Enhancing Interactive Immersive Applications with Real-Time Data Science

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INTRODUCTION

This poster presents a summary of **four publications** that explore how **machine learning** can provide intelligence to immersive **virtual reality (VR)** systems. The aim is to allow digital environments to adapt automatically to the specific user (skill level, affective state, or behavioral preferences) and provide personalized interactions that improve the performance in a VR-based task. This research consists of three main pillars:

Time-Series Acquisition

Physiological, kinematic and behavioral time-series collected from wearable health sensors (heart rate, BCI), VR systems (headset), and usage activity (peripherals, controllers).

Real-Time Data Science

Time-series based methods are employed to build classification models that can understand intrinsic aspects of the user from available continuous data streams.

Virtual Reality Systems

A digital environment that provides adaptive custom interactions and can optimize outcomes in VR-based tasks such as medical rehabilitation, professional training, or games.

PROBLEM

Most time-series classification algorithms require long training times to create a specific user profile. There is a need for classifiers that can be embedded in VR-based environments and understand, in a short time, the characteristics of the user that is currently interacting with the system.

RESEARCH QUESTION

How can immersive applications in virtual reality provide more personalized interactions using real-time data science?

METHODS AND MATERIALS

The methodology intersects two different research areas:

Data Science

The creation of data collection systems for real-time data science, following a *design science* research approach.

The machine learning algorithms involve areas such as *real-time feature extraction, time-series classification, and early stage prediction*.

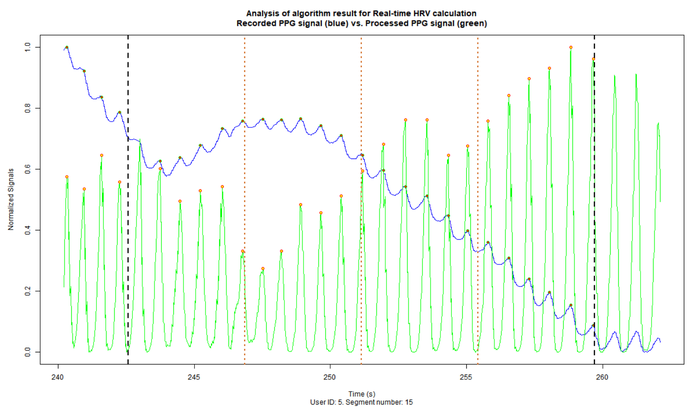
Virtual Reality

The evaluation of algorithms in real-life VR applications involves *user studies* and *experimental research*.

The custom adaptations of a VR environment need to be validated with *usability tests*.

RELEVANT PUBLICATIONS

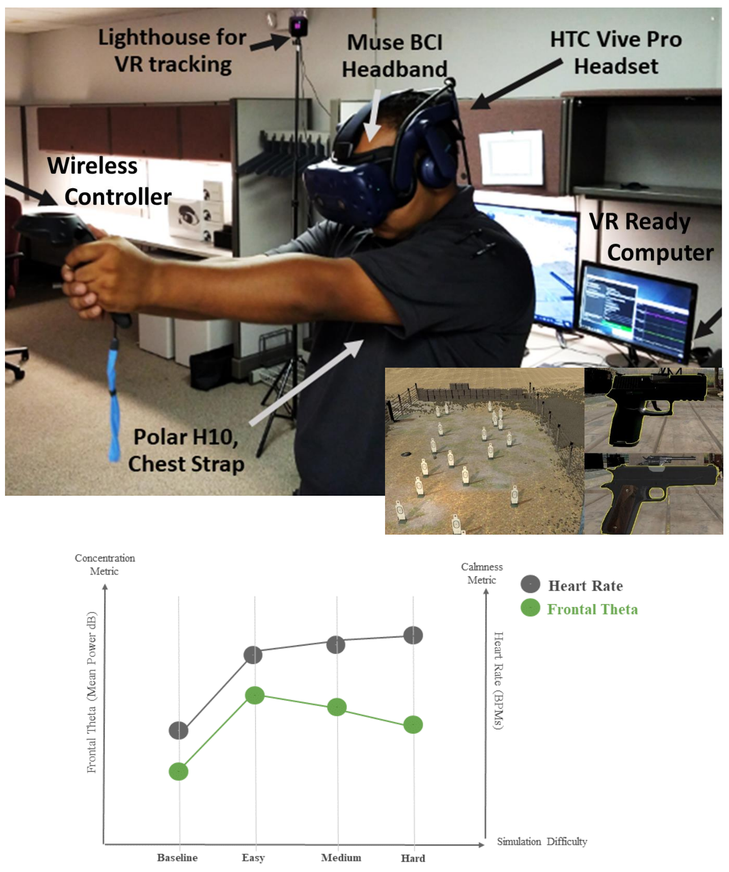
Results Paper [1]



Real-time feature extraction of signals

A new approach for real-time feature extraction from heart rate signals. It enables acquisition from wearable sensors and reliable performance. Useful for VR-based healthcare applications in psychology and physiotherapy.

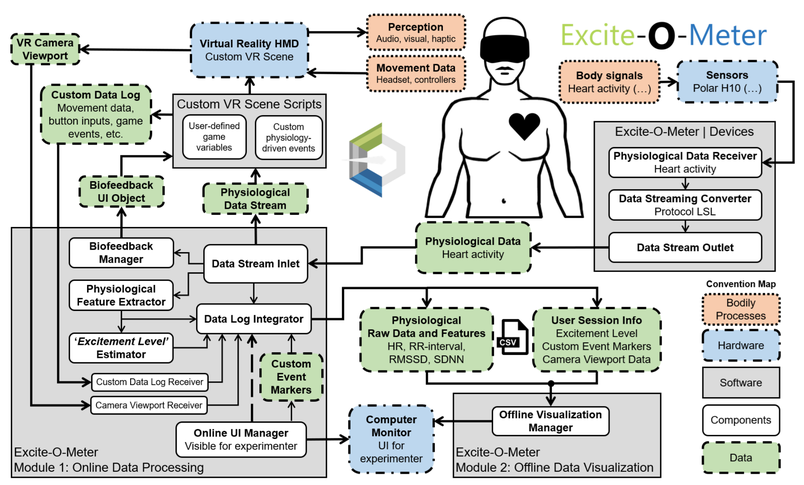
Results Paper [2]



Adaptation model for VR-based training

A computational rule-based model that allows real-time adaptation of VR-based training. The model was built from heart and brain data collected from 10 experienced police officers.

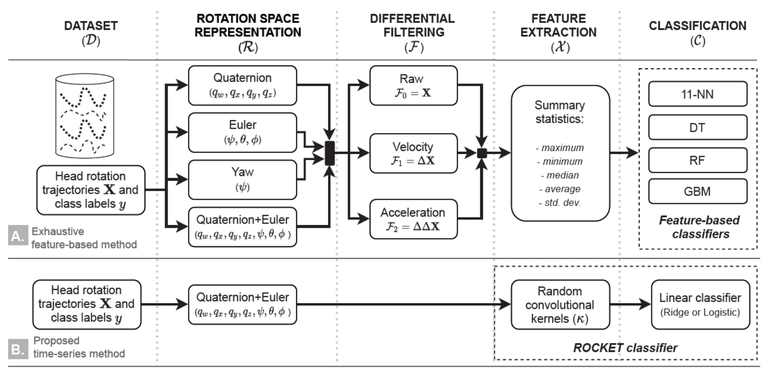
Results Paper [3]



Multimodal time-series acquisition

An open-source software to facilitate acquisition of physiological and kinematic time-series from existing VR applications. A user study led to a preliminary model that estimates "*excitement level*" from VR videos only using heart rate signals.

Results Paper [4]



Classification of head motion in VR

A pipeline that adapts the ROCKET time-series classifier to specific kinematic (motion) data captured through VR headsets. This approach is faster and more accurate than other methods involving manual feature extraction.

FUTURE WORK

The problem will be explored further in the upcoming years from three perspectives:

- Design algorithms for **early time-series classification** from physiological and kinematic data using existing datasets.
- Use **reinforcement learning** to create models of users in a virtual environment.
- Conduct more **user studies in VR** with applications in healthcare and training.

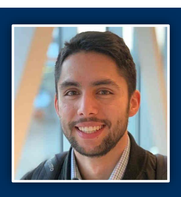
REFERENCES

[1] **Quintero L**, Papapetrou P., Muñoz J., Fors U. Implementation of Mobile-based Real-time Heart Rate Variability Detection for Personalized Healthcare. *IEEE International Conference on Data Mining Workshops (ICDM)*, 2019. [URL]

[2] Muñoz JE., **Quintero L**, Stephens CL and Pope AT. A Psychophysiological Model of Firearms Training in Police Officers: A Virtual Reality Experiment for Biocybernetic Adaptation. *Frontiers in Psychology*, 2020. [URL]

[3] **Quintero L.**, Muñoz JE., De Mooij J., and Gaebler M. Excite-O-Meter: Software Framework to Integrate Heart Activity in Virtual Reality. *IEEE International Symposium on Mixed and Augmented Reality (ISMAR)*, 2021. [In press]

[4] **Quintero L.**, Papapetrou P., Hollmén J., Fors U. Effective Classification of Head Motion Trajectories in Virtual Reality using Time-Series Methods. *IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)*, 2021. [In press]



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