BikECG - A VR Bicycle Simulator Concept that Integrates Physiological Data and Tele-Cycling

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Abstract

Different fitness levels during group cycling tours pose a challenge and have a negative impact on fairness, motivation and inclusivity within the cycling community. To solve this problem, we present a novel, physiology-adaptive Virtual Reality (VR) bike simulator concept. Using a road bike mounted on a Wahoo KICKR Smart Trainer and a Varjo XR-3 HMD, we implemented a VR bicycle simulator using Python and Unity 3D. Real-time ECG data acquisition via a Polar H10 chest strap enhances adaptive capabilities and provides a versatile framework for investigating the dynamic relationship between virtual experiences and physiological responses. This collaborative project, involving two universities, aims to explore tele-cycling and physiologically adaptive scenarios, with a second simulator under construction to expand the possibilities. The integration of real-time physiological monitoring improves the adaptability of the simulation, making it a valuable tool for studying human responses in VR-based cycling scenarios.

Author Keywords

Cycling; ECG; Physiological Sensing; Virtual Reality; Simulator; Exergaming.

CCS Concepts

•**Human-centered computing** → **Human computer interaction (HCI);** *Virtual reality;*

Figure 1: *Depiction of cyclists collaboratively biking through a forest in a virtual environment. In our work, we aim to utilize physiological data such as heart rate as an input metric for engagement and effort. In contrast to traditionally used cycling power or speed-based input methods, this allows cyclists with different fitness levels to work out together while achieving a good training effect for every team member.*

Introduction

Individuals with different fitness levels might face challenges or barriers when engaging in collaborative rides or exercises. The potential disparity in performance or difficulty level experienced by participants can have a negative influence on the overall sense of fairness, motivation, and inclusivity within the cycling community. Unequal challenges may lead to frustration or demotivation among individuals facing greater difficulty, potentially hindering their engagement and long-term commitment to the collaborative fitness goals. Tele-cycling can address these challenges by implementing features like artificial handicaps, fostering inclusivity, and creating a collaborative virtual environment that allows users with different fitness levels to engage, train together, and collectively pursue fitness goals. The introduction of artificial handicaps is presented as a solution which allows participants of varying fitness levels to engage in collaborative rides or challenges, leveling the playing field by introducing virtual handicaps that adjust the difficulty for each individual. This not only promotes inclusivity but also fosters a supportive environment where users can train together, share experiences, and collectively strive towards fitness goals.

Related Work & Background

Our main motivation is the work by Agharazidermani et al. [1]. This paper discusses the development and evaluation of a prototype interface designed for co-located training partners engaged in cycling. The interface allows partners to share real-time data, specifically heart rate (HR), with each other. The study involved six participants in a pilot study, and the findings suggest that the real-time display of

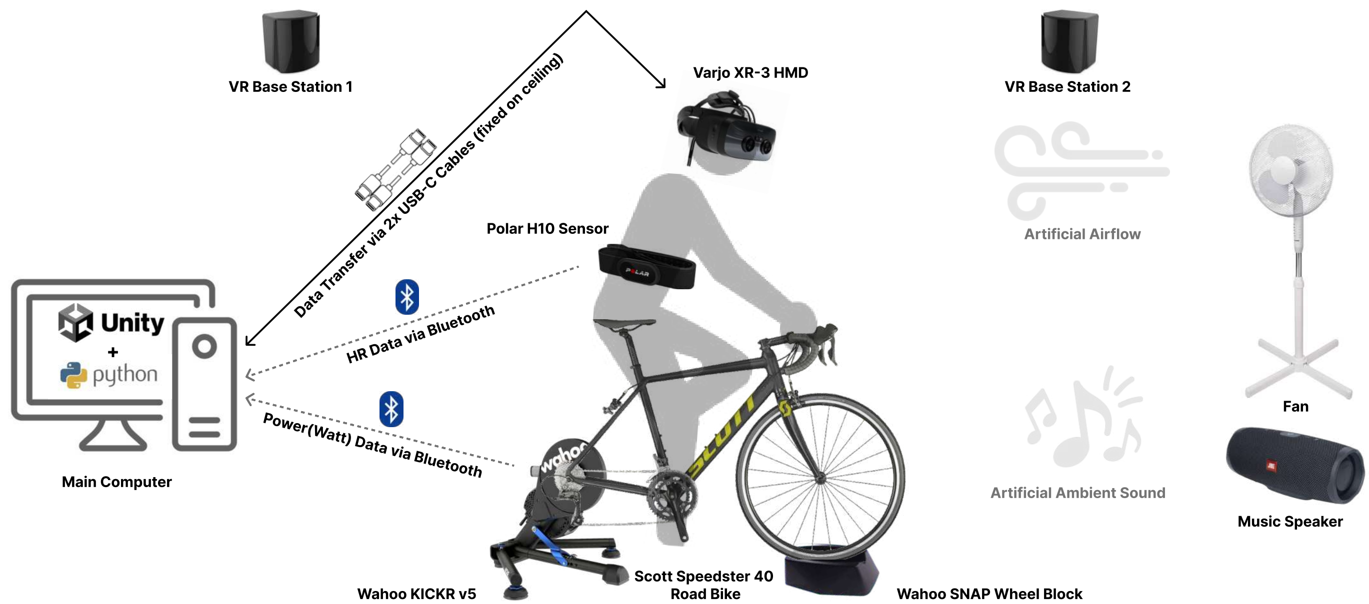

Figure 2: *Setup of our VR Cycling Simulator.*

HR information can be beneficial for both less experienced recreational cyclists and highly experienced cyclists, especially in dynamic road conditions. The paper emphasizes the potential of real-time interfaces for exercise and highlights the importance of further research in this area to facilitate successful collaboration. We propose to commence our investigation/initiative from this juncture.

Apparatus & Implementation of Our Simulator

We implemented the VR environment using Unity 3D (Version 2022.3.20f1). For the VR Bike Simulator, we mainly use a road bike, a bike training device, a Mixed Reality (XR) HMD, and a computer. We decided on a Scott Speedster 40 road bike. We chose a Wahoo KICKR Smart Trainer v5 as the training device. The KICKR uses the Bluetooth *Cycling Power-Service* [1], which made it possible for us to establish a connection to the KICKR from the main computer and receive the *Cycling Power Measurement* data by a python script, which is mainly the currently produced Watts by the cyclist. We use a common method to convert this to an estimated velocity in km/h [5]. We fitted the gearbox of our bike to the Wahoo KICKR and replaced the bike's rear wheel with the device. To ensure the bike stays in position, the bike's front wheel is locked in a Wahoo SNAP Wheel Block. This block is fixed to the ground using duct

[1] https://www.bluetooth.com/specifications/specs/cycling-power-service-1-1/

tape. This makes it impossible to steer, and there turn left or right in the simulation at the moment. For the XR HMD, we decided on a Varjo XR-3 HMD. Additionally, we use two HTC Steam VR Base Station 2.0 for outside-in tracking.
We acquire ECG via PolarH10 chest strap (Polar, Finland, 130 Hz). The strap must be placed around the user's lower chest for optimal recordings, with a short adjustment phase of around two minutes. We use a fan to create artificial airflow to increase immersion and prevent motion sickness [2]. We use external speakers to avoid disturbing the users with another device on their heads. The setup of our VR cycling simulator can be seen in Figure 2.

ECG Recording & Preprocessing: We collect ECG data at a sampling rate of 130 Hz using a Polar H10 chest strap (Polar, Finland). Before data collection, the ECG electrodes are moistened with lukewarm water and positioned over the xiphoid process of the sternum, just below the chest muscles. For real-time processing data, we utilized the Neurokit Python Toolbox [4]. Initially, we apply a Finite Impulse Response (FIR) band-pass filter with a range of 3 to 45 Hz and a 3rd order to preprocess the ECG signal. Subsequently, we employ Hamilton's method [3] to segment the signal and identify the QRS complexes.

Feeding HR & Power Data into Unity: From the main computer, we establish two Bluetooth connections with both the Wahoo KICKR and the Polar H10. ECG data and power(Watt) data is received by two separate python scripts and gets preprocessed. These scripts on the other hand transmit only the calculated HR and velocity in km/h in form of `float` values via a local TCP connection to our Unity project. The data is transmitted separately so we can make use of the simulator without the need for the Polar H10. This was also a huge advantage during the implementation phase. Using the simulator without the power data would theoretically also work, but has no practical sense.

Immersion: We integrated several elements aimed at enhancing immersion. First, we introduced a fan positioned in front of the user to create artificial airflow, serving to deepen immersion while also providing a cooling sensation. Secondly, we implemented a sound system capable of reproducing typical bike sounds like chain rattling and tire noise, as well as environmental noises such as those found in a forest, further enriching the user's experience. Although currently not possible in our current setup due to the fixed front tire, advancing the prototype could involve integrating steering input from the user to create a more adaptable biking experience.

Conducted Studies

So far, we have conducted one study with our VR bicycle simulator. Unfortunately, the paper is currently under review. We are therefore unable to provide any information on this project.

Lessons Learned

We chose a Wahoo KICKR Smart Trainer v5 as the training device for the simulator, as it supports lateral movements and features auto-calibration. According to the manufacturer, the device has a performance accuracy of +/-1 % [2]. Anyway, calibration of the KICKR is necessary from time to time to maintain accurate power (Watt) recordings. While the manufacturer mentions that the device supports ANT, ANT+ FE-C, WiFi, Bluetooth, and "Direct Connectivity", we figured out the most uncomplicated and reliable way was to use Bluetooth. Implementing all data streams separately increases complexity, but was really helpful in development, as it allowed us to test the simulator without the need of the HR sensor. For the XR HMD, we decided on a Varjo XR-3 HMD. We chose a XR HMD instead of a VR-only HMD for better adaptation to VR and to get participants out of the

[2] https://eu.wahoofitness.com/devices/indoor-cycling/bike-trainers/kickr-buy

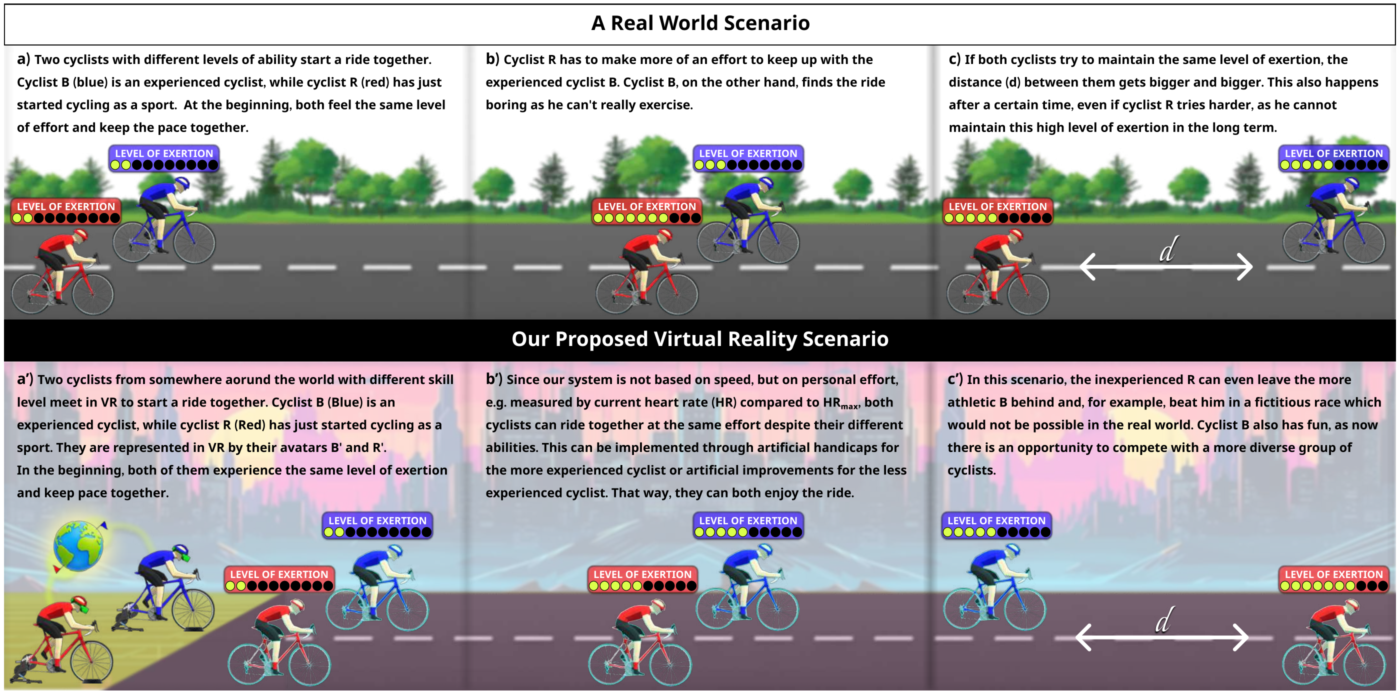

Figure 3: *Two Cycling Scenarios, One From the Real World and One From Our Proposed System*

simulation quick if motion sickness or similar should occur. This way, we can also ensure that participants take a seat on the bike correctly while already wearing the HMD in video pass-through mode. The fan we use to create artificial airflow to increase immersion and prevent motion sickness [2], actually helped a lot in coping with motion sickness, according to feedback by participants from our first study. The external speakers made it possible for us to be able to talk to the participants while they were immersed in VR. We do not know yet exactly how to convey our findings from VR to the real world, and from cycling to other sports.

Planned Study

Our VR cycling experience, depicted in Figure 3, seeks to explore the effects of artificial handicaps and improvements on enjoyment, engagement, and competition dynamics while cycling in a virtual environment. The research will investigate the effectiveness of these adjustments for less experienced cyclists, analyze psychophysiological responses, assess learning and skill transfer, and examine user preferences for customization. We will also consider long-term implications, including potential effects on participant engagement and retention in the virtual cycling scenario.

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