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Physiolyze: a Galaxy-based web service for Heart Rate Variability analysis with online processing

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Abstract

We developed Physiolyze, a Galaxy-based web framework to process Heart Rate Variability (HRV) data. Our framework includes the pyHRV library, an up-to-date collection of Python methods to calculate HRV indexes. Physiolyze can be use both through a web interface and a web service component for a fast and configurable embedding of HRV analysis in complex processing pipelines. The framework also provides support for online processing of heart rate streaming data.

Keywords: Heart Rate Variability, Physiological Measurements

I. INTRODUCTION

The analysis of Heart Rate Variability (HRV) aims to dissect the role of Heart Rate (HR) oscillations in specific physiological and emotional states [1][2]. Complex HRV indexes (e.g. multiscale, entropy based and non linear) [3][4] have the potential of being applied for physiological analysis and interpretation of cardiovascular oscillations in real life contexts, including in stress and disease states. The scientific contribution of pilot studies technically supported by online processing approaches can pave the way to real-time applications. However, novel tools providing a flexible interface for fast index calculation are needed to quantitative track large cohorts with the help of wearable device. In particular, the growth of physiological data stream sizes can be addressed by delegating the computationally-intensive tasks to adequate remote servers, and by employing online processing.

To the best of our knowledge, only three open-source libraries (PhysioToolkit [5], RHRV [6], HRVAS [7]) and two offline platforms (KubiosHRV [8], gHRV [9]) are available for HRV index extraction. KubiosHRV (MATLAB based, freely available) and gHRV (Python based, open source) are programs not easily integrable in computational pipelines; they require user interaction, and parameter customization is not straightforward. PhysioToolkit, RHRV, and HRVAS are instead integrable in personalized pipelines, but require scientific programming skills. Moreover, they are not predisposed either for online

processing or the delegation of computationally-intensive tasks to remote hosts.

In this work we answer the call for an up-to-date HRV analysis framework by introducing Physiolyze, an online resource offering custom workflows supported by the Galaxy environment [10][11].

II. PLATFORM DESCRIPTION

Physiolyze is a framework composed by two modules:

1) The low level Python-based library pyHRV, which implements algorithms used for the HRV analysis;

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2) A Galaxy-based front-end providing workflow-based computing as well as a graphical user interface.

A. pyHRV

The Python library pyHRV¹ provides algorithms for extracting about 40 up-to-date HRV indexes, listed in Table I.

Algorithm implementations from PhysioToolkit [5], gHRV [9] and RHRV [6] were used as inspiration, and further expanded to cover non-linear and entropy-based indexes [3][4]. The library operates on RR measures, and it also features a peak detection function for data from Electrocardiogram (ECG) or Blood Volume Pulse (BVP) recording devices.

Fig. 1. Definition of a HRV analysis pipeline through the Physiolyze web interface. Three processing modules (preprocessing, HRV index extraction, random forest predictor) from the left panel are linked together to form the workflow in the central panel. The panel on the right gives access to parameters of a selected module: the parameters for HRV index extraction are shown in this screenshot.

B. Galaxy-based online framework

The Physiolyze framework is based on Galaxy [10], a platform originally developed to support data-intensive bioinformatics analysis. We adopt its graphic workflow editor as a web interface to the Physiolyze data processing pipelines (Fig. 1). Specialized modules based on pyHRV have been introduced for HR signal processing, HRV index extraction, and online processing (through a web service). Inputs (also through ftp services), outputs and function parameters can be specified on the web interface. Further, we use the Galaxy

environment to support reproducibility: the source code of each module and the workflows defining the pipelines can be shared through Tool Shed, a Mercurial-based revision control

manager; Physiolyze output data can be accessed by sharing links generated by the web interface, while a history panel tracks all settings and processes.

¹Source code available at <http://github.com/MPBA/pyHRV>

TABLE I LIST OF SUPPORTED HRV INDEXES.

Name	Time Domain	Frequency Domain	Non-Linear
KubiosHRV [8]	RRmean, HRmean, RRSTD, HRSTD,	VLF(abs, %, peak) ^a , LF(abs, %, peak) ^a ,	SD1, SD2, ApEn, SampEn, D2, DFAa1,
v2.1 (June 2012)	RMSSD, NN50, pNN50, triang, TINN	HF(abs, %, peak) ^a , LFn, HFn, LF/HF	DFAa2, Lmean, Lmax, REC, DET, ShanEn
gHRV [9]	RRmean, HRmean, RRSTD, HRSTD,	ULF, VLF, LF, HF, LF/HF	SD1, SD2, FracDim, ApEn
v1.5 (Dec 2013)	RMSSD, SDANN, SDINDXX, pNN50, IRRR, MADRR, triang, TINN		
RHRV[6]	RRmean, SDNN, SDANN, RMSSD,	ULF, VLF, LF, HF	ApEn, DFAa1, DFAa2, CorrDim, InfDim,
v4.0 (Jan 2013)	MADRR, pNN50, TINN		maxLyap, FracDim, SampEn
HRVAS [7]	RRmean, HRmean, HRSTD, RMSSD,	VLF(abs, %, peak) ^a , LF(abs, %, peak) ^a ,	SD1, SD2, SampEn, DFAa1, DFAa2,
v1.0 (Oct 2010)	SDNN, NNx, pNNx, SDNNx triang, TINN	HF(abs, %, peak) ^a , LF/HF	DFAall
Physiolyze	RRmean, HRmean, RRSTD, HRSTD,	VLF(abs, %, peak) ^a , LF(abs, %, peak) ^a ,	SD1, SD2, SD12, Sell, ApEn, SampEn, D2,
v0.1 (Jan 2014)	RMSSD, NN50, pNN50, NN25, pNN25, NN10, pNN10, triang, TINN, MADRR	HF(abs, %, peak) ^a , LFn, HFn, LF/HF	FI, DFAa1, DFAa2, pfd, maxLyap, FracDim, SpecEn, SVDEn, hurst

Index definitions as in the cited references. ^aabs: absolute Power Density (PD); %: PD relative to total PD; peak: peak frequency (in band).

III. APPLICATIONS

Physiolyze pipelines were tested on HR data of diverse input types and for different applications. To identify HRV patterns associated to behavioural states of infants, we first considered signals collected with a Light WP Holter ECG recorder (GE Healthcare) [12]. A random forest regression module was applied in concatenation to two pyHRV modules for signal processing and HRV index estimation (see Fig. 1). The predictor and feature extraction methods in the randomForest R library were directly called by the Galaxy workflow manager in this experiment.

The HRV index extraction component was reused in a second pipeline specifically developed to process HR data collected with wearable devices. Data were collected with three different HR sensors. For outdoor activities we used the Mio Alpha and the Polar WearLink, which directly provide HR, while in an experimental setup for monitoring valence and arousal response to stressful sounds we employed the Empatica E3, which acquires a set of physiological signals including BVP through a pulse oxymeter. The BVP signals were first processed with a peak detection algorithm implemented in pyHRV to extract the RR intervals.

Finally, we tested the Physiolyze environment for online processing with a standard Intel Xeon e5520 blade with 16Gb RAM on a stream of data extracted from the infants HR dataset, in order to emulate a real-time analysis. A subset of the HRV index extraction routines (e.g. RRmean, pNN25) were adapted to successfully handle streams of data as input.

The three studies were run from the web interface, storing and sharing parameters and workflows between collaborators. The web interface masks the technical aspects of setting up an online processing pipeline, still giving full control and reproducibility of the HRV index extraction process.

IV. CONCLUSIONS

We introduced Physiolyze, a novel web-oriented resource for HRV analysis. Its core library, pyHRV, extends the set of indexes available in other existing tools. A Galaxy-based framework yields a system for building highly

customizable pipelines, as well as data management and sharing functionalities through a web interface. Scripts and pipelines can be shared between users, which warrants analysis reproducibility. We are testing the Physiolyze platform on data from different HR sensors, also supporting HRV analysis of streams of HR data.

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