PREDICTIVE ERGONOMIC EVALUATION OF AUTOMOTIVE DIGITAL WORKSPACES

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Introduction

Modern-day industrial environment constantly evolves towards autonomous technological systems. Still, the human factor remains crucial. Human - machine interfaces (HMIs) are devices that enable and regulate smooth physical and cognitive interactions between humans and software or hardware systems. Therefore, a thorough evaluation of HMI designs adopting multiple criteria is imperative. In this work, we present a software framework that can be applied to perform ergonomic analysis of physical and digital prototypes using physiology-based digital twins in a simulation environment. The software was developed and tested for ergonomic evaluation of automotive HMI designs.

Methods

The framework is built upon OpenSim, a dedicated biomechanics software tool and is developed through Python scripting. It requires: (a) a digital twin of the assessed HMI design, (b) motion capture (MoCap) data of the user's physical interactions with the HMI elements, and (c) a musculoskeletal OpenSim model. In cases where motion data is not available due to hardware limitations or experiment complexity, we have developed a separate module for predicting user – HMI interactions, based on the OpenSim MOCO software tool. The musculoskeletal model was scaled to represent different human body sizes based on anthropometric data acquired from the NHANES database [1]. There are two core ergonomics analysis modes, namely the Static and Dynamic Posture Analysis. The former evaluates the user's static posture at the time instant of interaction with individual elements of the HMI design and estimates three ergonomic indices depending on the task load, namely RULA, LUBA, and NERPA [2]. The latter can be applied to assess the overall user performance throughout the entire range of interactions within a given driving scenario. A collection of physics - based and anthropometric ergonomic indices is estimated, such as the Mean Torque Factor, Angular Impulse, Energy, RoM comfort factor, and RoM - torque comfort factor [3].

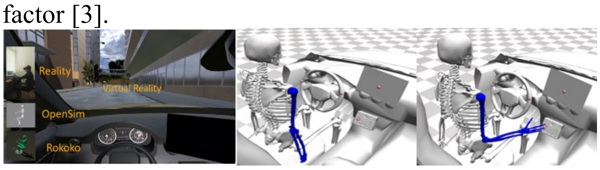

Figure 1: (Left) Real-world experiment to record driver – HMI interactions. (Right) Predictive Tool generated user - HMI interactions in a simulation environment.

We assessed the capability of the predictive tool to yield similar ergonomic results compared to real MoCap data – based analysis. An appropriate scaled musculoskeletal model was selected, the HMI elements' locations were defined, and the model's joint angle trajectories were predicted by the tool. The real-world experiment was performed in a virtual reality (VR) setting at the VVR lab in University of Patras.

Results

The comparison results between the predicted and real MoCap data - based cases are presented in Figure 2 for the Static and Dynamic Analysis, respectively. These showcase minimal differences regarding Static Analysis scores and similar behaviour for the Dynamic Analysis indices.

	RULA(r)	RULA(l)	NERPA(r)	NERPA(l)	LUBA(r)	LUBA(l)
Moco_upat_HMI	3	2	2	2	7	2
RT_upat_HMI	2	2	2	2	7	2

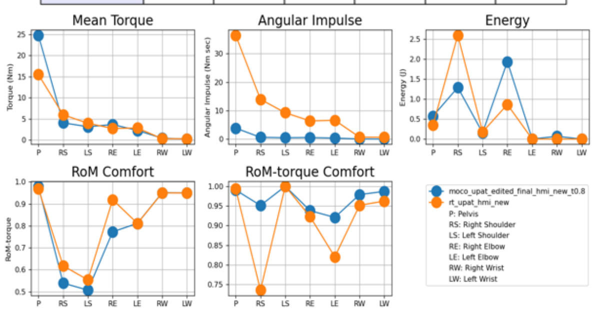

Figure 2: Static (top) and Dynamic Analysis (bottom) results comparing the analysis using the predictive tool generated motion and real MoCap data, respectively.

Discussion

The developed system can be used to ergonomically assess digital HMI prototypes in virtual and physical environments regardless of MoCap hardware availability. Comparative analysis of multimodal HMI designs can be efficiently conducted in a simulation environment to assist manufacturers during product development phase, while reducing complexity and cost of experimental setups. The system can be further improved to be applied in an augmented reality (AR) digital twin simulation context.

References

1. Fryar CD et al. Vital Health Stat 3(39). 2016.
2. Sanchez-Lite A et al, PLoS One. 2013 Aug 16;8(8):e72703.
3. Kaklanis et al, (2013). 12. 10.1007/s10209-012-0281-0

Acknowledgments

This work was supported by the EU's Horizon 2020 programme and the Trustonomy (GA 815003) and Didymos-XR (GA 82344) projects.