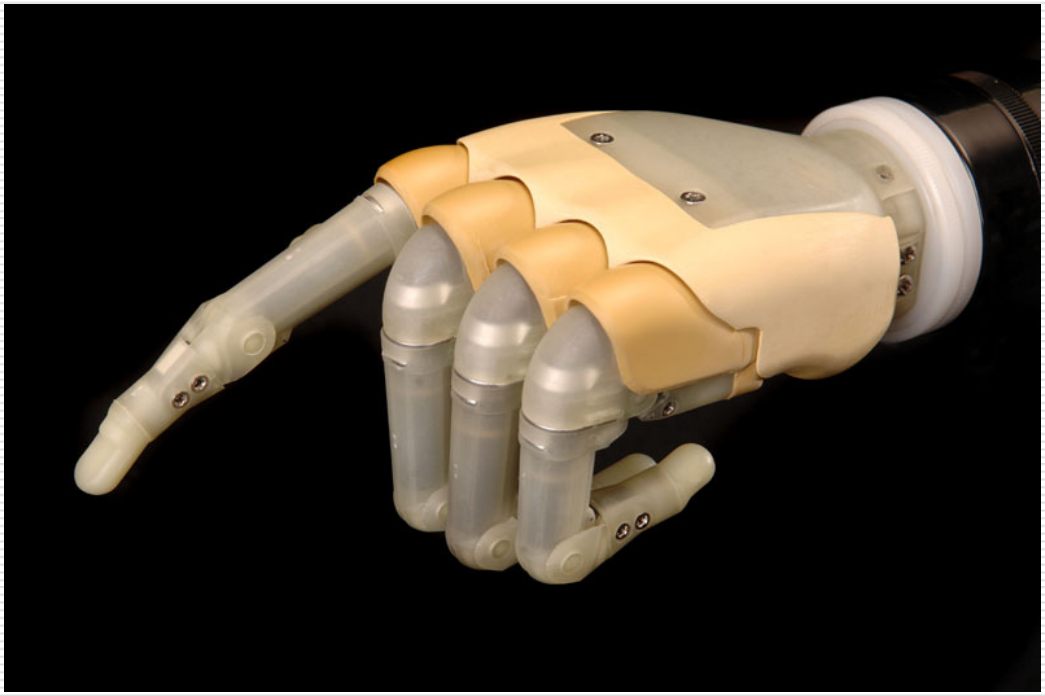
non-invasive adaptive hand prosthetics

claudio CASTELLINI[1], emanuele GRUPPIONI[2], angelo emanuele FIORILLA[1,4], patrick VAN DER SMAGT[3], angelo DAVALLI[2], giulio SANDINI[1,4]

[1] *advanced robotics laboratory*, university of genova, italy
[2] *inail prosthetics research center*, bologna, italy
[3] *german aerospace research center*, oberpfaffenhofen, germany
[4] *italian institute of technology*, genova, italy

emg and prosthetic hands

- claim: surface electromyography suffices to finely control dexterous prosthetic hands



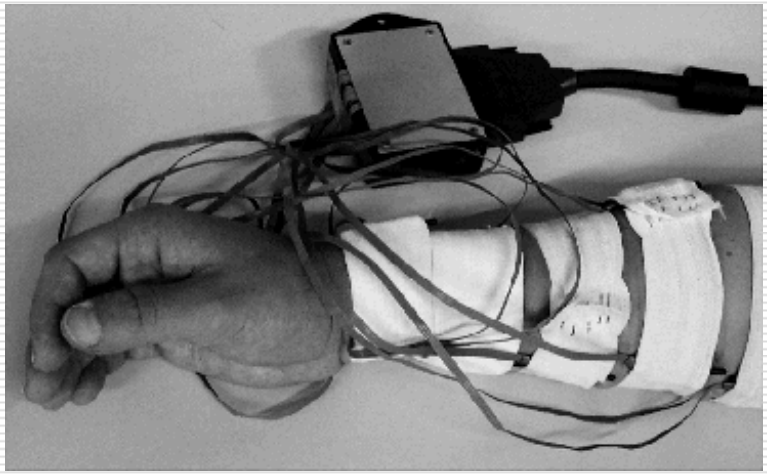
commercial s.o.a.:
touch bionics's **i-Limb** prosthetic hand

(reproduced from **www.touchbionics.com**)

surface emg

- pros:
  - non-invasive
  - cheap
  - well known
- cons:
  - badly conditioned
  - noisy
  - subject to sweat / muscle fatigue etc.
  - feeling: not accurate enough

experiment 1 (dlr)

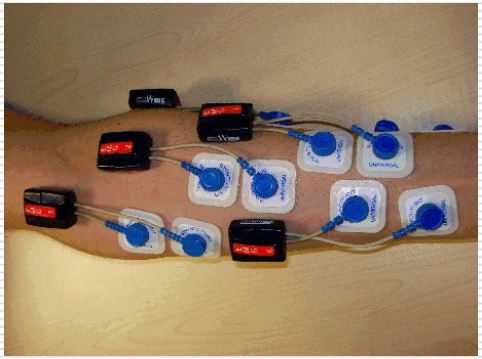


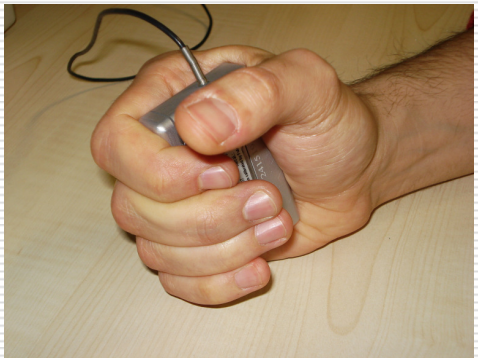
- 10 ottobock surface electrodes
- one healthy subject in controlled conditions
- position *and* force control

movie!

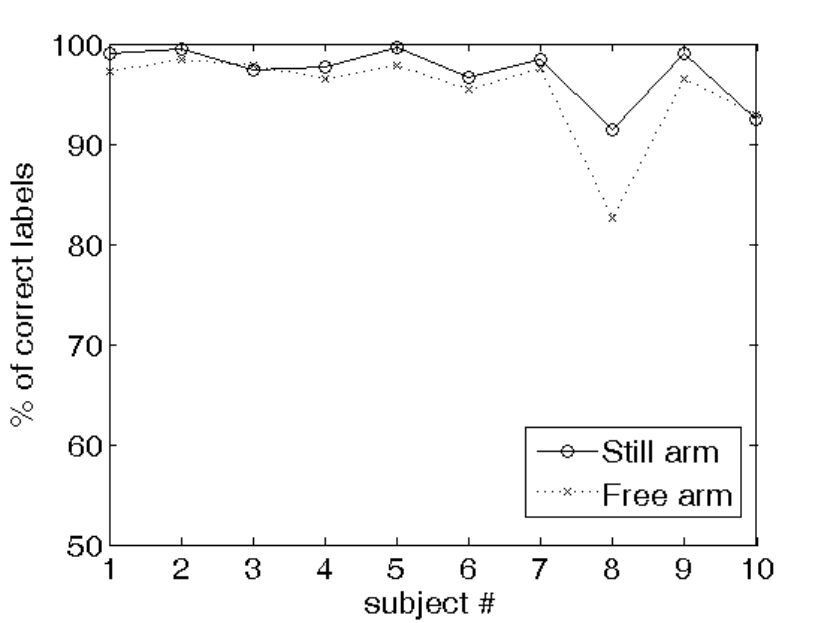
experiment 2 (iit)

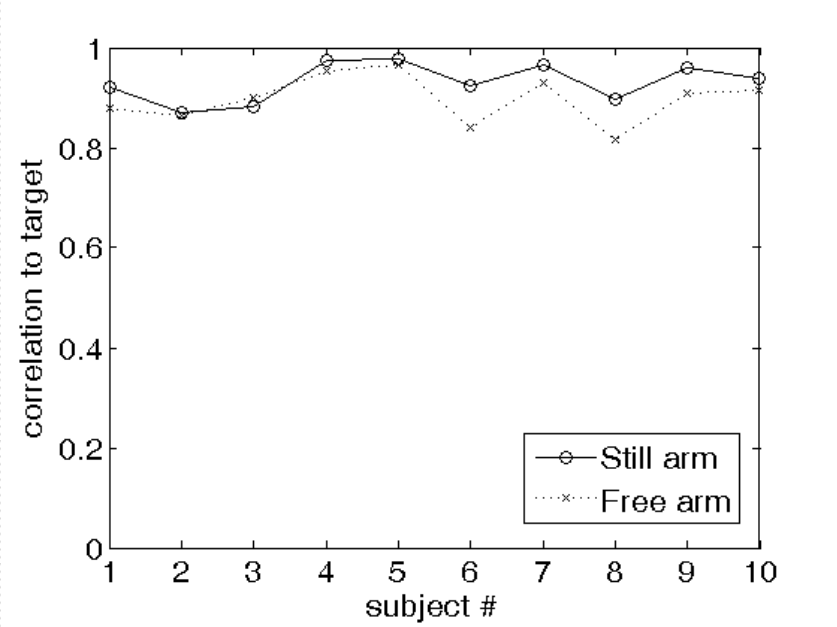
- 7 wireless emg electrodes
- 10 healthy subjects
- freely moving condition: walking, raising the arms, etc.





experiment 2: results

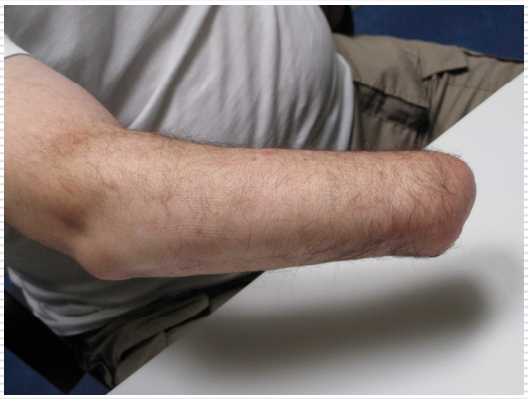




classification accuracy (left) and regression correlation (right) per subject. still arm vs. freely moving

experiment 3 (inail)

subject 1



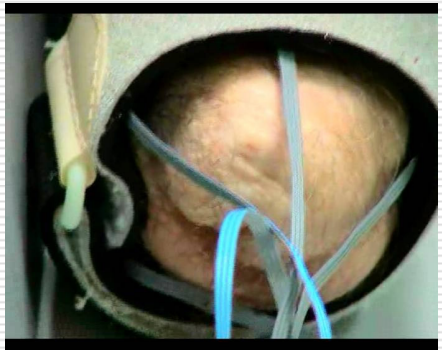
subject 2

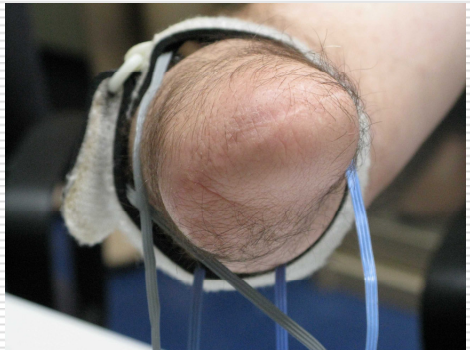
subject 3

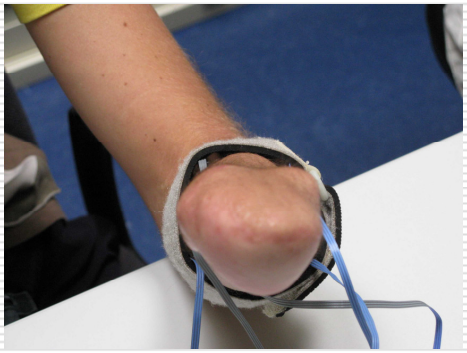
1. male, aged 63, trans-radial one-third proximal, amputated in 1963, 9cm stump
2. male, aged 56, trans-radial one-third distal, amputated in 1972, 20 cm stump
3. male, aged 25, trans-carpal, amputated in 2007, complete forearm

experiment 3: setup

5 Otto Bock electrodes and a force sensor

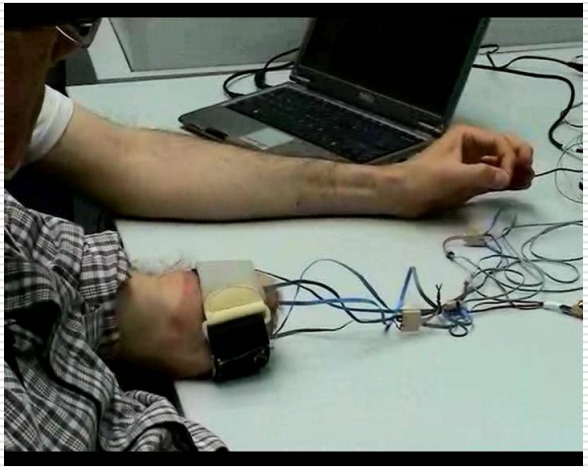


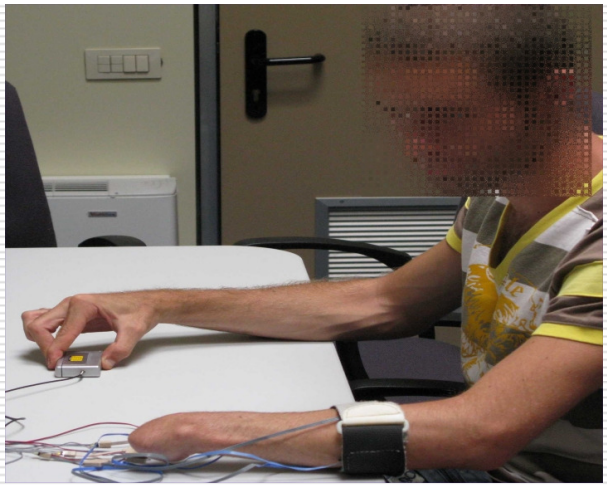


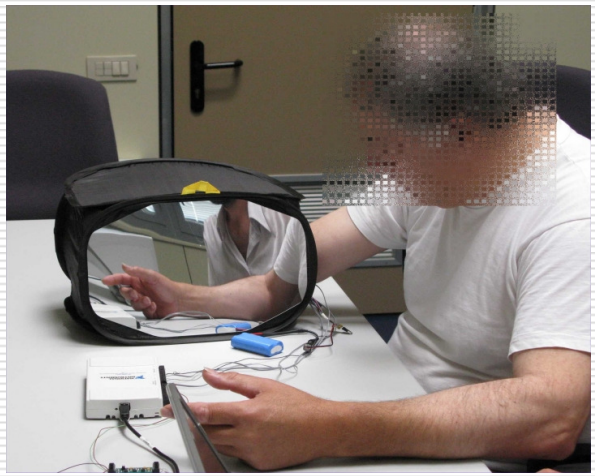


electrodes are positioned in a uniform, non-supervised way

experiment 3: training



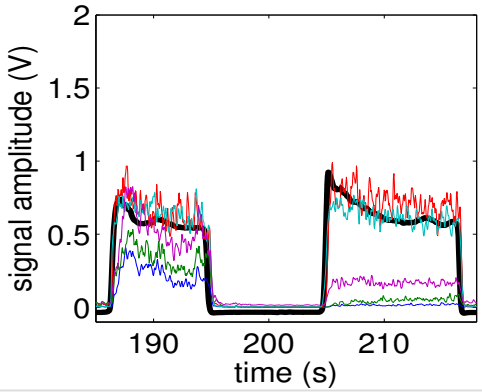


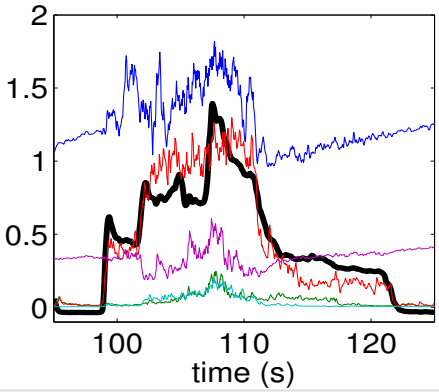


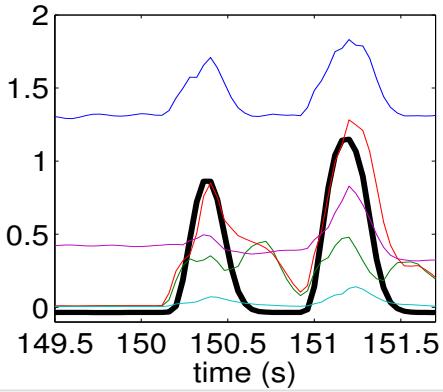
teacher imitation

bilateral action

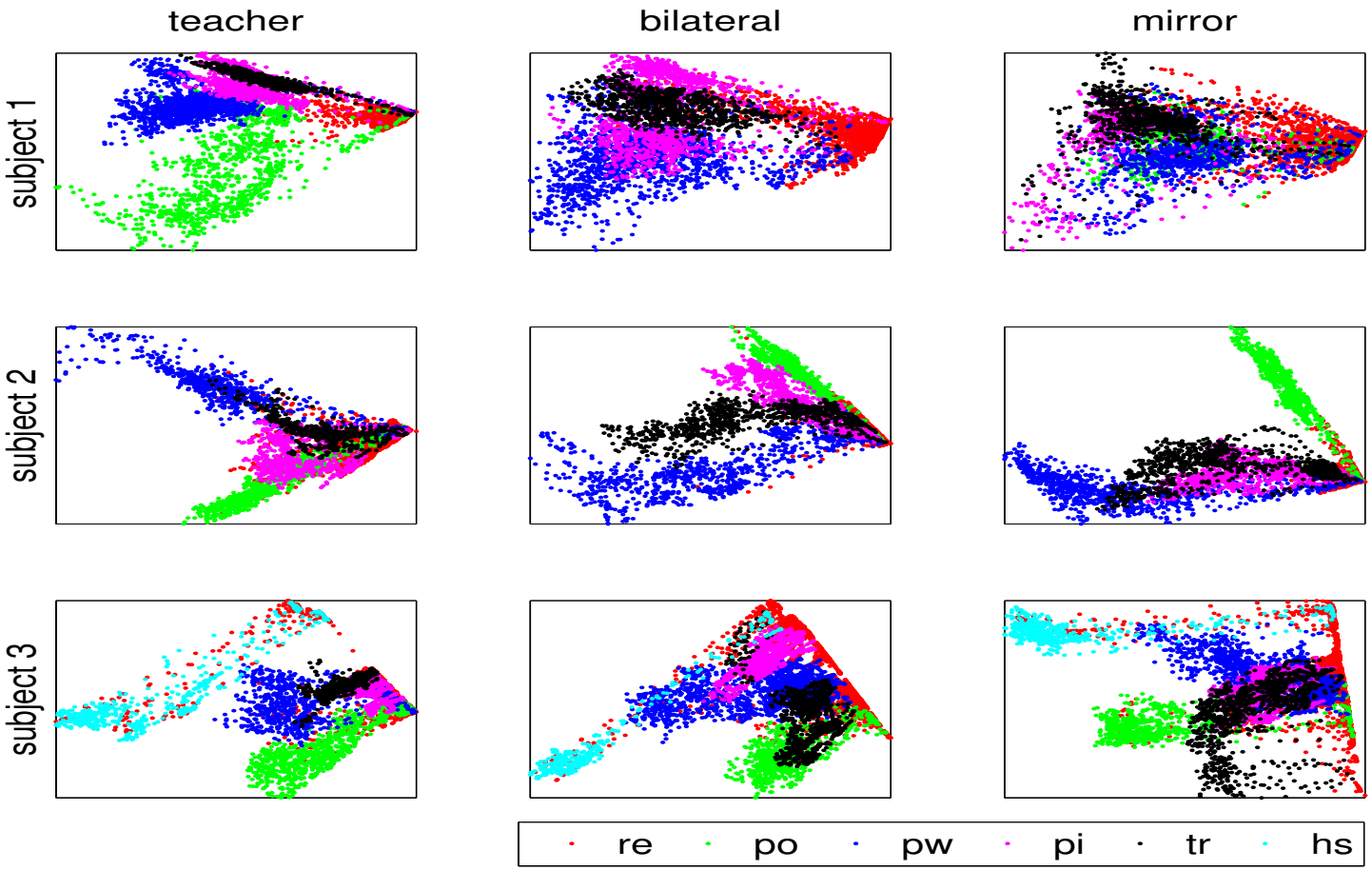
mirror-box



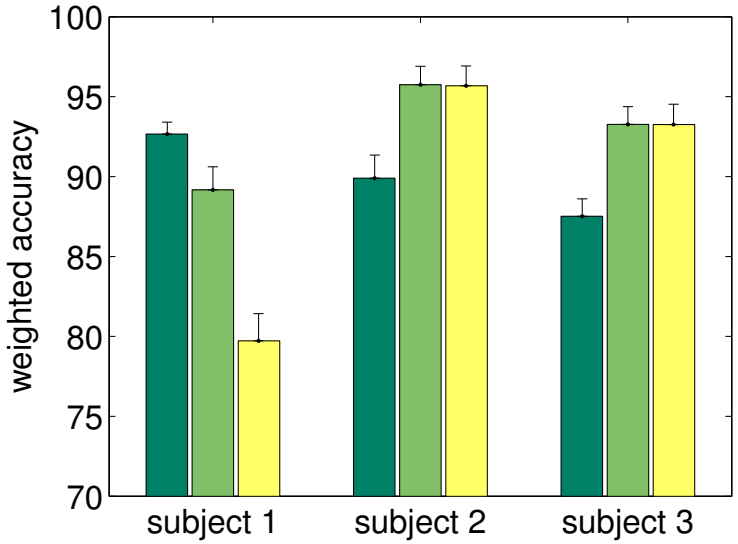


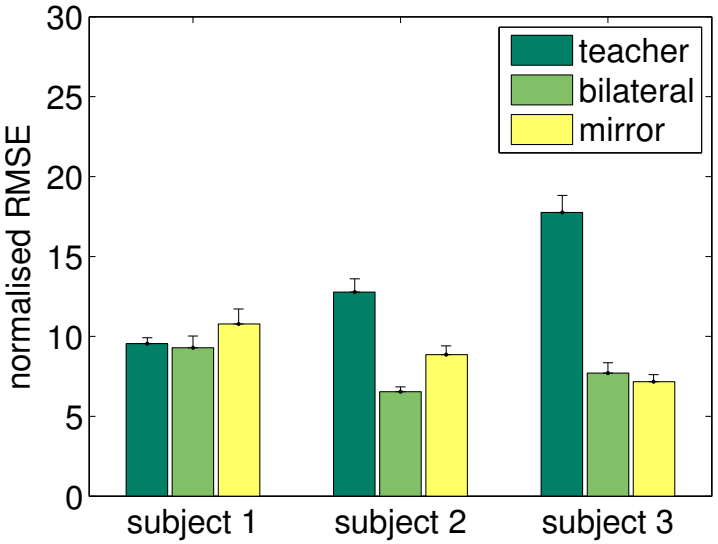


experiment 3: data



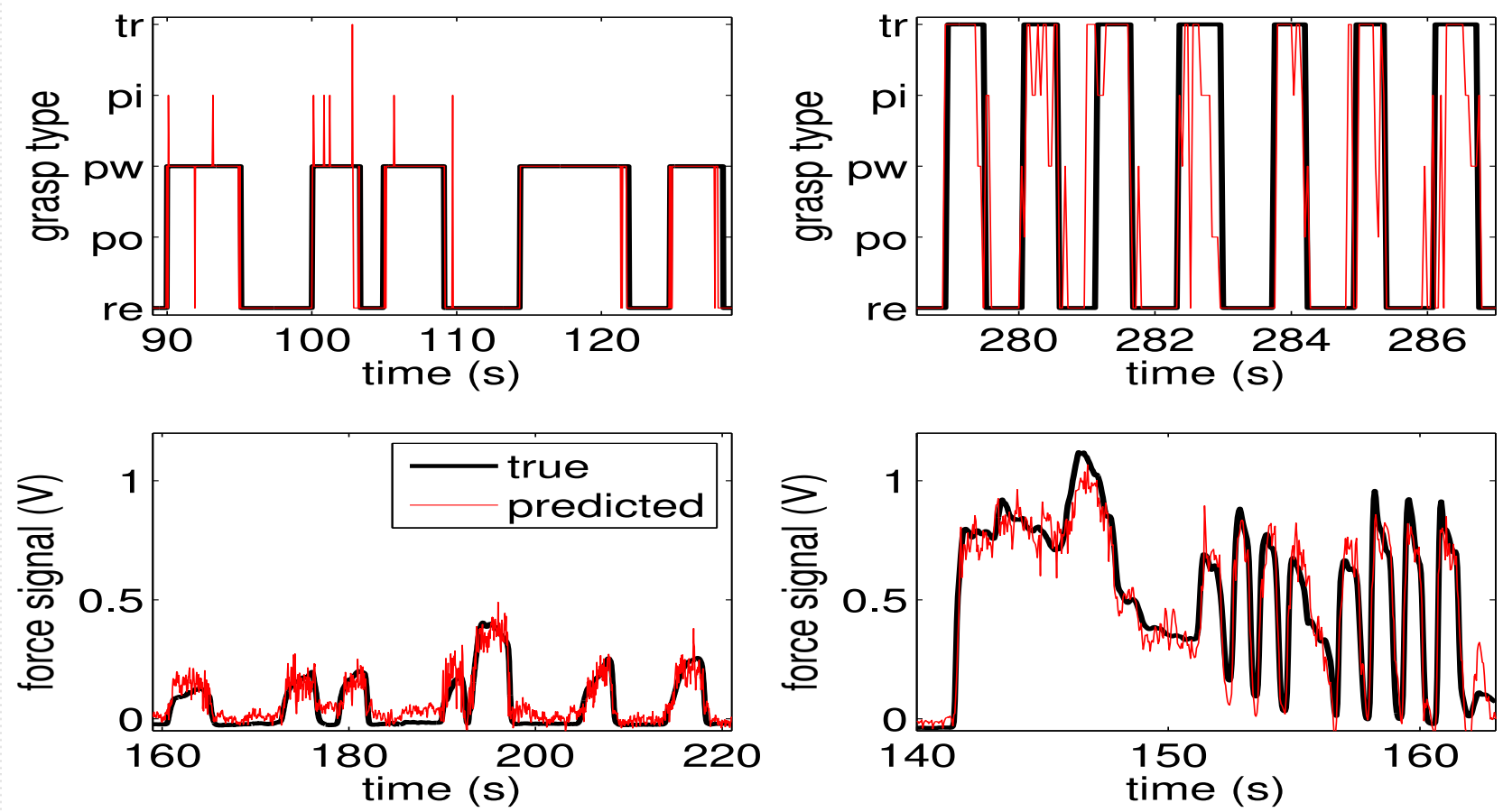
experiment 3: performance





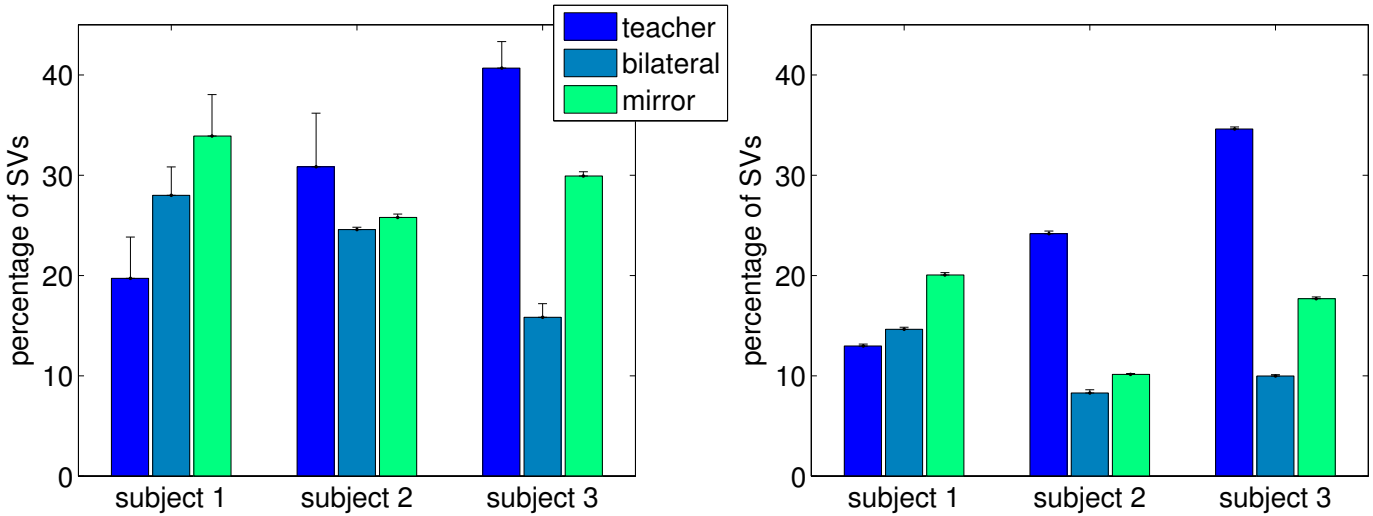
(left) classification accuracy, (right) regression on force

experiment 3: examples



(upper) classification accuracy, (lower) regression on force

experiment 3: hardness



(left) classification SV%, (right) regression SV%

discussion

- performance is comparable to experiment 1: it will work!
- non-invasive; no medically-assisted electrode positioning required; essentially no patient preparation
- surprisingly good muscular activity in elderly patients, operated a long time ago, with diverse types of amputations (matches emg/tms experiments of 2006)
- from the p.o.v. of machine learning, the problem is easy

main references

[1] C. Castellini and P. van der Smagt, **Surface EMG in Advanced Hand Prosthetics**, *Biological Cybernetics*, 100(1)

[2] C. Castellini, E. Fiorilla and G. Sandini, **Multi-subject/DLA analysis of surface EMG control of mechanical hands**, submitted to the *Journal of Neuroengineering and Rehabilitation*

[3] C. Castellini, E. Gruppioni, A. Davalli and G. Sandini, **Fine detection of grasp force and posture by amputees via surface electromyography**, Journal of Physiology (Paris), in press