Sensory integration in human balance control

Lorenz Assländer

Albert-Ludwigs-Universität Freiburg

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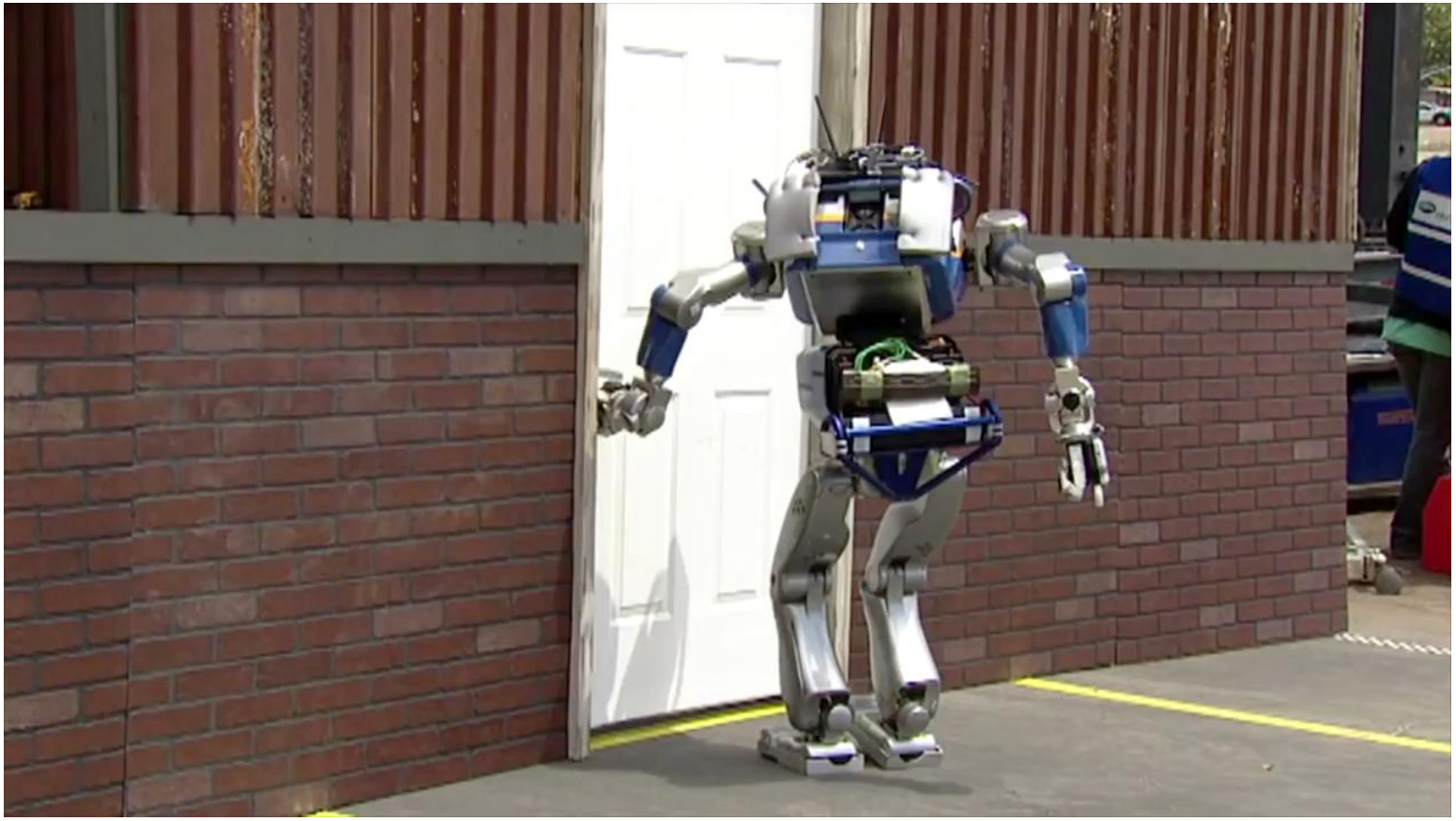
Fails in DARPA challenge



https://www.youtube.com/watch?v=_oP4eMUT9Xw

Outline

- Background
  - Biological aspects
  - Human experiments
- DEC – Model of human balancing
- Current work
  - Parameter estimation with non-linear thresholds
  - Interaction of noise and non-linear thresholds
  - Modularity and from posture to movement

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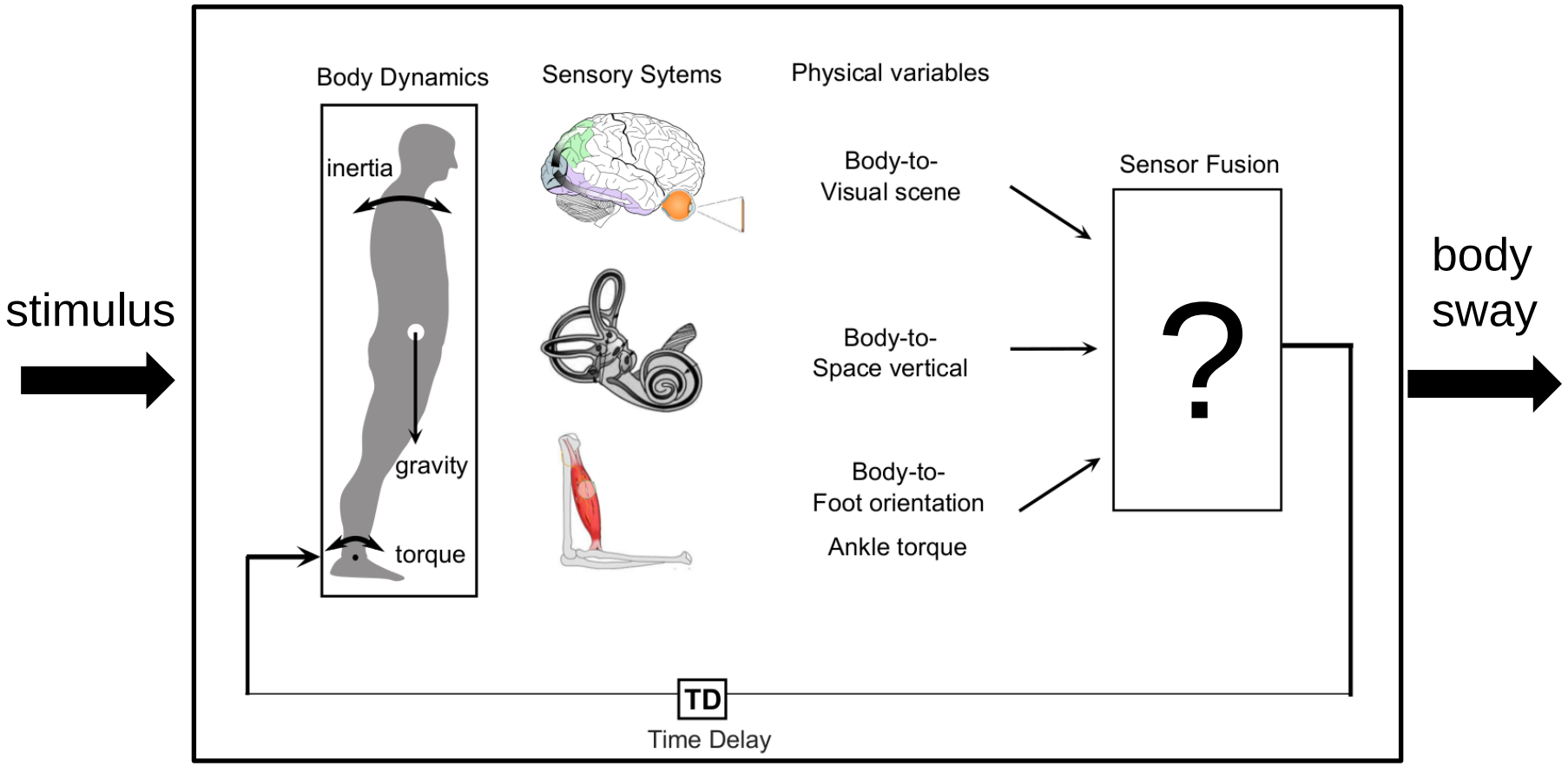
Biological aspects

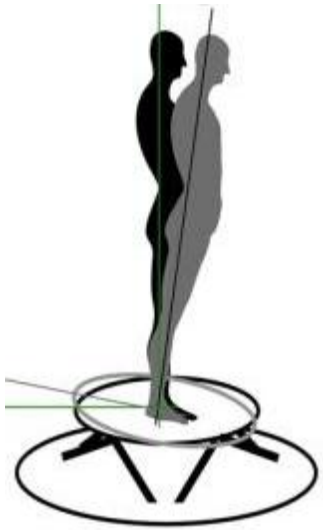
- Sensor concept
  - Action potentials → continuous signals
  - Biological transducers → physical variables
- Mostly non-linear systems
- Noisy and inaccurate sensory information
- Long neural time delays
- Self adapting and calibrating system
- …

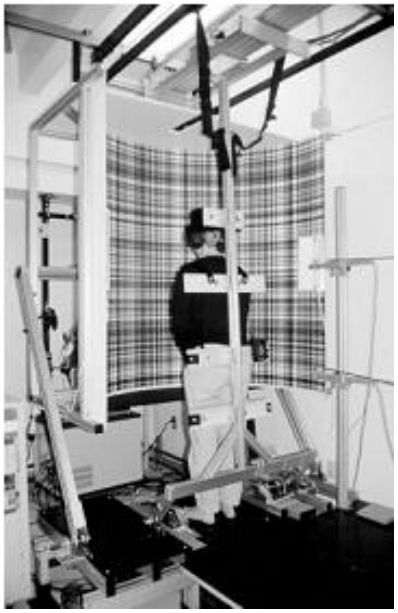
Black Box approach



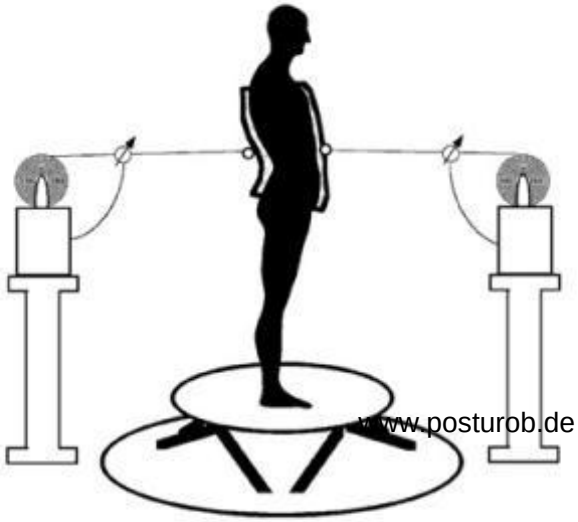
Some stimuli

Support surface motion
tilt / translation





Push/ Pull stimuli

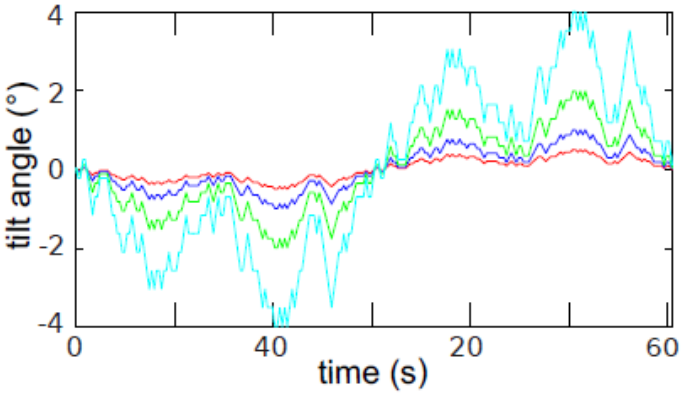


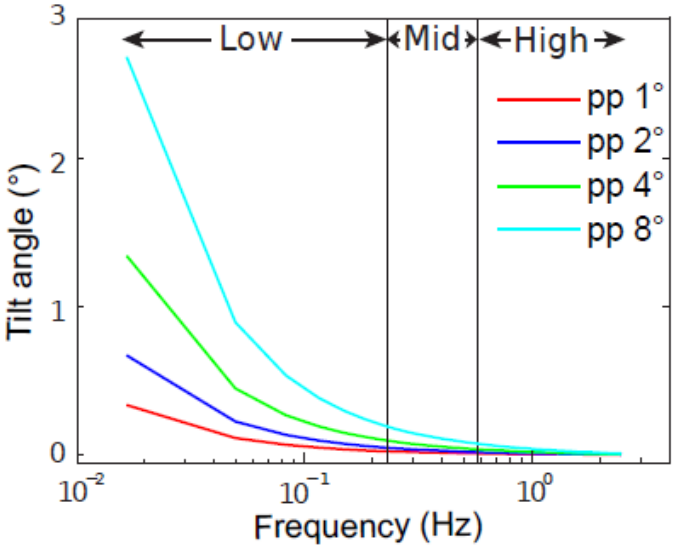
Visual Scene motion

Human experiments

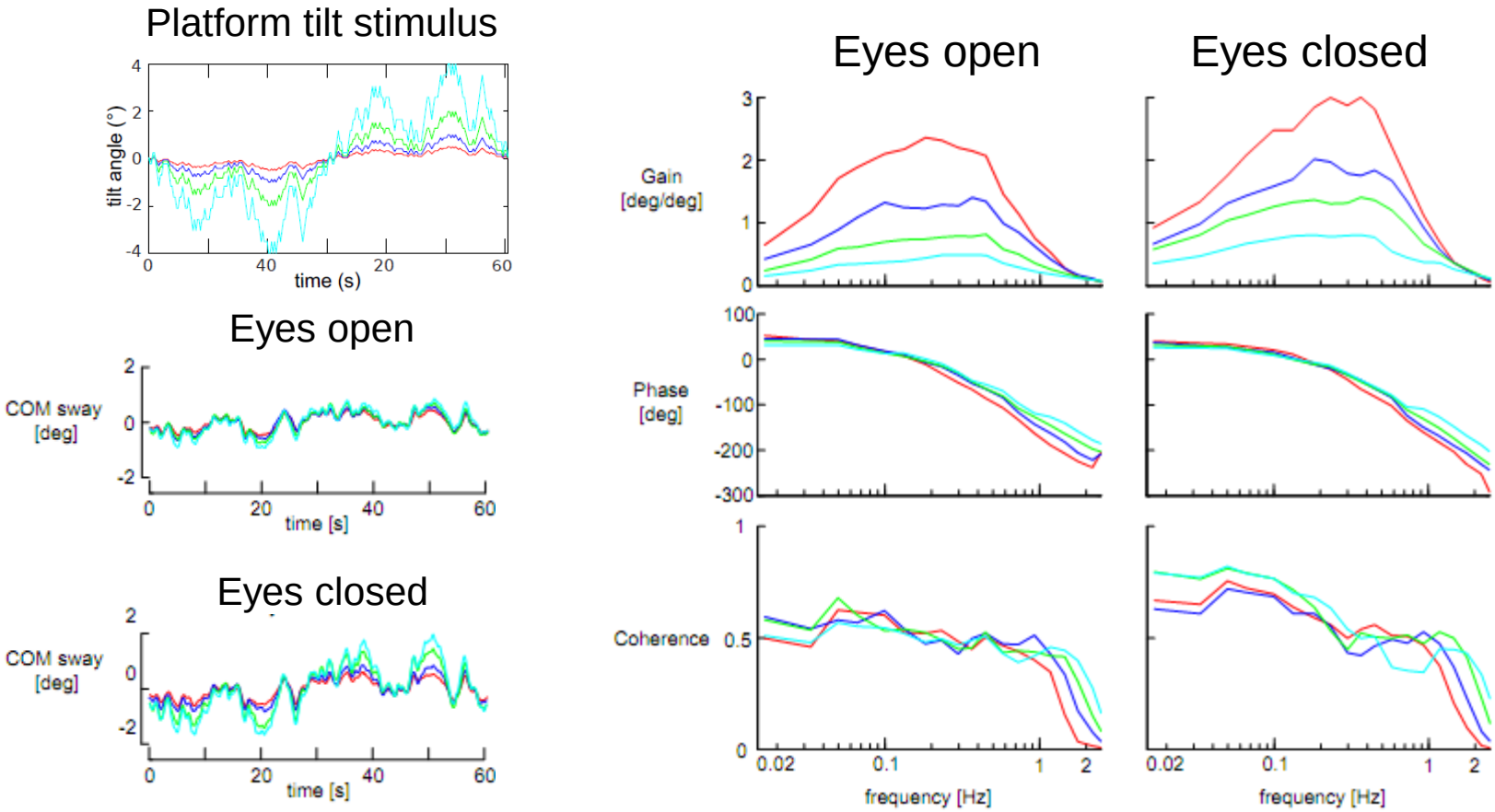
Eyes open Eyes closed

Stimulus sequence



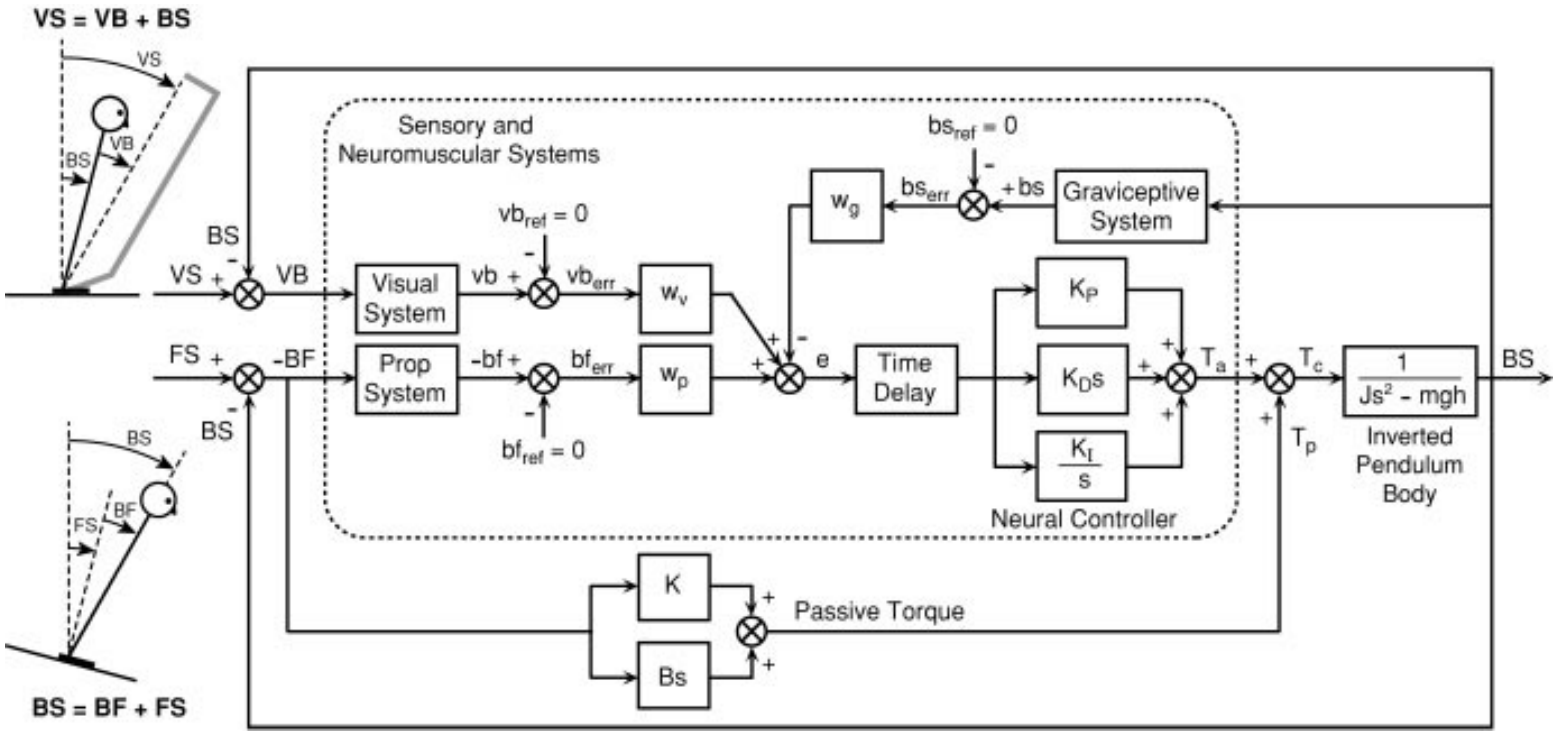


Human sway responses



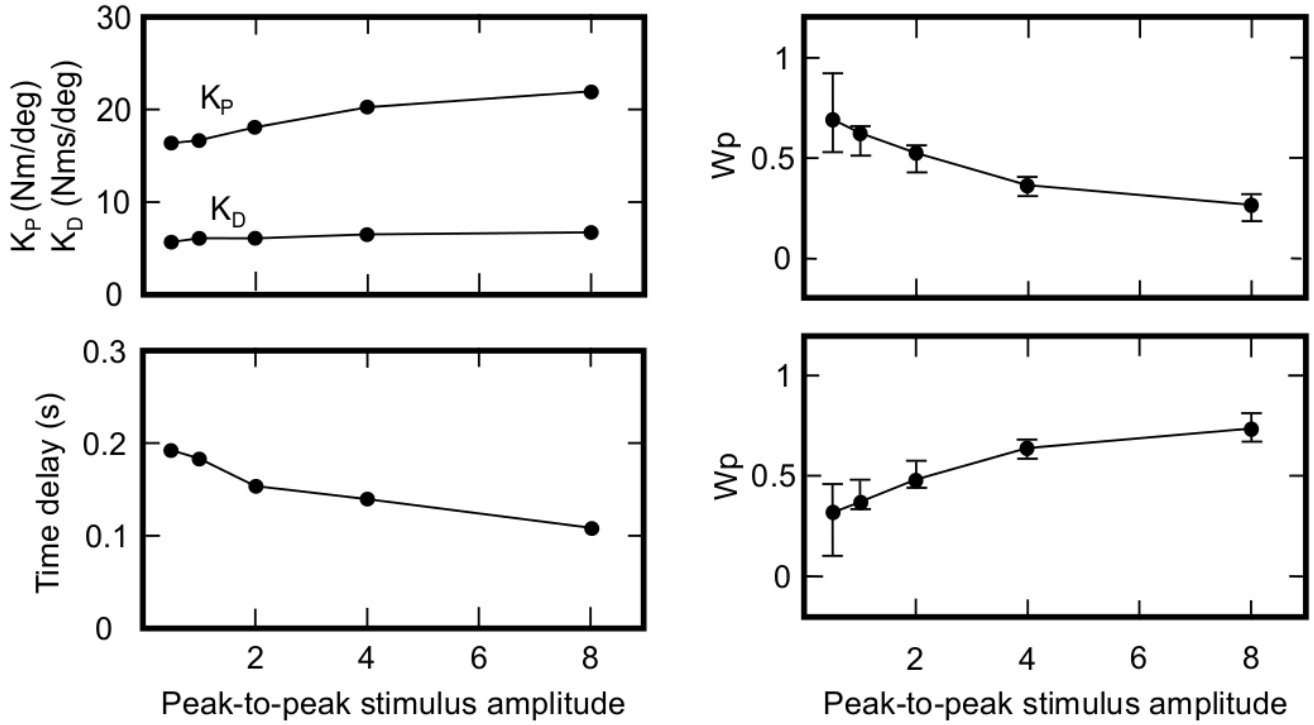
7 subjects, 10 cycles per subject

IC Model



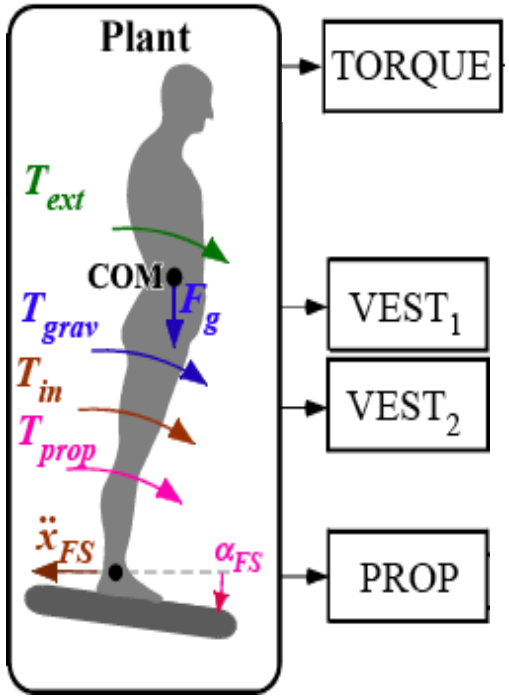
Peterka 2002

IC Model Parameters



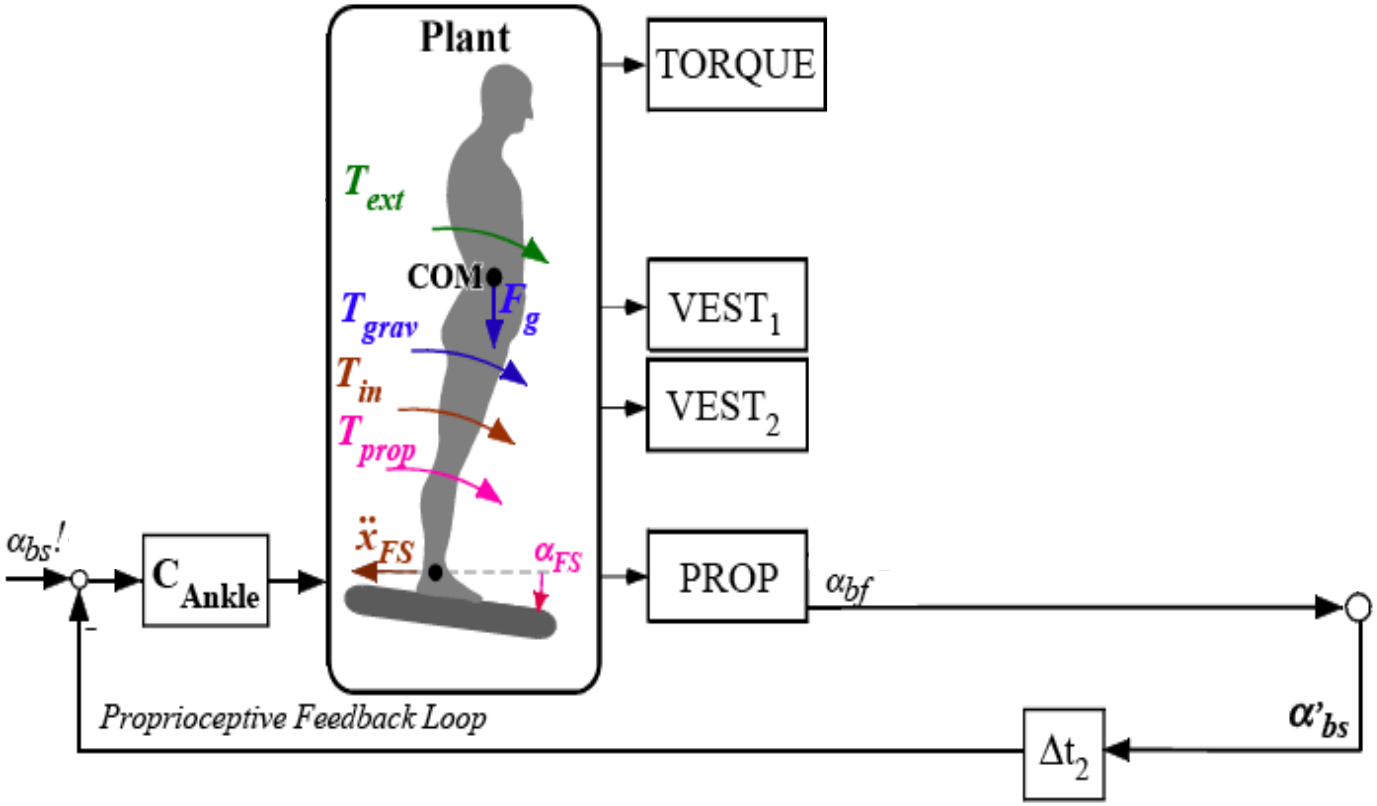
Data from Peterka 2002

DEC model – Neurological perspective



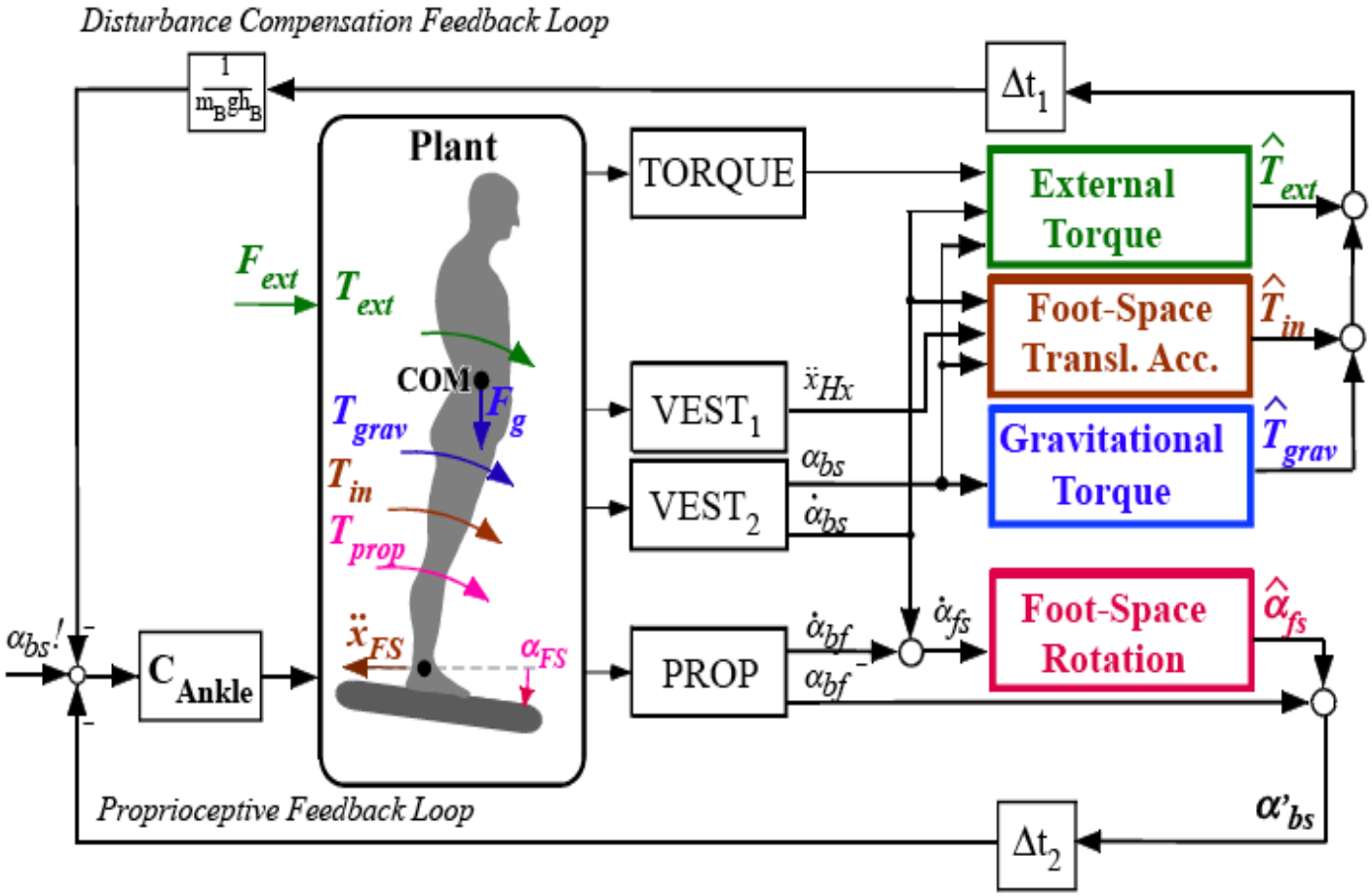
Mergner 2010

DEC model – Neurological perspective



Mergner 2010

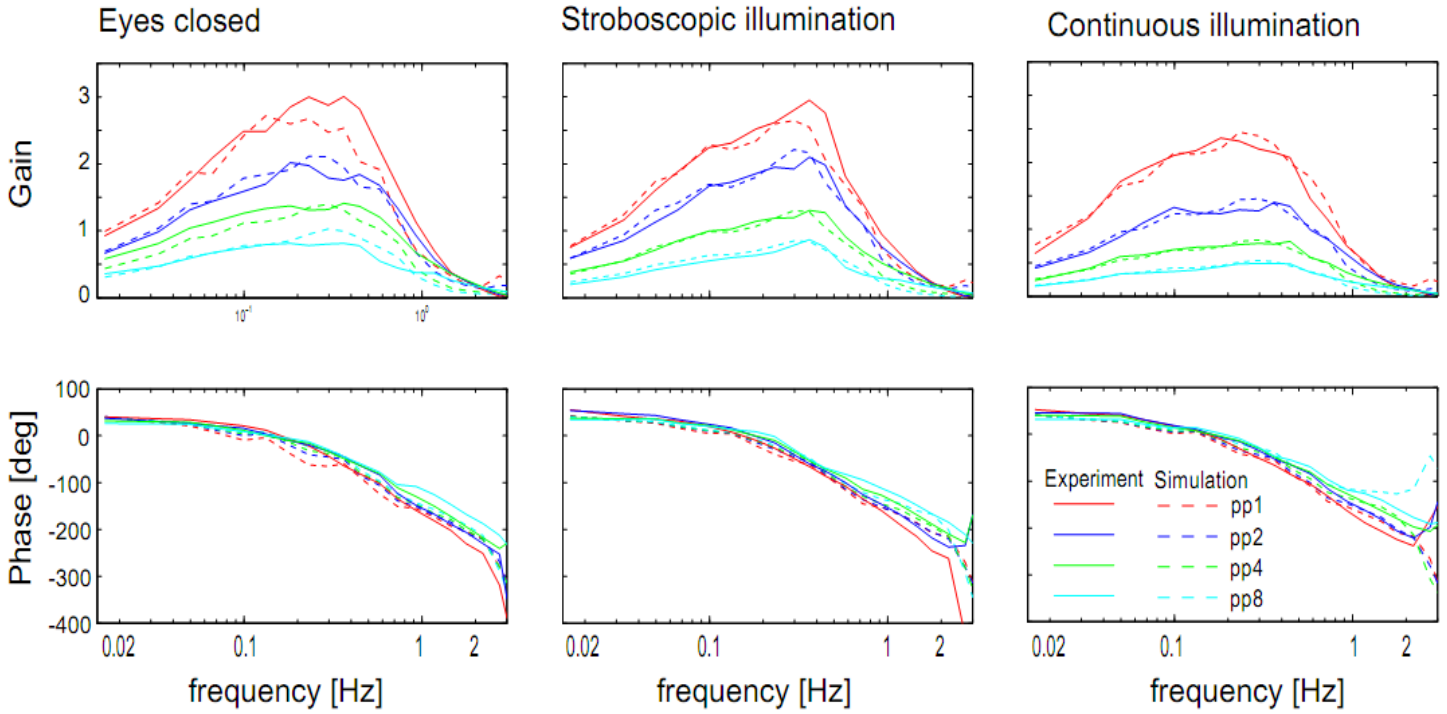
DEC model – Neurological perspective



Mergner 2010

Success of the model

- Accurate description of experimental data

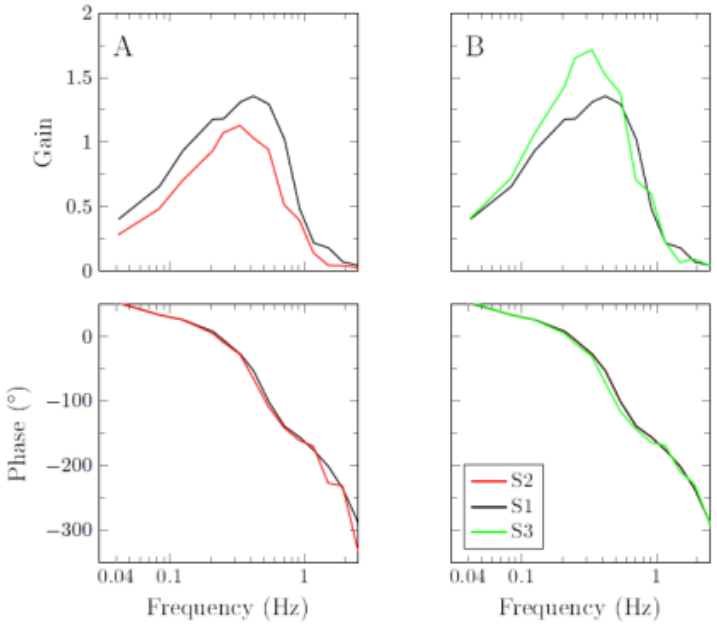


Assländer et al. 2015

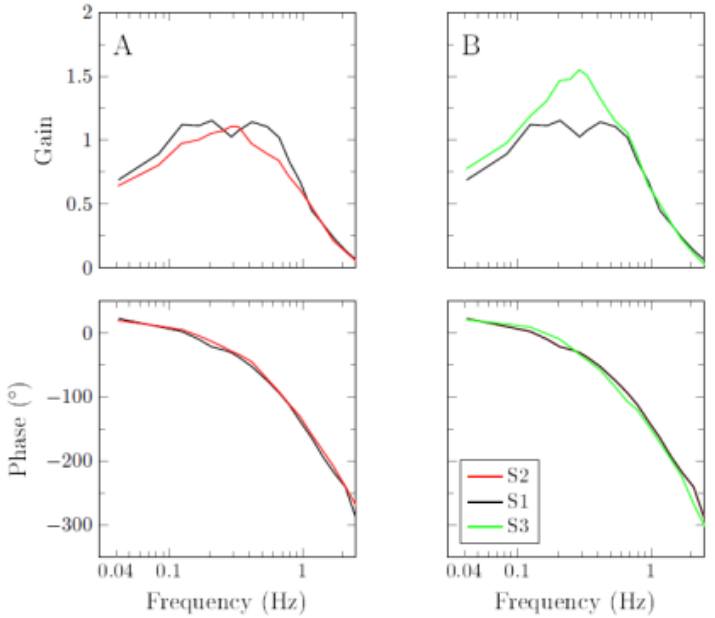
Success of the model

- Prediction of sway responses

Simulation prediction

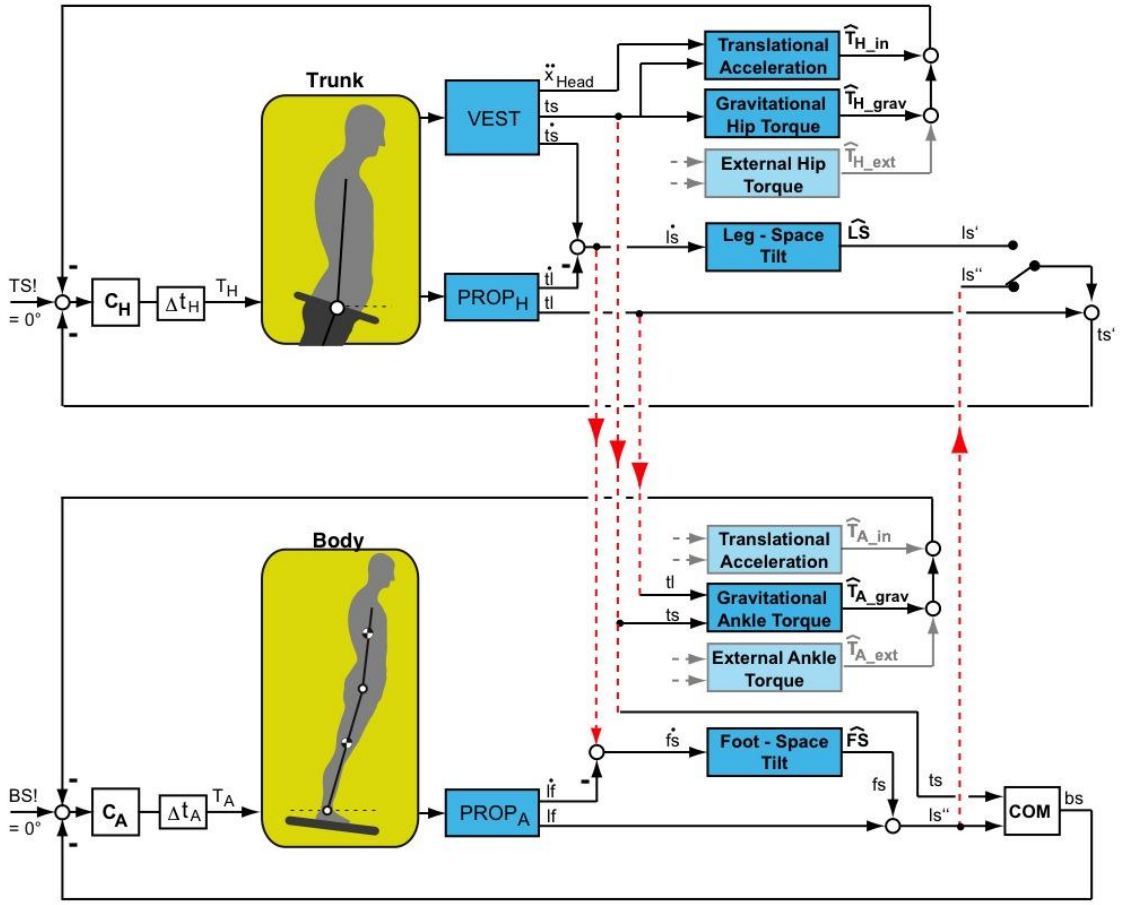


Experimental results



Assländer [in preparation]

3) Upper body

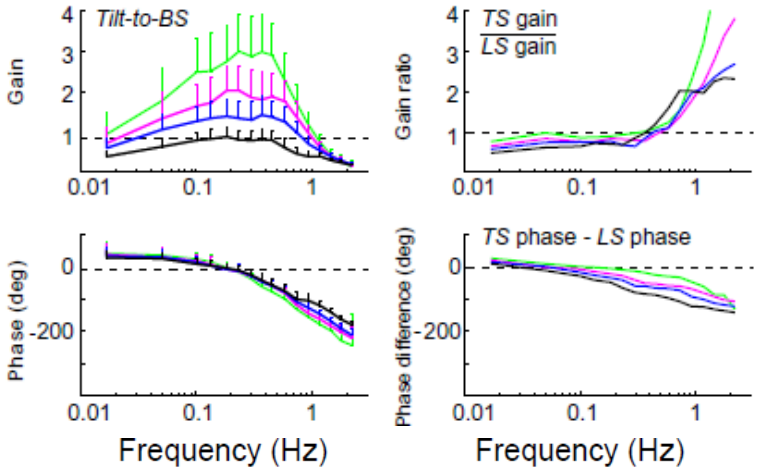


Hettich et al. 2014

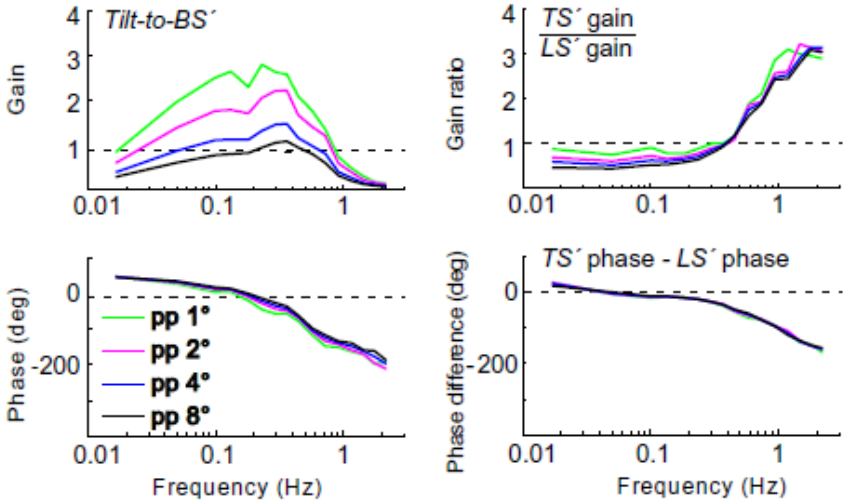
Success of the model

- Accurate description of experimental data

Human experiments



Model simulations

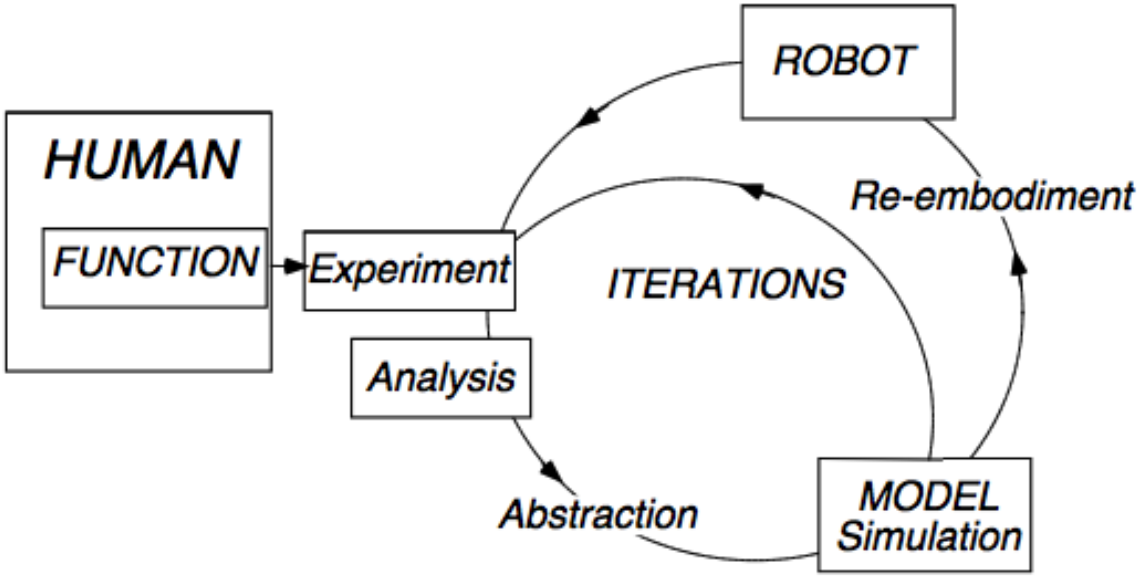


Hettich et al. 2014

Success of the DEC model

- Describtion of non-linear characteristics
- Guideline for visual effects
- Prediction of sway responses
- Can be extended to multiple DoF

Research approach



DEC concept – human likeness

http://www.posturob.de/de/simulationen/posturob-ii/

1) Fast parameter estimation

→ Clinical diagnostic applications
(diseases, ageing)

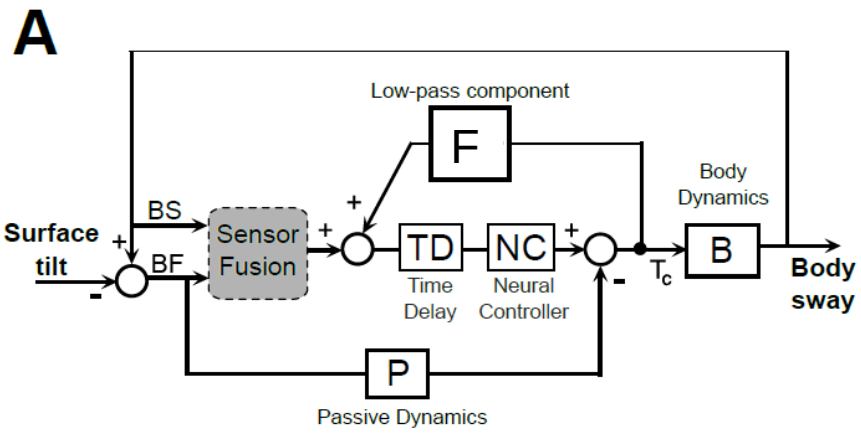
→ Effect of treatment (medication, DBS)

→ Effect of training

→ Inter-individual differences

Surface tilt DEC model

1) Fast parameter estimation

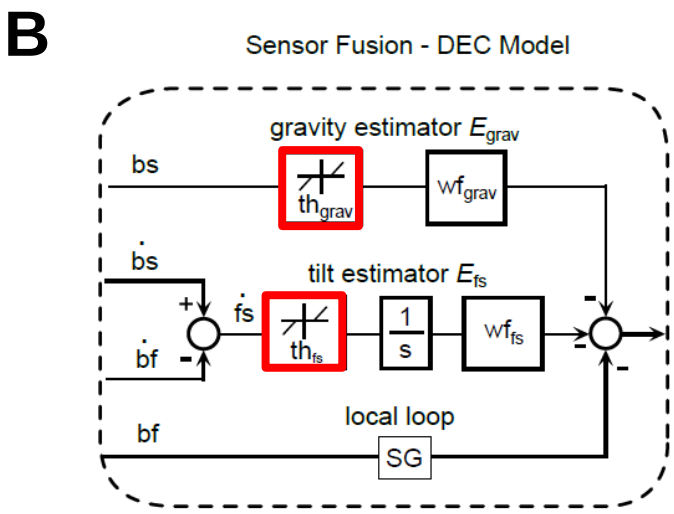


$$B = \frac{1}{J \cdot s^2 - mgh}$$

$$NC = Kp \cdot (1 + PD \cdot s)$$

$$TD = e^{-\tau \cdot s}$$

$$F = \frac{G_{LP}}{F_{LP} \cdot s + 1}$$

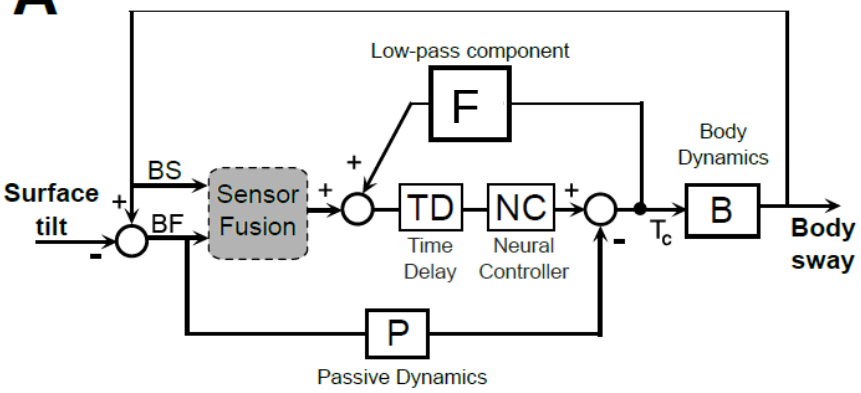


Assländer [in preparation]

Surface tilt DEC model

1) Fast parameter estimation

A



$$B = \frac{1}{J \cdot s^2 - mgh}$$

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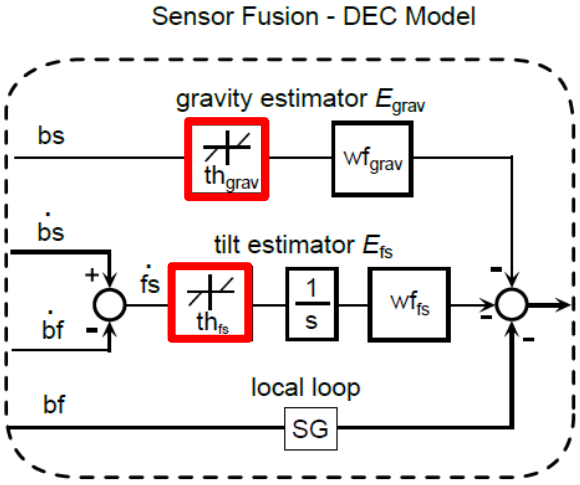
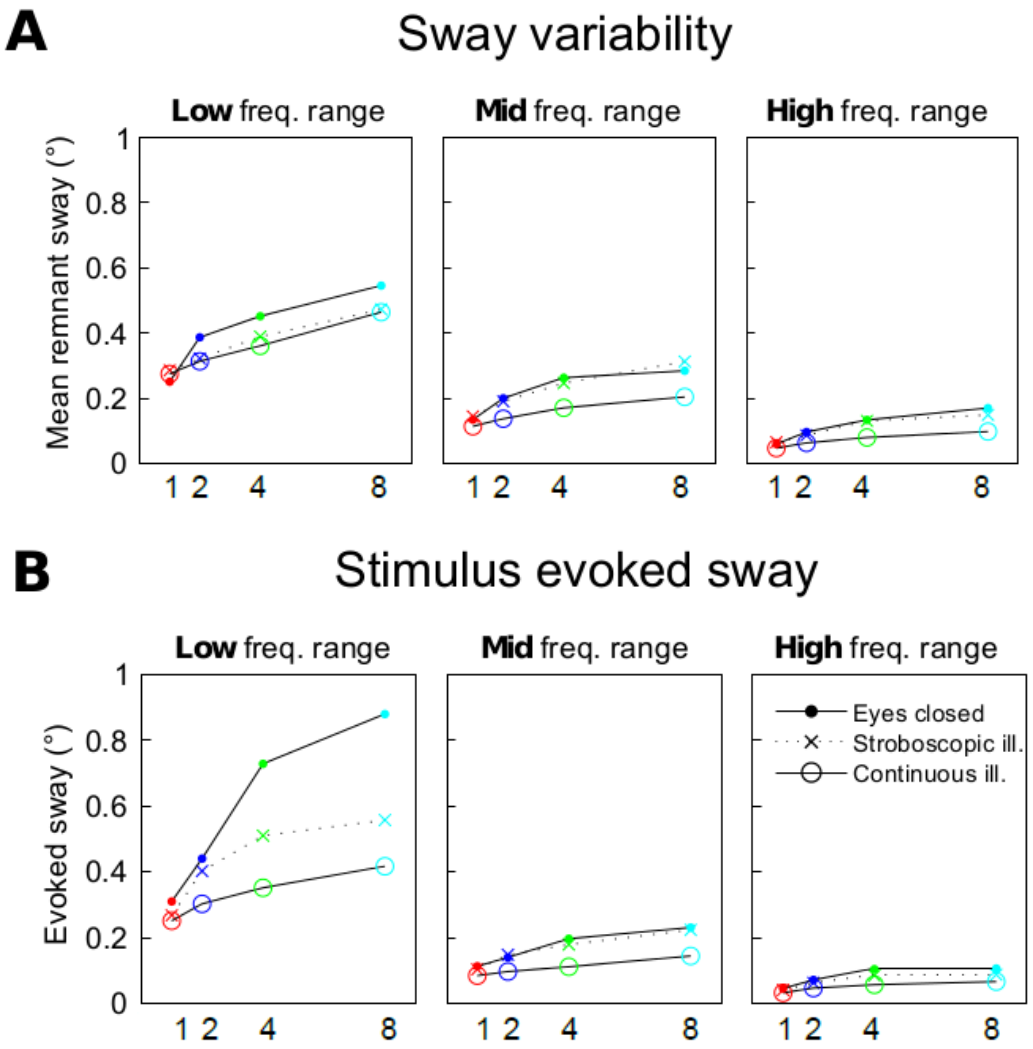
B



$$\frac{BS(s)}{FS(s)} = \frac{P \cdot B + (SG - E_{fs})) \cdot NC \cdot B \cdot TD}{1 - F \cdot NC \cdot TD + P \cdot B + (SG + E_{gr}) \cdot NC \cdot B \cdot TD}$$

Assländer [in preparation]

2) Noise and thresholds



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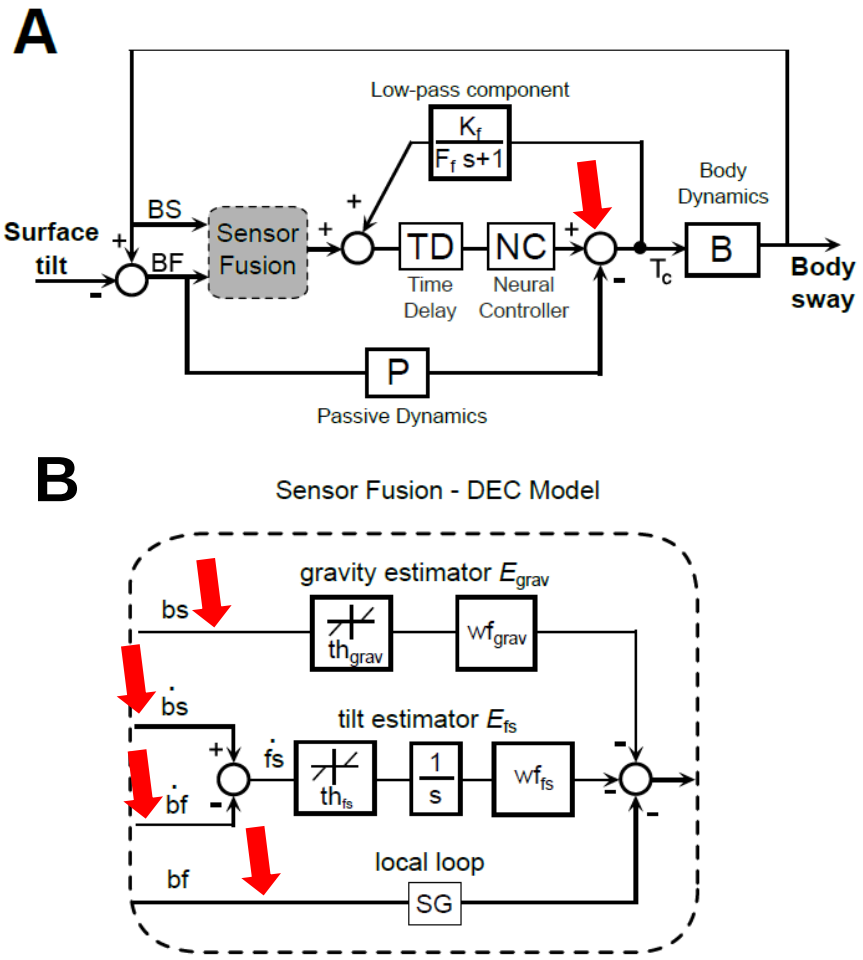
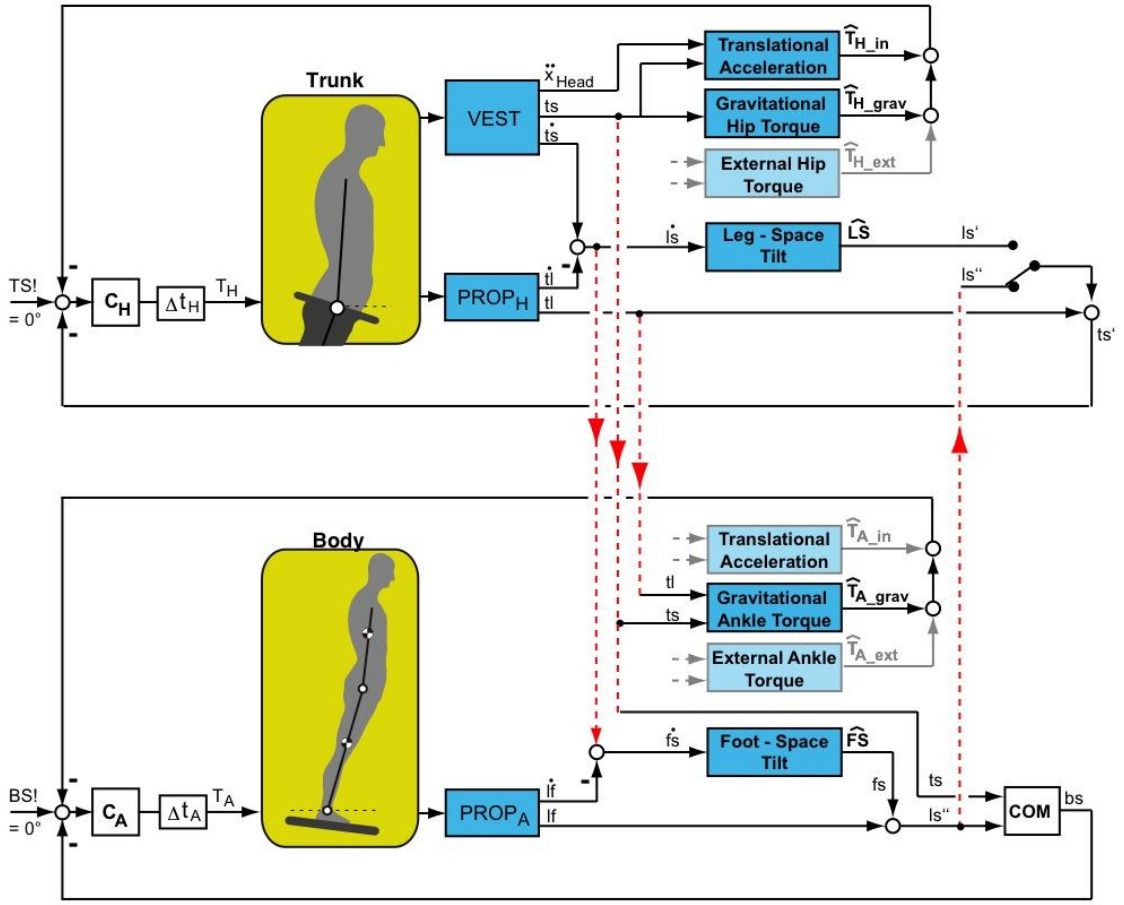


Noise source

- Interaction noise and thresholds
- Noise color?
- Source?

3) Modularity



Hettich et al. 2014

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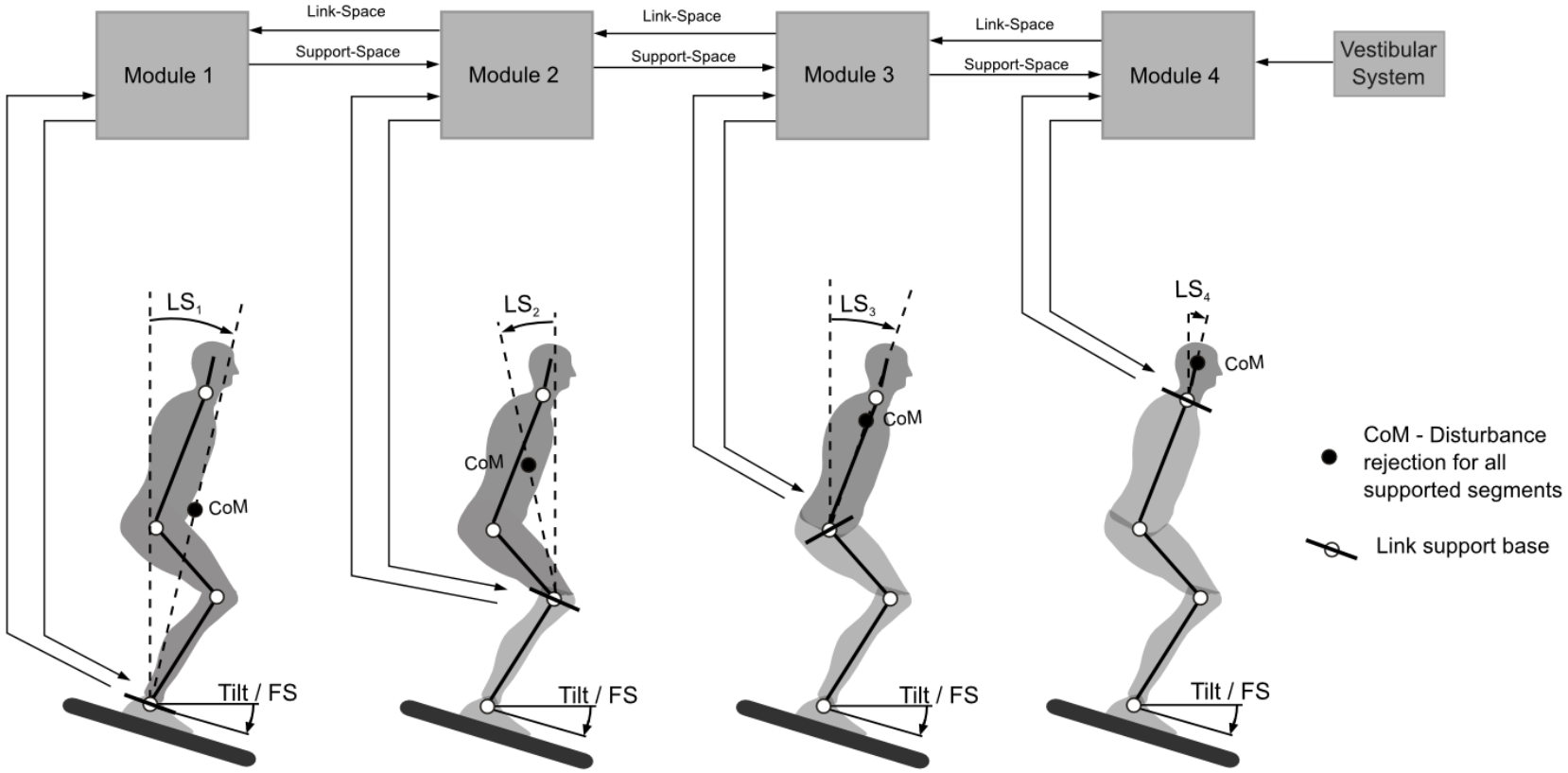
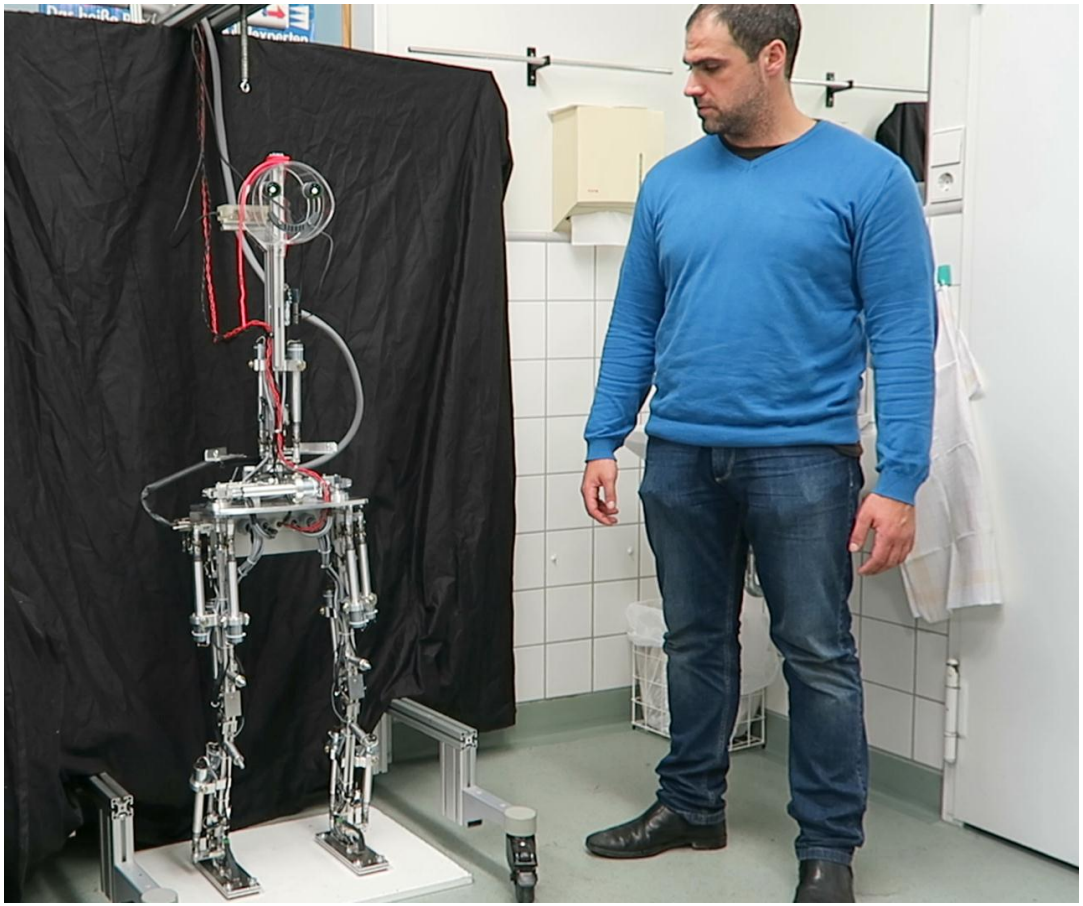


Movement from posture

3) Modularity



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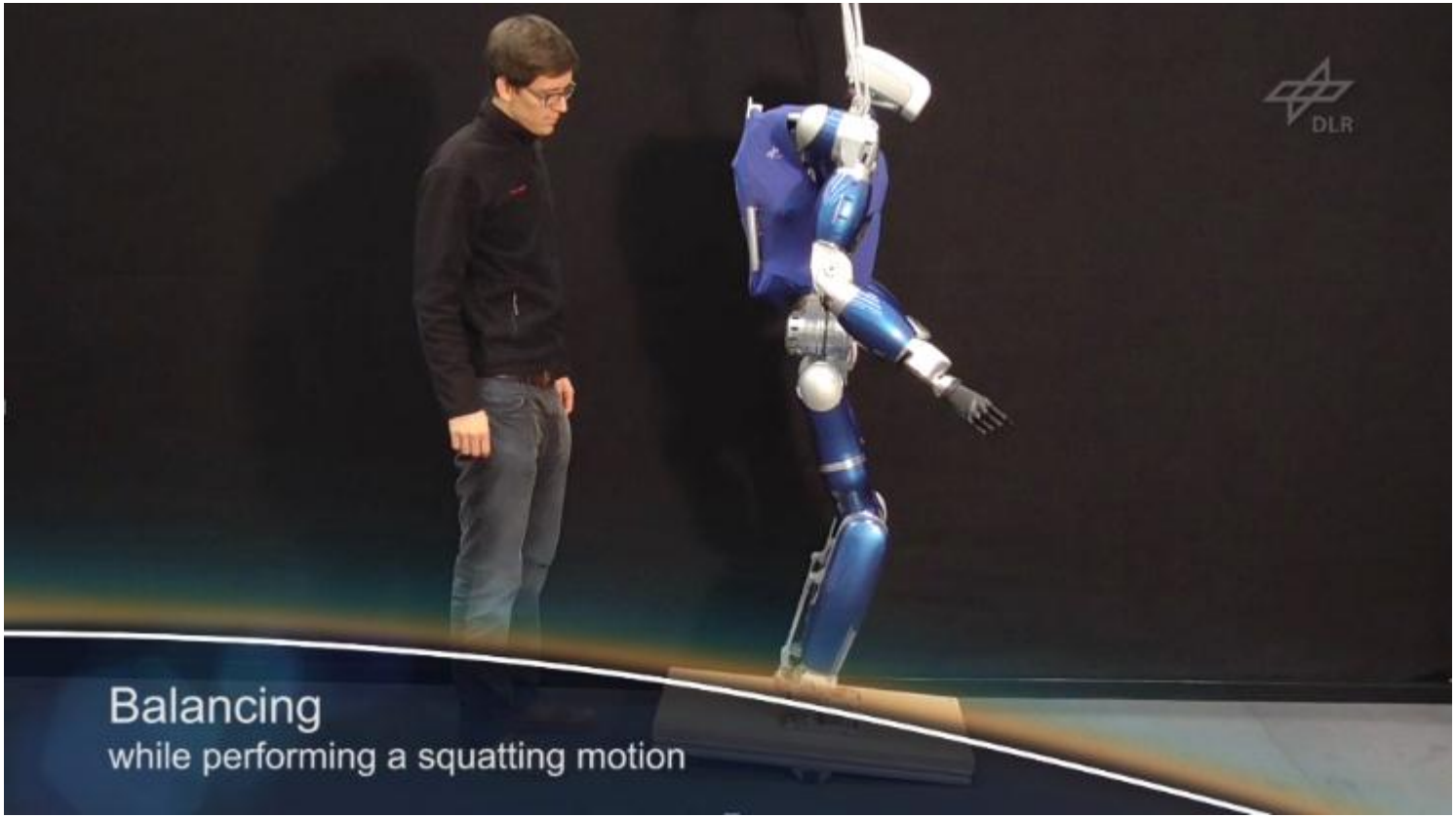
Toro robot using DEC controller

3) Modularity



http://www.posturob.de/de/projekte/toro-2/

Team

Thomas Mergner
Lorenz Assländer
Vittorio Lippi

Ehemalige:
Georg Hettich
Melak Zebenay
Lu Fennel

Workshop: Frank Hüthe und Tom Günter

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