model adaptation with ls-svm for adaptive hand prosthetics

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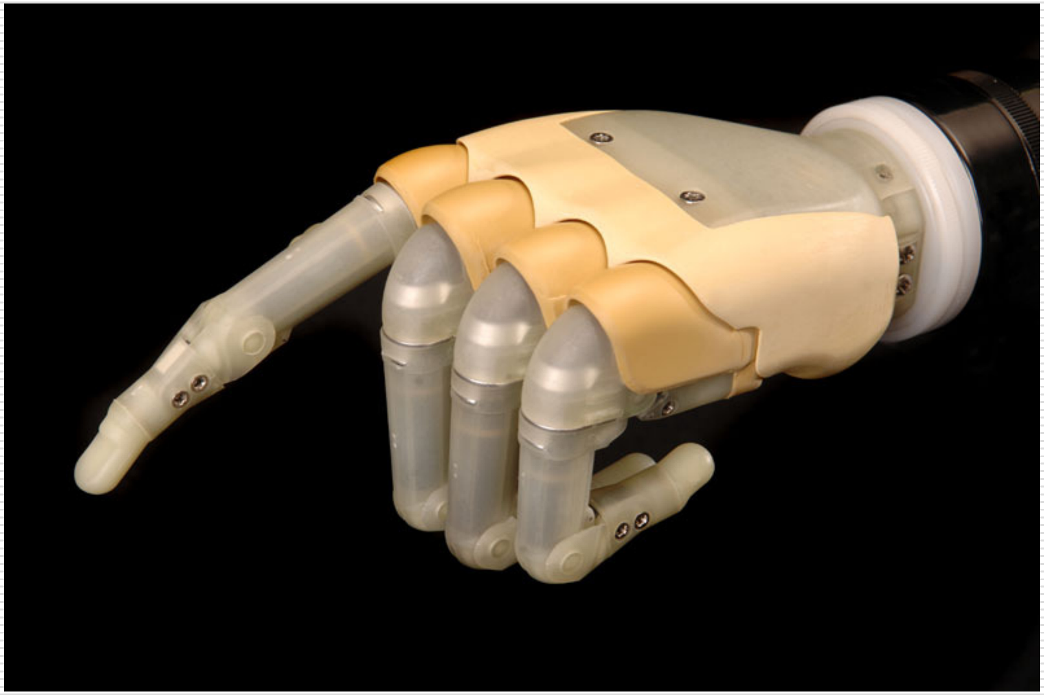
prosthetic hands

- wishlist: cheap, cosmetic, lightweight, long-running, dexterous, finely controlled both in position *and force*

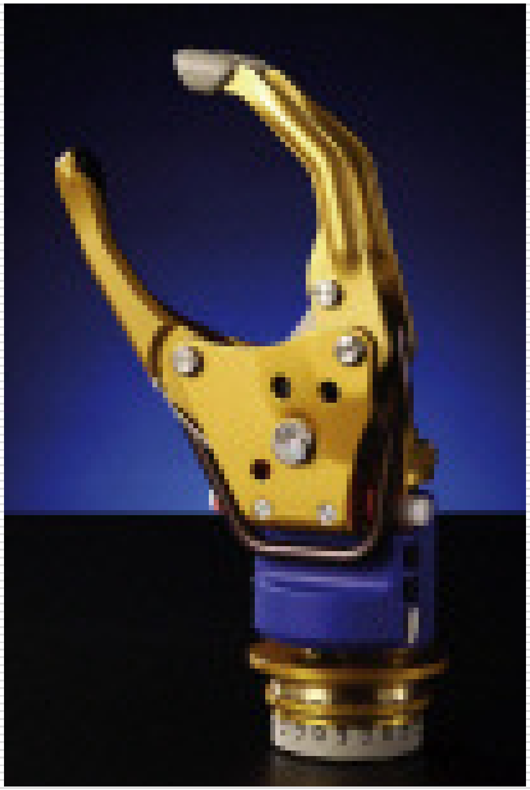


commercial s.o.a.:
touch bionics's **i-Limb** prosthetic hand

(reproduced from www.touchbionics.com)

prosthetic hands

- soa:
  - one dof (otto bock)
  - open-loop position control
  - no sensing, no biofeedback
  - very recent polyarticulate hand by touch bionics has 5 dofs, but
  - no known means of accurate control
- highly needed: fine control

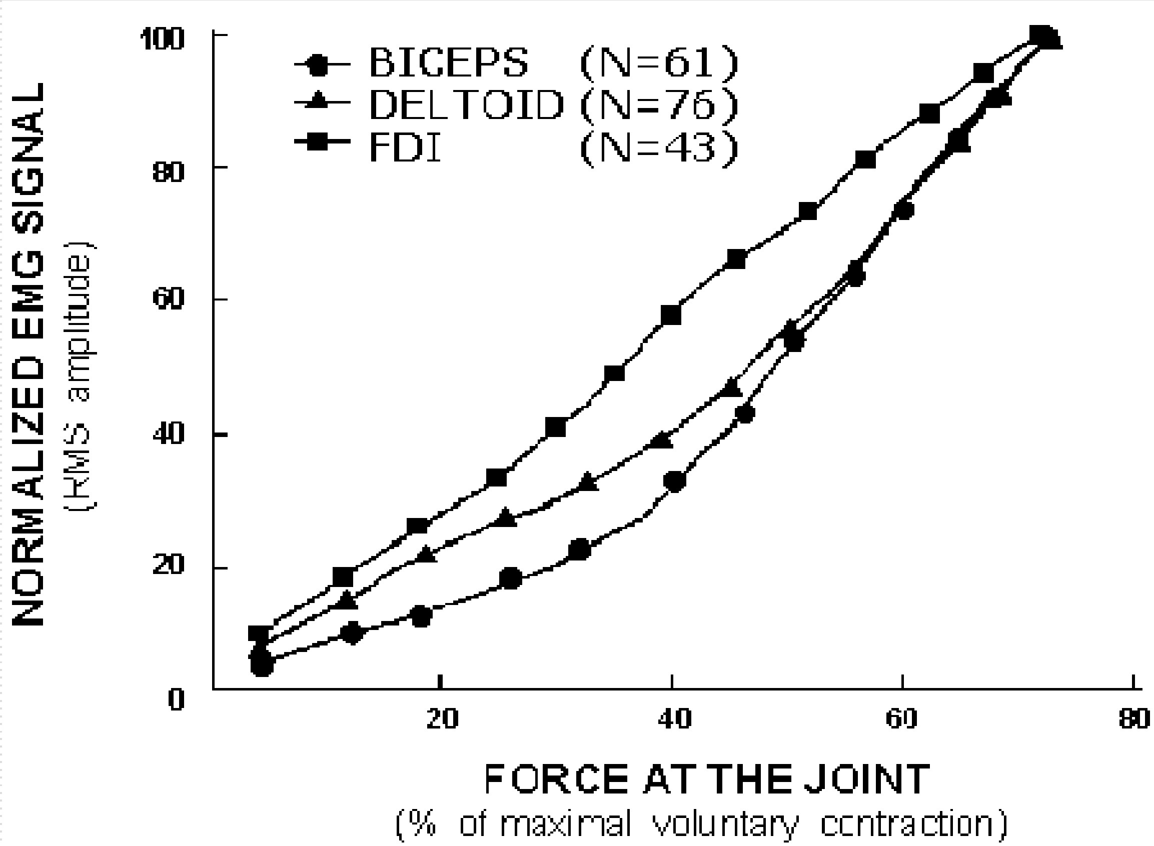


otto bock's sensorHand speed
(reproduced from **www.ottobock.us**)

problem

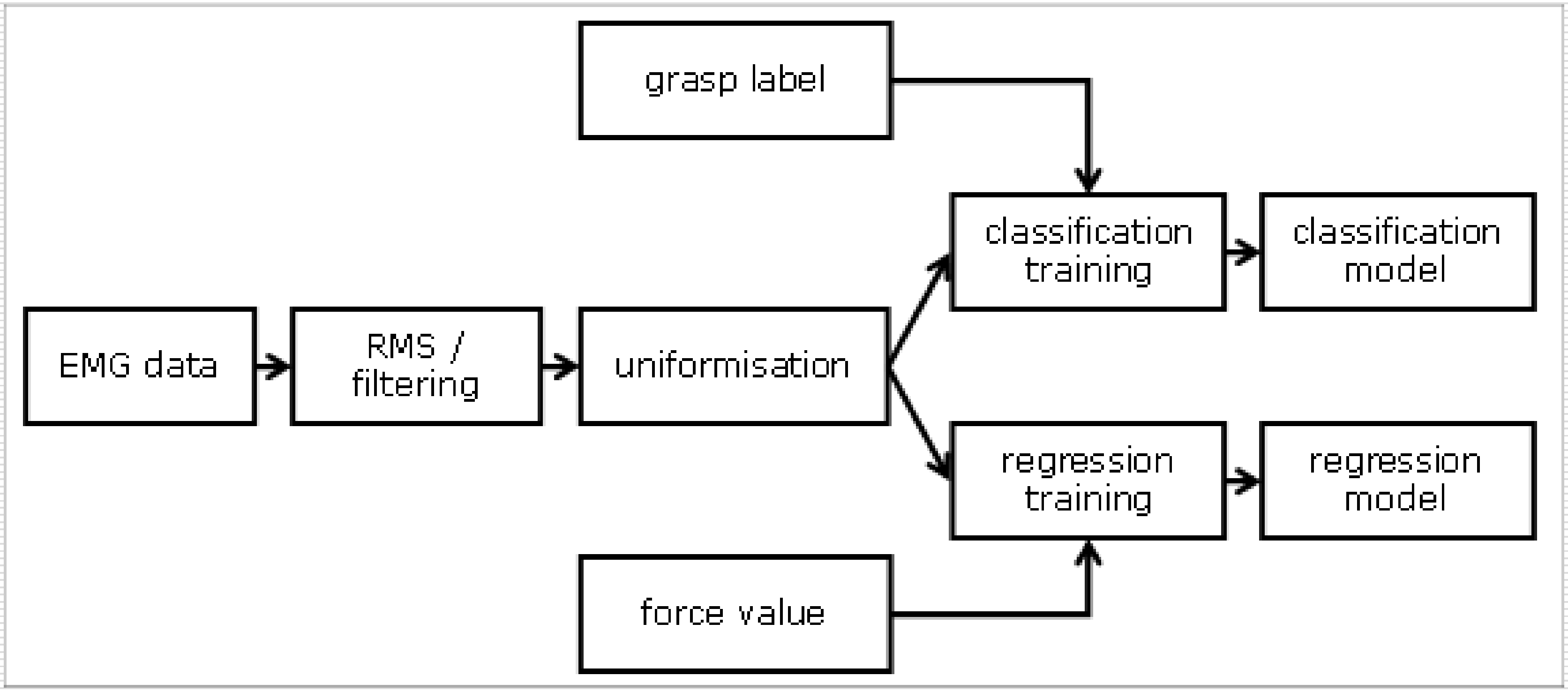
- little possibility of *control* by the patient: what interface?
- focus upon *non-invasive* interfaces, particularly upon
- **forearm surface electromyography**
- can a prosthetic hand be swiftly position- and force-controlled using the emg?

emg (in principle)

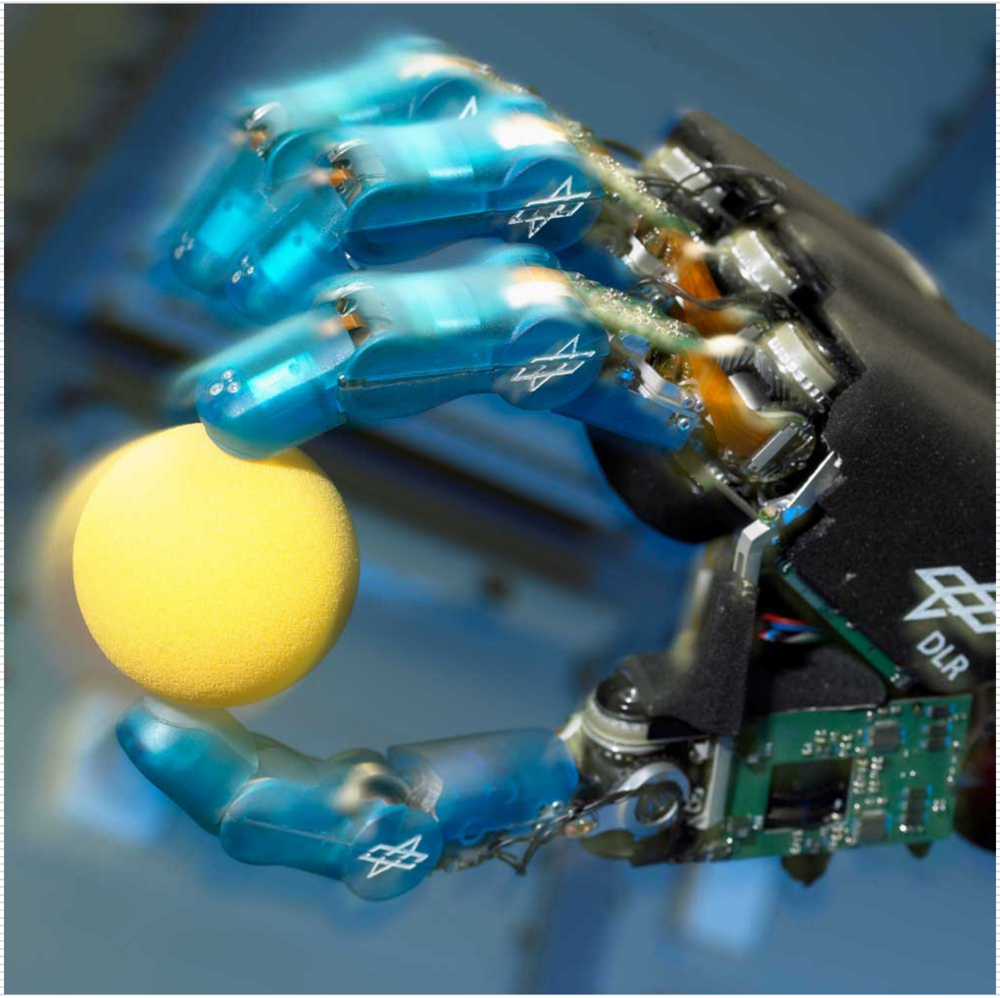


- RMS non-linearly related to the *force* applied by a muscle

proposed schema



demo



(movie)

[2008] C. Castellini, P. van der Smagt, G. Sandini and G. Hirzinger, *Surface EMG for Force Control of Mechanical Hands,* **ICRA 2008 @ Pasadena, US**

the rest of this talk

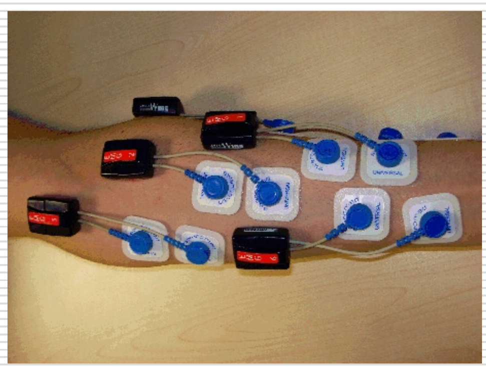
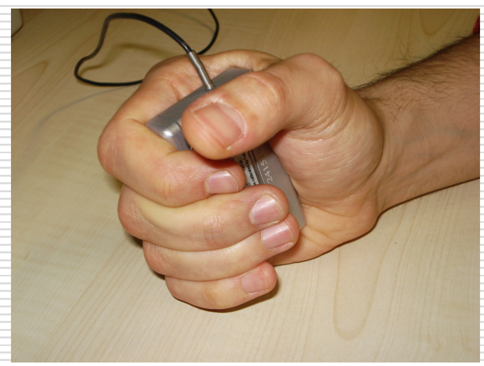
- experiment on multi-subject and non-controlled conditions (daily life activities)
- model adaptation, that is: can we use one subject's models for the others?
- discussion

extending the approach to…

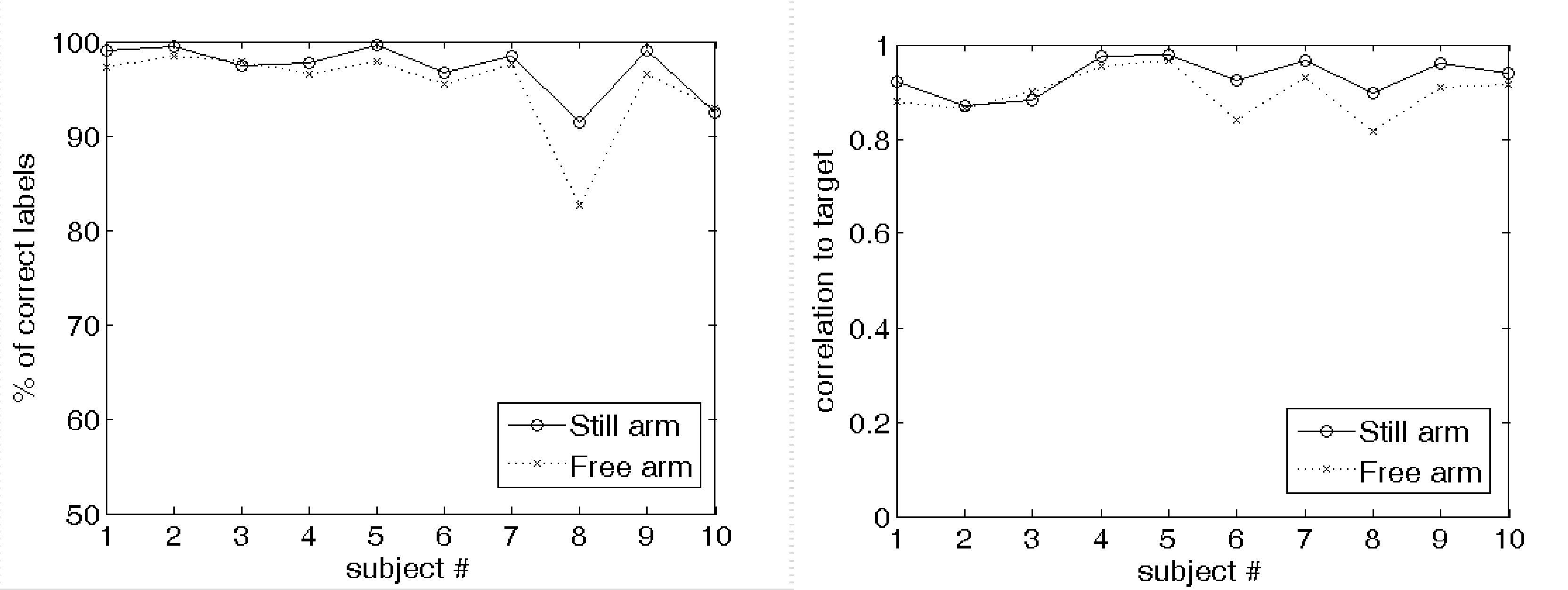
- *any* subject (heatlhy, so far)?
- what if the forearm / arm / body is moving, as is expected in daily-life activities? can the system learn how to deal with the added noise?

experiment

- 7 (wireless) emg electrodes
- 10 healthy subjects
- comparing the still-arm condition with a freely moving condition: walking, raising the arms, etc.

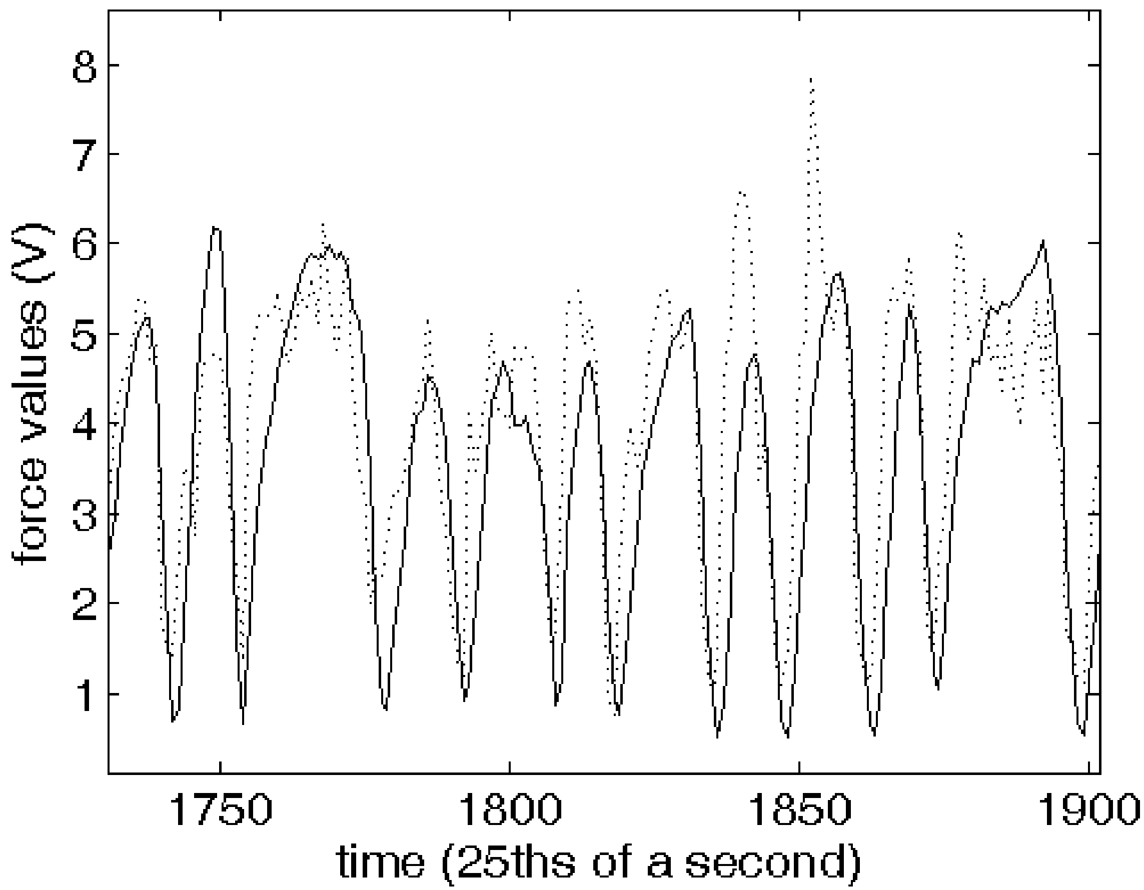




results



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

results (cont'd)



model adaptation

- further problem:
  - training guarantees adaptation (→ accuracy) to the patient, but might be long and uncomfortable
- idea: ship the prosthesis with a prior knowledge, automatically exploited by the system
  - leading to shorter training time

questions

- how to weigh the prior knowledge and the newly acquired one?
- computational efficiency?

- but most interestingly, *what prior knowledge?*

model adaptation

- svms are trained by minimising a *regularization* term plus a *loss* term

$$\min \frac{1}{2}\|w\|^2 + \frac{C}{2}\sum \xi$$

- change the regularization so that the new solution is *close* to the previous one

$$\min \frac{1}{2}\|w - \beta w'\|^2 + \frac{C}{2}\sum \xi$$

- change the error term in order to evaluate the leave-one-out error in closed form

$$\min \frac{1}{2}\|w - \beta w'\|^2 + \frac{C}{2}\sum \xi^2$$

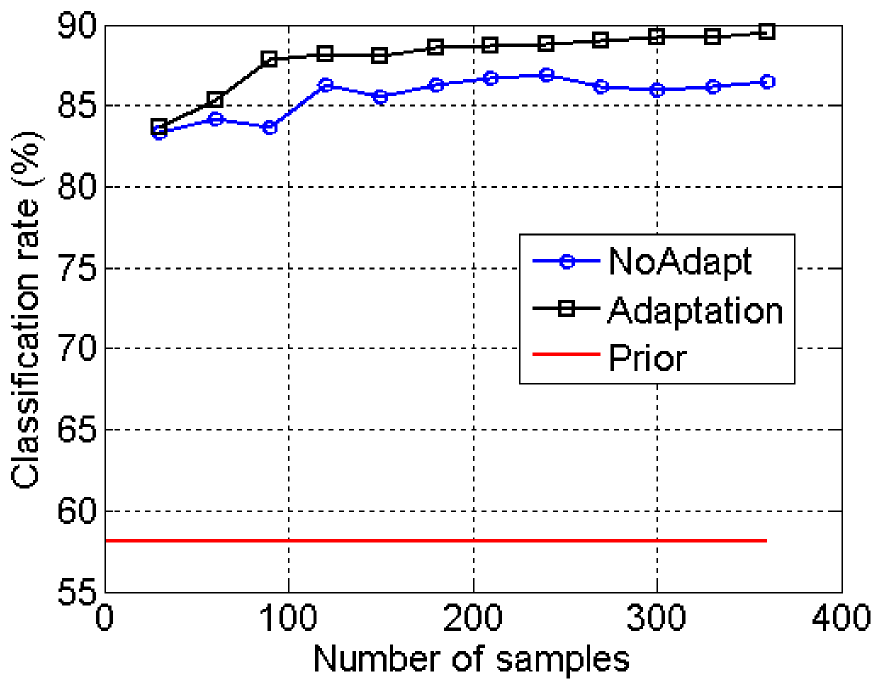
the leave-one-out error

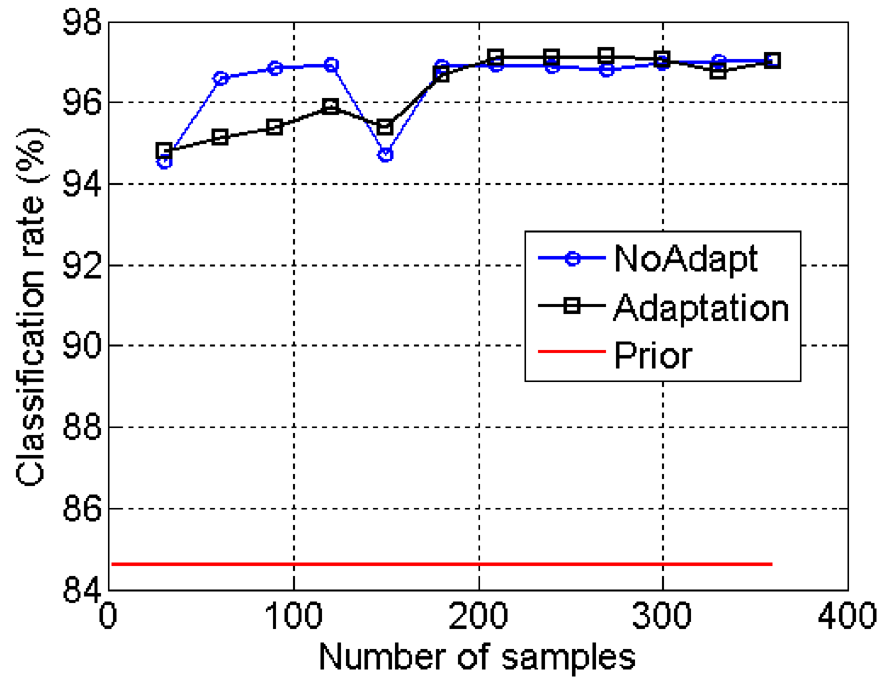
- the *average error* on each single training sample when it is removed from the training set
  - the "best cross-validation" one can have
- the leave-one-out error is an *almost* unbiased estimate of the error on a given set
- in general, evaluating the l.o.o. for *n* samples implies training *n* models with *n-1* samples each…
- …but if you can compute it quickly, it also gives you a way to find the optimal *β*

prior knowledge

- consider nine training subjects and one testing subject
- build *model*$_i$ with $i=1,\ldots,9$
- incrementally train model for the testing subject and evaluate error using each training model as prior
- output the prediction of the best one

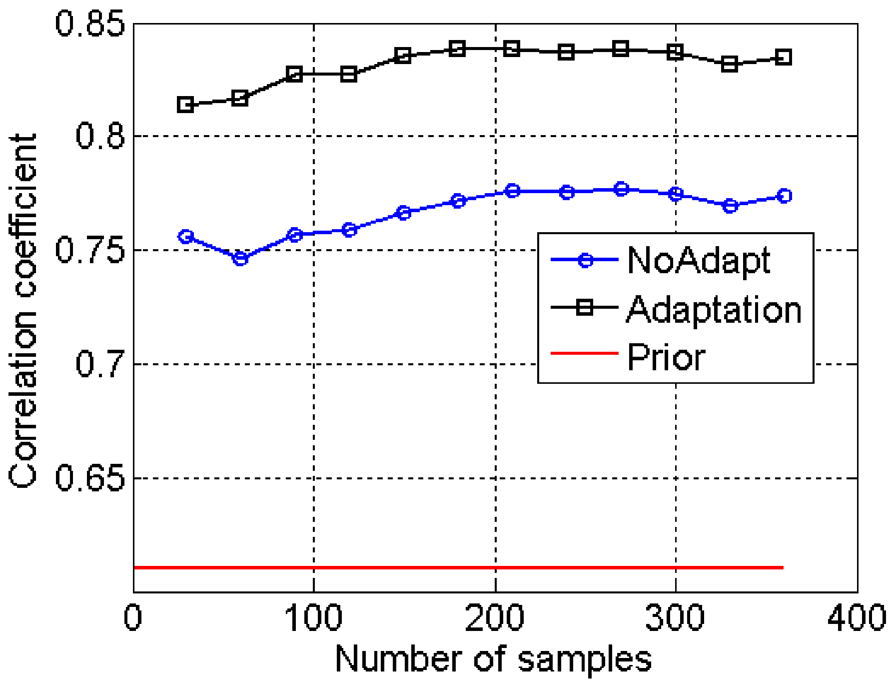
classification

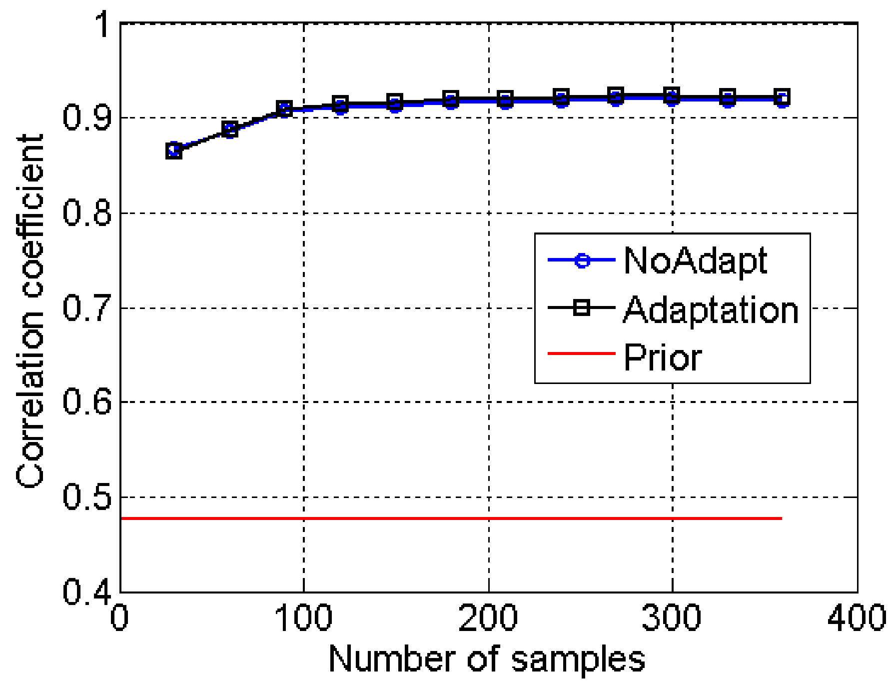




(left) best case, (right) worst case

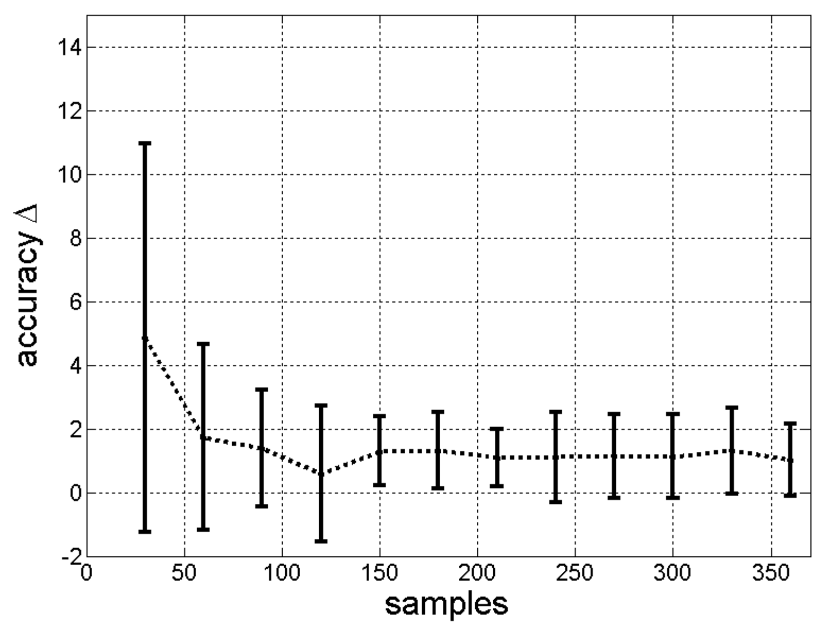
regression

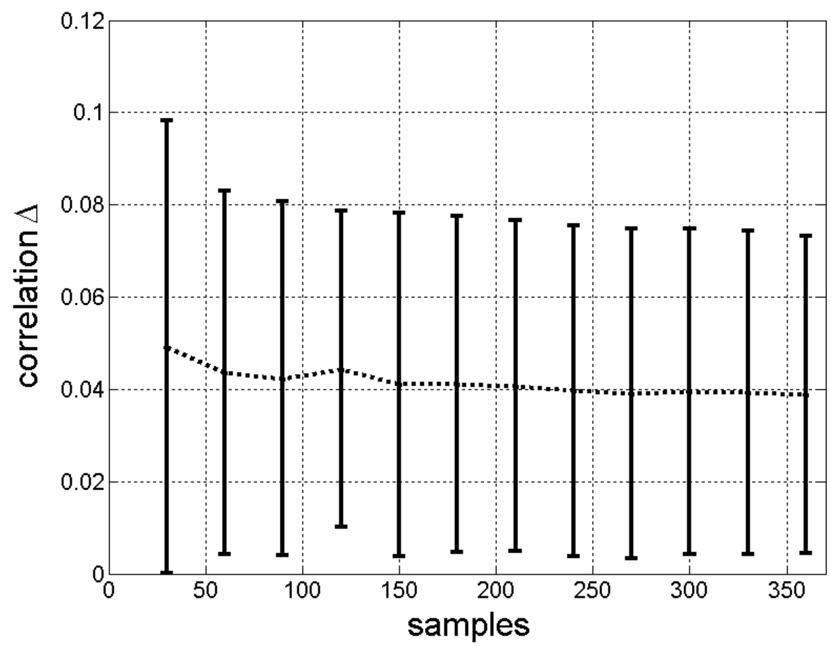




(left) best case, (right) worst case

overall comparison





(left) classification, (right) regression

discussion

- ls-svm model adaptation consistently and uniformly improves both classification and regression accuracy
- pre-trained models give *better* performance than starting-from-scratch
- denoting analogies among models, that is, among subjects

thank you!

- [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