Model-space regularization and white-box algorithms in postural control quantification

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Problem

Machine learning in medical applications

- How to learn accurate results understandable by practitioners
- That capture the characteristics of underlying biological systems

Contribution

- New postural control model
- White-box fully interpretable algorithms
- Regularization that embeds heuristics into models

Medical issue: Fall prevention in the elderly population

An important concern in public health [3]

- Each year more than a third of population older than 65 faces a fall
- Those falls can have devastating consequences
- Early detection of balance deterioration is crucial

Data

We consider 3 groups of subjects:

- Group 1 : **young healthy** individuals (67 signals)
- Group 2 : **healthy elderly non faller** individuals (60 signals)
- Group 3 : **elderly faller** individuals (56 signals)

Groups are ordered according to their supposed quality of balance

Romberg test

Each subject is recorded

- on a Wii balance board
- standing still
- arms laying on the side
- 25 seconds with open eyes
- 25 seconds with closed eyes

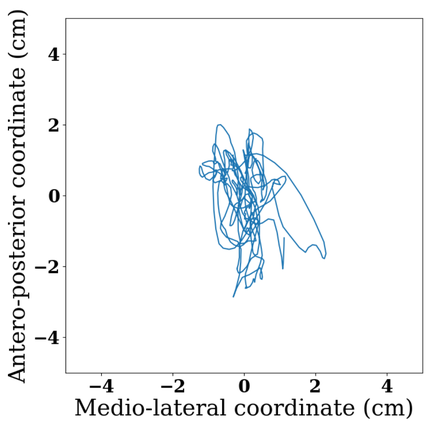

Figure: Trajectory of the COP, open-eyes

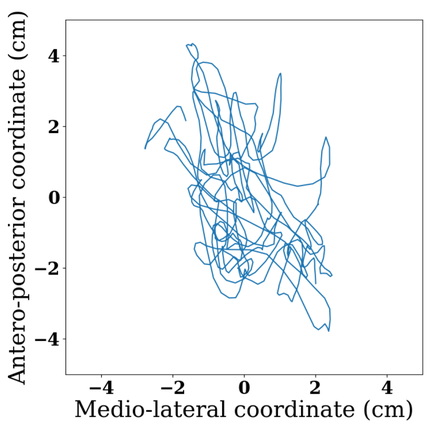

Figure: Trajectory of the COP, closed-eyes

Measurements

- Deplacement of the **center of pressure** (COP) is recorded
- Approximates the projection of the center of gravity
- Bidimensional signals
- Strongly irregular sample frequency (from 10 to 1000 Hz) resampled at 25 Hz
- Small and noisy dataset: protocol related inconsistencies, intra-subject variability (tiredness), sensor noise...

Postural control model

Model: Hypothetical Posturographic Target (HPT)

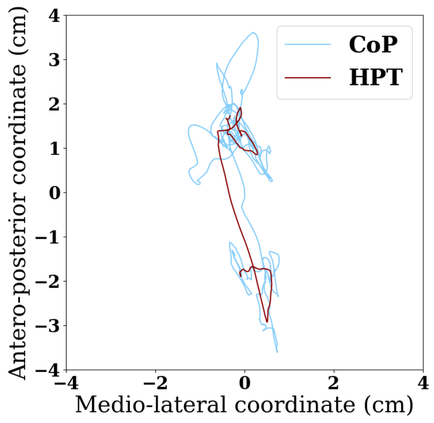

Figure: Trajectories of COP and HPT

Concept of Posturographic Target (PT) based on [1]

Alternating phases of
1) oscillations around a PT
2) rapid movement to the next PT

We compute an hypothetic continuous approximation of the PT

Scoring algorithms and model-space regularization

Two key guidelines:

- The use of simple models that are more robust and interpretable
- A regularization specifically designed for this medical application

Good balance related values | Bad balance related values

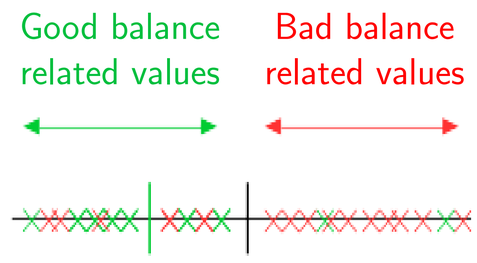

Figure: Heuristic based Weak Classifier

Bad balance related values are constrainted to be below the threshold and vice versa.
By limiting the number of possible classifiers, this constraint acts as a model-space regularization.

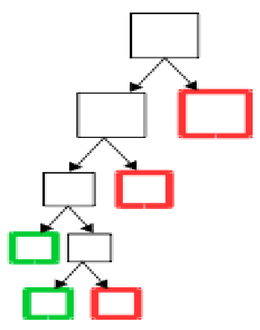

Figure: Heuristic based Decision Tree

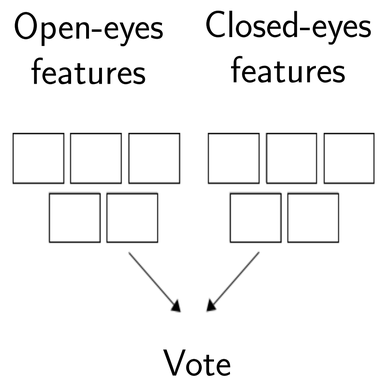

Figure: Heuristic based Bagging

Results

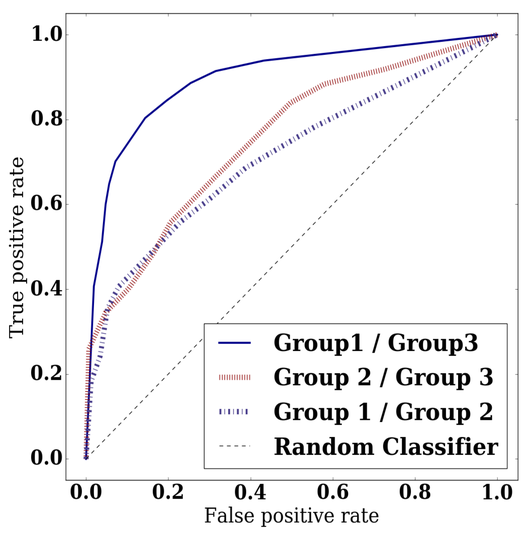

Figure: Inter-groups ROC curves

Groups	1-2	2-3	1-3
RF	0.70 (±0.08)	0.65 (±0.06)	0.85 (±0.04)
Adaboost	0.74 (±0.06)	0.60 (±0.08)	0.86 (±0.06)
HBagging	0.72 (±0.07)	0.75 (±0.07)	0.90 (±0.05)
HDTrees	0.69 (±0.08)	0.70 (±0.07)	0.88 (±0.05)
HAdaboost	0.69 (±0.07)	0.73 (±0.08)	0.90 (±0.05)

Table: Mean and standard deviation of AUC of the different algorithms for each pair of groups.

Group	1	2	3
Mean(std)	0.09 (±0.14)	0.23 (±0.21)	0.37 (±0.21)

Table: Mean and standard deviation of group scores with HBagging.

- Simple models show the best performances
- Regularization based on heuristics improve model performances
- HBagging captures the Dose effect

References

[1] L. Baratto, P. G. Morasso, C. Re, and G. Spada. A new look at posturographic analysis in the clinical context: sway-density versus other parameterization techniques. *Motor control*, 6(3):246–270, 2002.

[2] A. Nicolaï and J. Audiffren. Model-space regularization and fully interpretable algorithms for postural control quantification. In *COMPSAC*, 2018.

[3] WHO. Who global report on falls prevention in older age. *WHO reports*.