Automatic biorythms description from actigraphic data

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INTRODUCTION

To monitor a subject's sleep/wake cycles over several days, actigraphic data are routinely recorded with the help of an "acti-watch" placed the subject's wrist. These data are scored manually to extract key parameters, e.g. sleep and wake time.

Manual scoring has two main disadvantages:

- Time consuming and tedious task for a trained expert
- Subjective procedure leading to non-reproducible results within and between experts

Ideally artefact detection should be *automatic*, *fast*, *reproducible* and *accurate*. The *Crespo* algorithm [1] is one such solution.

The aim of this work was to produce a software that:

- **works for (healthy) subjects with regular sleep episodes**
- ***automatically* detects the sleep/wake transitions from actigraphic data in a *fast*, *accurate* and *reproducible* way,**
- **intuitively displays the results,**
- **is free and open-source (GNU GPLv2 license).**

METHODS

Assumptions

Data are acquired:

- on healthy subjects, with normal sleep/wake cycle
- over several days, e.g. 1 week.

Overall organization

Proceed in 3 three successive steps :

- Pre-processing: importing and cleaning the actigraphic data
- Pre-scoring: 1st approximation of the sleep/wake transitions
- Final scoring: refining the transitions with a machine learning approach

1. Pre-processing

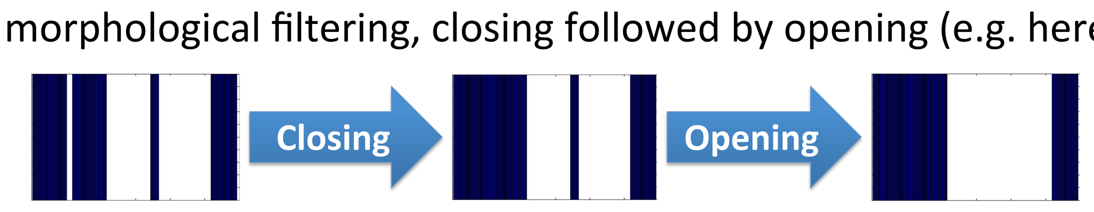
Importing and cleaning of raw actigraphic data, mainly:

- Reading in the raw actigraphic signal, and beginning date & time of the recording
- Removing flat signal at the beginning, e.g. actigraph switched on too early
- Filling "too long" episodes of flat signal, e.g. acti-watch momentarily not worn

2. Pre-scoring (similar to the 1st part of Crespo algorithm)

Apply classic signal processing to estimate the sleep/wake period:

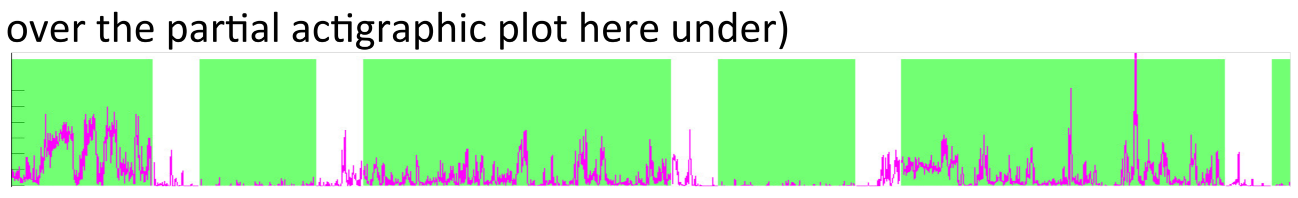
- padding begin/end with high signal
- filtering with a median operator
- applying a rank-order threshold (33% as about 8h of sleep over 24h)
- morphological filtering, closing followed by opening (e.g. here under)



3. Final scoring

Use a "neural network" (NN) [2] to refine the transition times:

- extract the actigraphic signal 'far'(by 1h) from the transition times (in green over the partial actigraphic plot here under)



- split signal and build local features, i.e. median, interquartile range, mean, standard deviation, max, min, mode & #zeros, in 15min windows
- train the NN on these features with their 'wake' or 'sleep' label
- split the signal in 15min windows around the transitions and build local features
- apply the trained NN on these features and derive new labels, 'sleep' or 'wake', for each time bin.

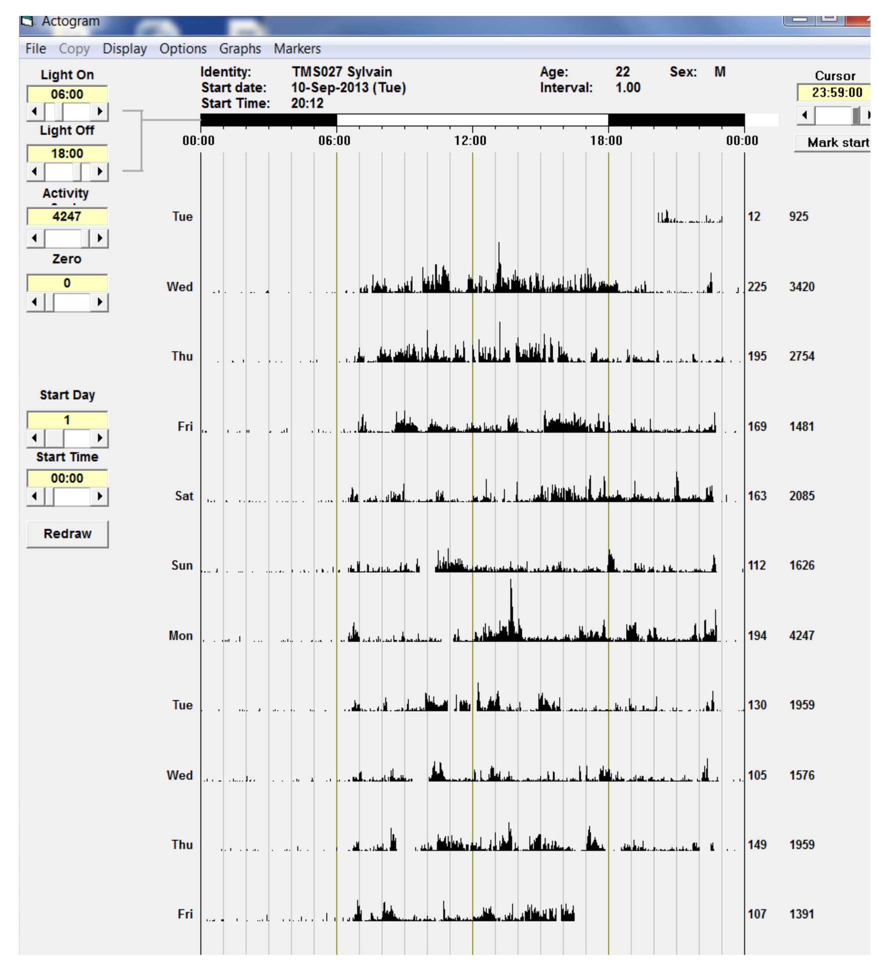
Output

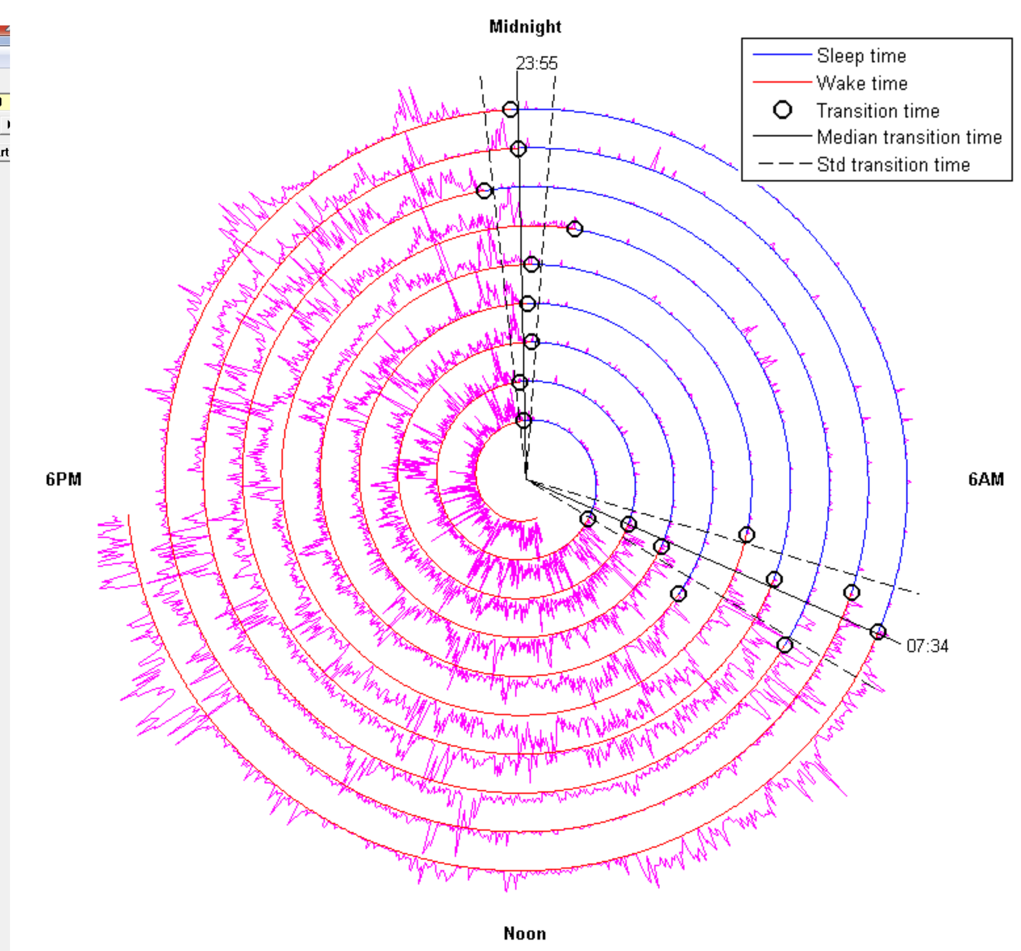
- binary Sleep/Wake time series (same resolution as the actigraphic data)
- other parameters: daily wake and sleep times

RESULTS

Presentation of actigraphic data

One subject over several days, with sleep/wake transitions: standard daily presentation (left) and continuous spiralling time line (right).





Validation of the method

Comparison between the "automatic scoring" and "manual scoring" (considered as the "gold standard"): score ('sleep' or 'wake') at each time bin of the actigraphic data & sleep and wake time.

Data:

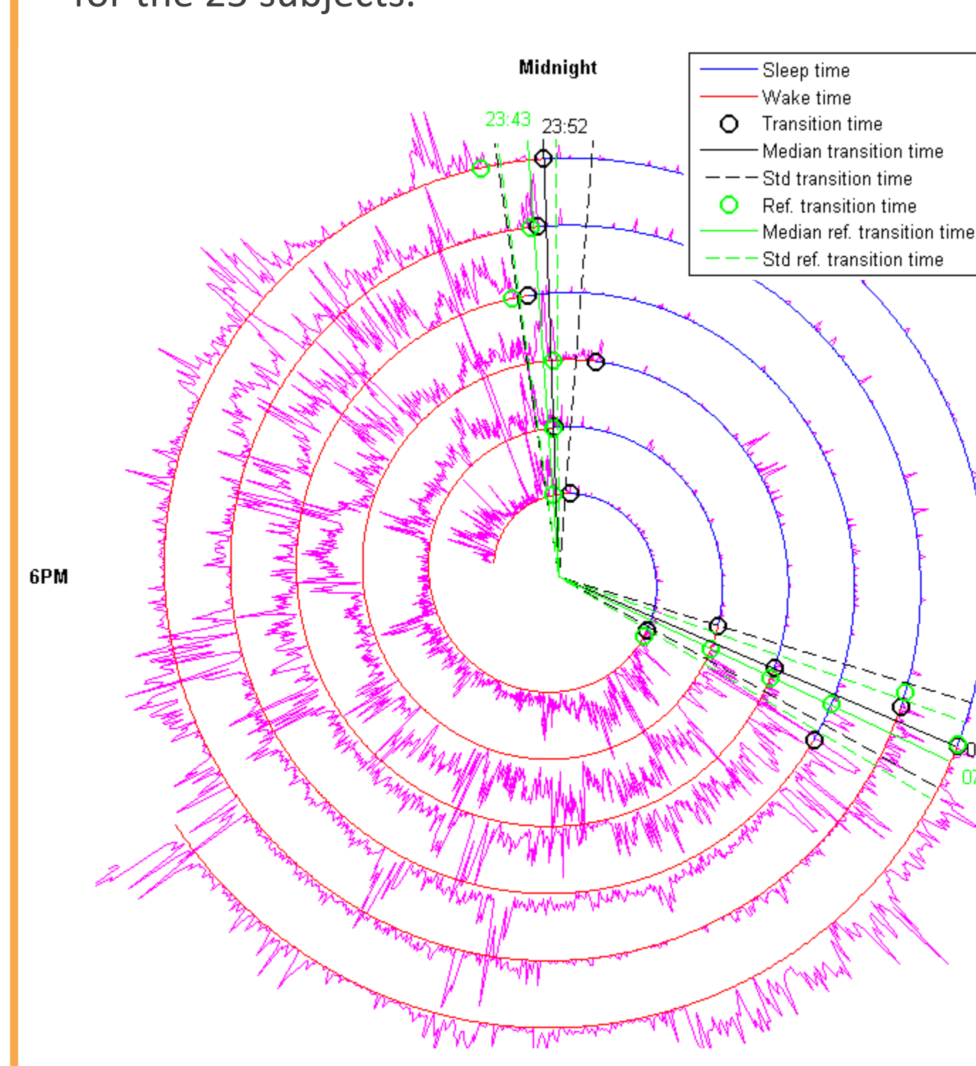
- 25 young healthy subjects, following regular sleep/wake cycles (for a specific study)
- recording of actigraphic data over more than a week
- manual scoring by an expert over the last 7 days of recording

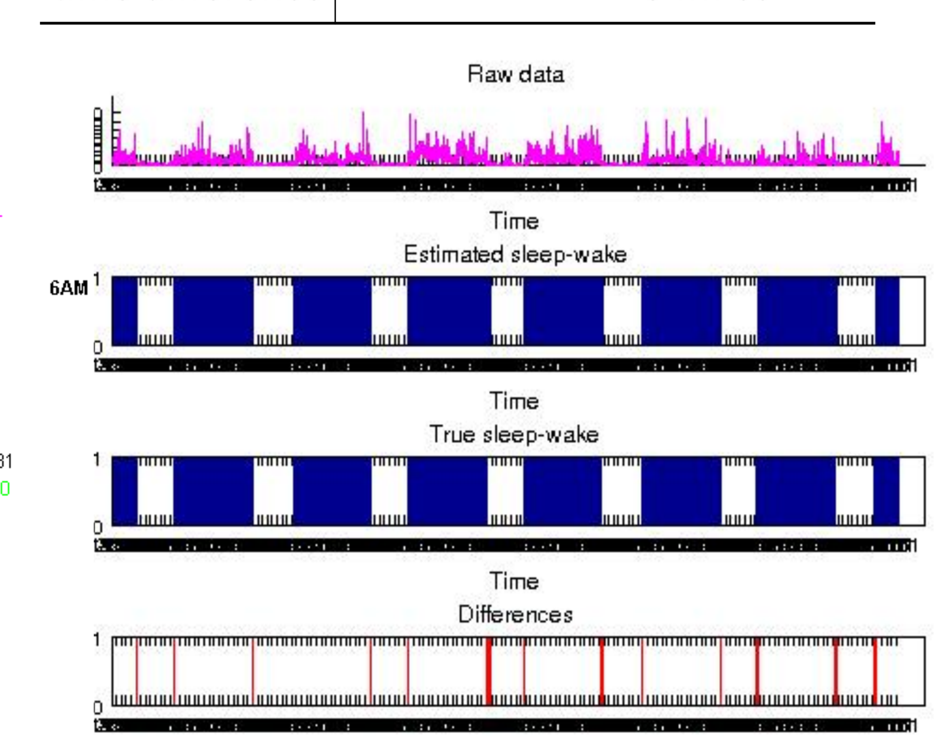
Criteria

- error rate, i.e. disagreement in scoring
- sensitivity/specificity of 'wake' detection
- Cohen's Kappa [3] (interrater reliability)
- difference in median sleep & wake time (over 7 days)

Mean values (with mininum and maximum) for the 25 subjects.

	Mean	min / max
Error rate	2.31%	1.20% / 5.01%
Specificity	96.26%	88.43% / 99.35%
Sensitivity	98.43%	93.81% / 99.51%
Kappa	94.83%	89.01% / 97.30%
Median wake time difference	7m 38s	- 14m 49s / 45m 0s
Median sleep time difference	11m 22s	-10m 0s / 34m 0s





CONCLUSION

The automatic method is automatic and faster than manual scoring. Results are *reproducible* and similar to those obtained by a trained expert.

The code is available here: http://CyclotronResearchCentre.github.io/Actigraphy

"To do" list:

- more validation by comparing with (and between) multiple human raters,
- derivation of other sleep/wake parameters of interest
- refining/improving the algorithm for all types of data

REFERENCES

[1] C. Crespo et al., Automatic identification of activity-rest periods based on actigraphy. *Med. Biol. Engineering and Computing, 50:*329-340*,* 2012; [2] C. Bishop, *Pattern Recognition and Machine Learning*, 2007; [3] T. Byrt et al., Bias, prevalence and kappa. *Journal of clinical epidemiology*, 46(5):423-429,1993.

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