A Fully-Immersive Hapto-Audio-Visual Framework for Remote Touch

F. Sanfilippo and L. I. Hatledal
Dept. of Maritime Technology and Operations
Aalesund University College Postboks 1517,
6025 Aalesund, Norway
{fisa, laht}@hials.no

K. Y. Pettersen
Dept. of Engineering Cybernetics Norwegian
University of Science and Technology 7491
Trondheim, Norway
kristin.y.pettersen@itk.ntnu.no

Abstract

This paper presents the development of an open-source low-cost framework for a fully-immersive haptic, audio and visual experience. This framework is realised by exclusively adopting commercial off-the-shelf (COTS) components and tools. In particular, vibration actuators and open-source electronics are employed in the design of a pair of novel and inexpensive haptic gloves. These gloves allow for establishing a kinesthetic link between a human operator interacting with a computer-generated environment. Remote touch applications are possible. In the context of Smart Cities, this technology may be adopted to enhance the interface between nature and culture by stimulating the senses or as a complement to the landscape.

1. Introduction

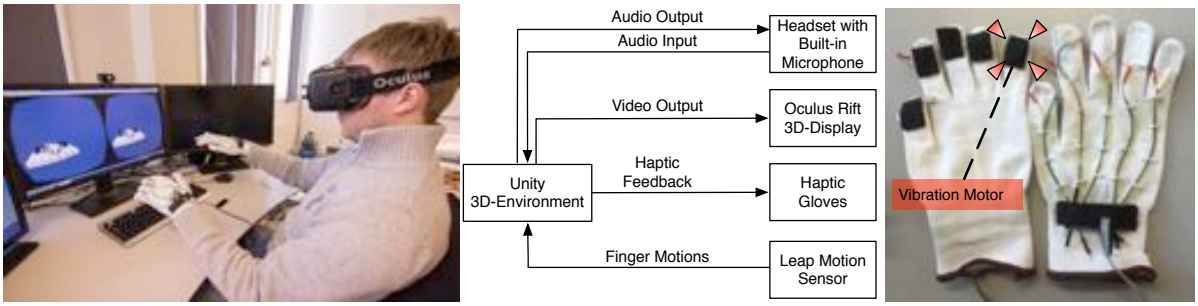
Touch is one of the most reliable and robust sense, and is fundamental to our memory and in discerning. In order to provide the user with additional and intuitive information, haptic technology can be employed [1]. Haptic feedback, also known as haptics, is the use of the sense of touch in a human-computer interface. A variety of applications are made possible with the use of haptics, including expansion of human abilities: increasing physical strength, improving manual dexterity, augmenting the senses, and most fascinating, projecting human users into remote or abstract environments.

Nowadays, different commercial off-the-shelf (COTS) haptic feedback devices exist. However, most of the currently available devices are still quite expensive. Besides, the majority of these devices are based on proprietary hardware and software. Even though different haptic software libraries are available, the integration of these devices still requires significant programming skills [2]. Therefore, this process may be a tedious and time-consuming task, which may force researchers to focus too much on language and syntax, preventing them from giving enough attention to application logic. In addition, most of the currently available libraries do not offer flexible tools for modelling, simulation and analysis. Consequently, researchers are forced to develop custom-made solutions that often suffer from a lack of generality. Most importantly, it is not possible to fully address the realisastion of a combined and fully-immersive haptic, audio and visual experience with currently available COTS devices.

In order to allow researchers to add haptic capabilities to their applications in a more flexible, interactive and transparent fashion, an open-source, low-cost framework for a fully-immersive haptic, audio and visual experience is proposed in this work. The framework allows for the flexible, interactive and seamless addition of haptic capabilities to applications. This framework employs vibration actuators and open-source electronics in a newly-designed, low-cost pair of haptic gloves. Hand and finger motions are monitored with a *Leap Motion* sensor and a stereoscopic visual feedback is provided by an *Oculus Rift* head-mounted 3D display. A headset with a built-in microphone constitutes an additional bidirectional audio channel. The *Unity* cross-platform 3D-environment is selected in order to efficiently integrate these components. The underlying idea is shown in Fig. 1-a. The proposed framework allows for the creation of a truly immersive user experience. A real-time one-to-one correspondence between the real and the virtual world can be transparently created. As such, a variety of industry and research applications are made possible. For instance, this technology may be adopted in the contest of Smart Cities to enhance the interface between nature and culture by stimulating the senses or as a complement to the landscape [3]. To demonstrate the potential of the proposed framework, a case study is presented. Related preliminary simulations and experiments are carried out.

2. Framework Architecture and Case Study

The framework architecture is shown in Fig. 1-b. The principal component of the proposed framework is a pair of haptic gloves, shown in Fig. 1-c. These gloves are equipped with precise shaft-less vibration motors embedded on the fingertips. By means of these motors, distinctive haptic feedback patterns can be transferred to the user to accurately simulate virtual finger collisions. The controller for the gloves is implemented on an *Arduino Uno* board and is based on the *ATmega328*



(a) **(b)** **(c)**

Figure 1. (a) The concept for developing an open-source low-cost framework for a fully-immersive haptic, audio and visual experience (e.g. user playing the piano), (b) the framework architecture, (c) the pair of haptic gloves.

micro-controller. *Arduino* is an open-source electronics prototyping platform that employs flexible, easy-to-use hardware and software. *Arduino* provides a number of libraries to make programming the micro-controller easier. As such, software development and in turn, hardware development, are simplified, thereby reducing the time needed to get the system running. The choice of using *Arduino* boards makes the system controller easy to maintain and makes it possible to add new features in the future. Compared to similar COTS devices that are currently available on the market, the newly designed gloves represent a major innovation because, they are easy to build by only using off-the-shelf components, they are based on open-source hardware and software, and they are very robust and low-cost.

A *Leap Motion sensor* is adopted to sensorise the gloves for tracking the operator's hand and finger motions. An *Oculus Rift* head-mounted 3D display is used to provide the user with immersive visual feedback. To further enrich the user experience, an additional bidirectional audio channel is provided by means of a headset with a built-in microphone. All these components are integrated in the same head-mounted set.

The *Unity* cross-platform 3D-environment is chosen as middleware for the integration of all framework elements. For each component, the corresponding application programming interface (API) is adopted to accomplish the desired integration.

To demonstrate the potential of the proposed framework, a case study is presented. In particular, a virtual scene in which the user can play the piano is developed. The experiment setup is shown in Fig. 1-a. Once collisions between the user's virtual fingertips and the piano keys are detected, the corresponding vibration motors on the gloves are actuated. A demo video is available on-line at http://youtu.be/ywCmqn_SuDo. By implementing a network connection between two instances of the proposed framework, a piano player can remotely teach another player by transmitting the tactile interaction. This same application can be extended to a possible scenario for a remote tactile interaction.

3. Conclusions and Future Work

An open-source low-cost framework for a fully-immersive haptic, audio and visual experience was presented in this work. The framework enables researchers to easily add haptic capability to their systems. Different functionalities can be achieved including tracking the operator's hand and finger motions, detecting collisions between the operator's virtual fingers and the virtual objects, computing reaction forces in response to contacts and motion, and exerting an intuitive force feedback. A variety of local and remote applications are therefore possible. In the context of Smart Cities, this technology may be adopted to enhance the interface between nature and culture by stimulating the senses or as a complement to the landscape [3]. This approach may contribute to create a communicative macro-environment that has the characteristic to propose an expanded, increased, hybrid and ubiquitous space to go through and to live in more of a haptic way that optical [4].

4. References

[1] A. Tirmizi, C. Pacchierotti, and D. Prattichizzo, "On the role of cutaneous force in teleoperation: subtracting kinesthesia from complete haptic feedback," in *Proc. of the IEEE World Haptics Conference (WHC)*, 2013, pp. 371–376.

[2] F. Sanfilippo, P. B. Weustink, and K. Y. Pettersen, "A coupling library for the force dimension haptic devices and the 20-sim modelling and simulation environment," accepted for publication in *Proc. of the 41st Annual Conference of the IEEE Industrial Electronics Society (IECON-2015)*, Yokohama, Japan, 2015.

[3] C. J. Lim, and Ed Liu, "*Smartcities and eco-warriors,"* Routledge, 2010.

[4] Karon E. MacLean, "Haptic interaction design for everyday interfaces," *Reviews of Human Factors and Ergonomics* 4.1, 2008, pp. 149-194.