‘Visual-fidelity’ dataglove calibration

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Motivation

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- fine manipulation/precision grasps
  - ubiquitous
  - most important for object interaction

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  - ubiquitous
  - most important for object interaction
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  - $\Longrightarrow$ should provide such facility
  - $\Longleftrightarrow$ still. . .
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    - limited and unnatural manipulation

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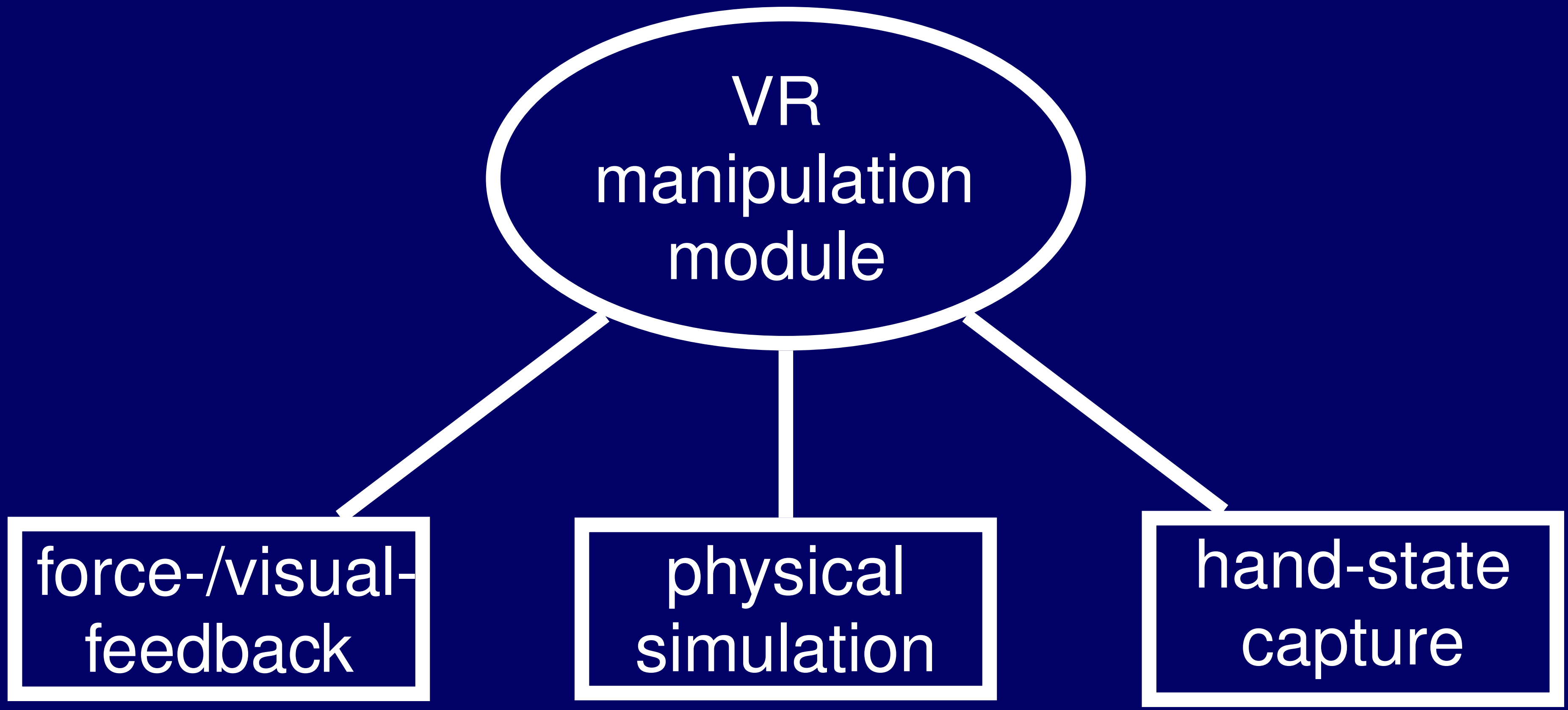
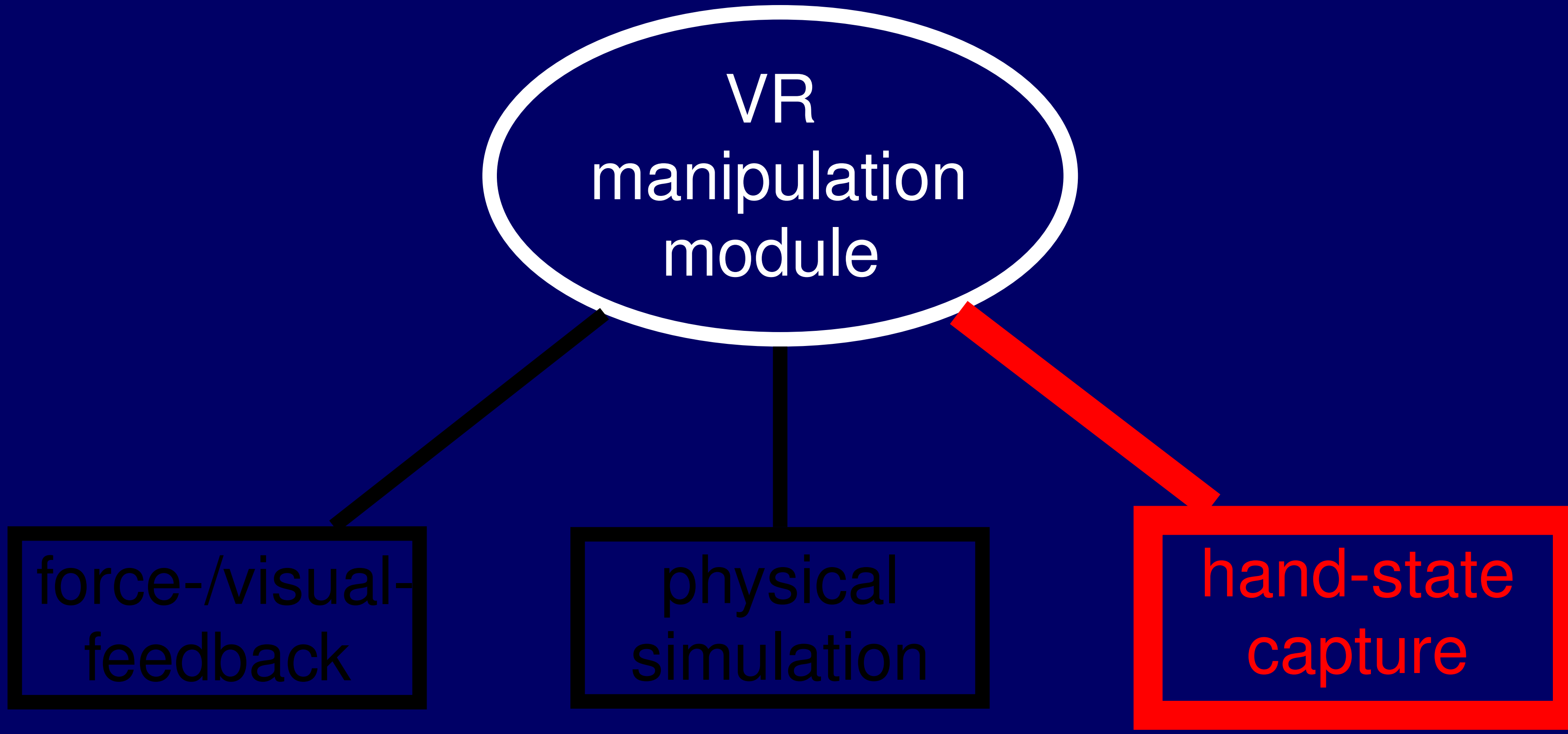
- VR wants to be “real”
  - $\Longrightarrow$ should provide such facility
  - $\Longleftrightarrow$ still. . .
    - “crude gestures” for
    - limited and unnatural manipulation
- WHY?

Motivation



VR manipulation module
force-/visual-feedback
physical simulation
hand-state capture

Motivation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$\boxed{\text{simulation}}$

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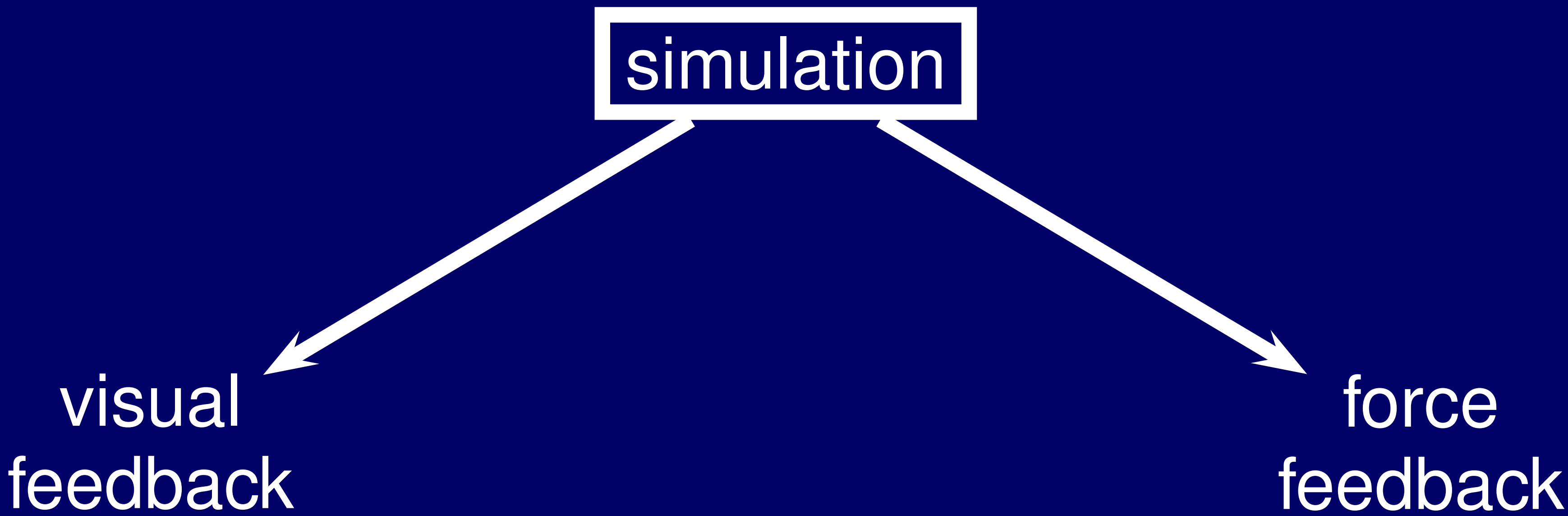

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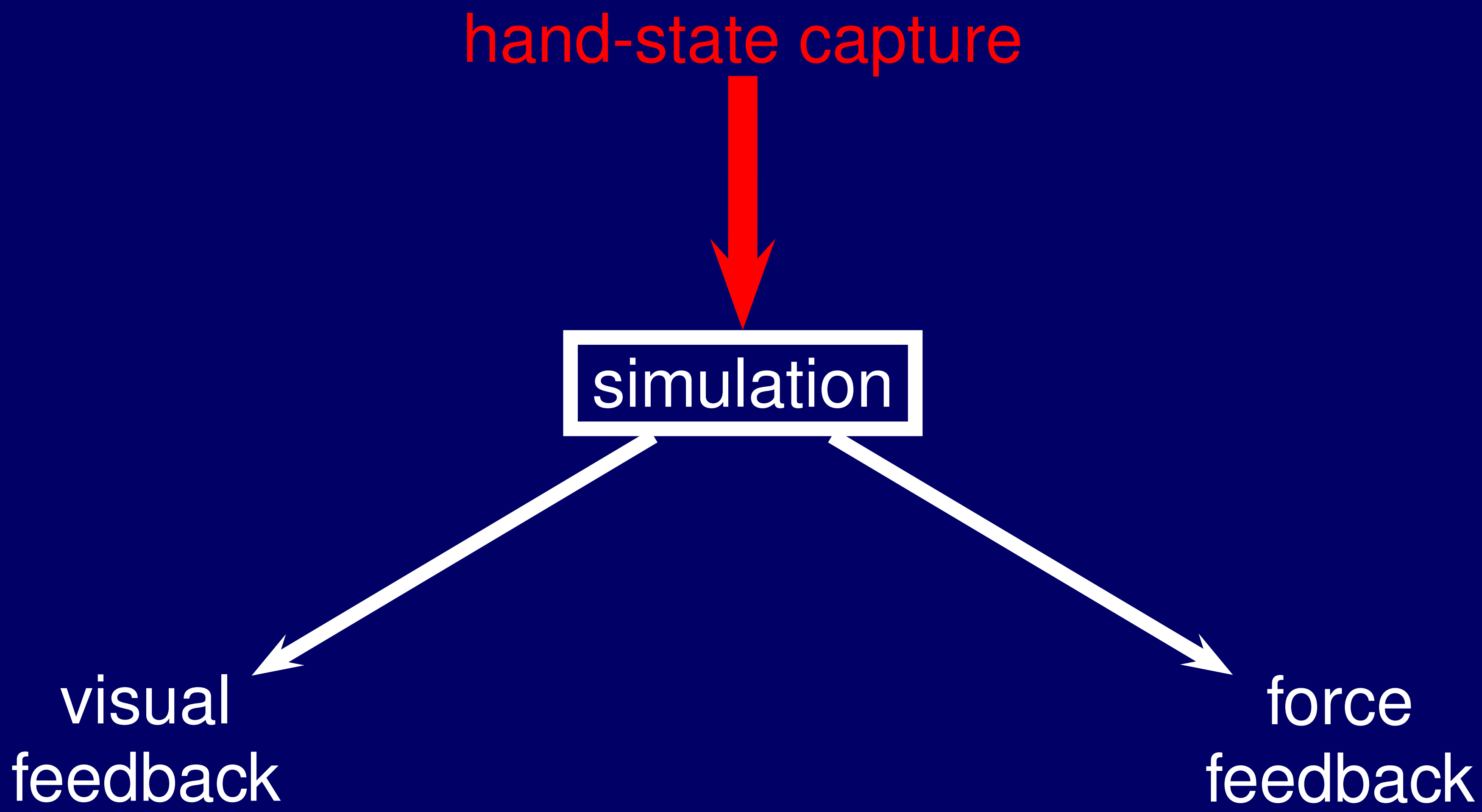

hand-state capture
simulation
visual feedback
force feedback

Motivation

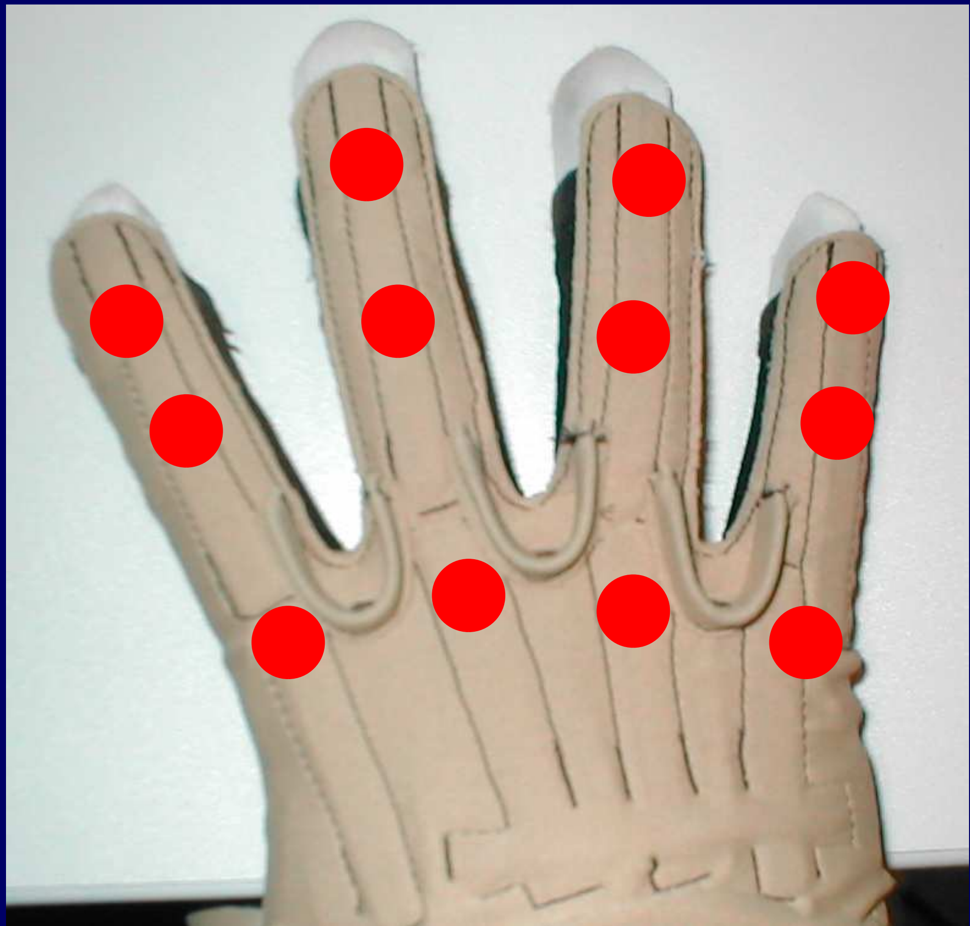
- hand-state capture
  - hand-master (exoskeleton)
  - high-DOF datagloves
    - work (more or less) ☺
    - *de facto standard* ☺
    - expensive ☹
    - intrusive ☹
  - vision-based methods
    - promising (non-intrusive, inexpensive) ☺
    - do not work ☹☹☹

Motivation

- high-DOF datagloves

Motivation

- flex sensors (up-down, fist)



Motivation

- abduction sensors (left-right)

Motivation

- measure: sensor readings
- need: joint-angle values
- define a function f_i and determine its parameters ω_i : $\theta_i = f_{\omega_i}(\mathbf{s}_i)$, where
  - θ_i: i-th joint angle
  - f_{w_i}: mapping from sensor space to θ_i with parameters ω_i
  - s_i: set of sensor readings used for the mapping

Motivation

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- $\Longrightarrow$demand for calibration methods
  - simple and easy
  - without expensive extrenal sensory
  - robust tracking

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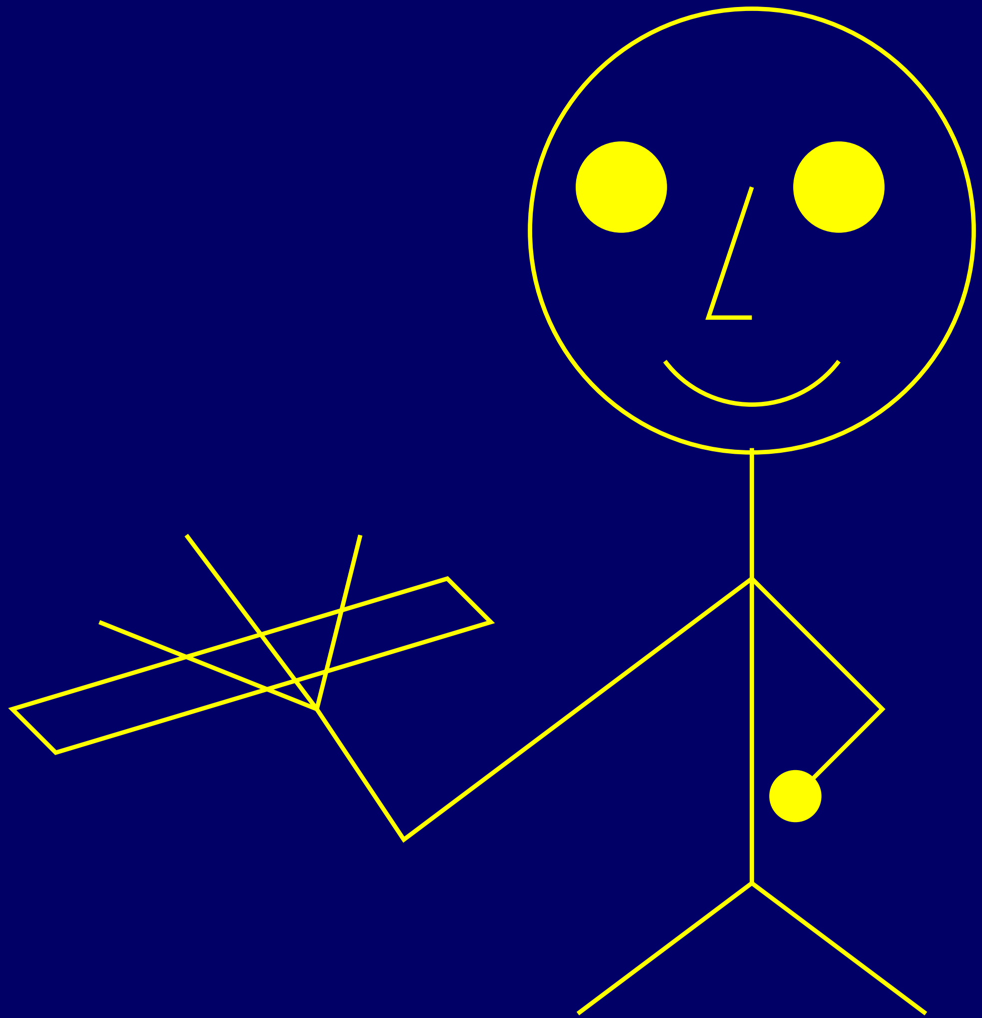
- $\Longrightarrow$datagloves need to be calibrated
- $\Longrightarrow$demand for calibration methods
  - simple and easy
  - without expensive extrenal sensory
  - robust tracking
- great(er) absolute accuracy $=$ the only way?
  - no, because...

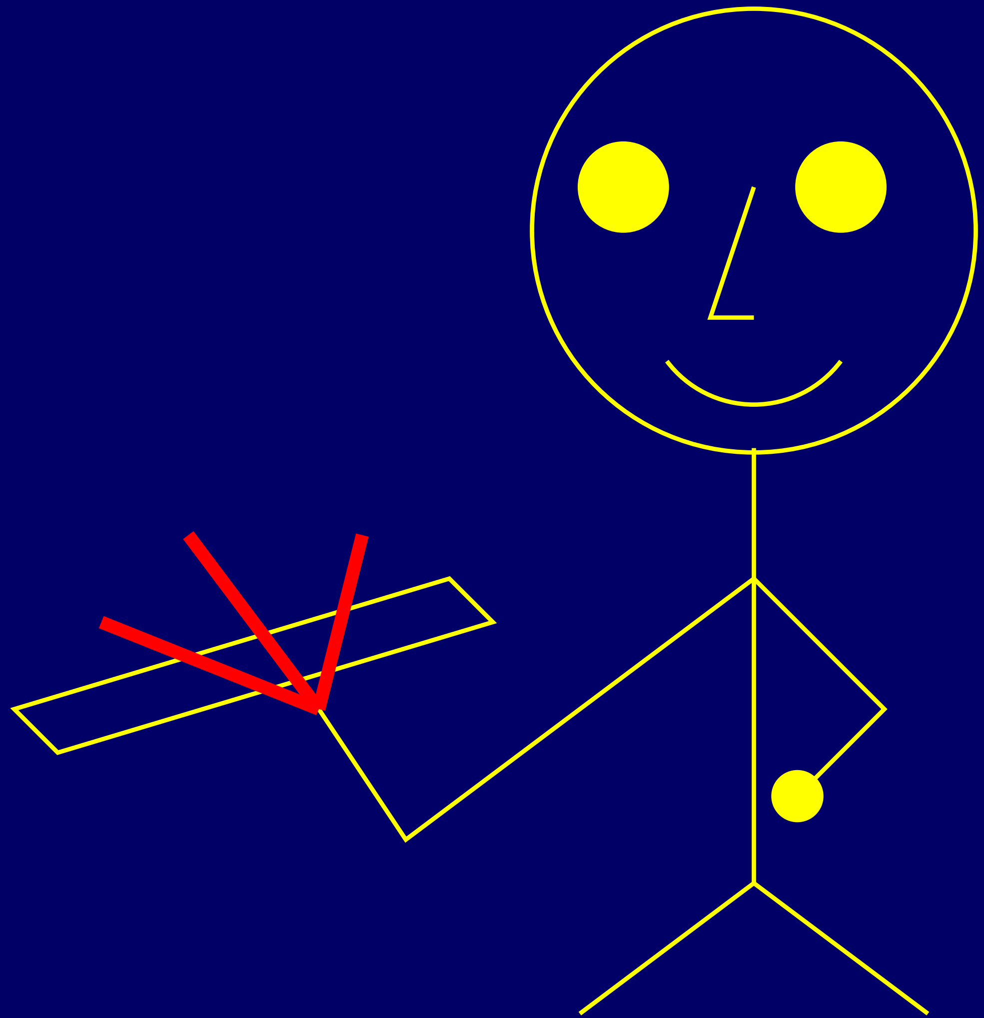
Motivation

- Somebody. . .



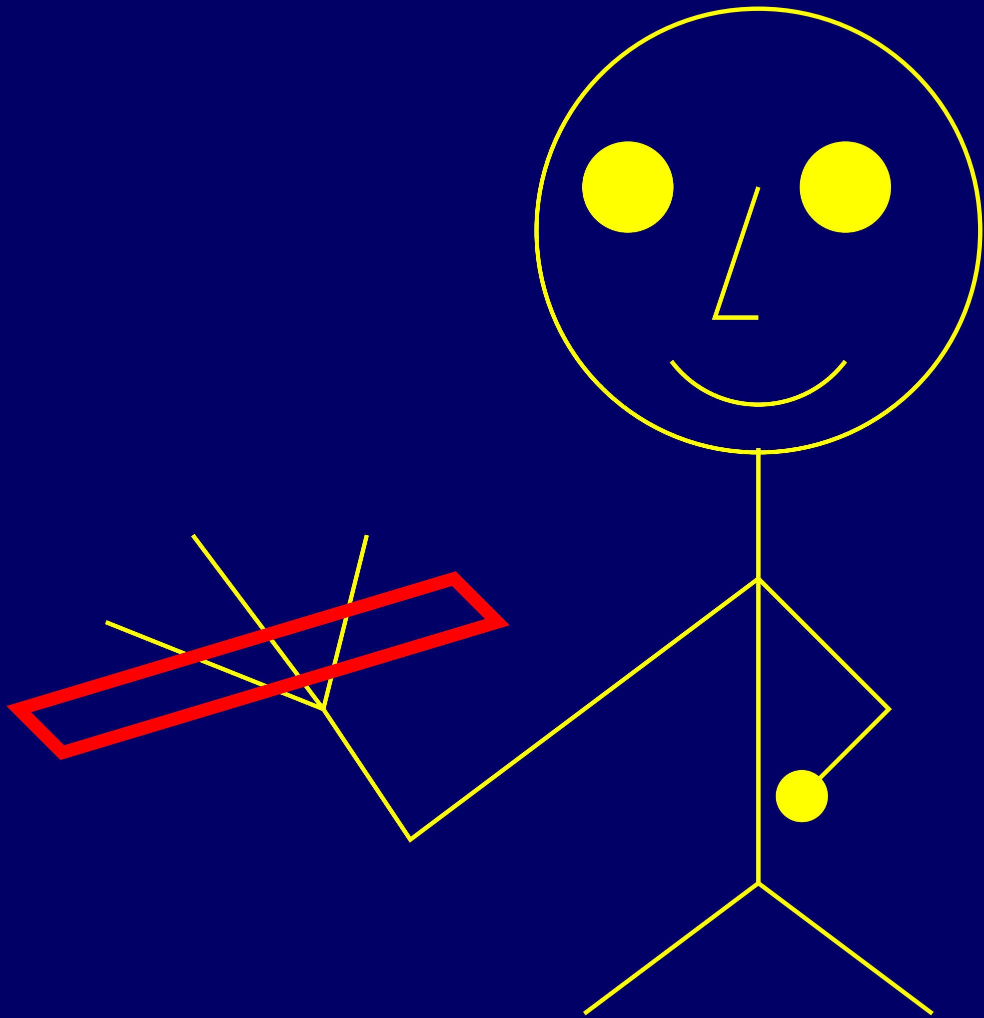
Motivation

- . . . fine-manipulates. . .



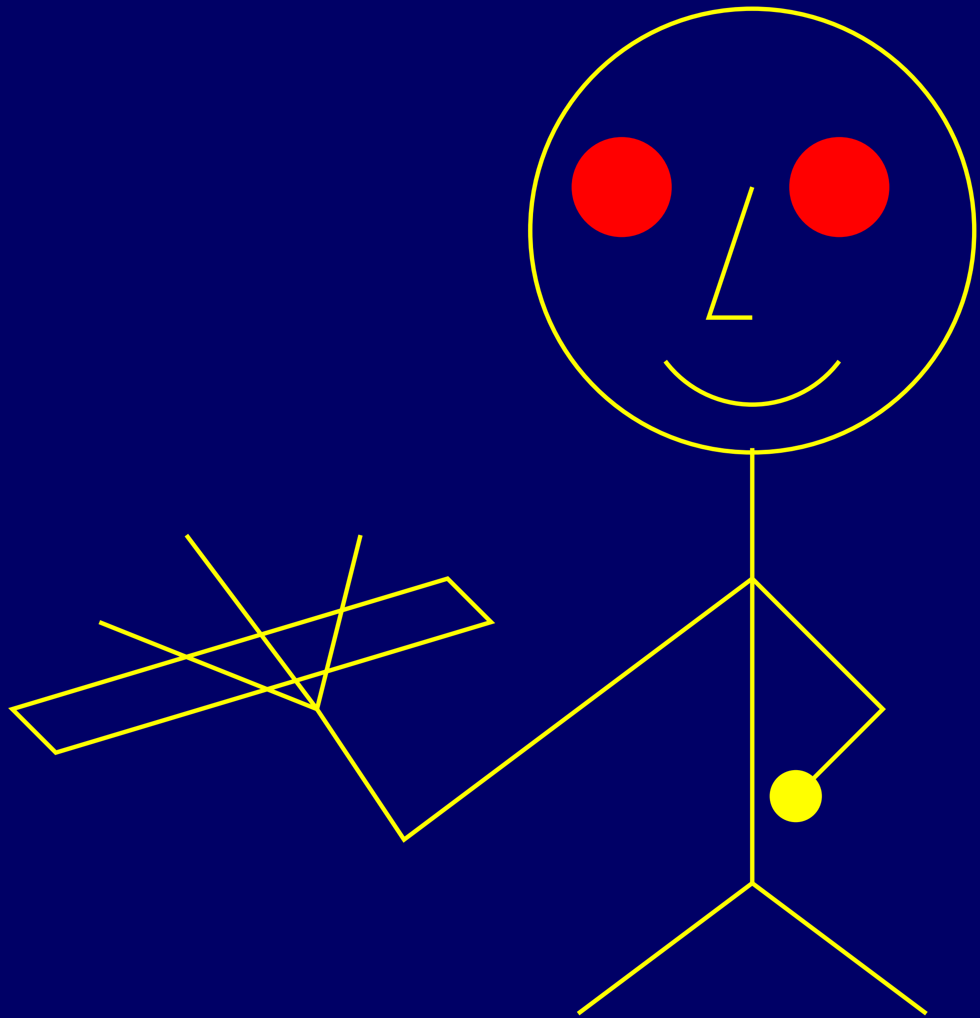
Motivation

- . . . a real object. . .



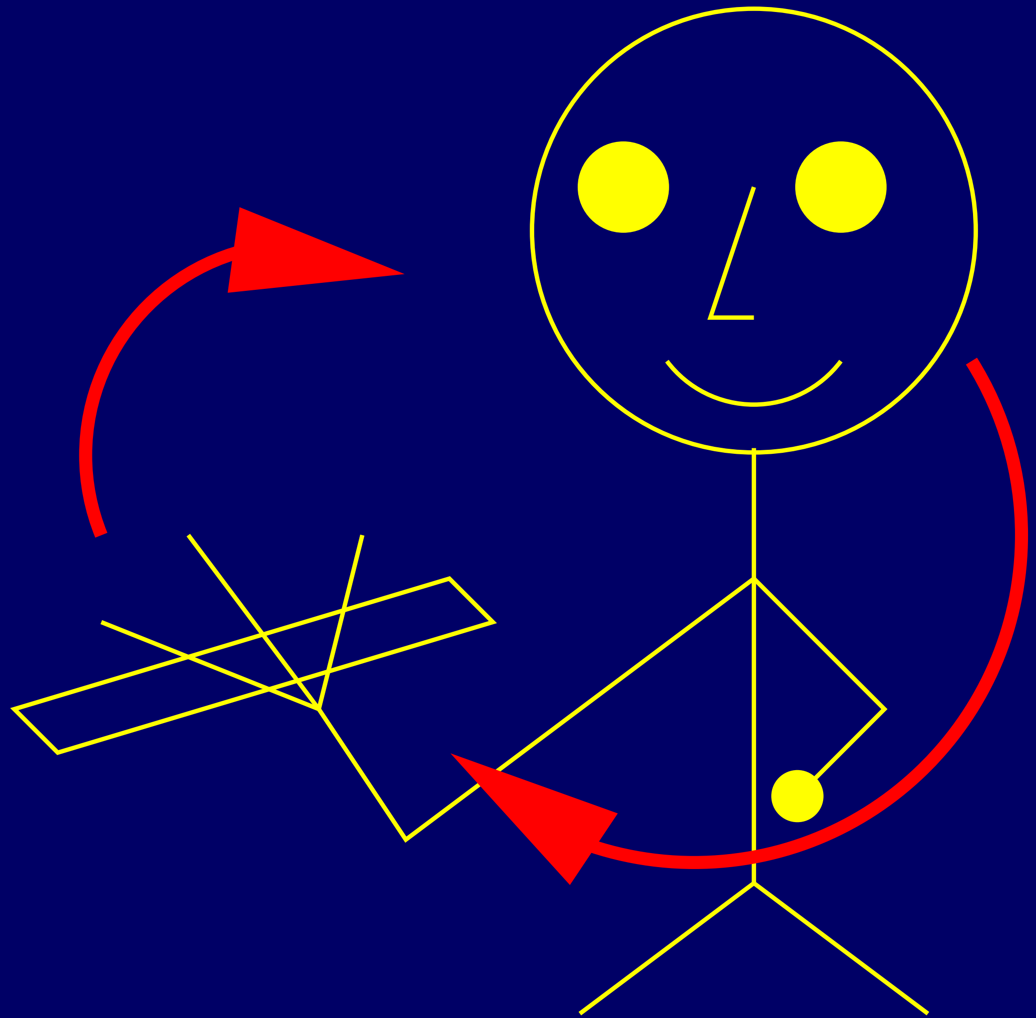
Motivation

- the most important feedback is visual



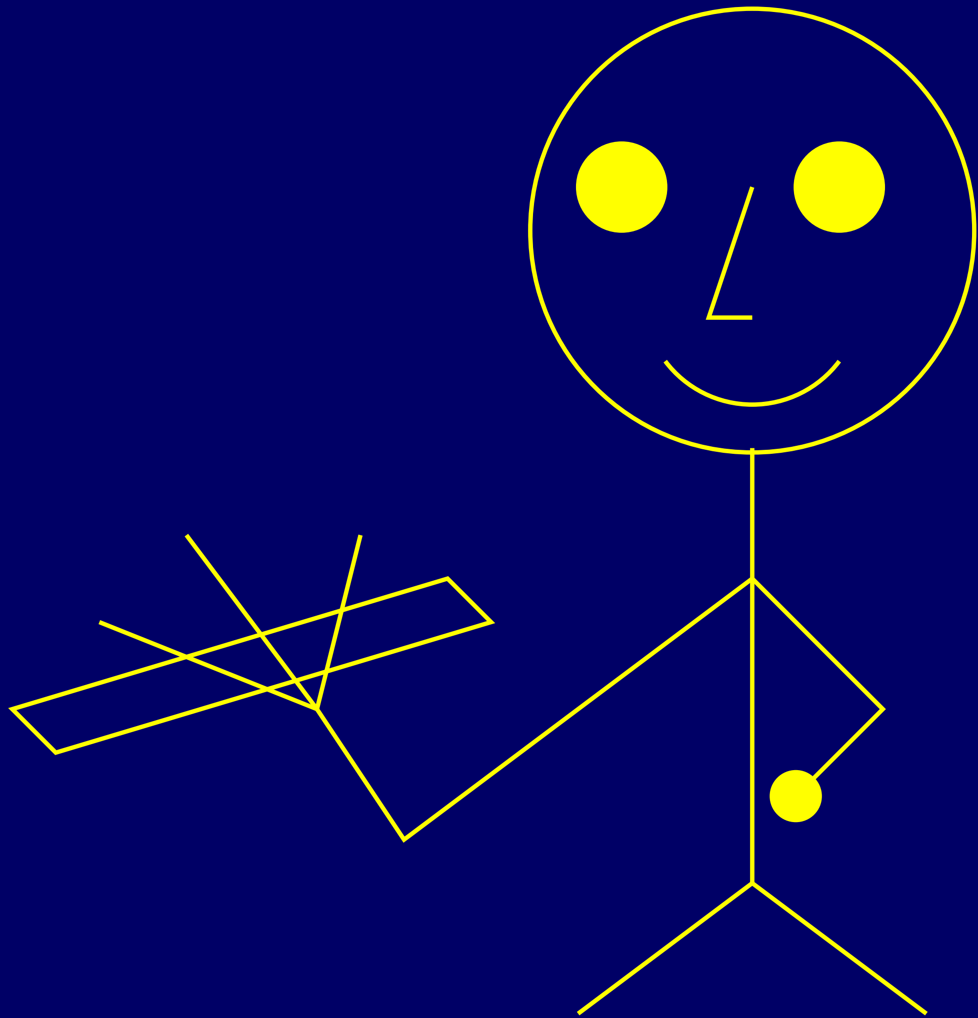
Motivation

- perception action loop



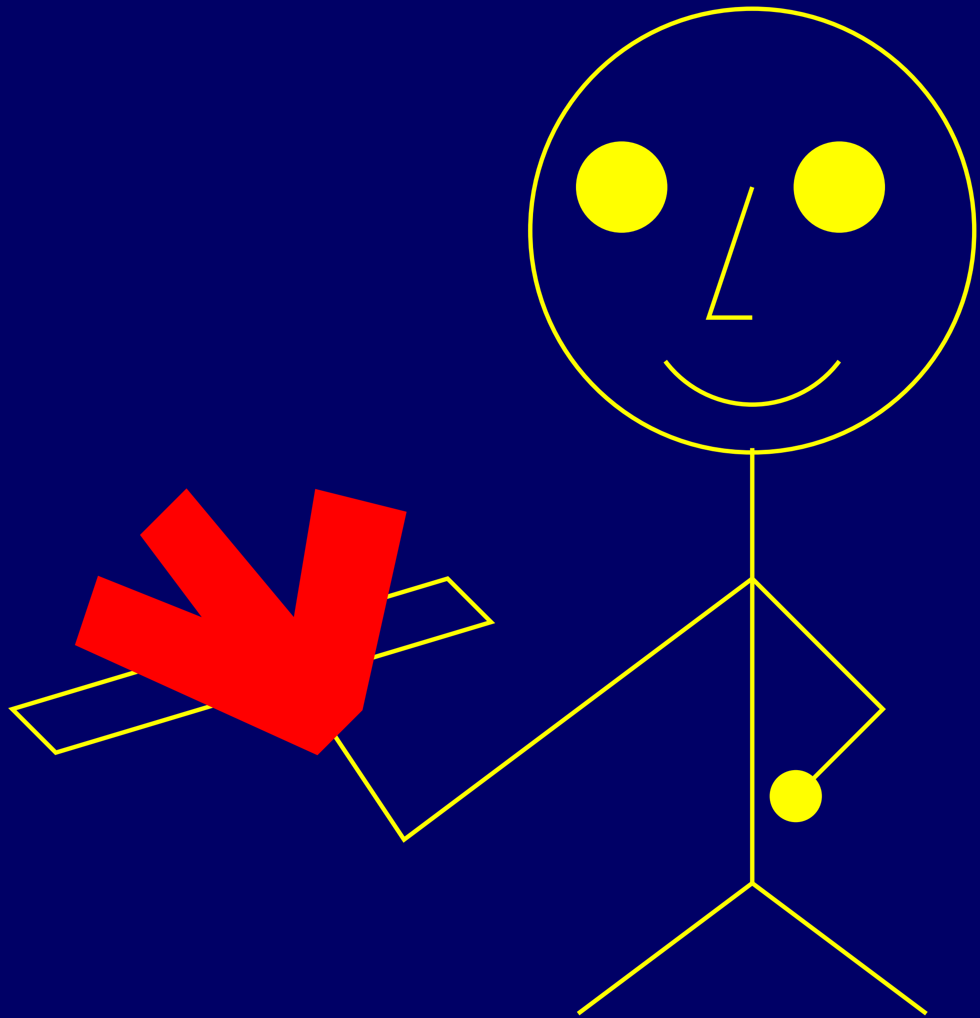
Motivation

- Now if she…



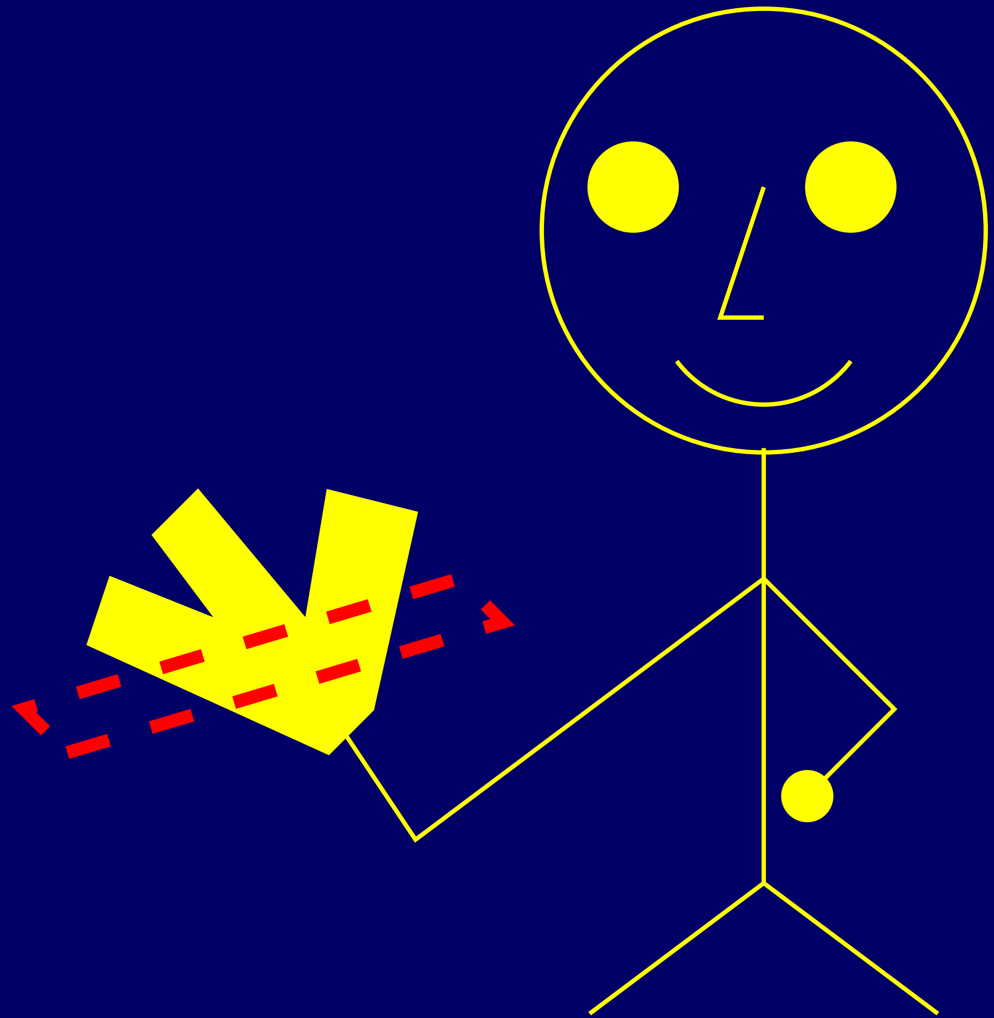
Motivation

- . . . gets a dataglove to manipulate. . .



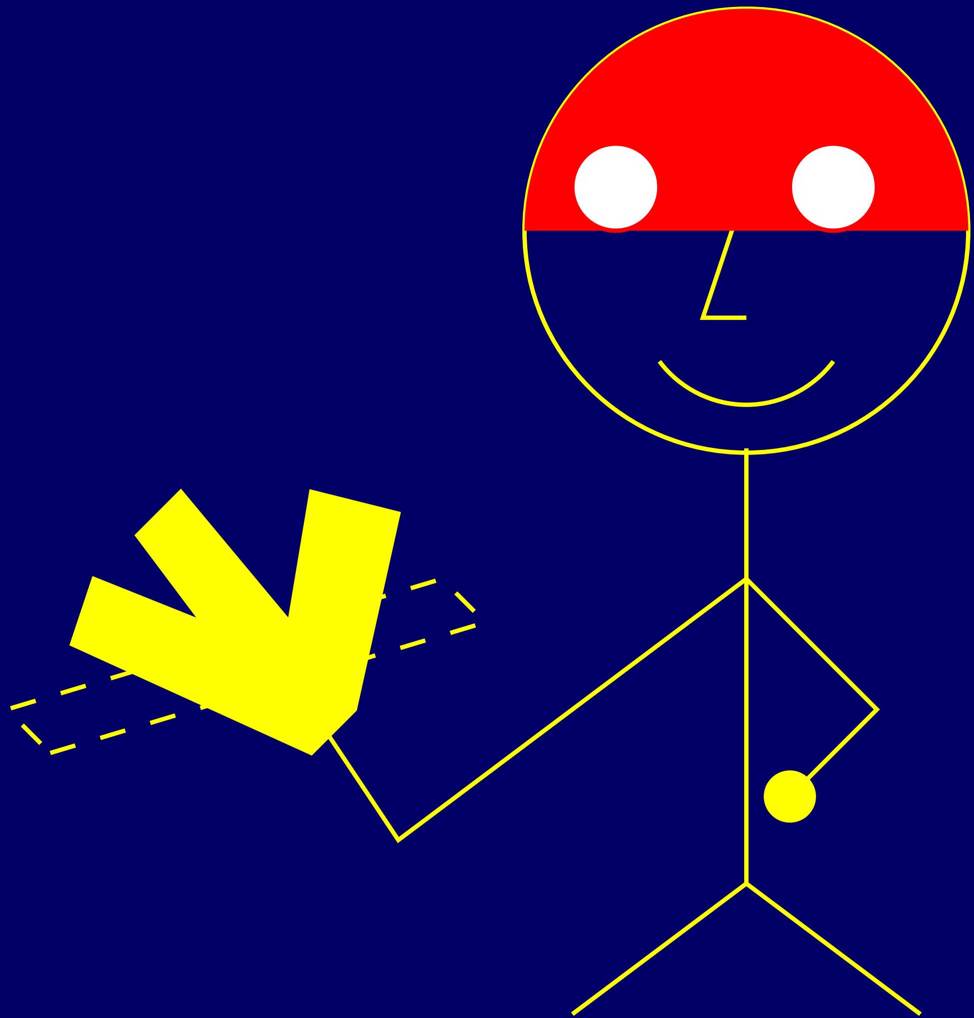
Motivation

- . . . a virtual object. . .



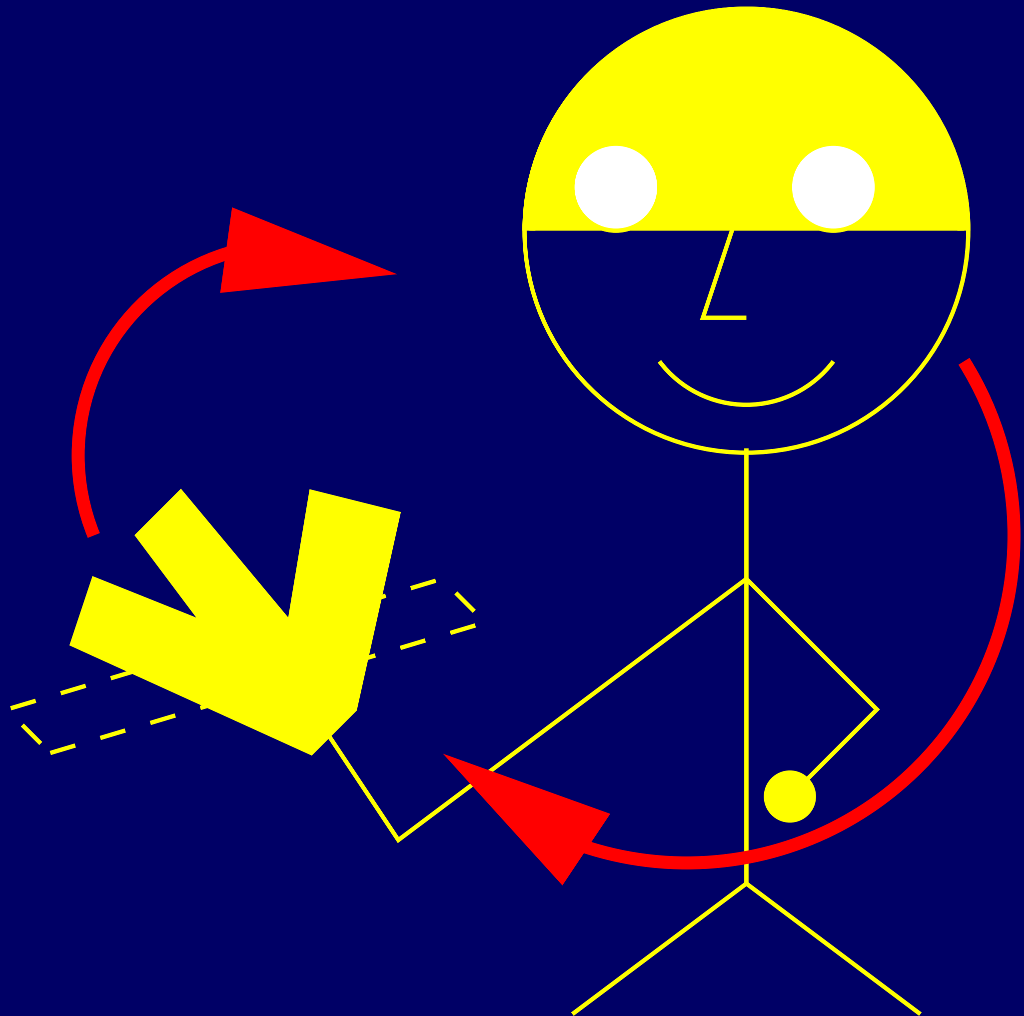
Motivation

- . . . head mounted display. . .



Motivation

- . . . same feedback!!!



Motivation

- better relative accuracy
  - will improve purely virtual interaction
  - more similar
    - virtual postures to real
    - object-hand relative pose

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- better relative accuracy
  - will improve purely virtual interaction
  - more similar
    - virtual postures to real
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- sacrifice
  - absolute accuracy
- gain
  - better iteraction
  - easier calibration

Overview

- previous work
- linear calibration
- cross-coupled sensors
- calibration of cross-coupled sensors
- results
- conclusions & future work

Previous work

- absolute accuracy, gesture-based
  - official VirtualHand®User's Guide and Immersion's FAQ document
  - Chou et al., 2000: Hand-Eye: A Vision Based Approach to Data Glove Calibration

Previous work

- high absolute accuracy, trajectory-based
  - Fisher et al., 1998: Learning Techniques in a Dataglove Based Telemanipulation System for the DLR Hand
  - Weston et al., 2000: Calibration and Mapping of a Human Hand for Dexterous Telemanipulation

Previous work

- relative accuracy, gesture-based
  - Menon et al., 2003: Using Registration, Calibration, and Robotics to Build a More Accurate Virtual Reality Simulation for Astronaut Training and Telemedicine
- relative accuracy, trajectory-based
  - our method

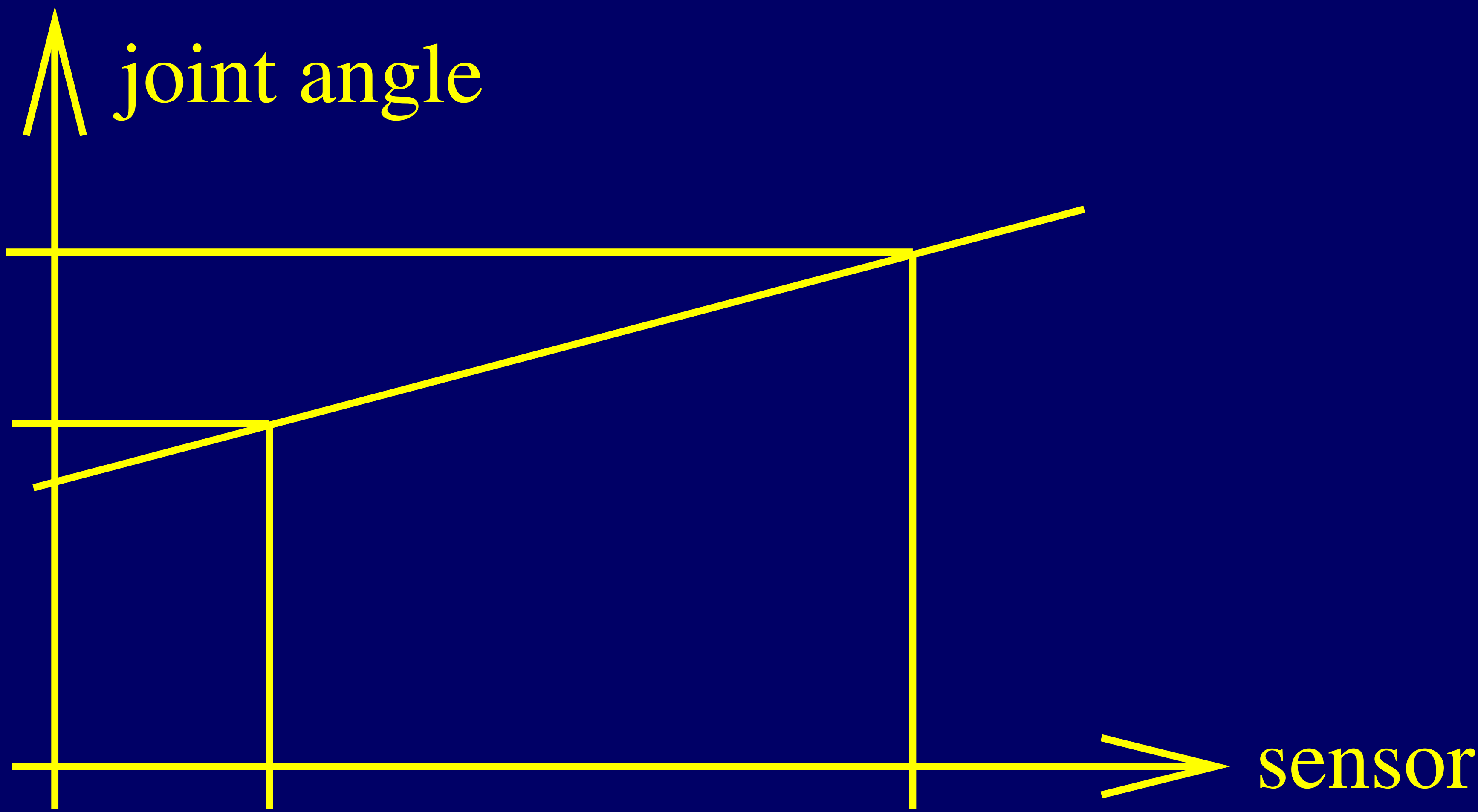
Linear calibration

- “straight”, angle = 0°

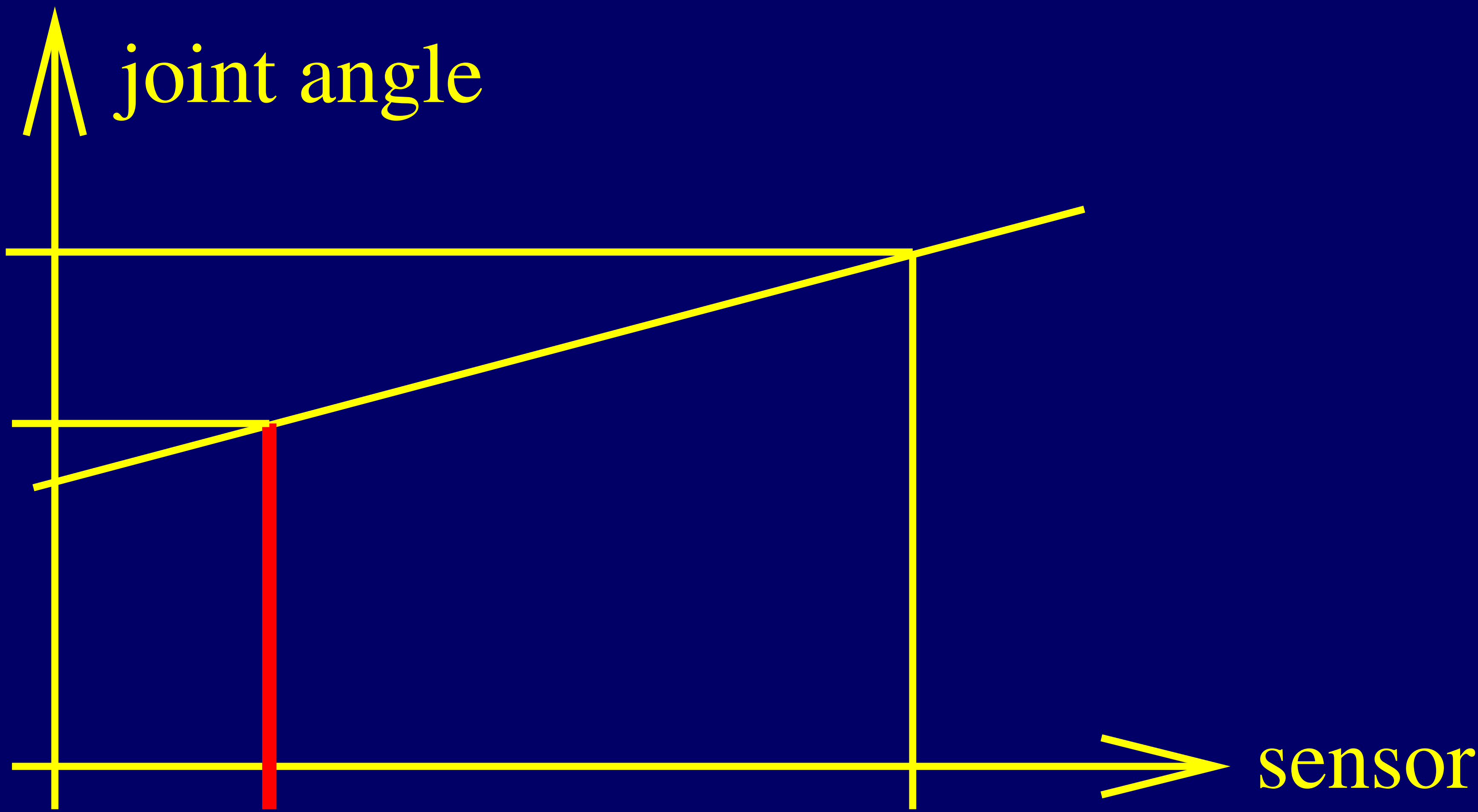
Linear calibration

- “fist”, angle = 90°

Linear calibration



Linear calibration



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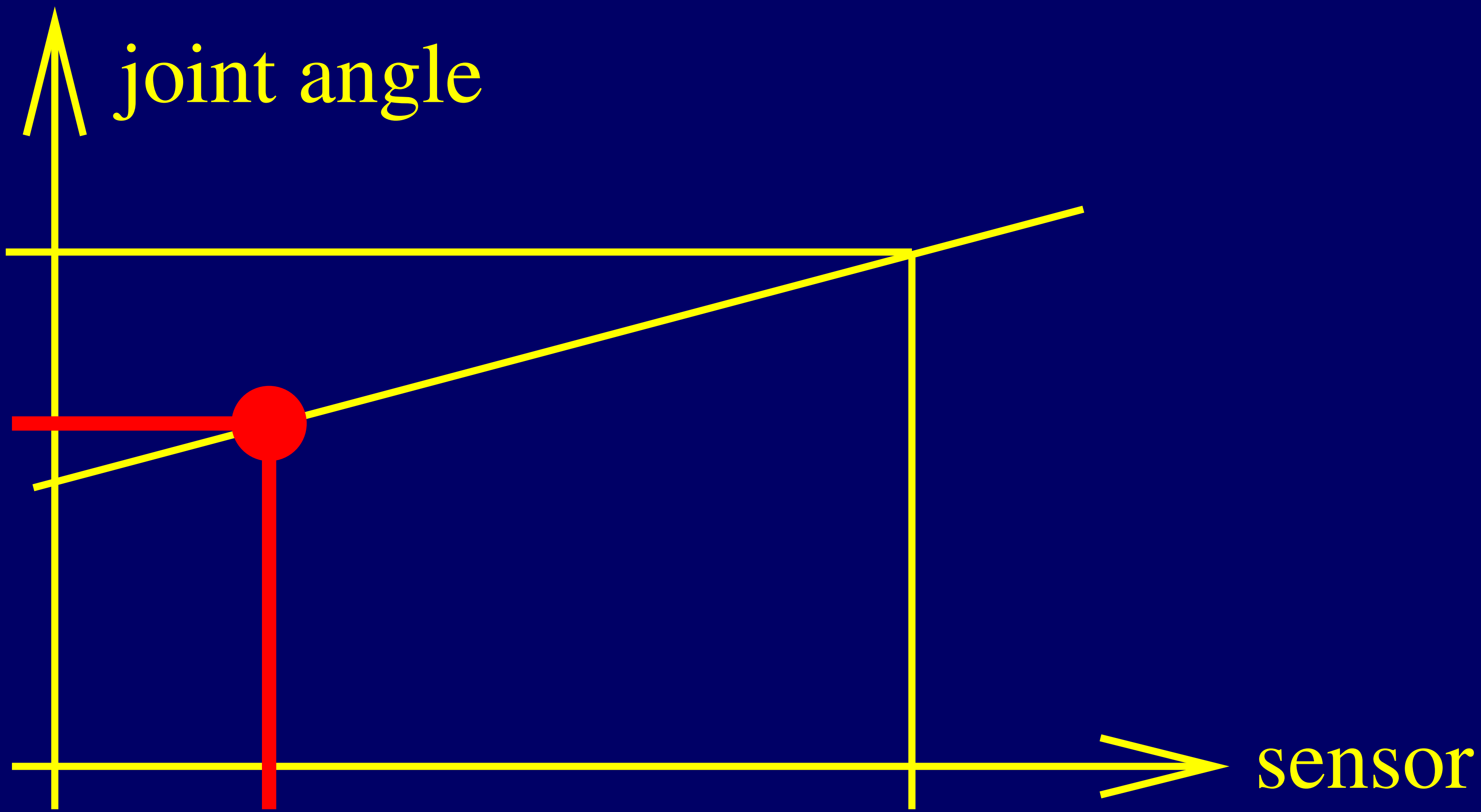

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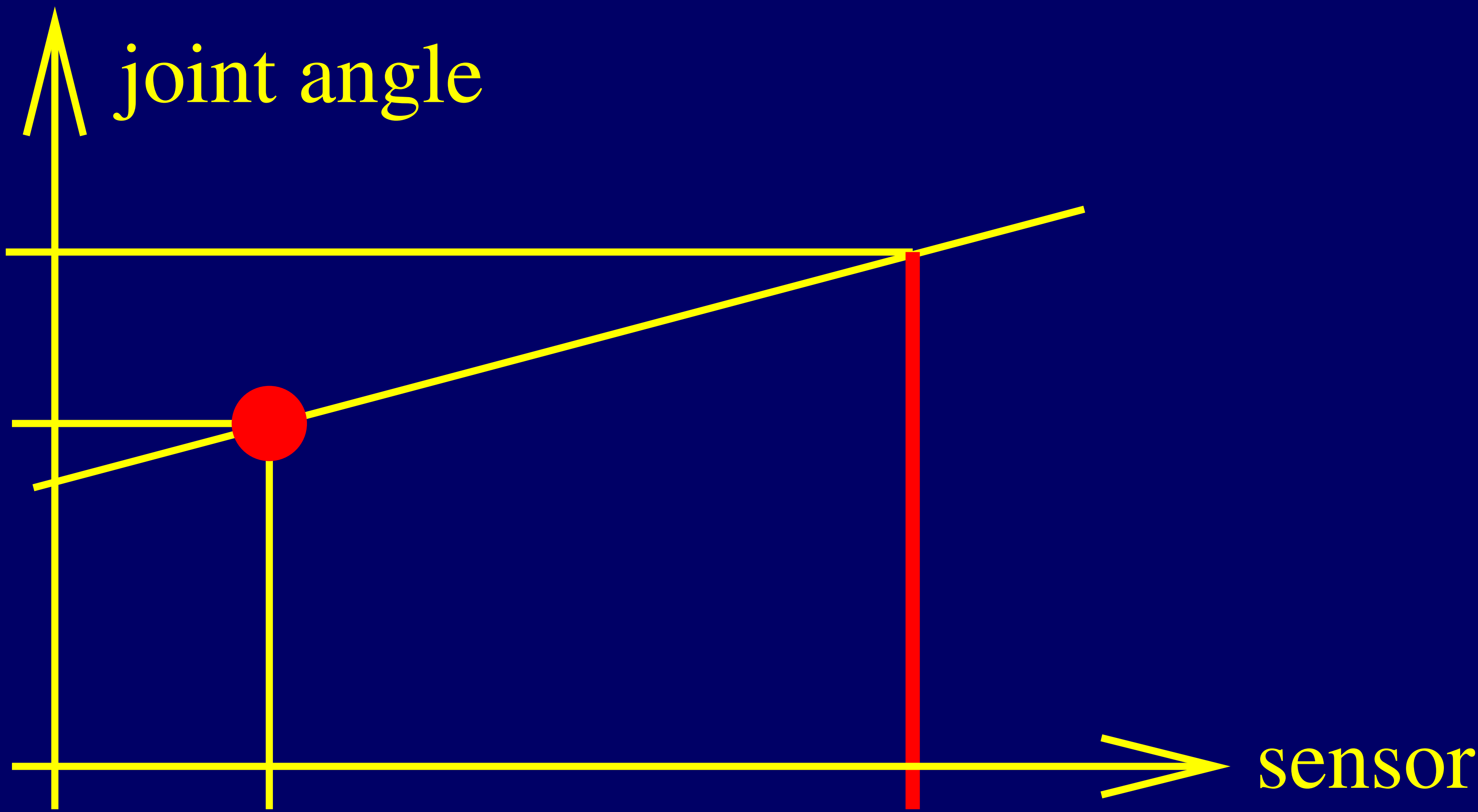

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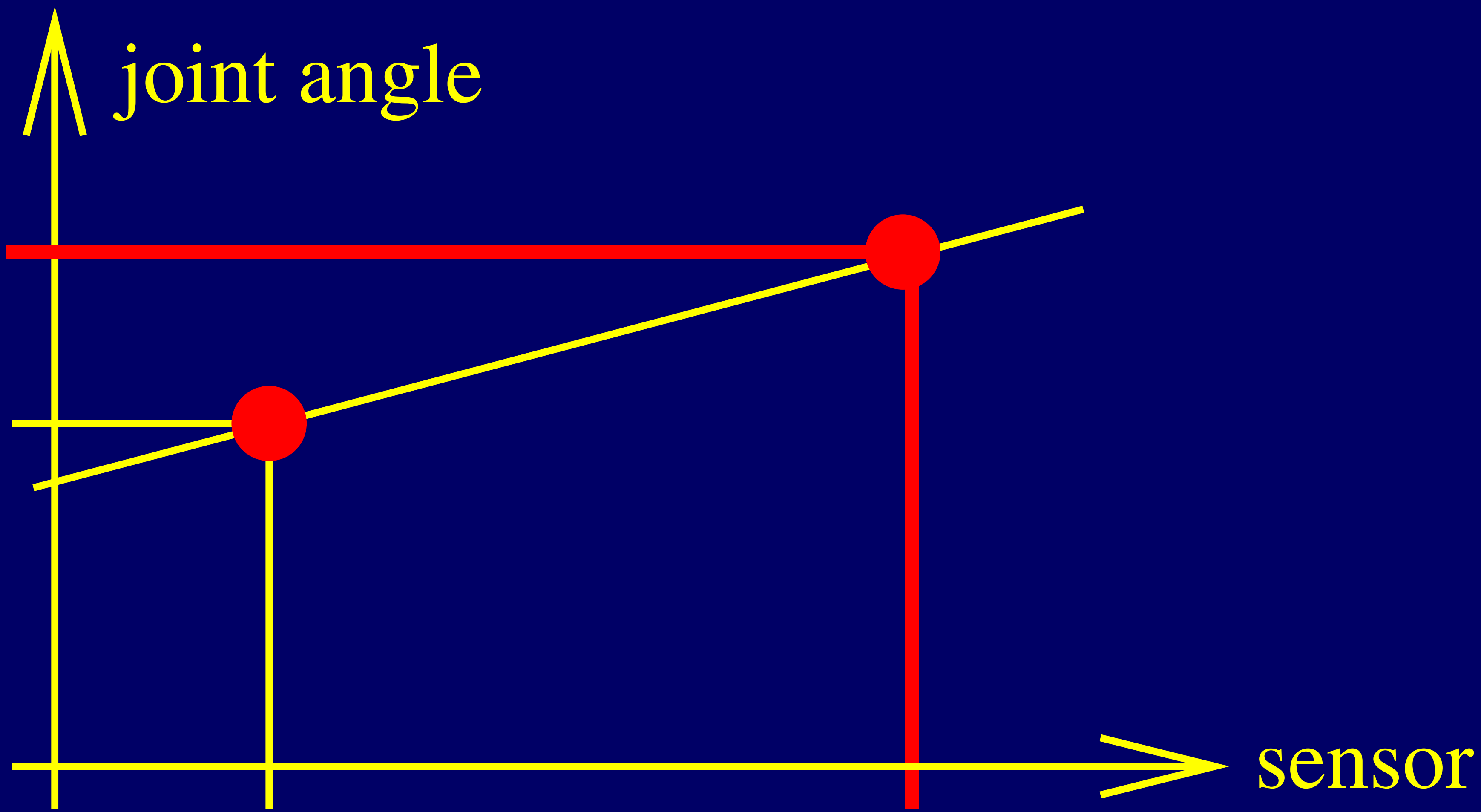

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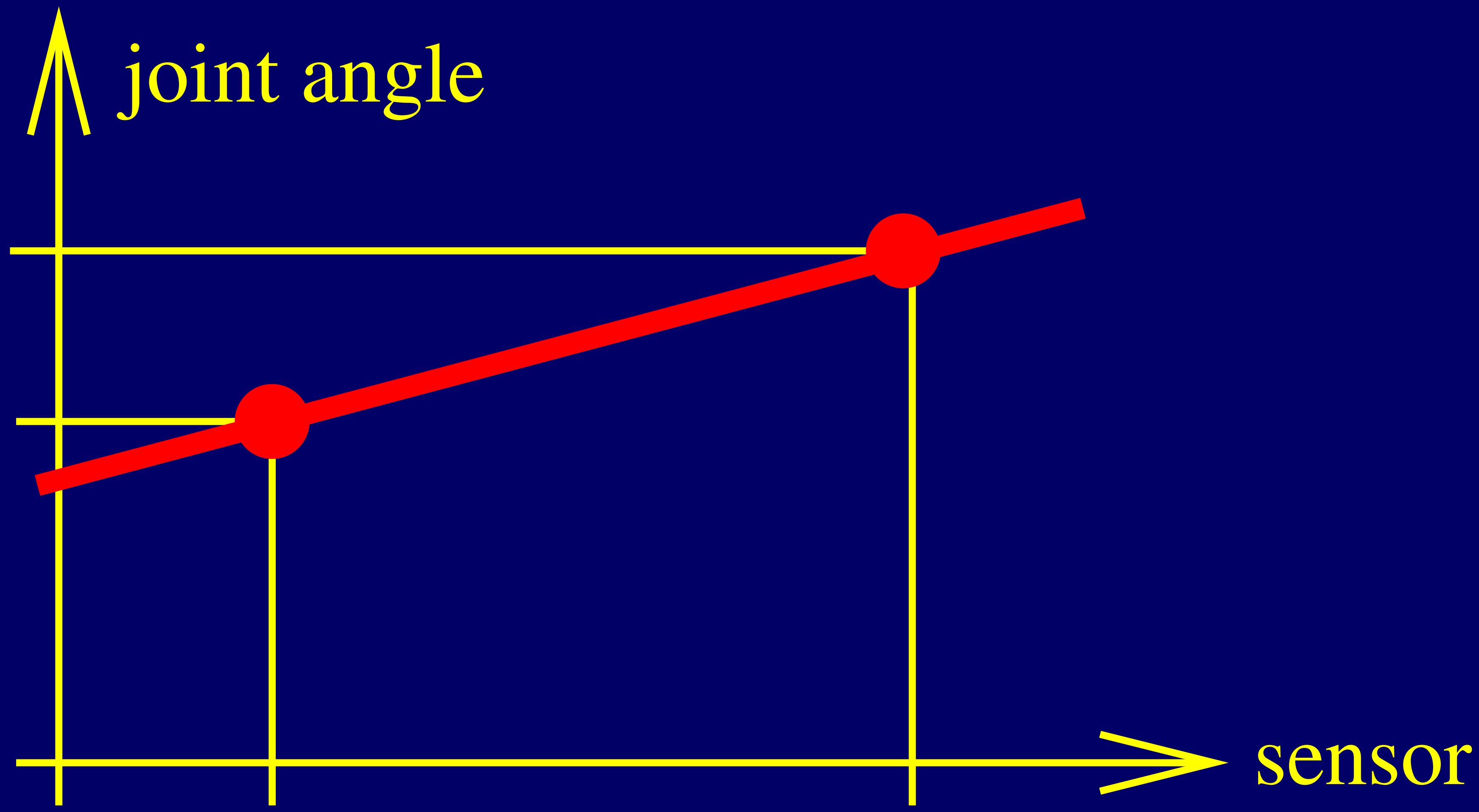

Cross-coupling of sensors

- ground-truth: abduction $= 0^{\circ}$

Cross-coupling of sensors

- fingers are paralell

Cross-coupling of sensors

- but the abduction sensor

Cross-coupling of sensors

- stretches…

Cross-coupling of sensors

- stretch $\Longrightarrow$ change of measured value
- $\Longrightarrow$ computed joint angle value varies
- bending finger moves sidewards!

Cross-coupling of sensors

- stretch $\Longrightarrow$ change of measured value
- $\Longrightarrow$ computed joint angle value varies
- bending finger moves sidewards!
- $\Longrightarrow$ *this joint angle depends on more sensors*
- what are the interdependencies?

Cross-coupling of sensors

- sensor tests
  - not or neglibly coupled sensor?
    - $\Longrightarrow$ independent linear calibration

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    - with which ones?
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Cross-coupling of sensors

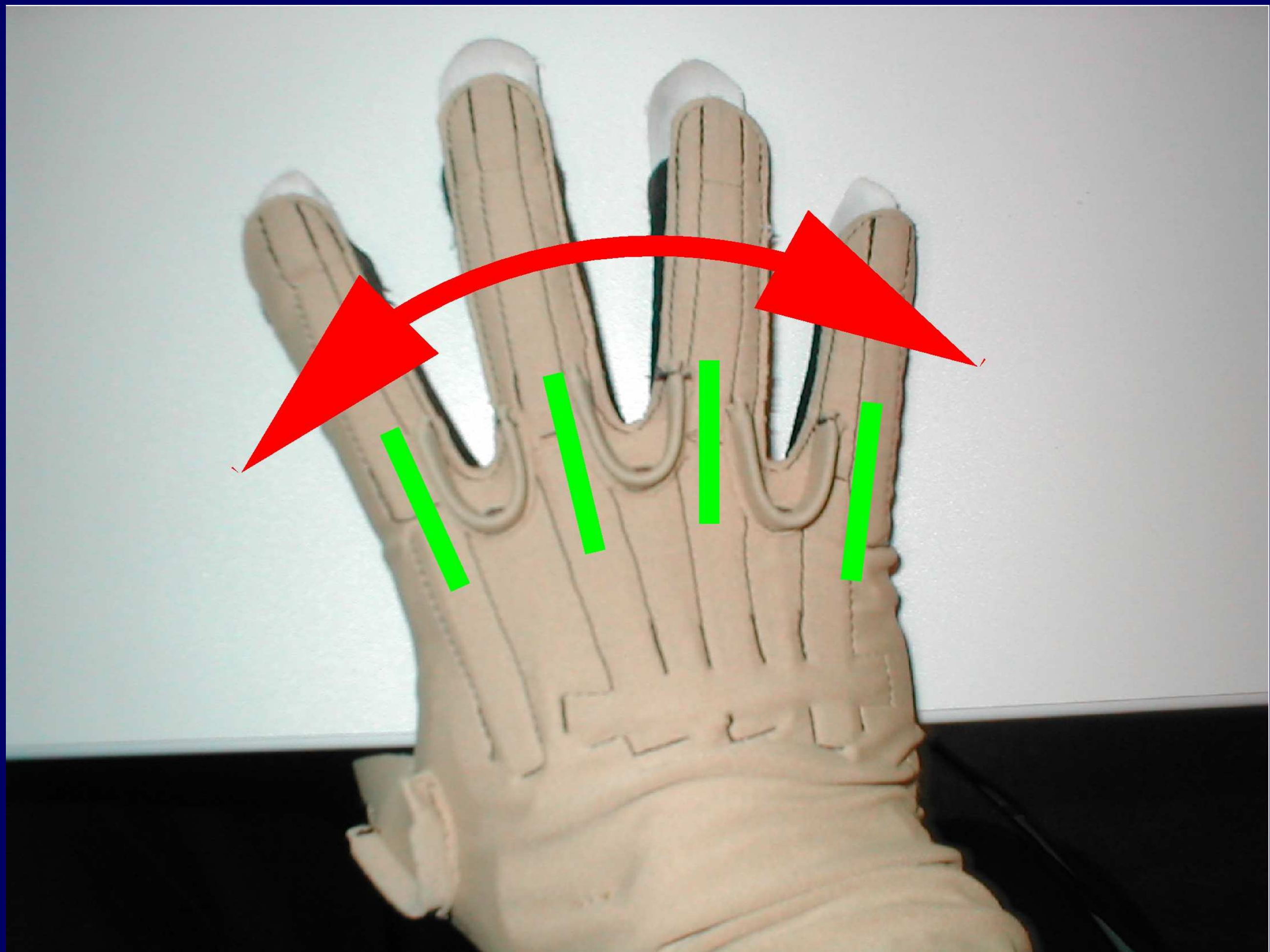
- sensor tests
  - not or neglibly coupled sensor?
    - $\Longrightarrow$ independent linear calibration
  - change correlated with other sensor changes
    - with which ones?
    - $\Longrightarrow$ (somehow) calibrate them together
- only glove couplings, not human “error”

Cross-coupling of sensors

- abduction/adduction

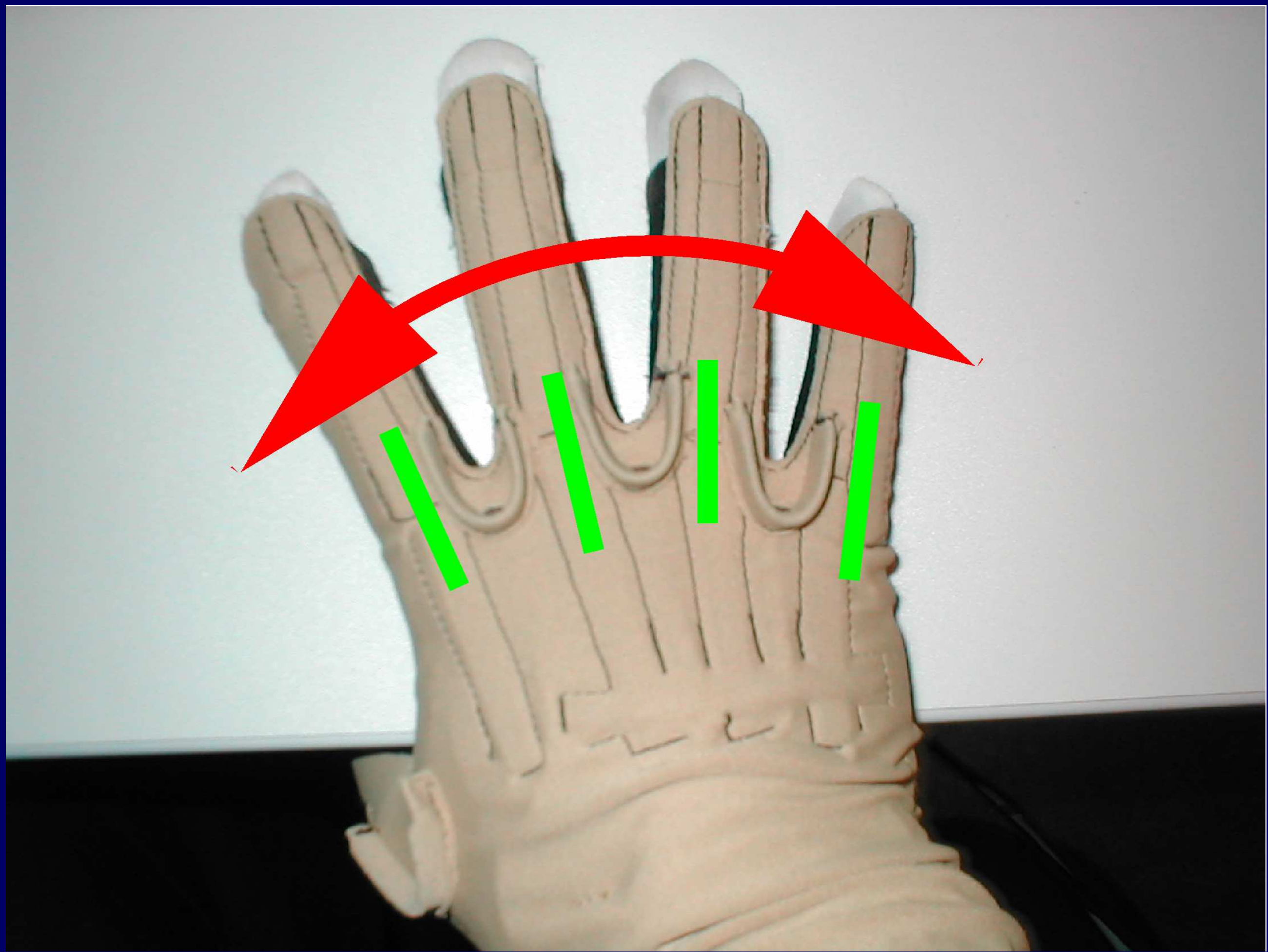
Cross-coupling of sensors

- abduction/adduction $\Longleftrightarrow$ proximal-flex?



Cross-coupling of sensors

- neglible (see paper)



Cross-coupling of sensors

- free movement of fingers

Cross-coupling of sensors

- free movement of fingers $\Longleftrightarrow$ one p. flex?

Cross-coupling of sensors

- neglible (see paper)

Cross-coupling of sensors

- neighbouring flex(es)

Cross-coupling of sensors

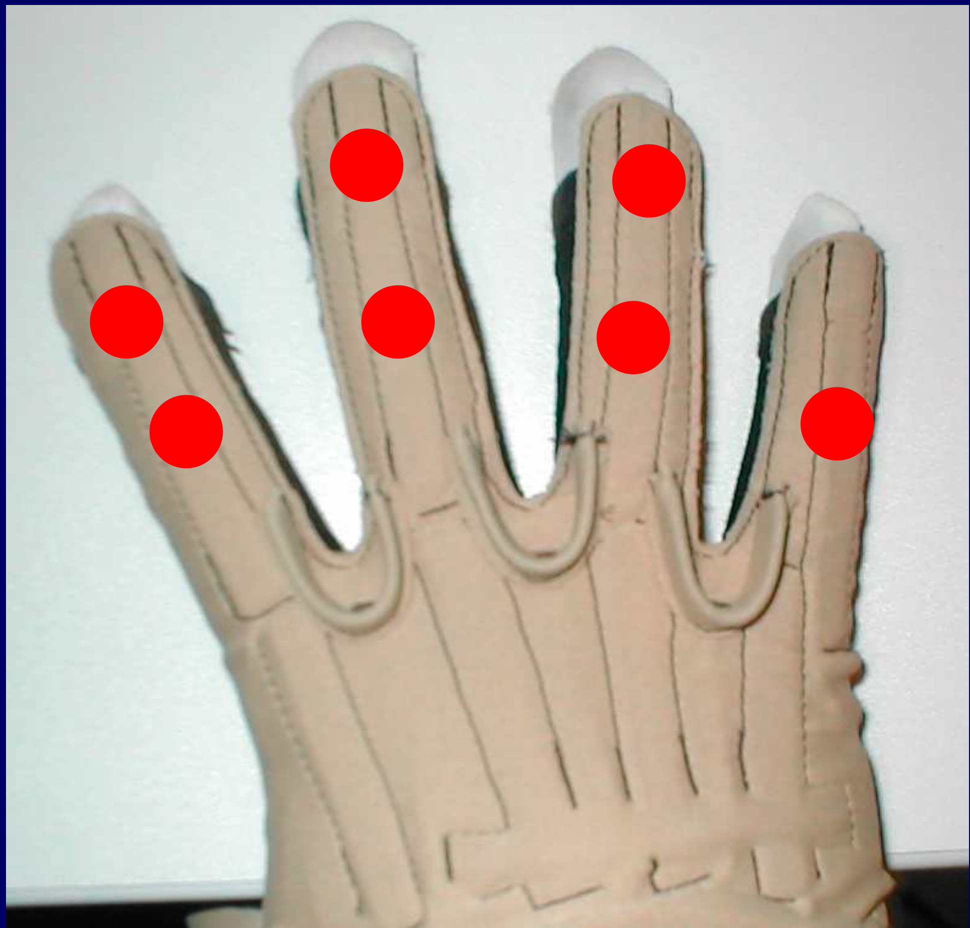
- neighbouring flex(es) $\Longleftrightarrow$ one abduction?

Cross-coupling of sensors

- should be compensated! (see paper)

Cross-coupling of sensors

- no tests, linear independent calibration



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Cross-coupling of sensors

- decisions
  - middle & distal flexes $\Longrightarrow$ independent linear
  - proximal flexes $\Longrightarrow$ independent linear
  - abduction $\Longrightarrow$ cross-coupled
- what function to take?
- which sensors should be taken into account?

Calibration of cc.-sensors

- $\theta_{ABD} = f(s_{ABD}, s_{FLEX}^{left}, s_{FLEX}^{right})$

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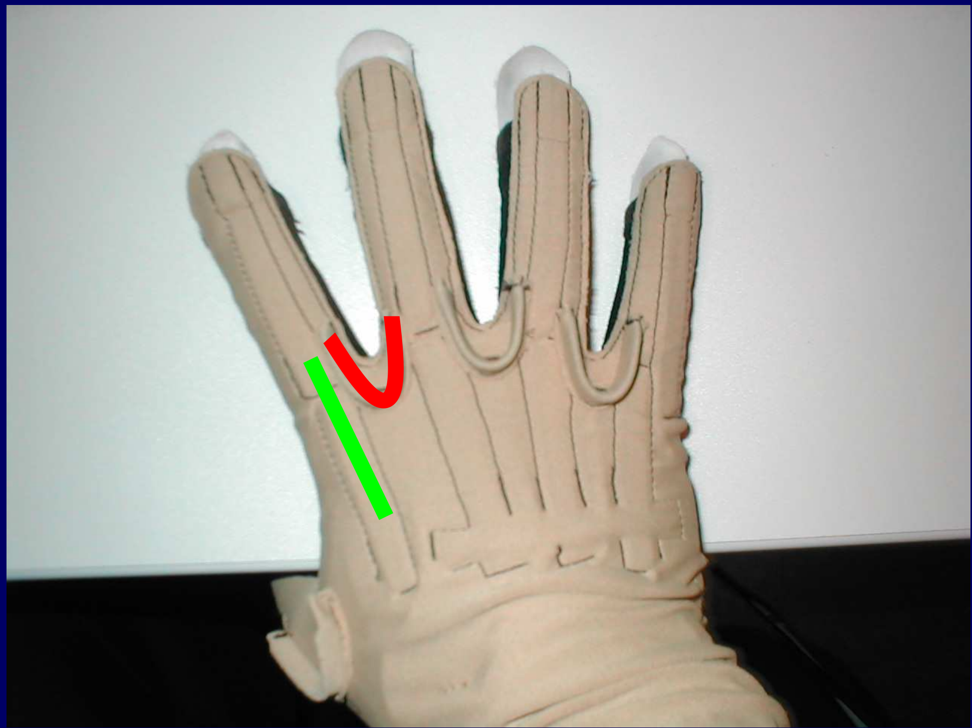

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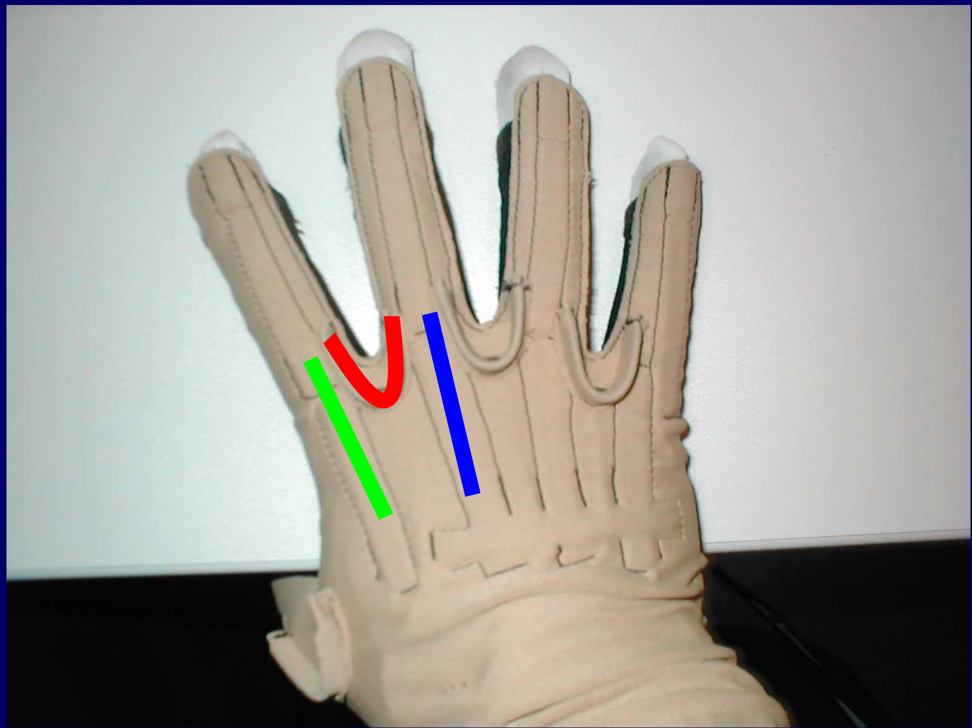

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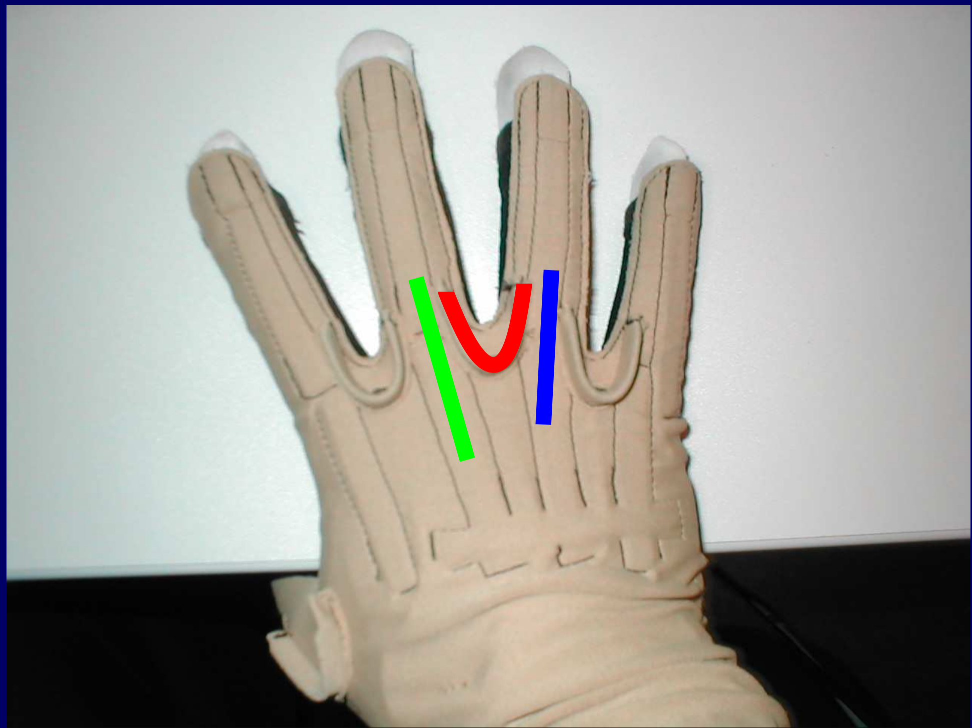

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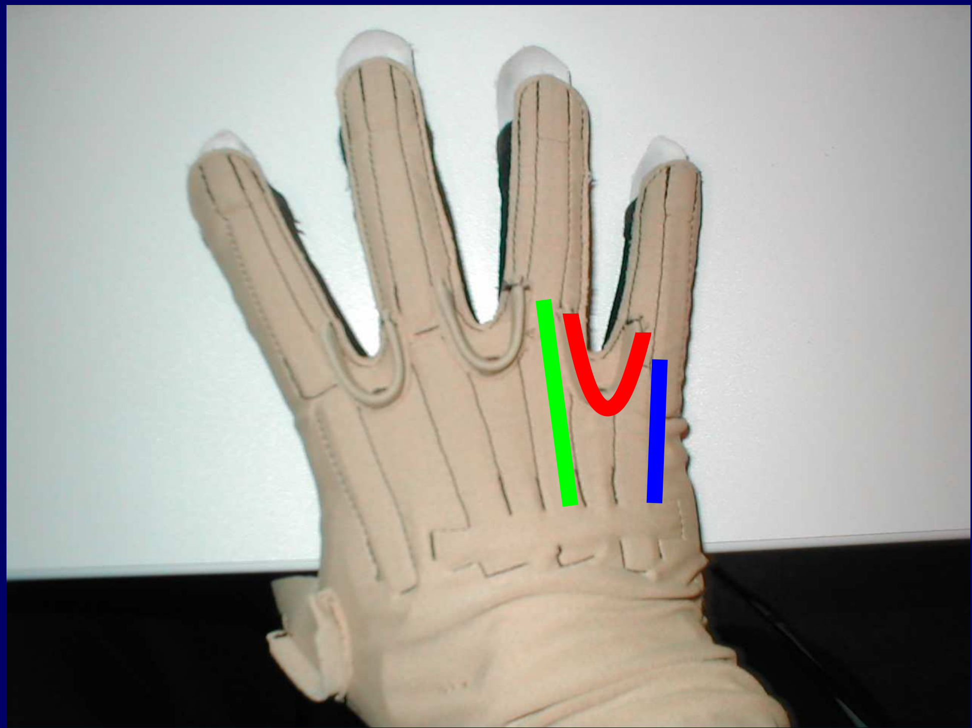

Calibration of cc.-sensors

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Calibration of cc.-sensors

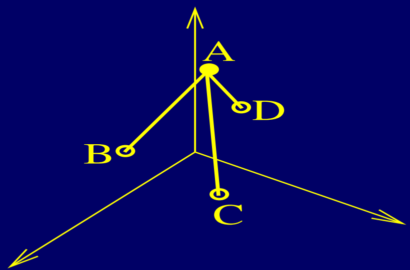
- decided about the variables
- sensible definition of f?
- $f : R^3 \rightarrow R^1$
- $\Longrightarrow$ points, whose corresponding joint angle is the same should define an isosurface
- estimate abduction based on
  - sensor readings
  - one or more predetermined isosurfaces

Calibration of cc.-sensors

- we know points on the 0-isosurface

A)


B)

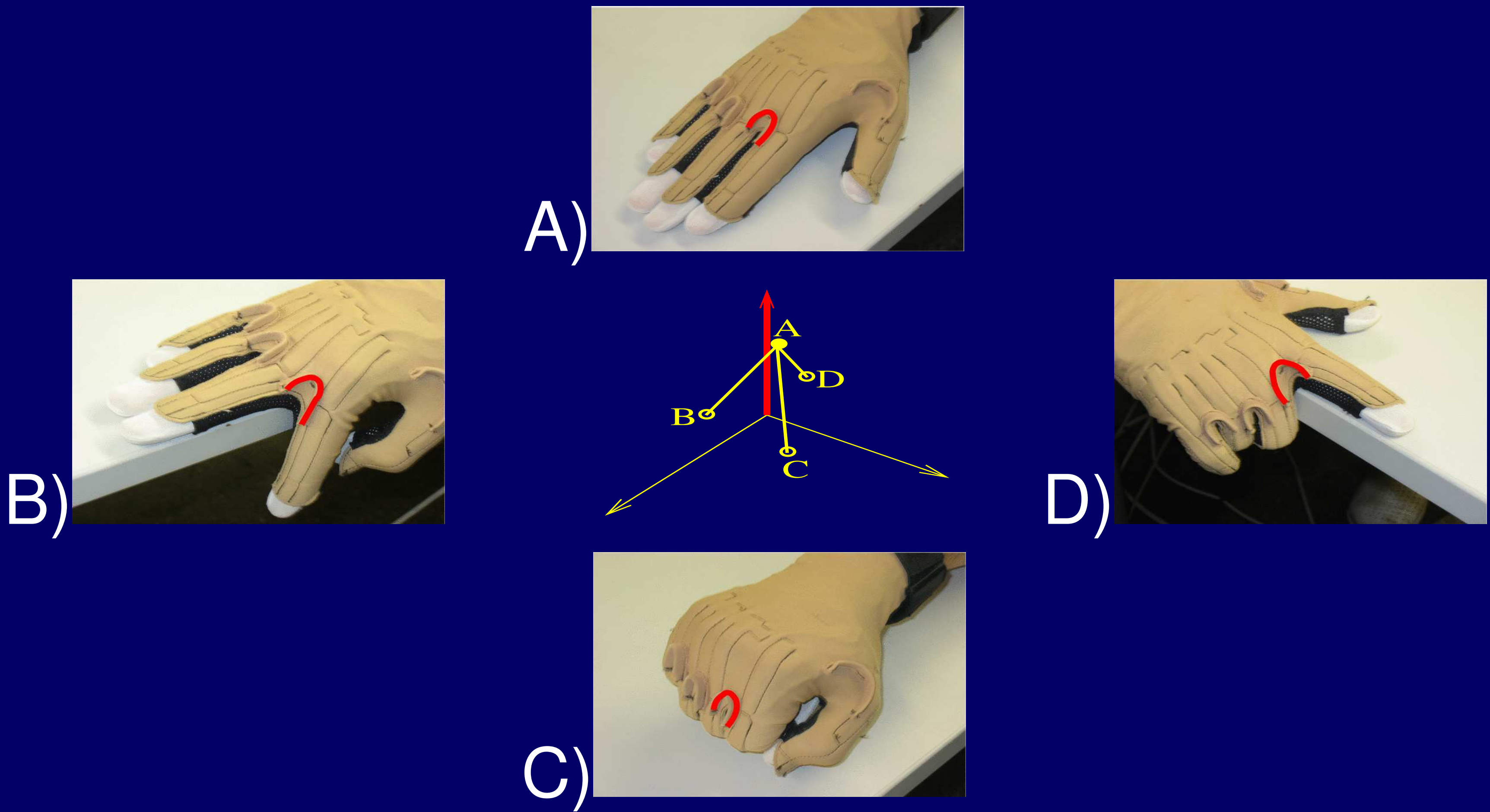



D)


C)

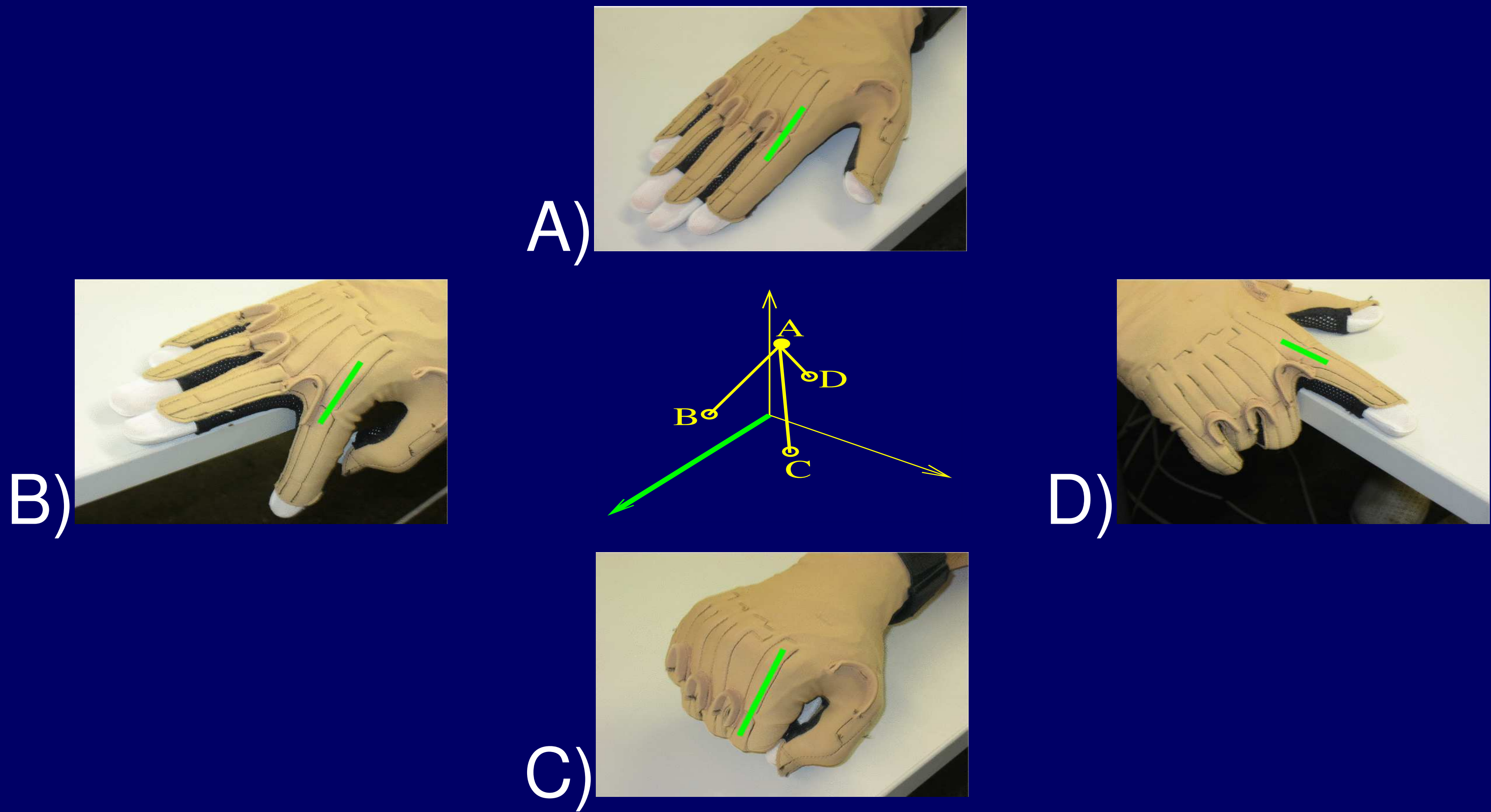

Calibration of cc.-sensors

- abduction



Calibration of cc.-sensors

- left flex

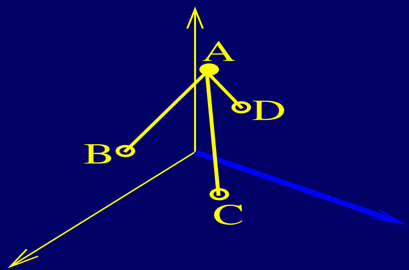


Calibration of cc.-sensors

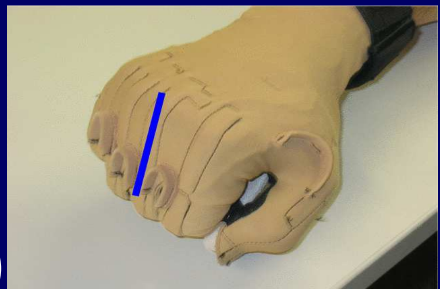
- right flex

A) 

B) 

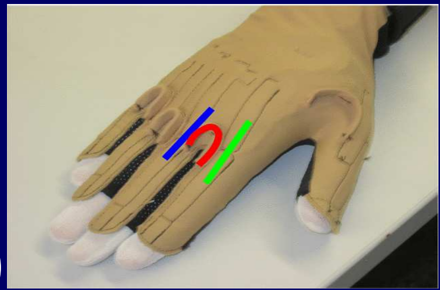


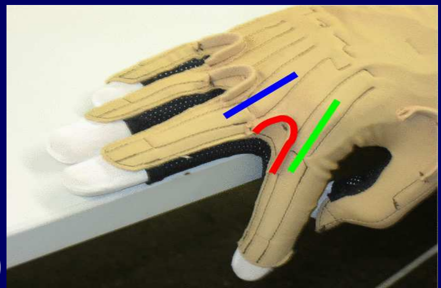
D) 

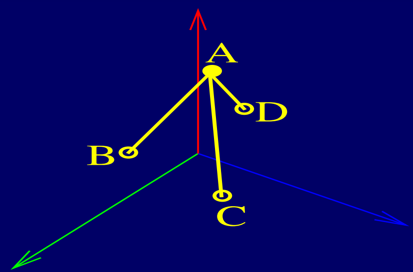
C) 

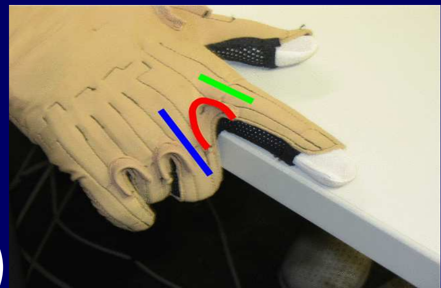
Calibration of cc.-sensors

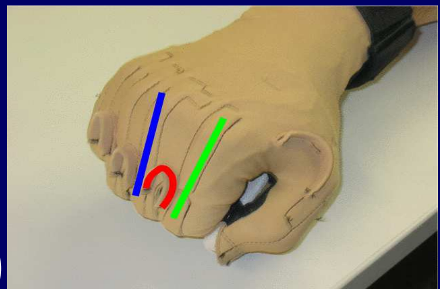
- positions corresponding to gestures

A) 

B) 

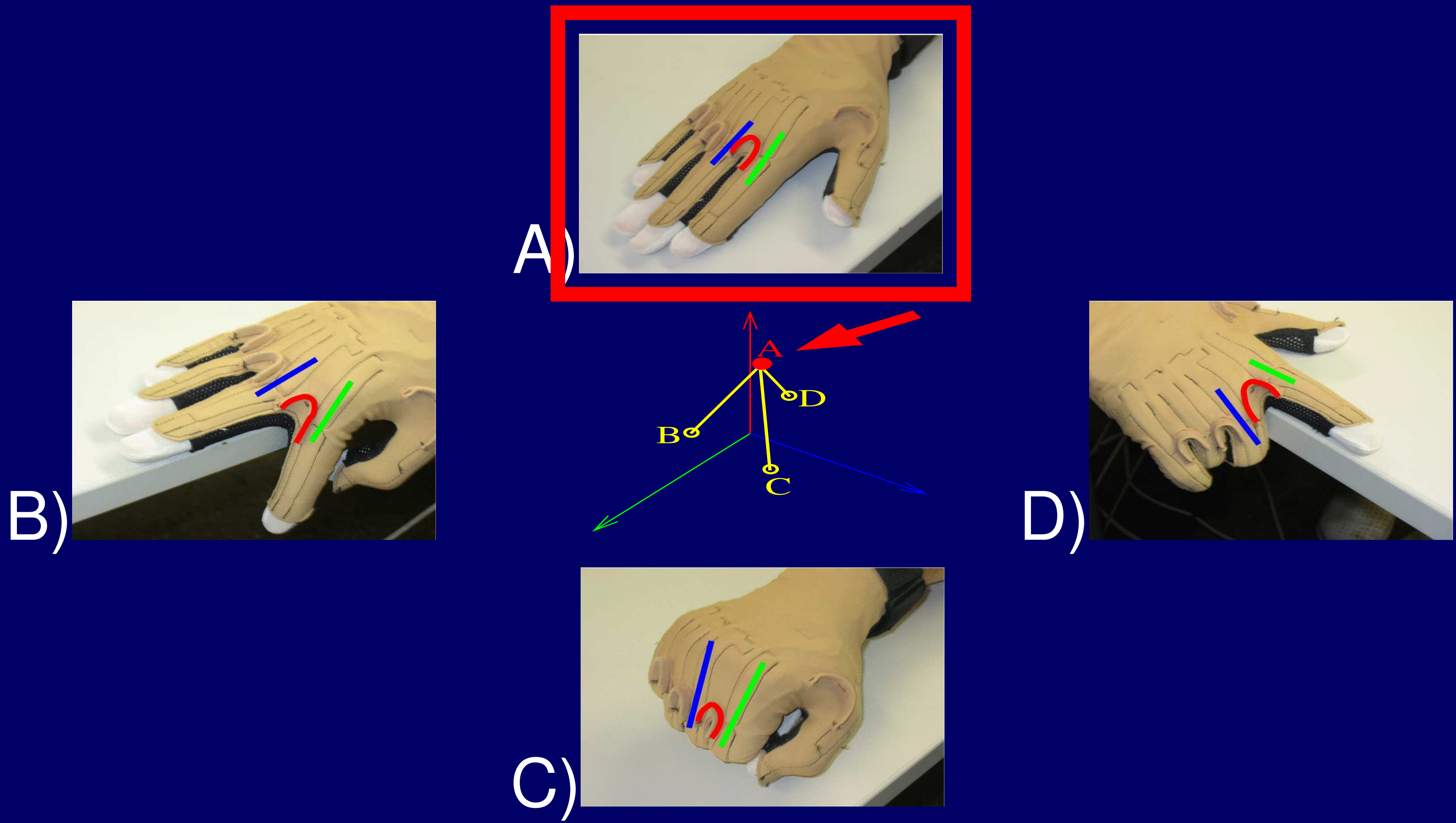


D) 

C) 

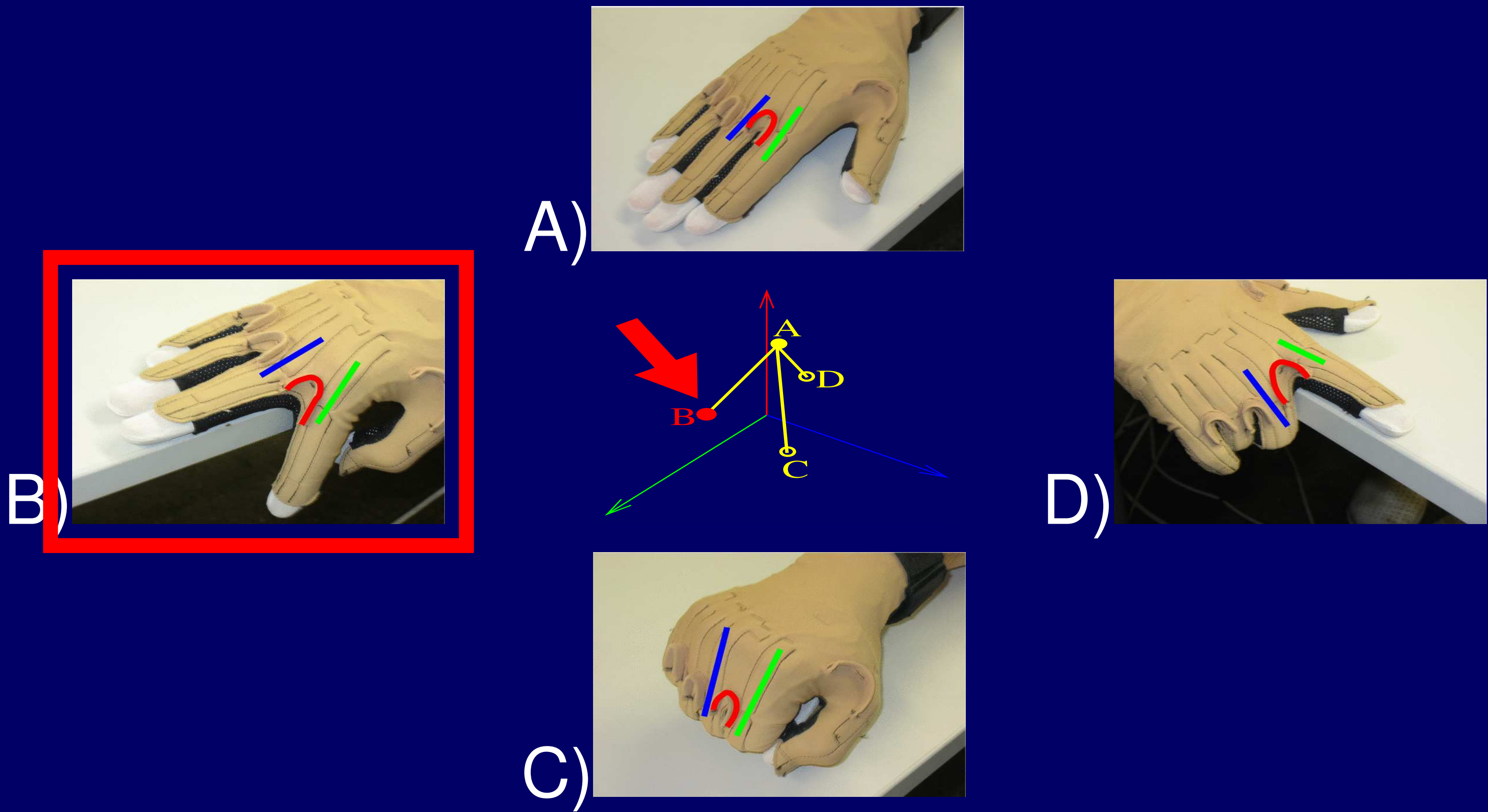
Calibration of cc.-sensors

- A



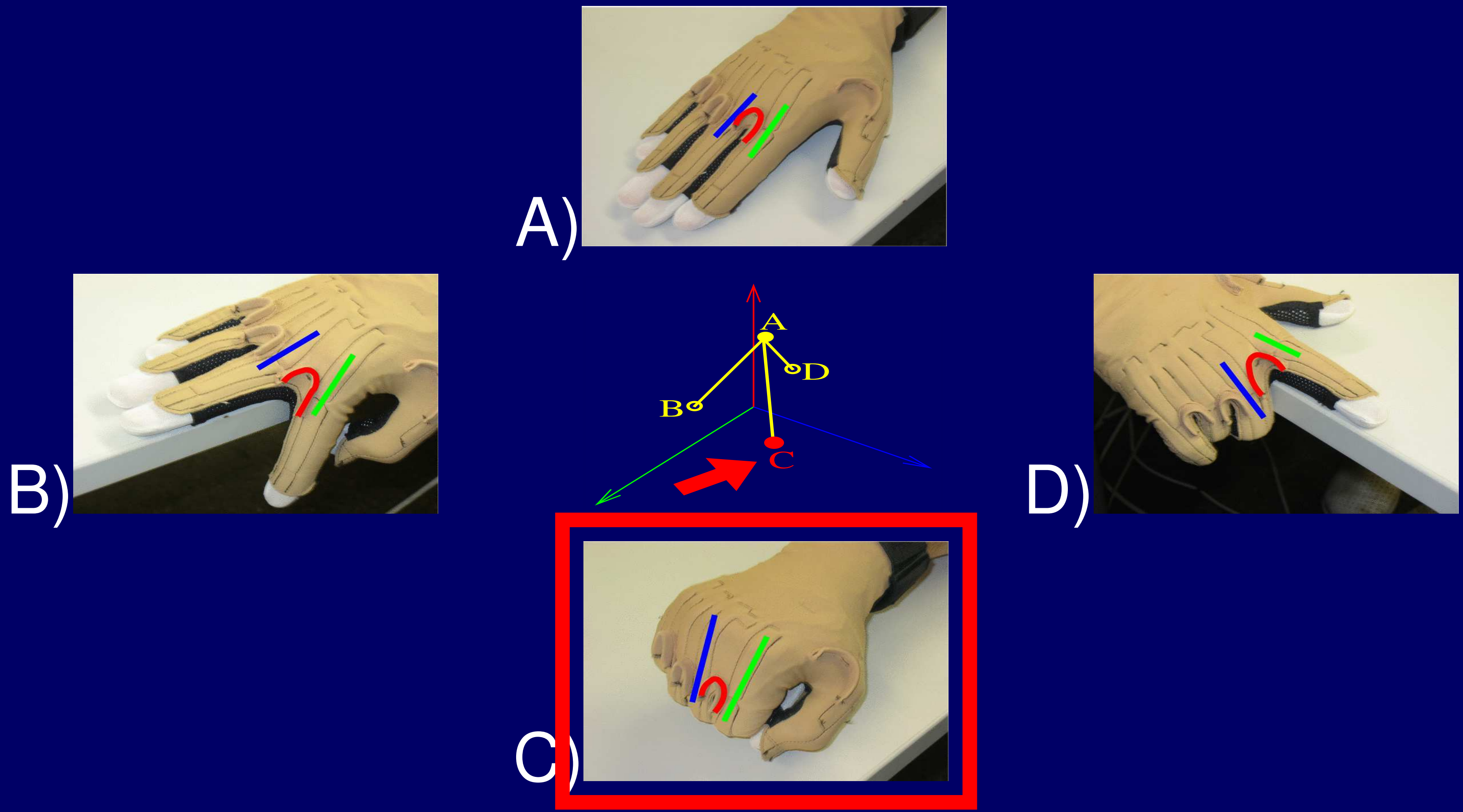
Calibration of cc.-sensors

- B



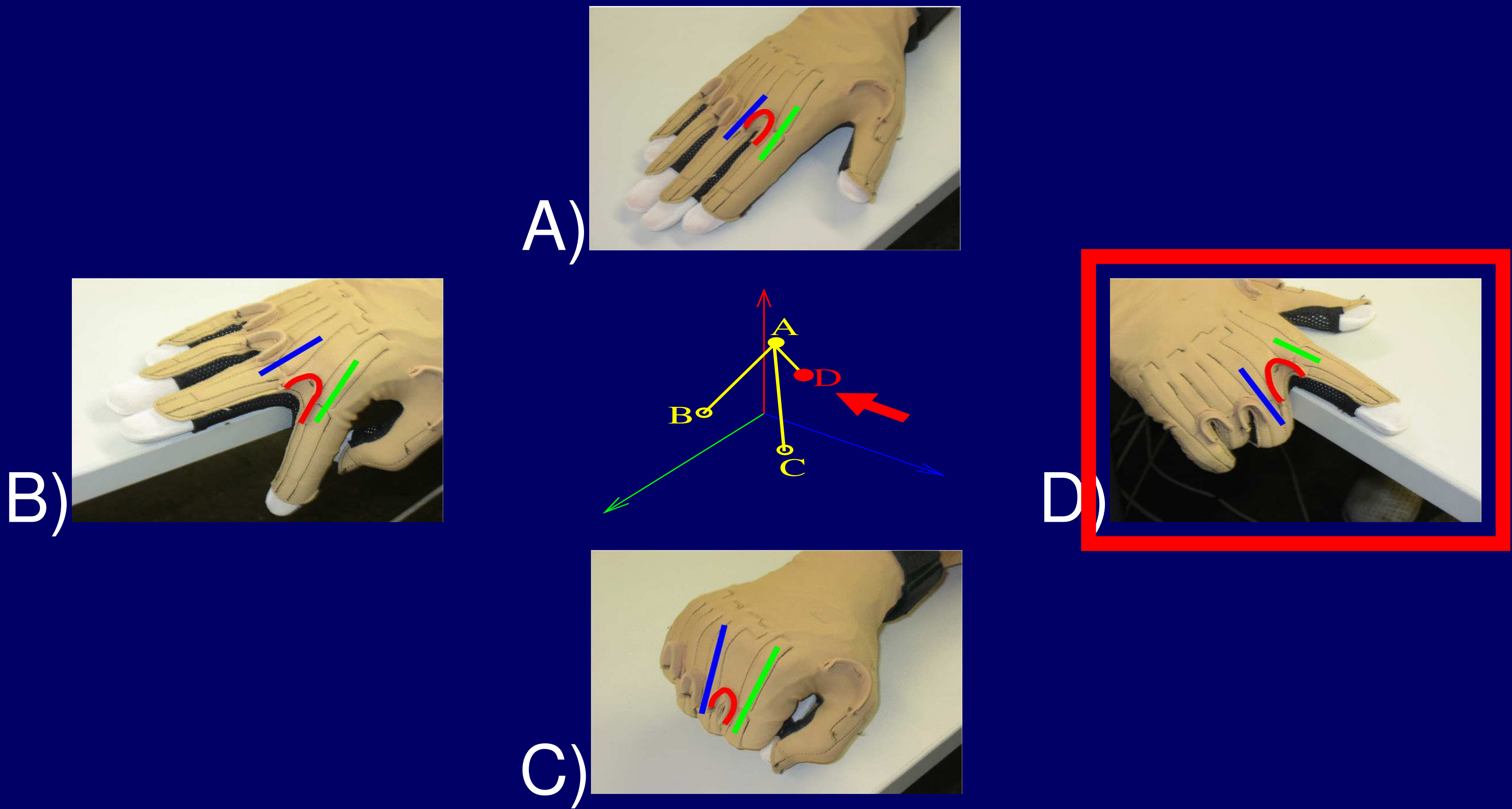
Calibration of cc.-sensors

- C



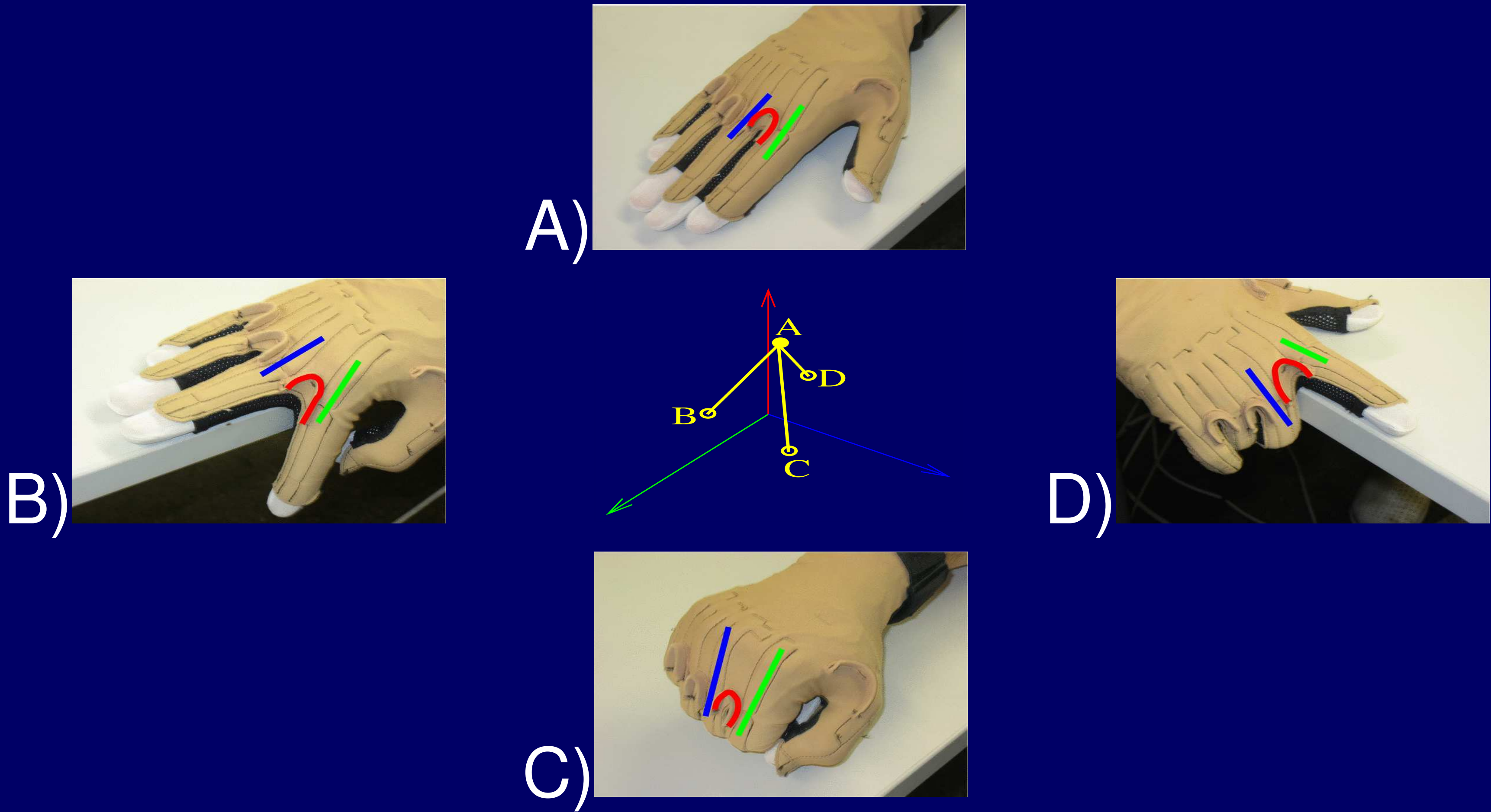
Calibration of cc.-sensors

- D



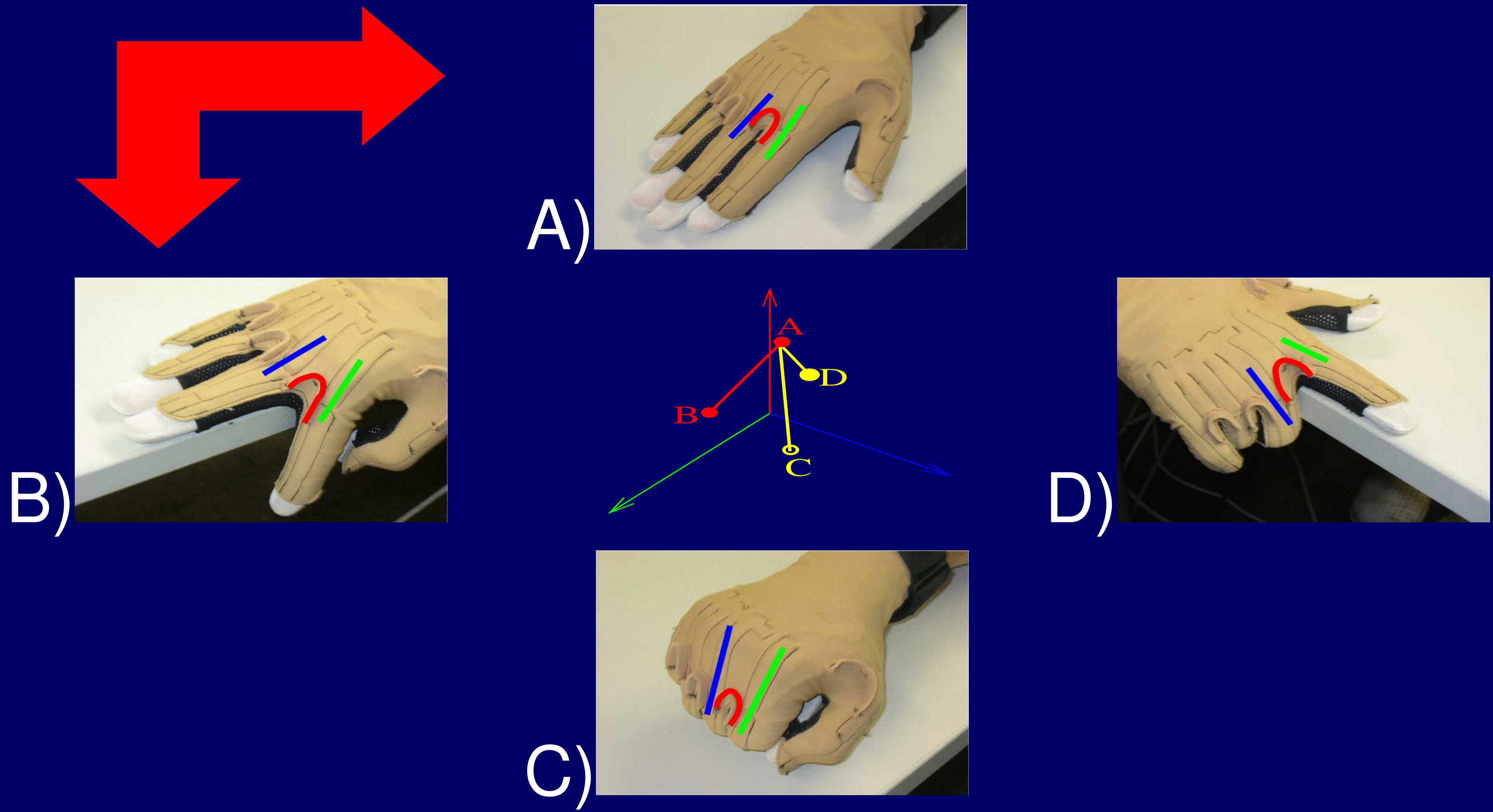
Calibration of cc.-sensors

- expected trajectories



Calibration of cc.-sensors

- $A \Longleftrightarrow B$



Calibration of cc.-sensors

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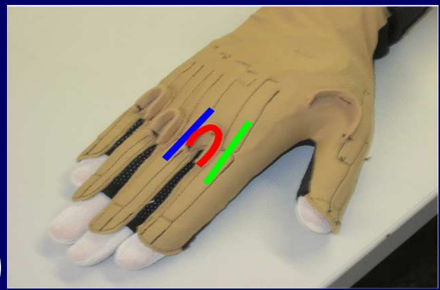
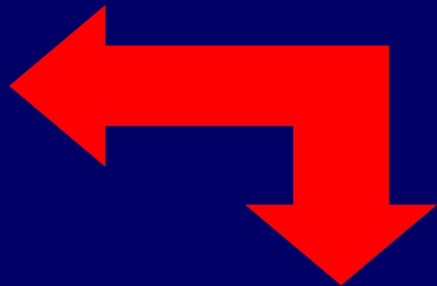
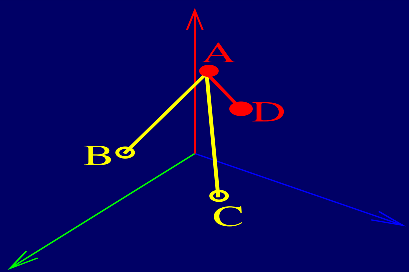
A)




B)

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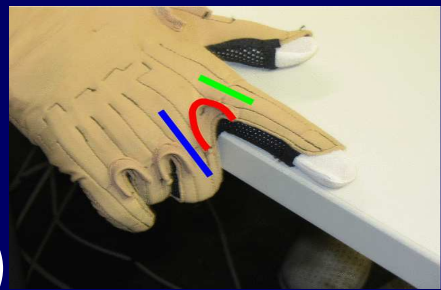

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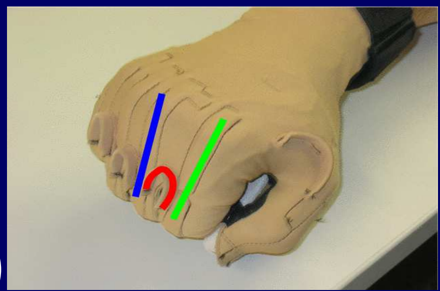
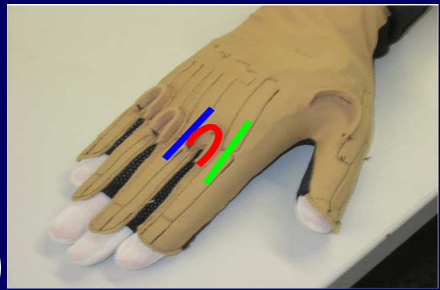


Calibration of cc.-sensors

- A$\Longleftrightarrow$C



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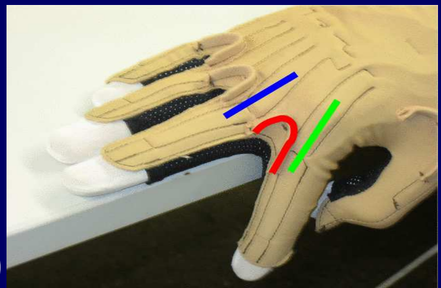
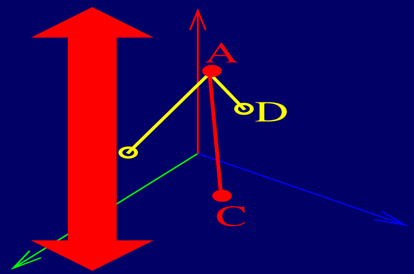
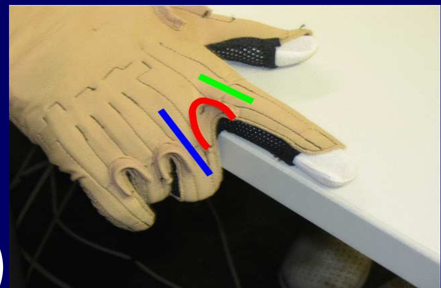
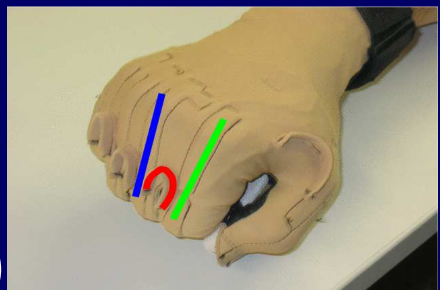


B)





D)



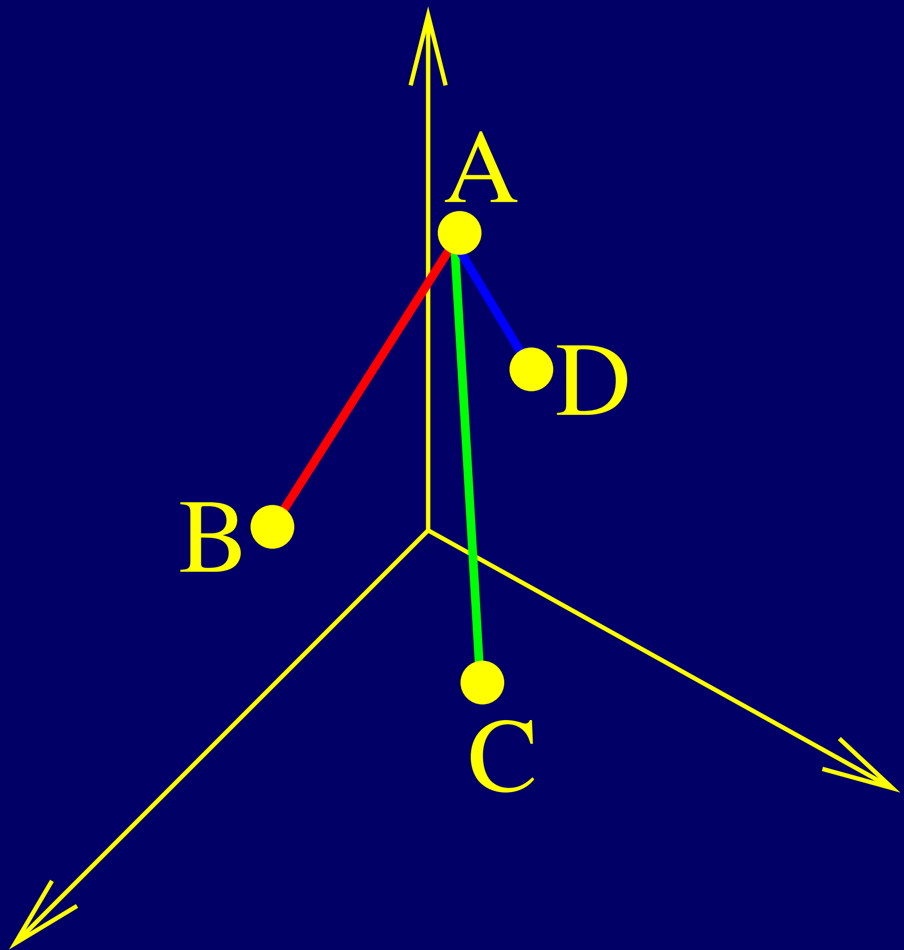
C)

Calibration of cc.-sensors

- creation of the 0-isosurface

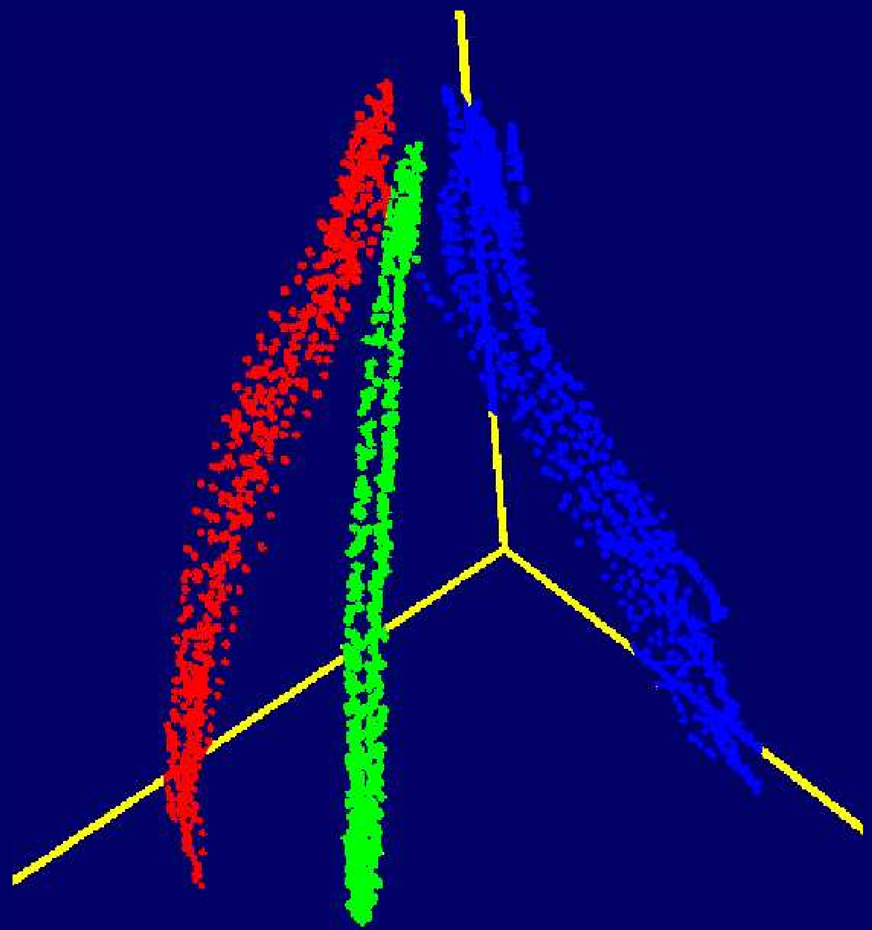
Calibration of cc.-sensors

- expectations



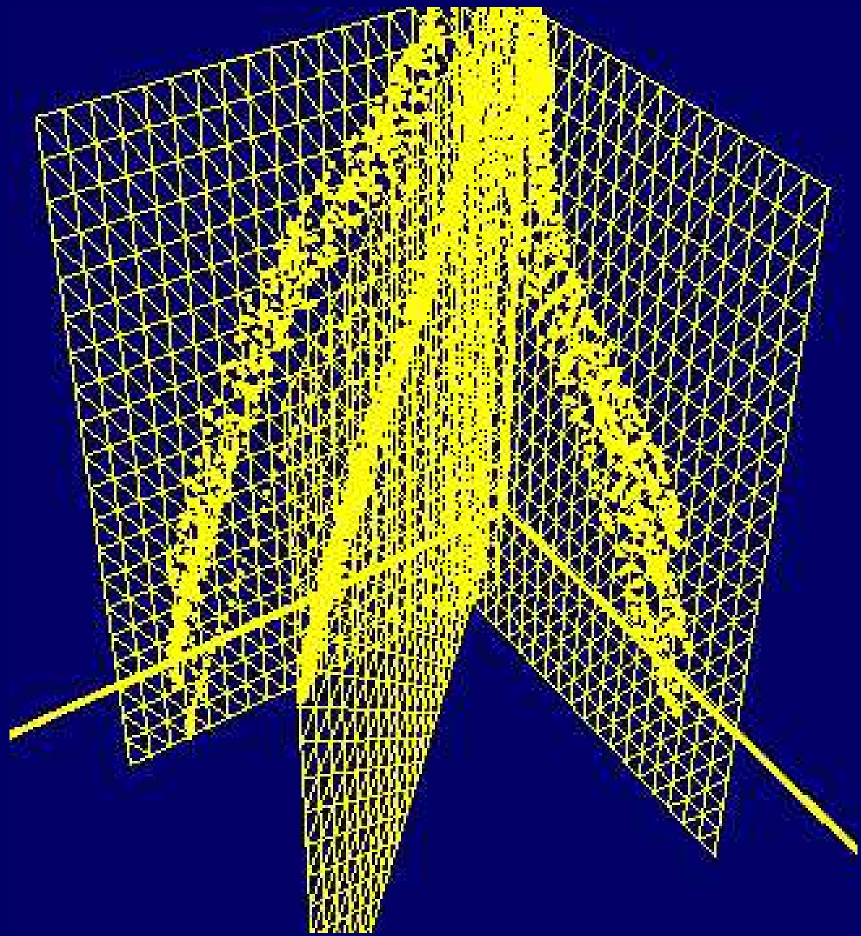
Calibration of cc.-sensors

- real trajectories



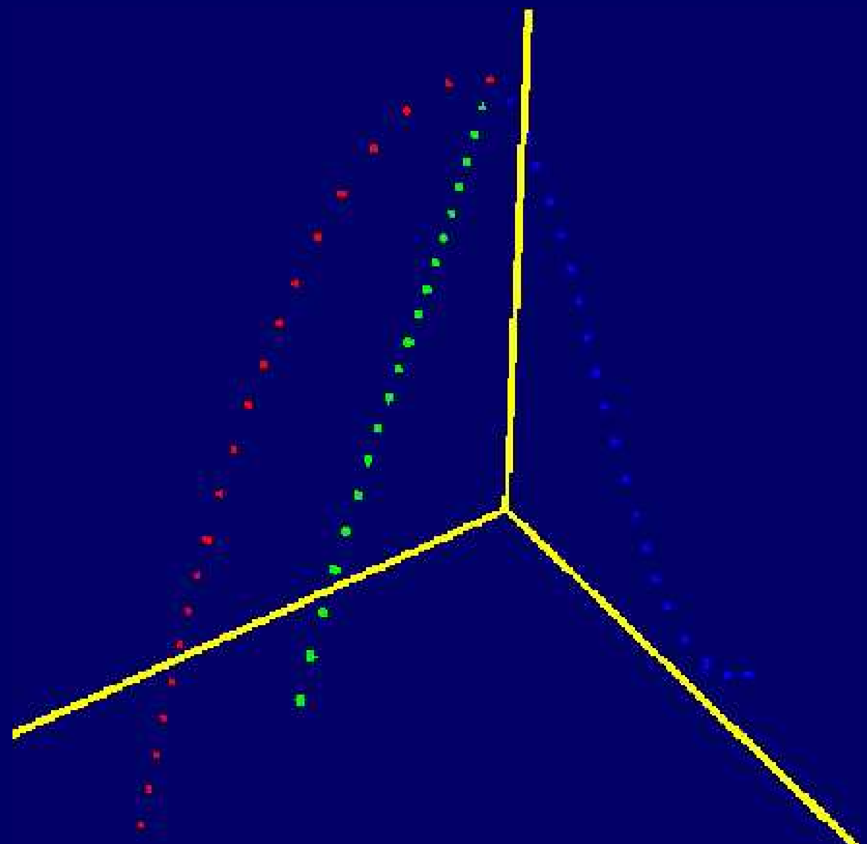
Calibration of cc.-sensors

- fitted projection planes



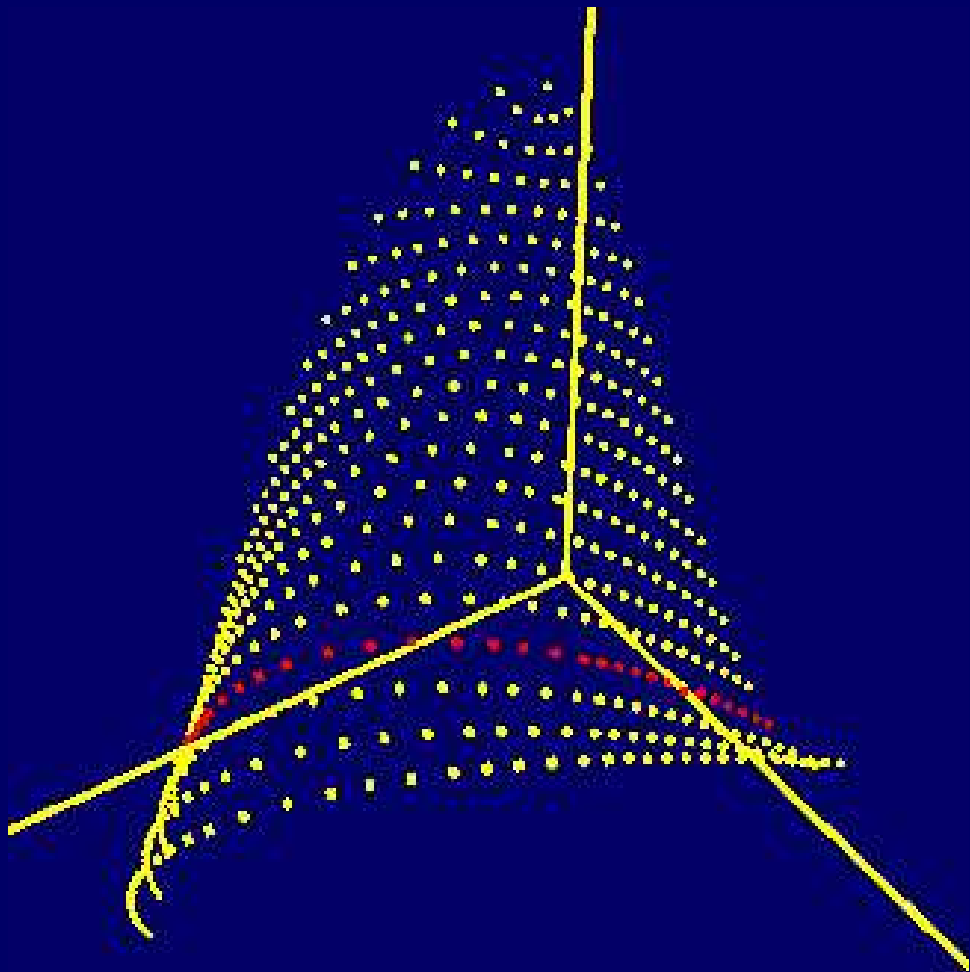
Calibration of cc.-sensors

- fitted curves



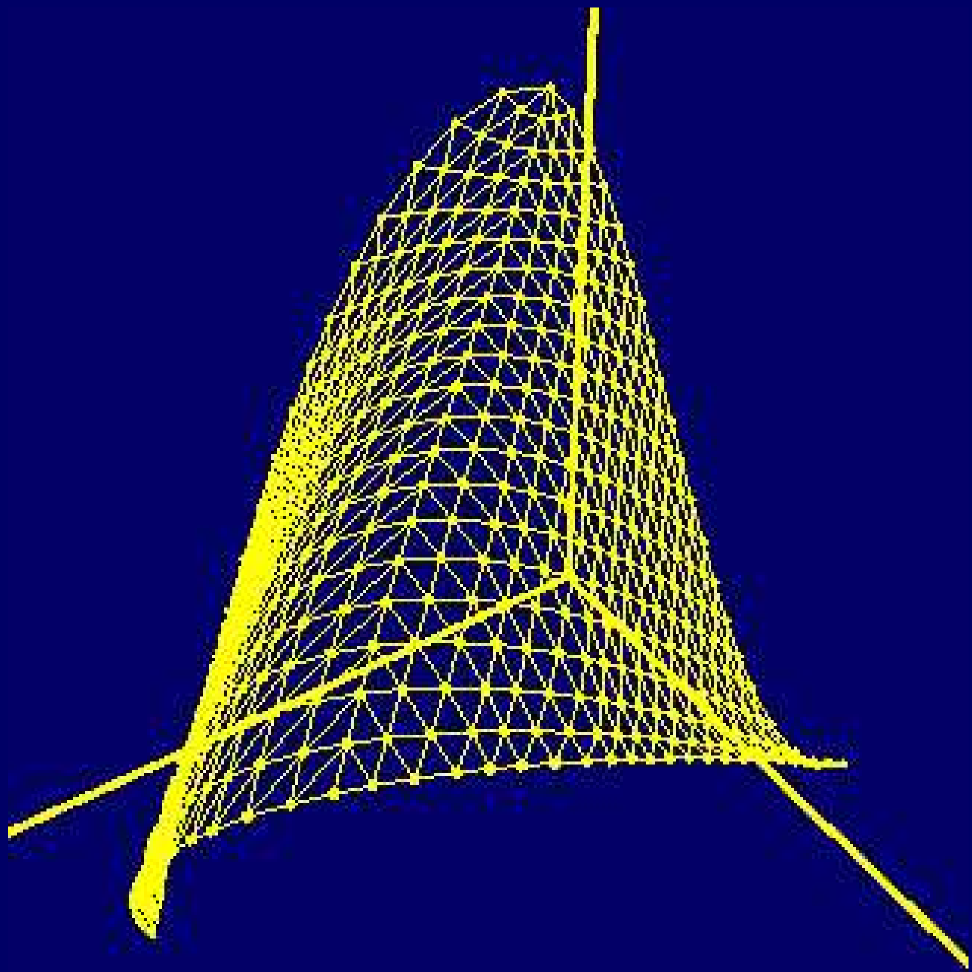
Calibration of cc.-sensors

- generated points



Calibration of cc.-sensors

- generated surface

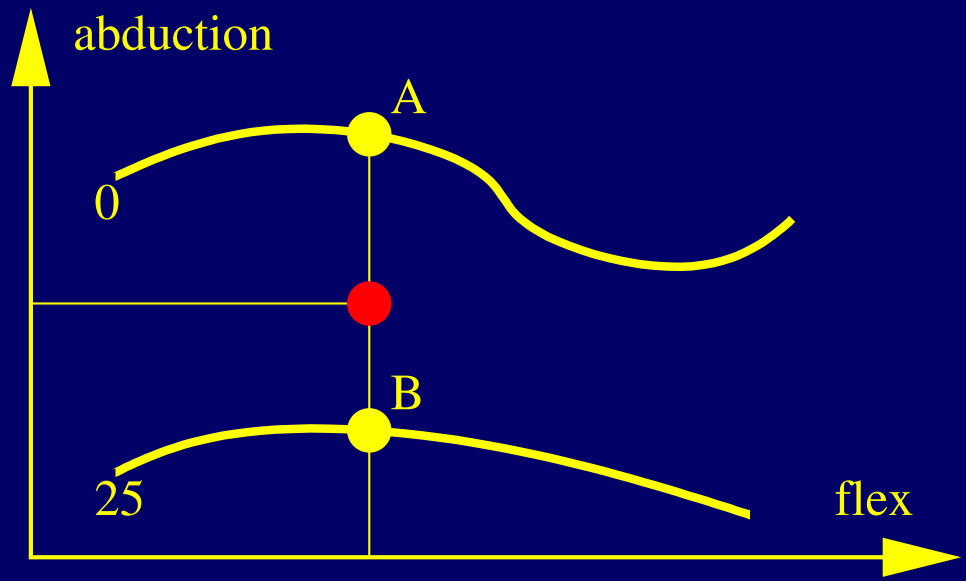


Calibration of cc.-sensors

- idea: record another isosurface. . .

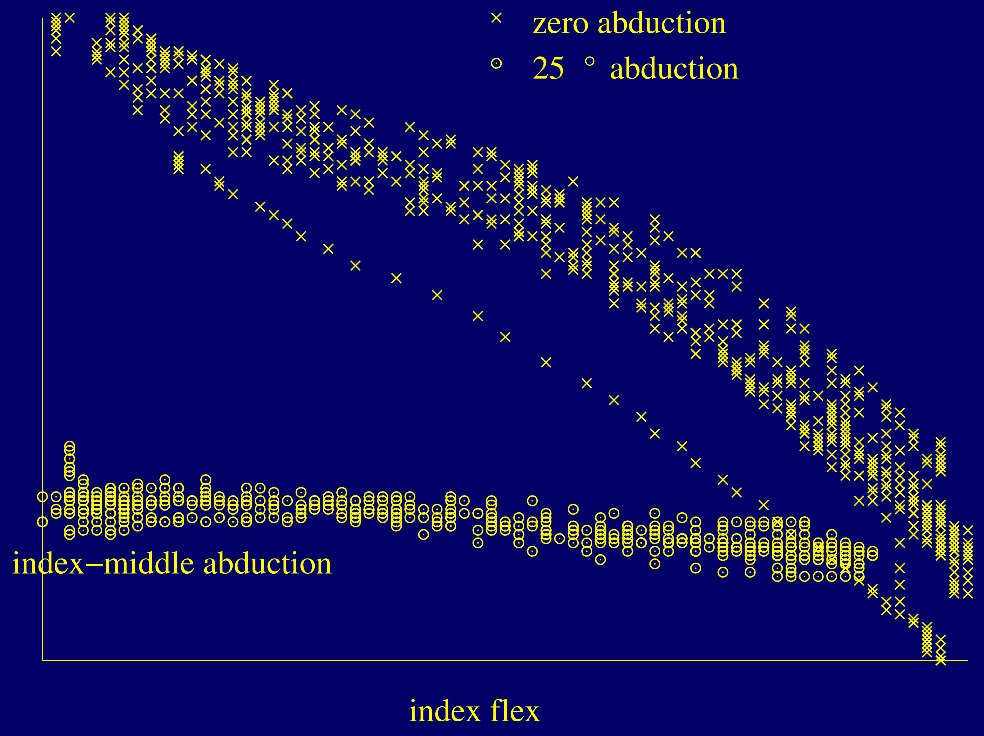
Calibration of cc.-sensors

- . . . and interpolate between the surfaces



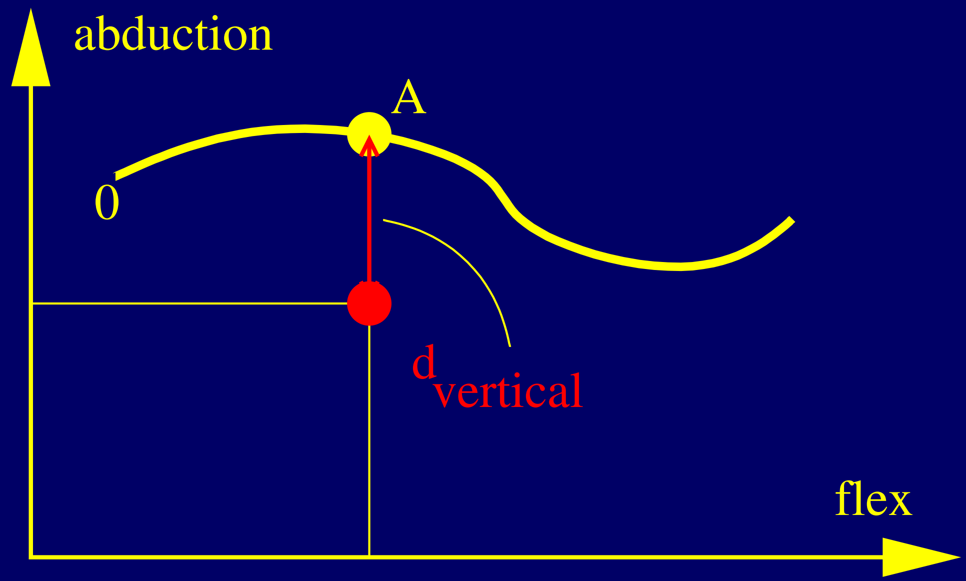
Calibration of cc.-sensors

- but. . .

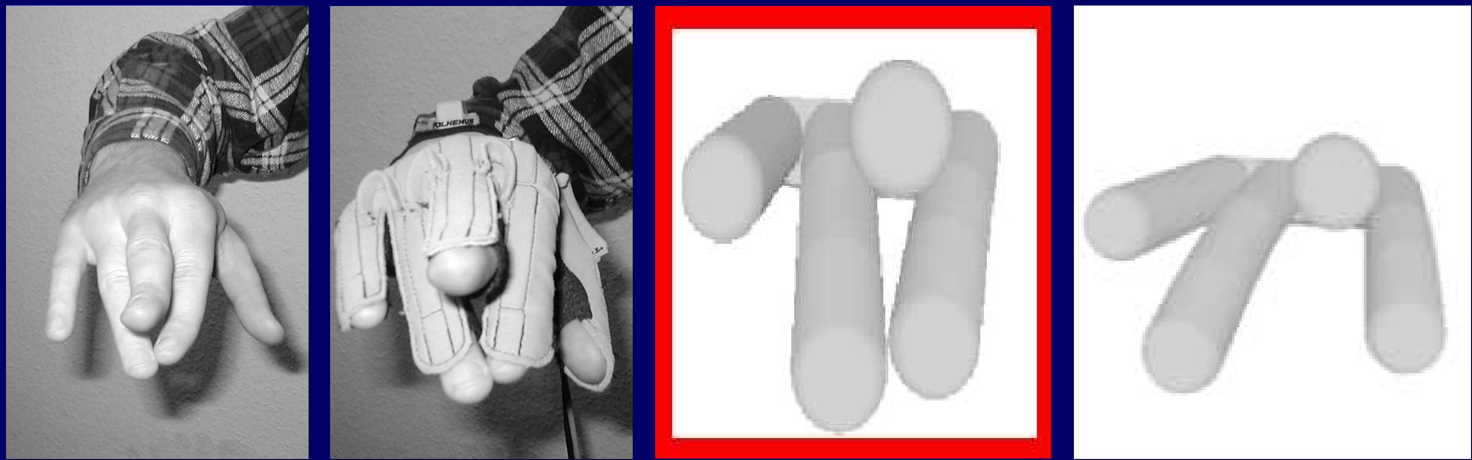


Calibration of cc.-sensors

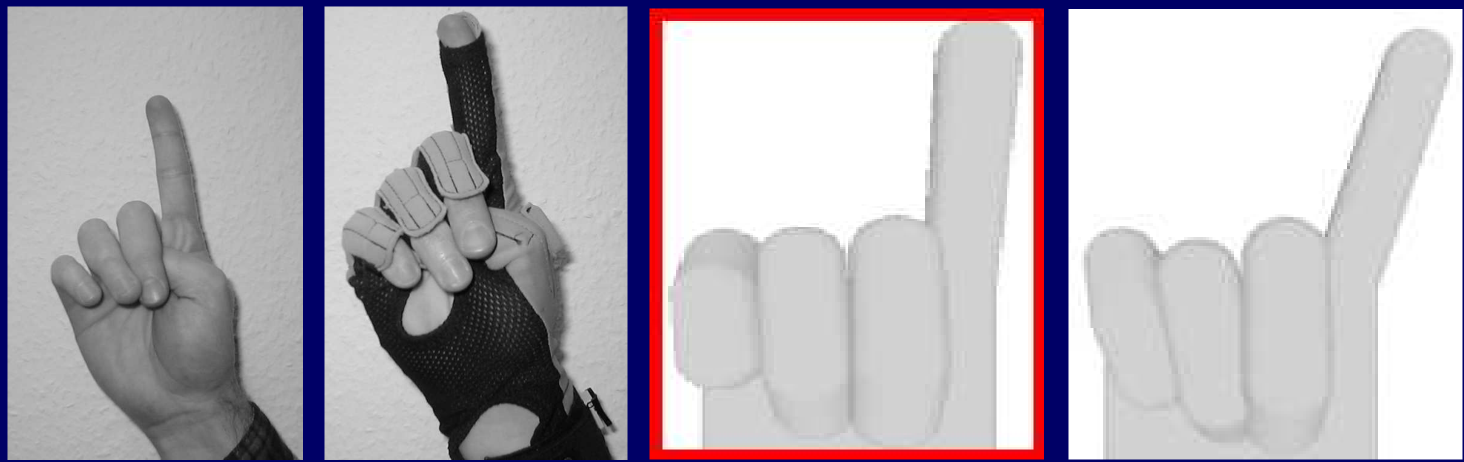
- compromise: $\theta = Ad_{vertical}(\cdot) + B$



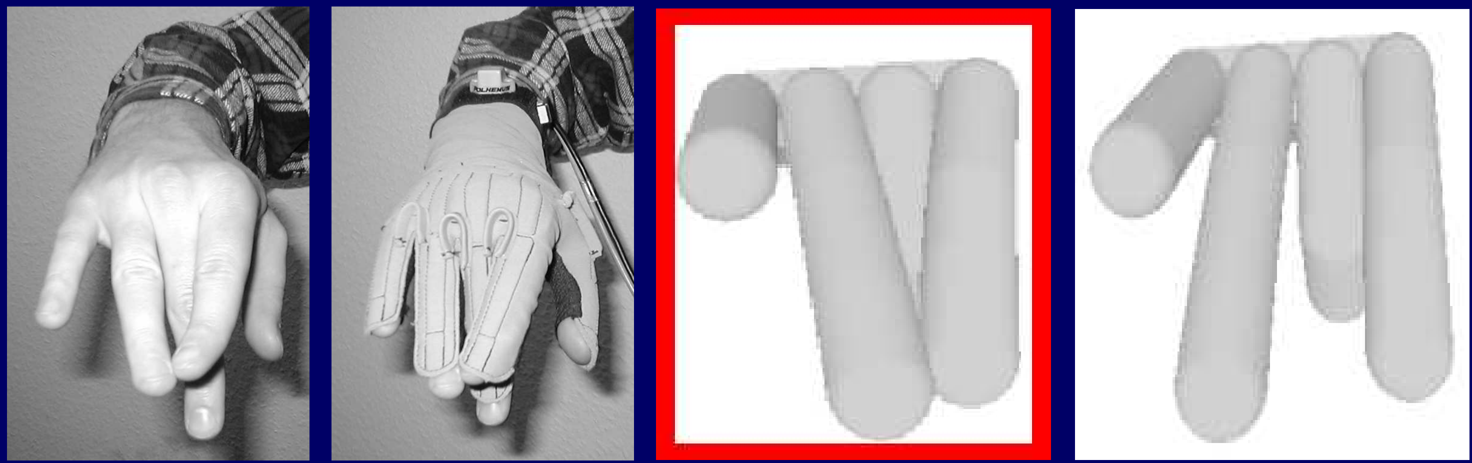
Results



Results



Results



Conclusions & future work

- ‘visual fidelity’calibration
- relative accuracy, trajectory based
- explicit cross-coupling model: abduction and neighbouring flex sensors
- more visually convincing hand postures
- incorportate thumb into the scheme
  - connecting fingers should connect!