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 automatically adapt to the specific user (their skills level, affective state, or behavioral preferences) and provide personalized interactions that improve their performance in a VR-based task. Our research is composed by 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 used to build classification models that can understand intrinsic aspects of the user using 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 that could be used to build user profiles require long training times. There is a need of time-series classifiers with short training times so that the VR-based environments can gain immediate understanding about the type of user that is currently using the system.

RESEARCH QUESTION

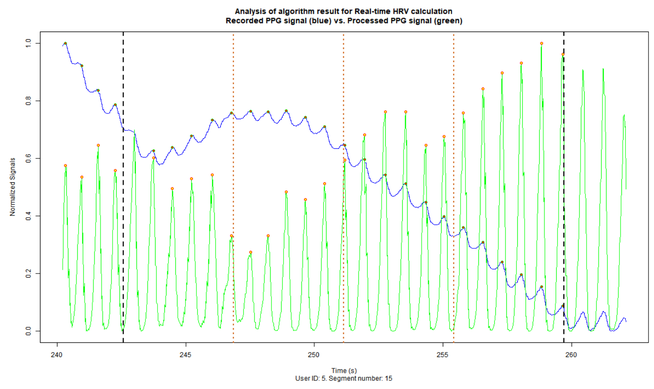
How can immersive applications in virtual reality provide more personalized interactions using real-time data science?

RELEVANT PUBLICATIONS

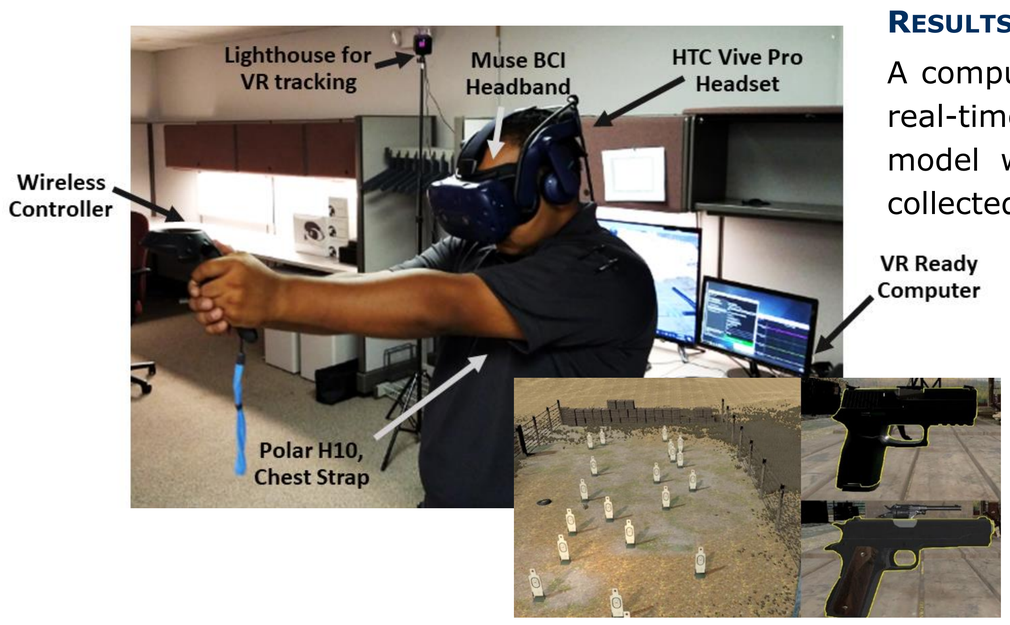
Real-time feature extraction of heart signals [1]

Results

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.

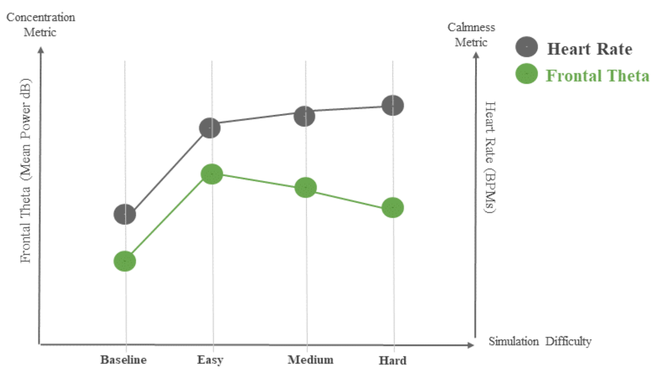


Model for adaptation of VR-based training [2]



Results

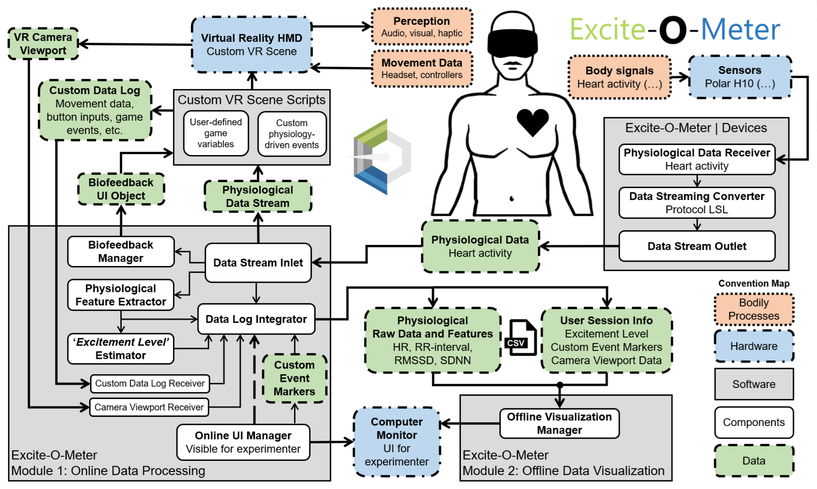
A computational rule-based model that allows real-time adaptation of VR-based training. The model was built from heart and brain data collected from 10 experienced police officers.



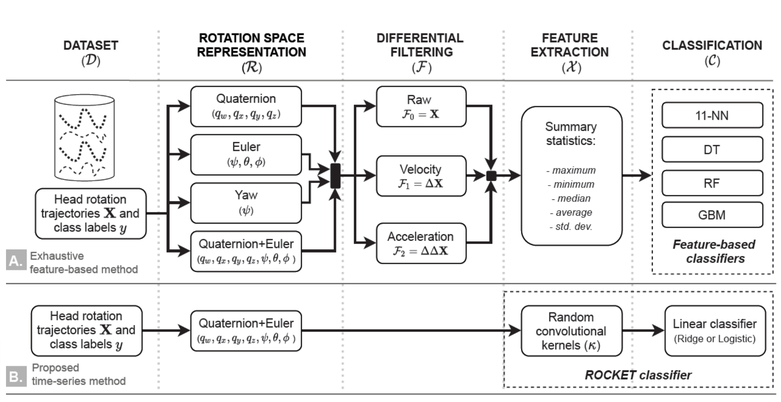
Multimodal time-series acquisition [3]

Results

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.



Classification of head motion in VR [4]



Results

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

METHODS AND MATERIALS

Our methodology intersects to different research areas:

Data Science

The creation of data collection systems for real-time data science follow 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 VR applications involves *empirical experimental research*, specifically user studies.

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

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 digital users in a digital scene.
- 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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