Wearable Haptics for VR Stiffness Discrimination

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Abstract

In this work, we introduce an integrated multi-finger wearable haptic setup which discriminate the stiffness of virtual objects. The overall setup is made of an Oculus Rift (Oculus VR, LLC) combined with a Leap Motion controller (Leap Motion, Inc) and five ERM vibro-tactile actuators, for the virtual immersion, the hand tracking and the 5-fingers haptic feedback, respectively. This setup is integrated with a Unity Game Engine customised software simulating stiffness of virtual objects and returning modulated amplitude of electrical signals for the vibro-tactile actuators on the end-user fingers. The system is under development for applications such as surgical training and pre-operative planning.

Keywords: Haptics, Vibro-tactile, Stiffness Perception, Virtual Reality

1 Introduction

Our sense of touch has abilities to differentiate objects based on softness, shape, size, texture, stiffness and much more. However, since this sense of touch is enhanced by the fusion of information coming from many receptors, it makes it difficult to provide holistic sensation by using haptic devices [1].

This work aims at developing a wearable and wireless solution to provide an immersive haptic feedback while experiencing and recognising the different stiffness of virtual objects. The virtual objects can be interpreted as virtual organs whose tissue stiffness perception can be used for surgical training applications.

Stiffness of each spring is defined as the amount of deformation caused by a unit of measured applied force. Therefore, the spring deformation visual effects may also give some information about stiffness levels [2]. A quantitative analysis of stiffness discrimination is made using virtual linear springs in the presence and absence of visual feedback [3, 4].

2 Methods

2.1 Haptic System

A multiple 5-fingers vibro-tactile wearable device is built to display touch feedback signal from virtual haptics environment (Figure 1).

The haptic device is made of 5 ERM vibro-tactile actuators (Precision Micro-drives 310-311) and haptic controllers (DRV2605). Bluetooth Communication protocol (IEEE 802.15.1) is used between the wearable haptic device and the Virtual Reality environment (VR). The system integrates an Oculus Rift DK2 with a Leap Motion (LP) controller (Orion). A Unity Game Engine processes the user hand movement as captured by the LP controller, maps the movement into the customised VR and returns the signal to the actuators as soon as the engine detects fingers' contact in the VR.

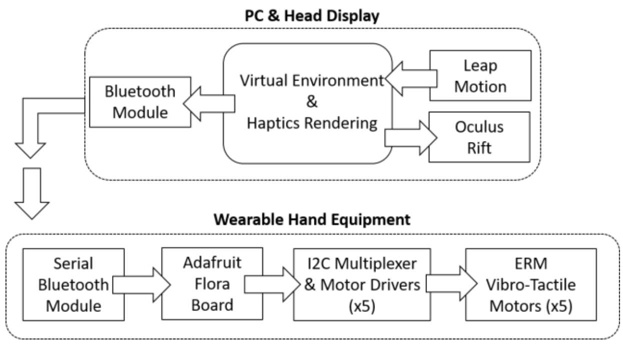

Figure 1 - The Wearable Haptic System Block Diagram

2.2 Virtual Setup

A set of virtual linear springs are modelled within the VR as pure mass-spring system: five different springs with specific stiffness values are implemented. The spring forces during virtual hand and virtual spring interaction are used to pragmatically control the vibration amplitude of the vibro-tactile motors coupled on the fingertips, according to Hookes Law, namely $F = - k * x$, where k is the prescribed stiffness value and x is the displacement of the virtual spring mass, respectively.

The stiffness perception is a multimodal combination of spring reaction force and displacement due to the applied force by the virtual fingers.

3 Physcophysics Experiment

To validate the perceptual efficacy of the system in terms of visual feedback (i.e. displaying stiffness of virtual springs) and tactile feedback (i.e. the mapping code of the stiffness into the vibro-tactile modulation), a quantitative physcophysics experiment has been performed with Two Alternative Forced Choice (2AFC) [5]: results show that human perception is significantly high and the analysis shows an average Weber Fraction (WF) of 0.25 and a Just Noticeable Difference (JND) of 14.7%.

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