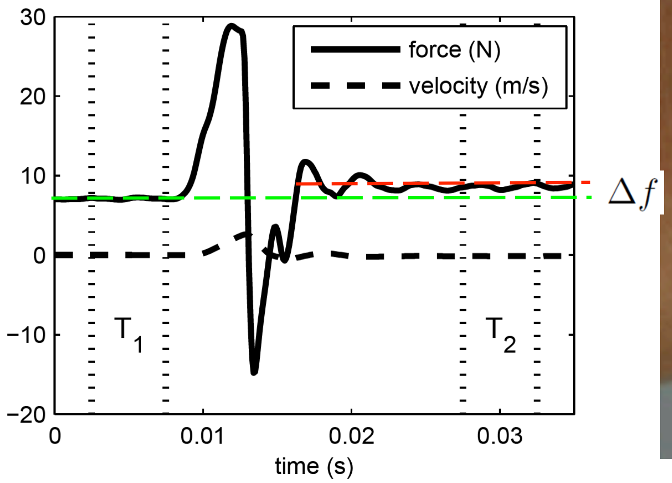
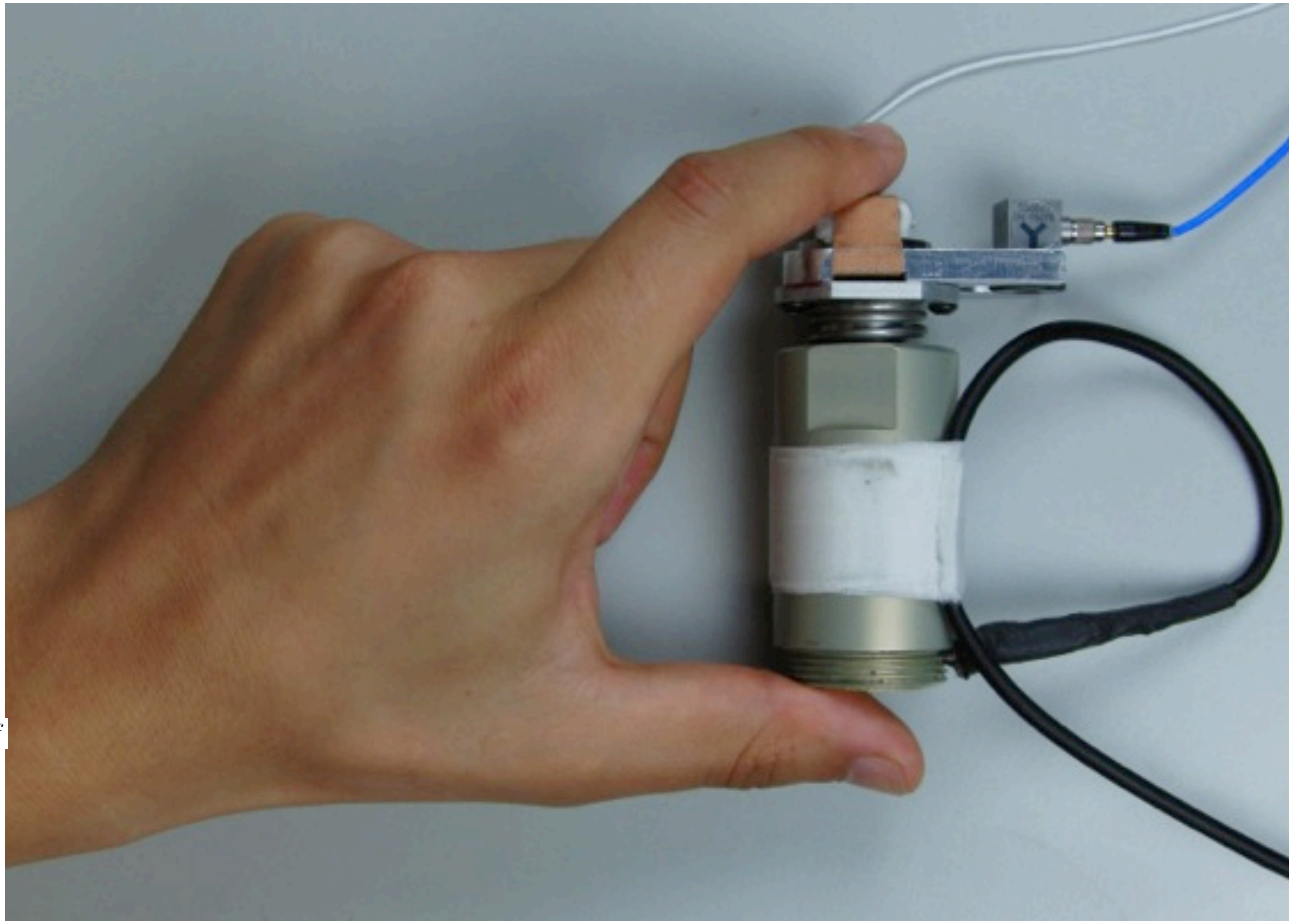
intrinsic stiffness of the human fingers



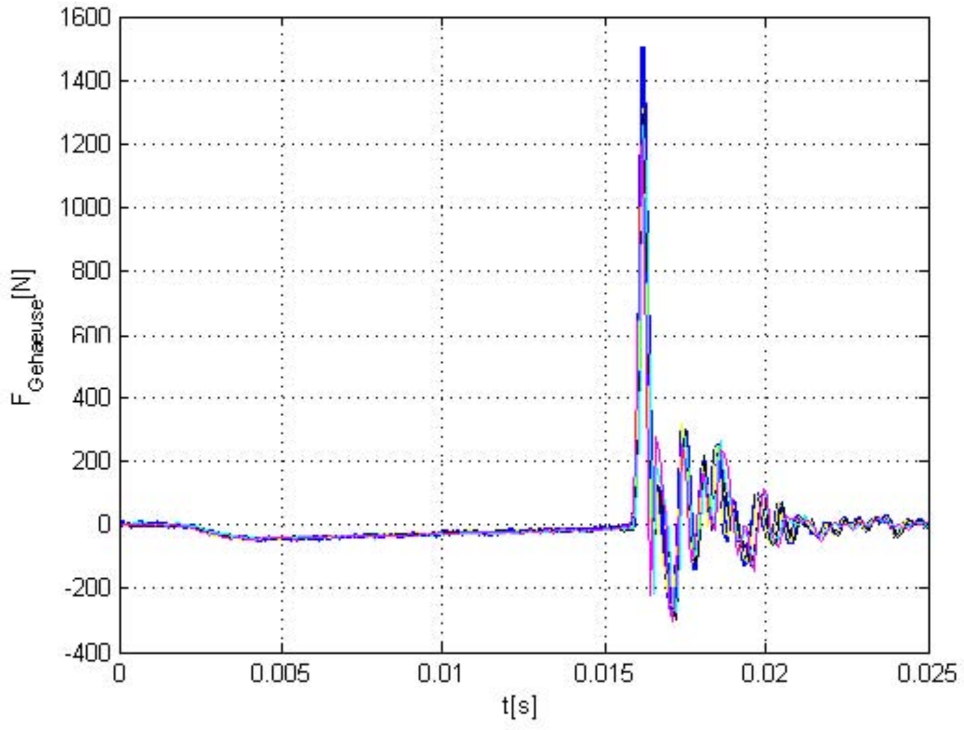


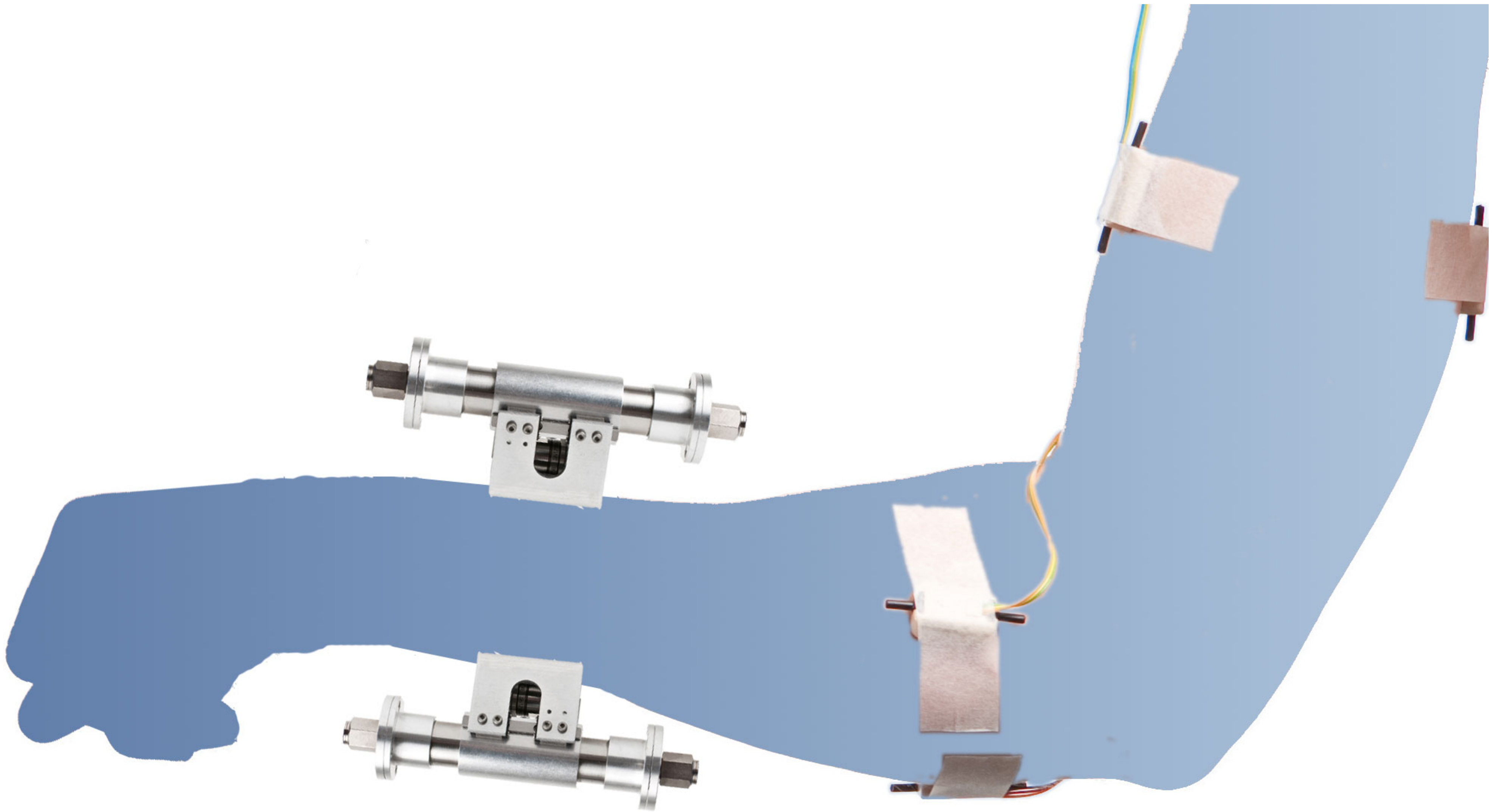




Höppner & & van der Smagt, IROS 2012

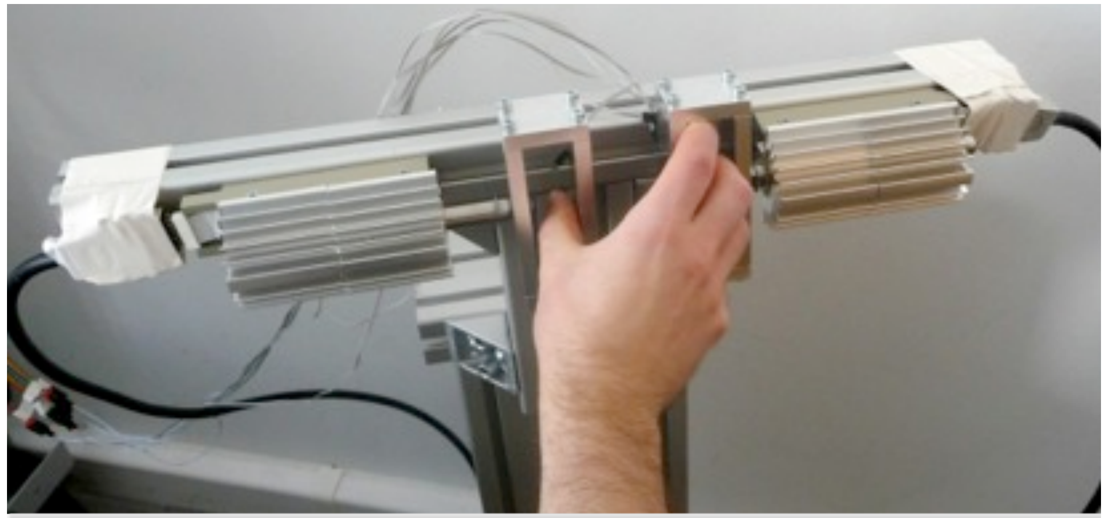
2 statics intrinsic stiffness of the human **limbs**

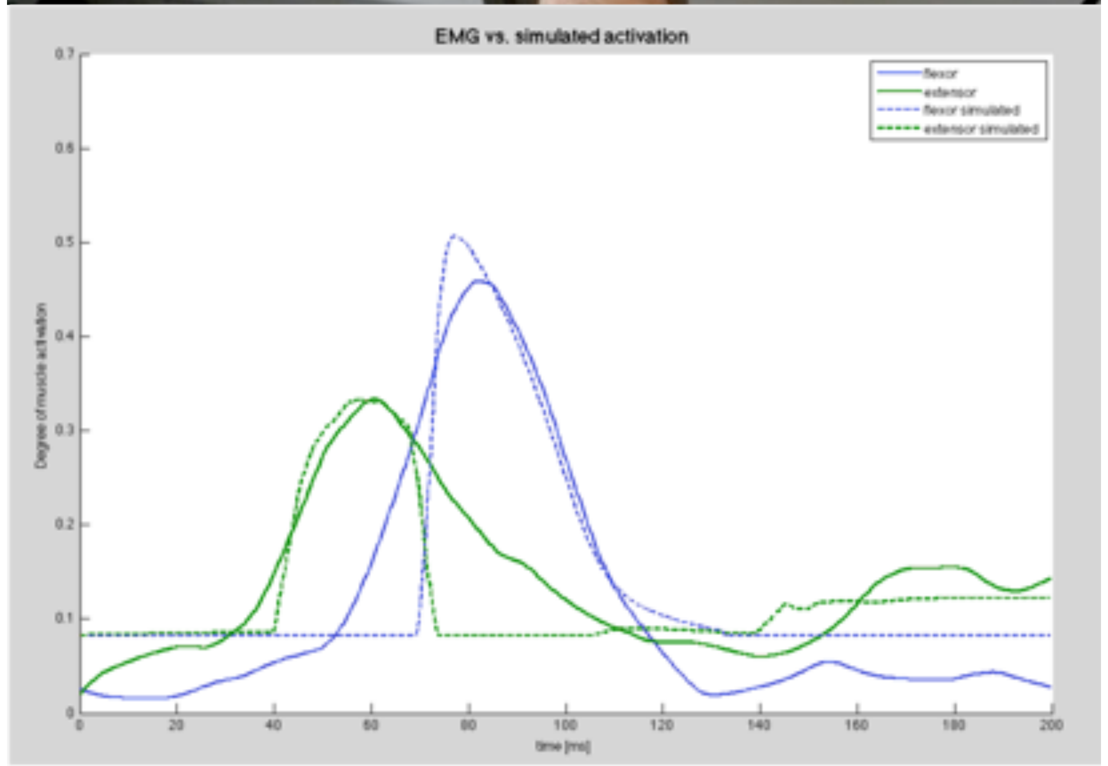


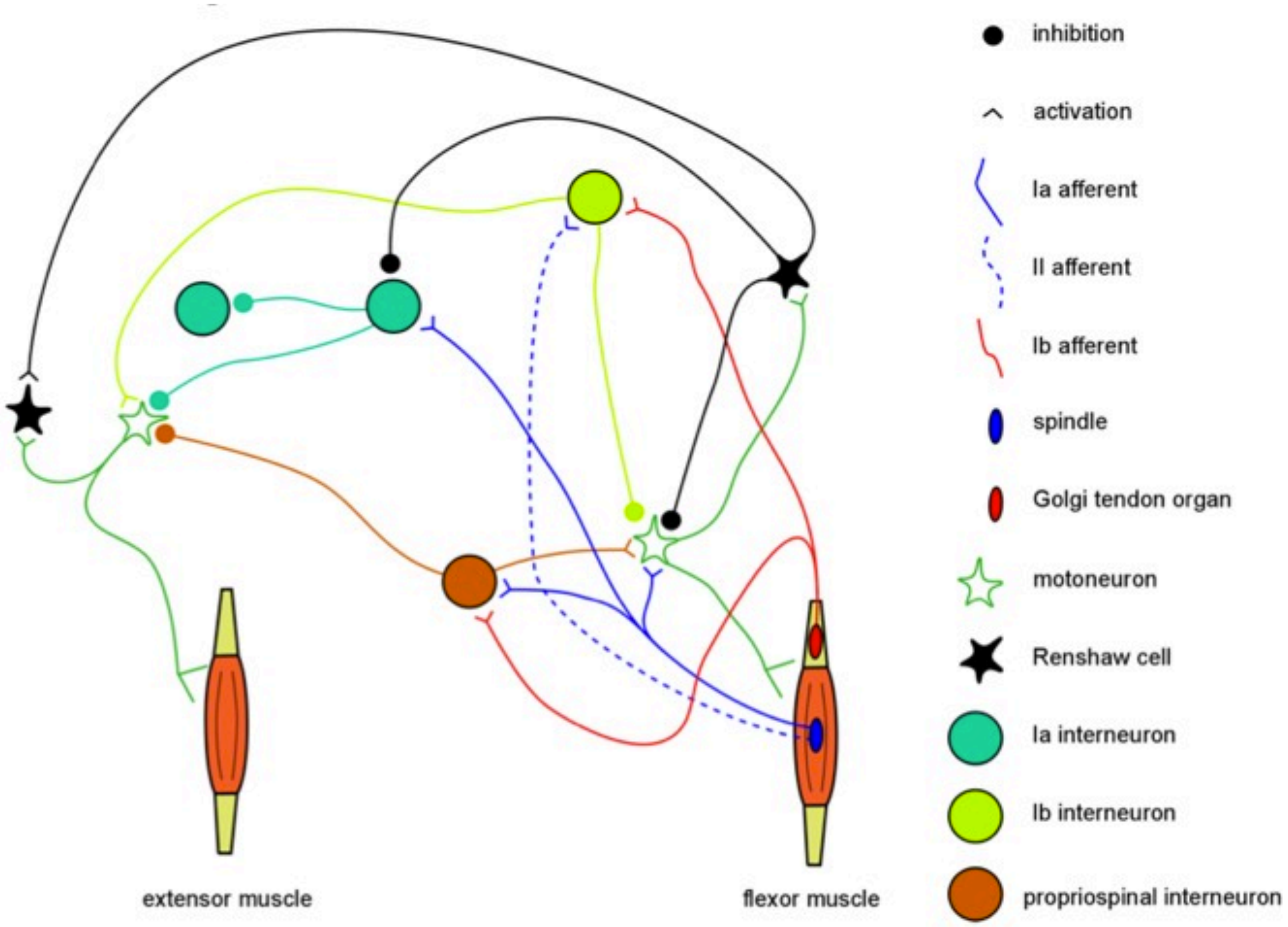


Höppner & & van der Smagt, Proc. ICABB, 2010

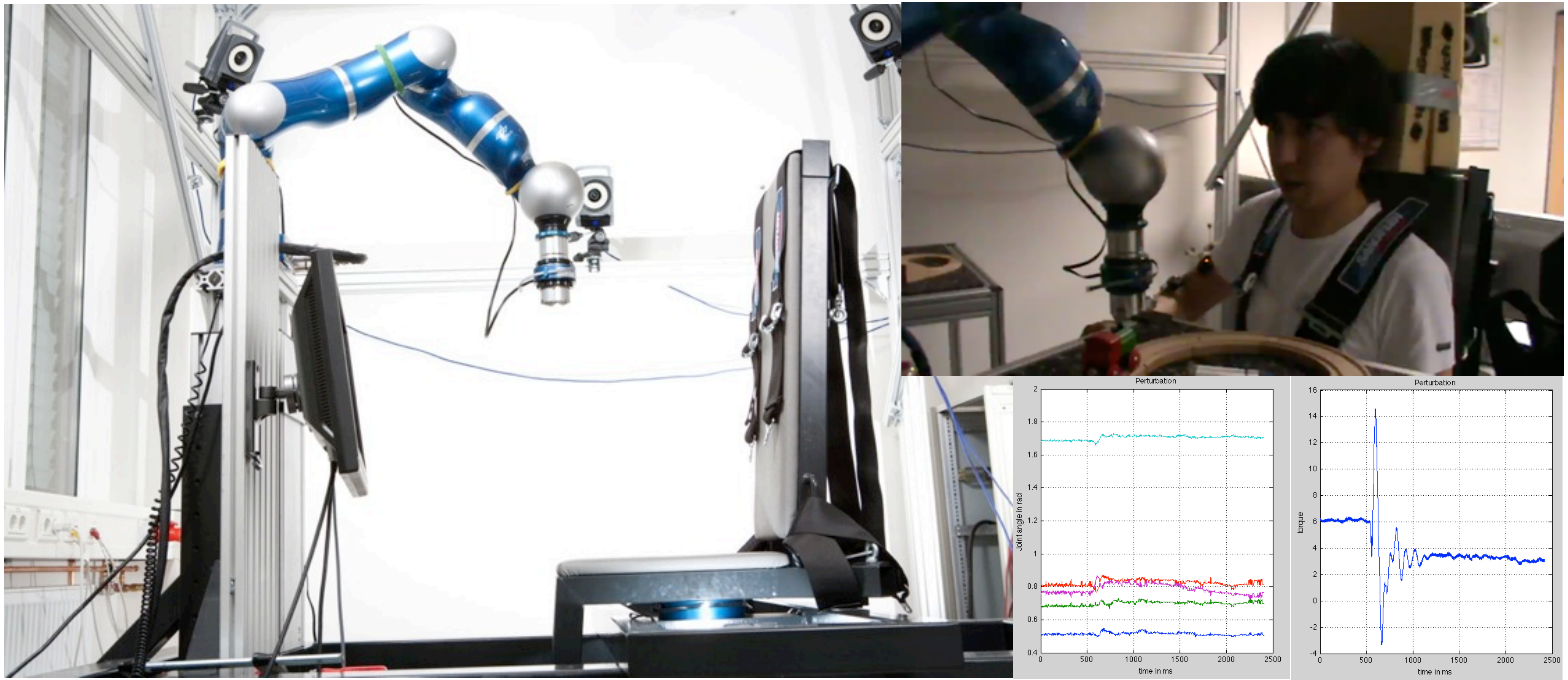
3 dynamics controlled stiffness of the human fingers







3 dynamics controlled stiffness of the human **limbs** (5D)



Lakatos & & van der Smagt, NCM 2012
Lakatos & & van der Smagt, ISER 2012

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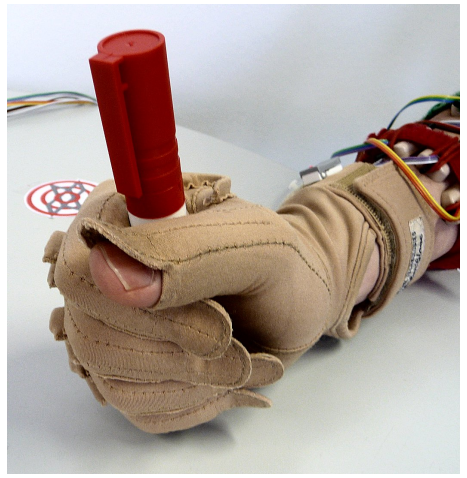
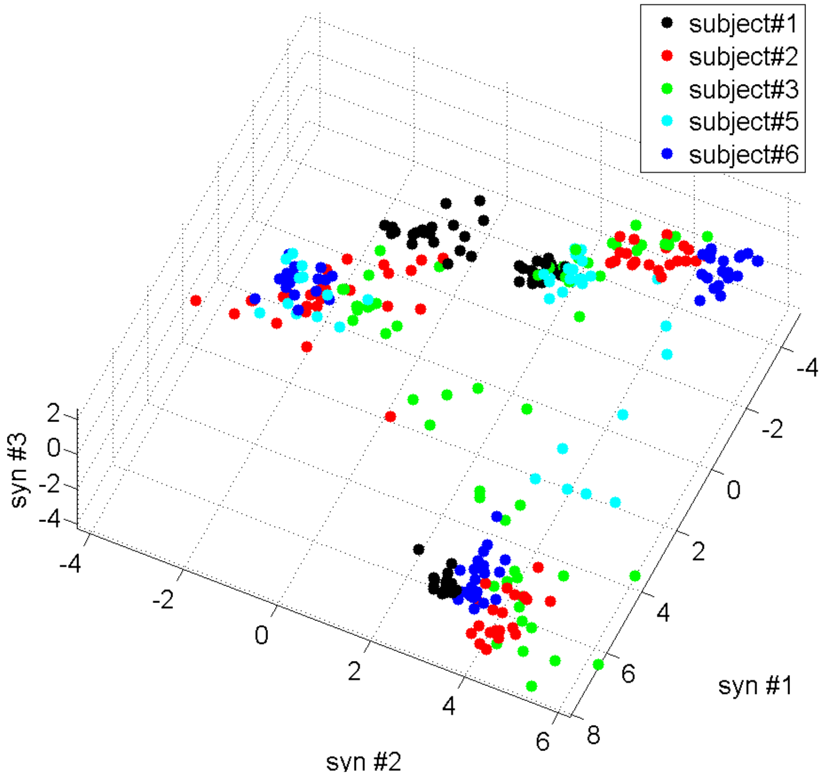
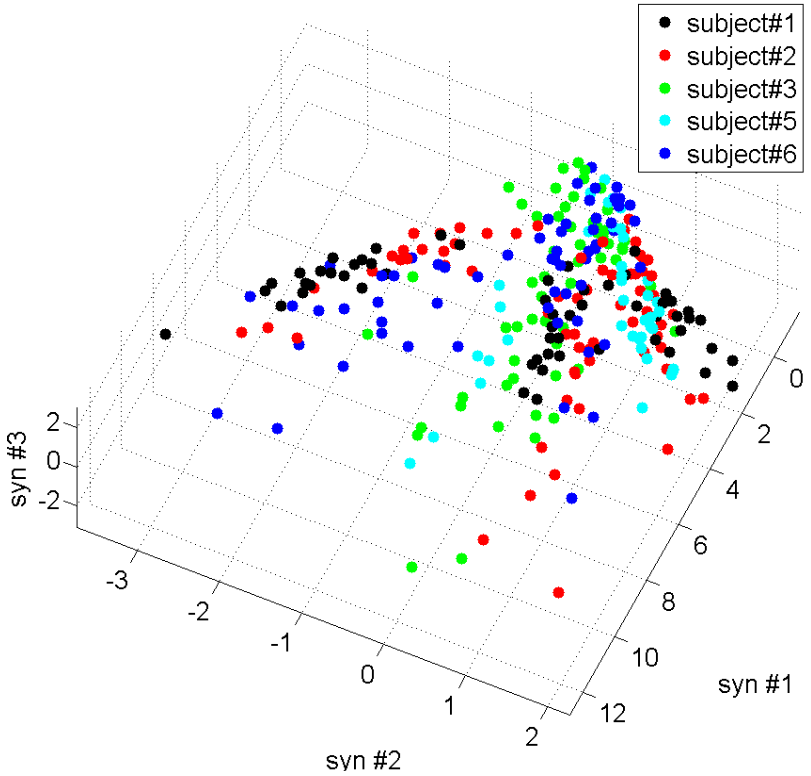
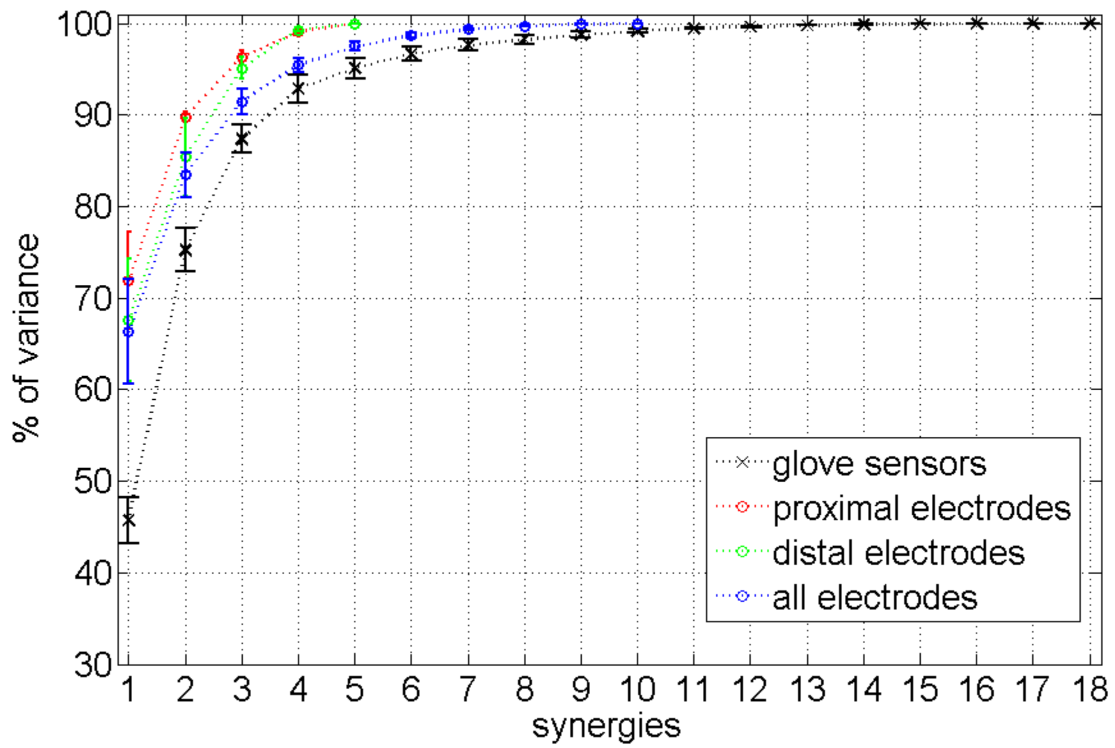
nature copes by reducing DoF to DoM



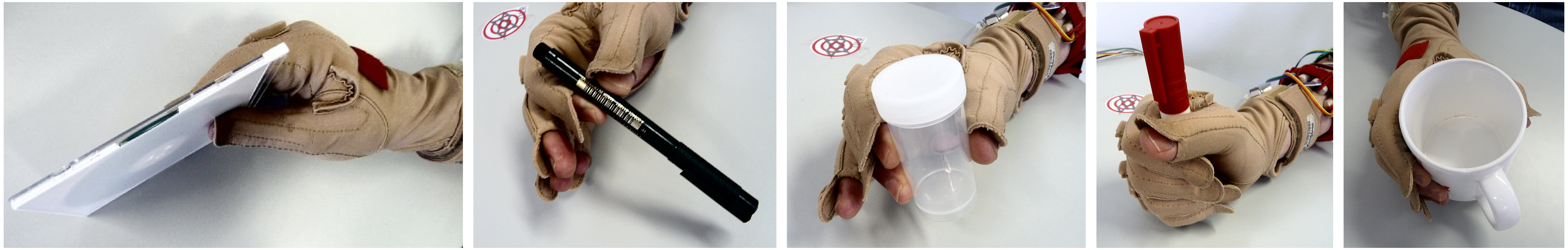


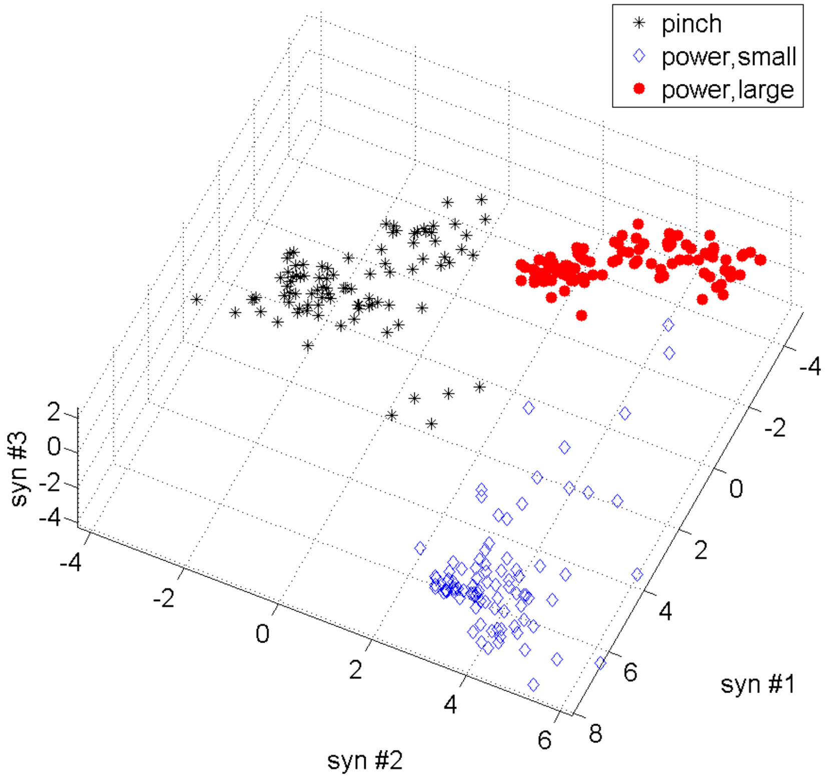


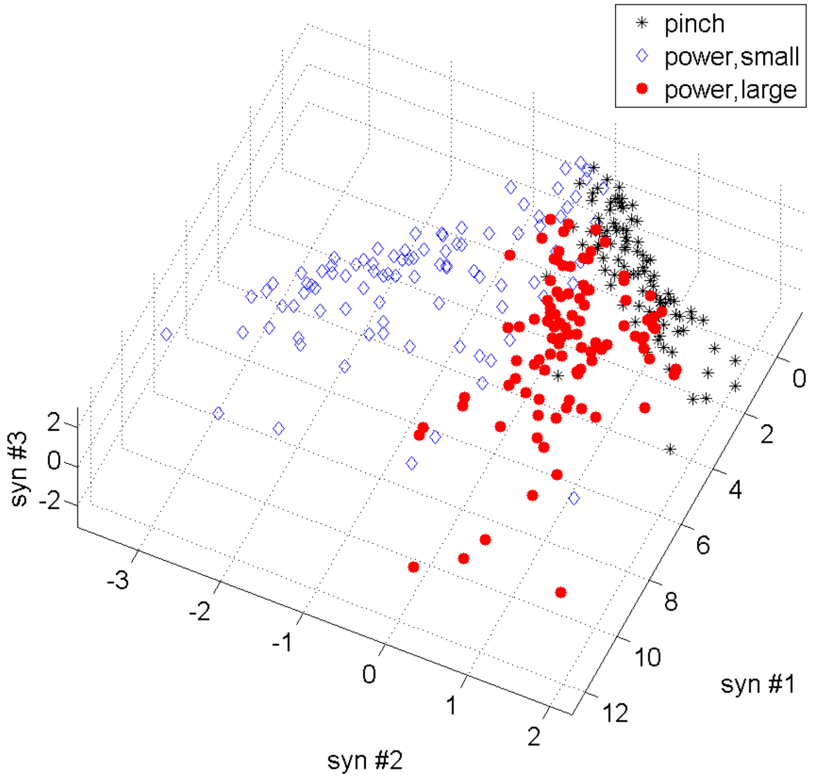
- PCA of EMG of all **grasps**, separated by **user**

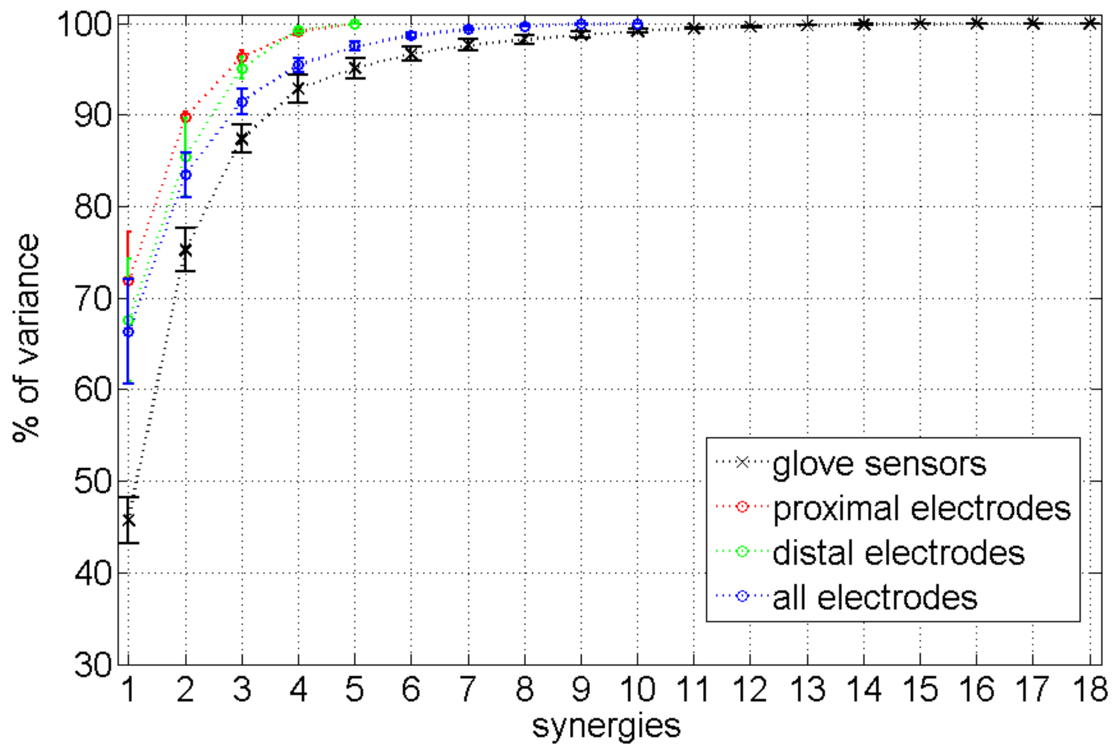
Castellini & van der Smagt, ICAR 2011

nature copes by reducing DoF to DoM









- PCA of EMG of all **users**, separated by **grasp**

Castellini & van der Smagt, ICAR 2011

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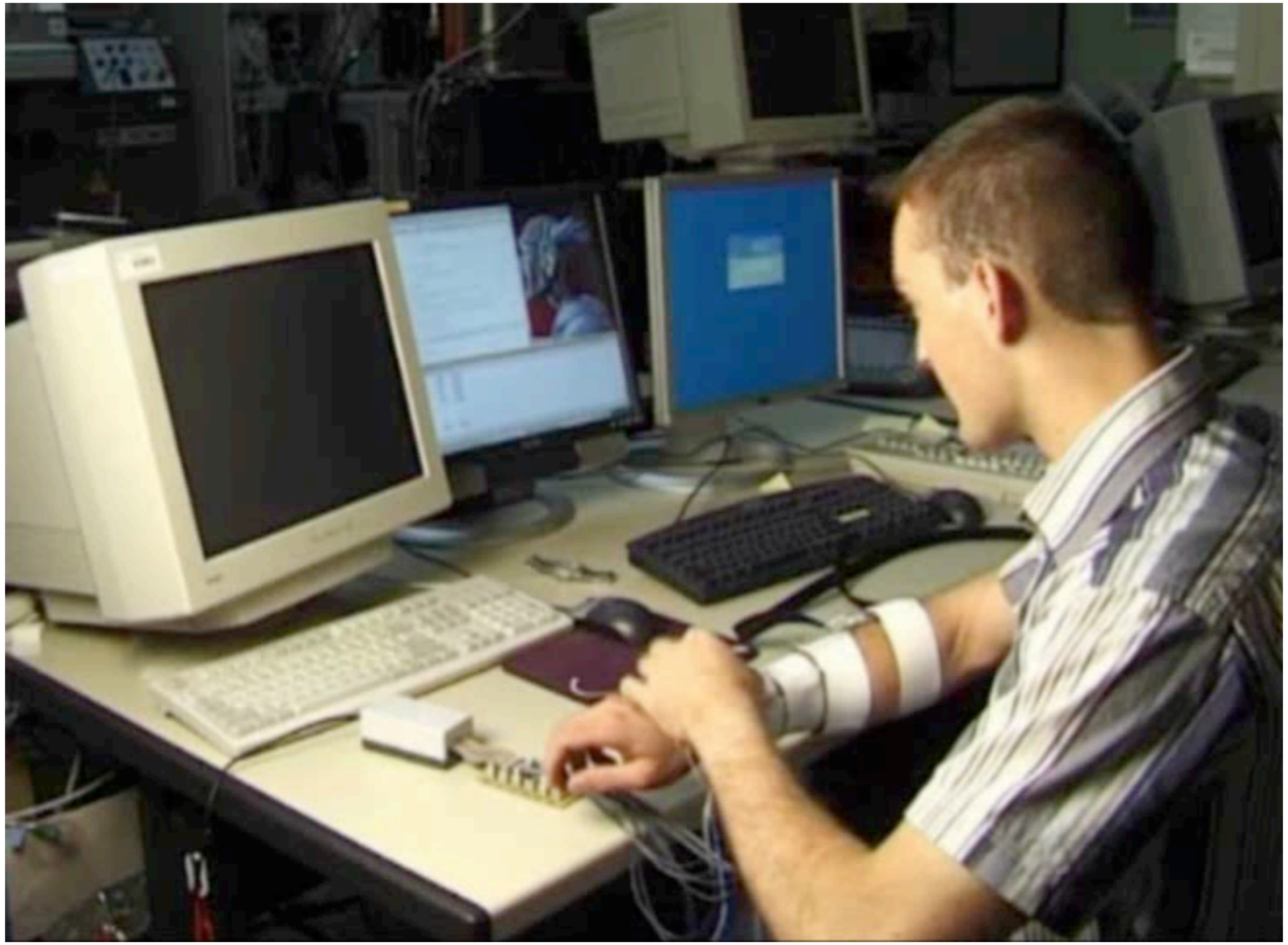
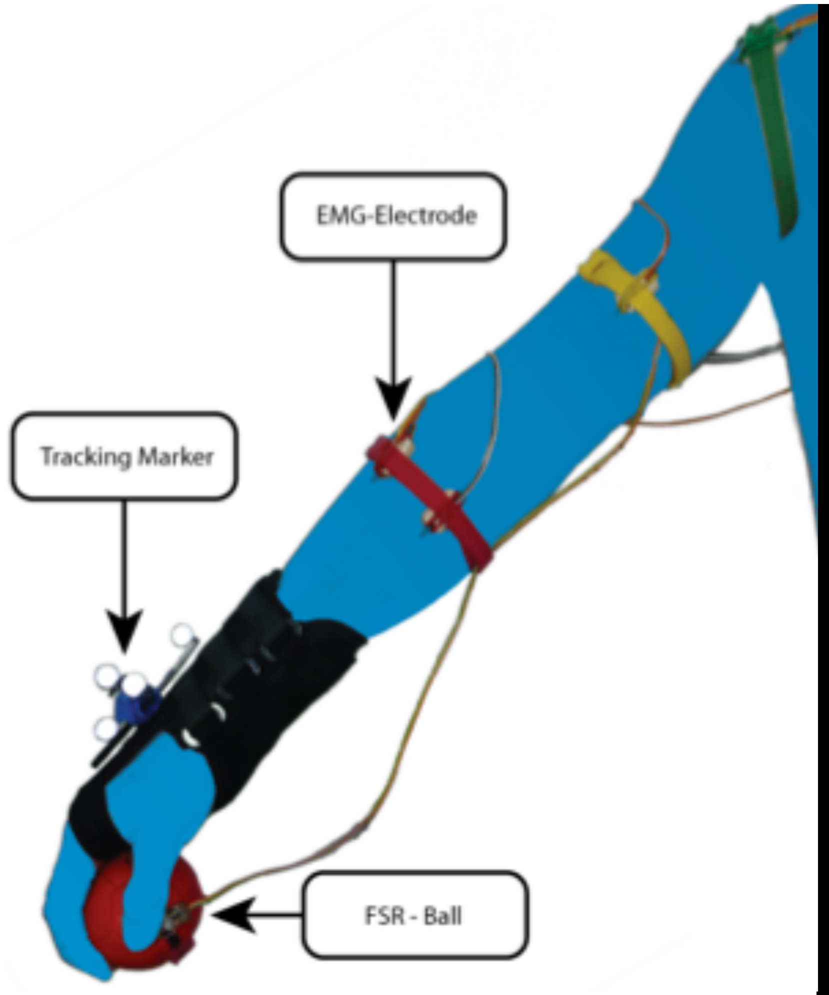


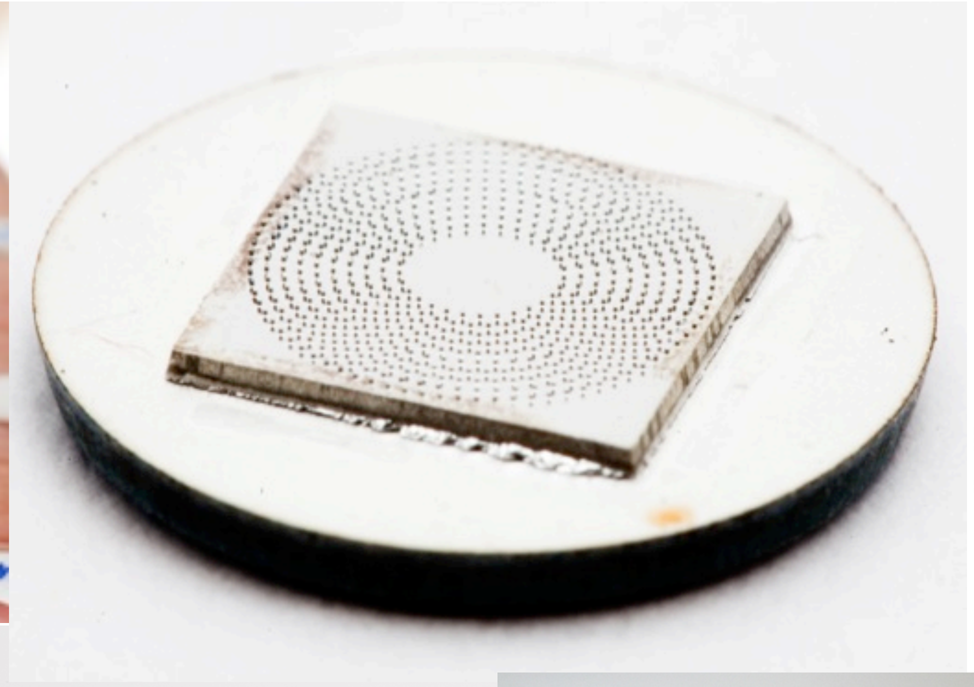
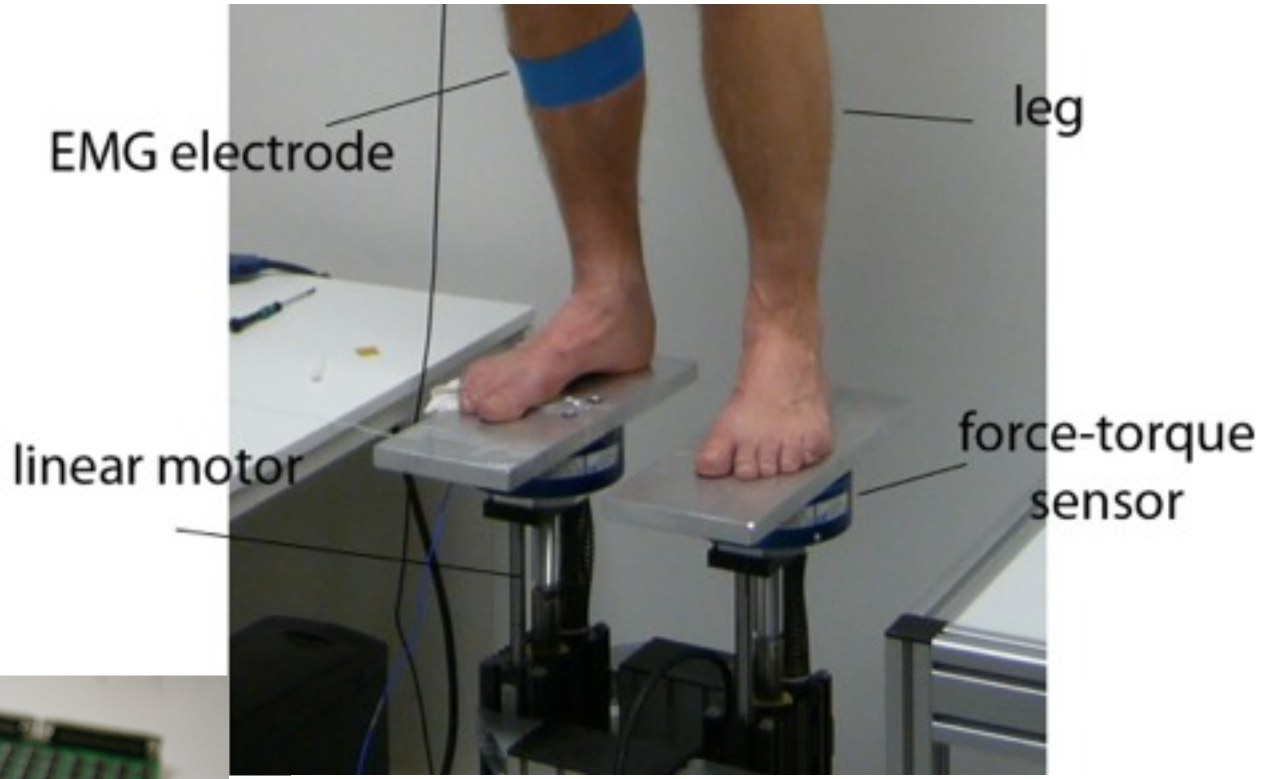
Bitzer & van der Smagt, 2006
Castellini & van der Smagt, 2009

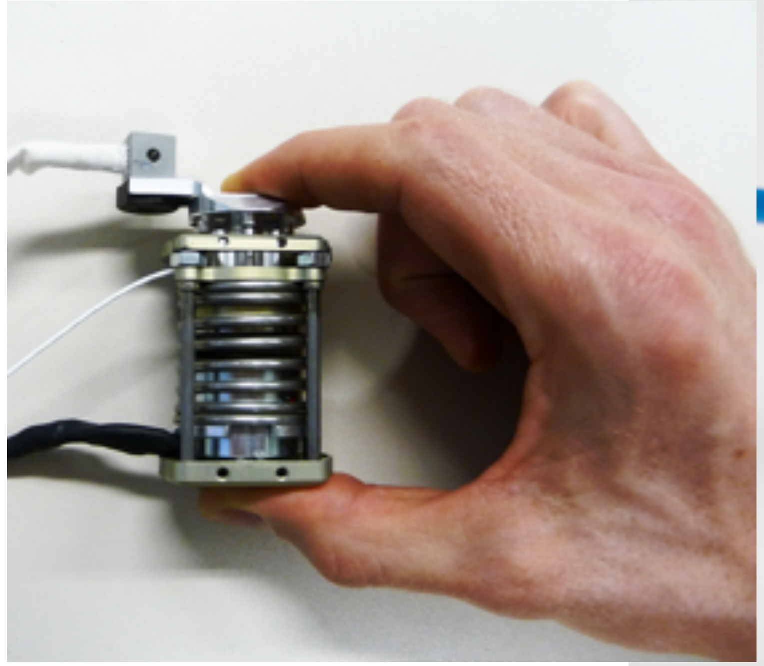
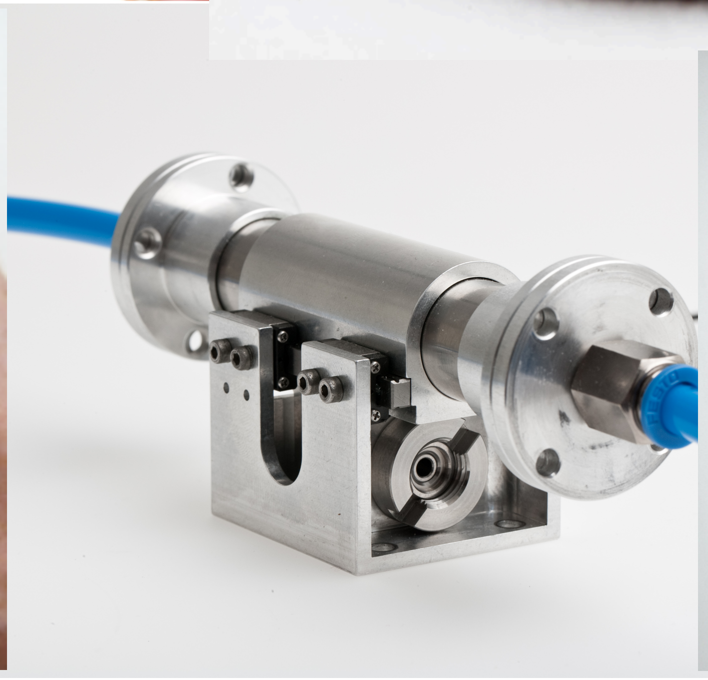
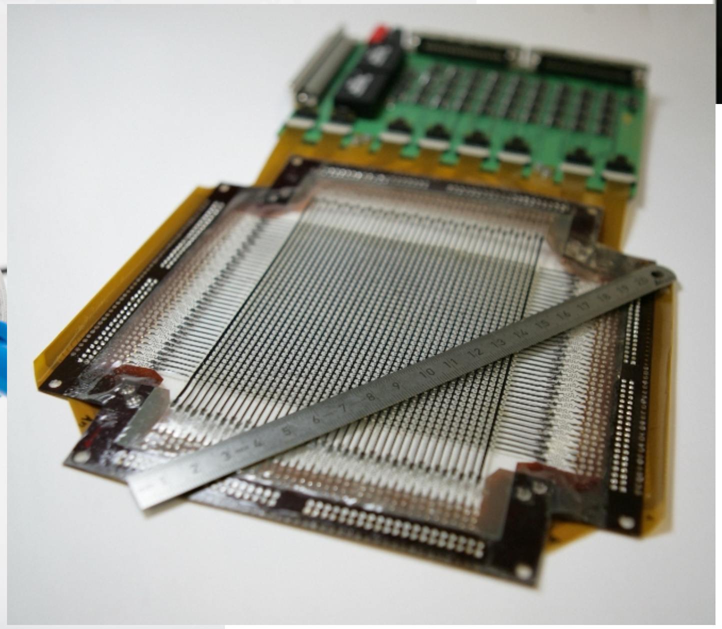
back to intelligent control arm



Vogel & & van der Smagt, IROS 2011

the technology we built


DLR TUM

credits

the 2012 BRML group:
Justin Bayer (time series learning)
Claudio Castellini (prosthetics)
Nadine Fligge (grasping)
Agneta Gustus (hand dynamics)
Hannes Höppner (arm dynamics)
Dominik Lakatos (robot dynamics)
Christian Osendorfer (deep nets)
Thomas Rückstiess (reinf. learn)
Georg Stillfried (hand model)
Michael Strohmayr (skin)
Sebastian Urban (map learning)
Holger Urbanek (EMG)
Jörn Vogel (BCI)

supported by:
The Hand Embodied (FP7)
NinaPro (SNF)
SPP autonomous learning (DFG)
STIFF (FP7) (past)
VIACTORS (FP7) (past)
SKILLS (FP6) (past)
CoTeSys (DFG) (past)
SENSOPAC (FP6) (past)
NEUROBOTICS (FP6) (past)

students:
Sebastián Aced (EMG electronics)
Constantin Böhm (arm impedance)
Daniele Casaburo (EMG source sep.)
Sarah Diot-Girard (deep networks)
Dominikus Gierlach (spinal models)
David Gonzalez (ultrasound)
Andreas Goss (finger model)
Barbara Hilsenbeck (finger EMG)
Rachel Hornung (learning)
Daniela Korhammer (EEG)
Marvin Ludersdorfer (feetback)
Stefan Zoell (design)

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