HaptWarp: Soft Printable and Motion Sensible Game Controller

Lee Jen Tun
School of Knowledge Science, Japan Advanced Institute of Science and Technology, 1 Chome-1 Asahidai Nomi, Ishikawa 923-1211, Japan[*]

R.P.C Janaka Rajapakse
†Graduate Institute of Animation and Film Art, Tainan National University of the Arts, No. 66, Daqi, Guantian Dist., Tainan City 72045, Taiwan[†]

Kazunori Miyata
School of Knowledge Science, Japan Advanced Institute of Science and Technology, 1 Chome-1 Asahidai Nomi, Ishikawa 923-1211, Japan[‡]

E-mail: [*]bmpsst511@gmail.com, [†]janakaraja@gmail.com, [‡]miyata@jaist.ac.jp

Abstract

Many interaction techniques have been introduced for controlling virtual reality contents and navigation. Traditional controllers need to map between two-dimensional inputs and three-dimensional actions while interactive surfaces enable more natural approaches, they still lack tactile feedback. We present real-virtual bend and twist, a tactile feedback technology that delivers the twist and bends effect into a virtual environment. The method uses two inertial measurement unit (IMU) sensors fixed on both sides on the 3D printed soft material bar to acquire object deformation to simulate the virtual deformation based on the changes in the angle exerted on a physical device. People can customize the 3D printed connection shape to apply to different virtual scenarios.

Keywords: Interaction, Game Controller, interactive bend, interactive twist, intuitive interaction

1. Introduction

During the development of haptic game control systems, careful consideration and devising are required to ensure system stability. Usually, efforts are focused on hardware and firmware improvement and as a result, an intuitive control method is of little concern. VR hand controllers are not dissimilar. Often a touchpad, trigger, or set of arrow keys are added seemingly as an afterthought. This may be sufficient in controlling systems for most of the games but for providing an intuitive experience and making it easier for users to understand how to interact in three dimensional virtual worlds, they often perform inadequately.

Over the past decade, the development of relatively three-dimensional haptic controllers from several companies has allowed experimentation in control with one important addition: inertia measurement unit (IMU). Our work has been applied to add a sensor system to a twistable and squeezable game controller through 3D printing, with the goal of giving users an intuitive operating experience. The software communicates with these systems and formulates a novel interaction between the player and the game.

Related work is presented in section 2. Section 3 explains the implementation of our system and the conclusion is stated in section 4 respectively.

2. Related Work

Research projects related to intuitive control and haptic applications aim to create an immersive experience, which can support the haptic feedback. We will not extract and review the entire area, but instead, discuss areas of the closest relevance to the work presented here.

Spatial user interaction plays an important role in Virtual Environments (VE). It allows the user to navigate the entire virtual environment to find a target or investigate a place or a virtual object in the world. In order to implement spatial interaction, this will often require 6 degrees of freedom (DOF). Inertial measurement unit (IMU) sensors play an important role to implement space manipulation [7]. Tseng et al [5] present the design of the EZ-Manipulator, a new 3D manipulation interface using smartphones that supports mobile, fast, and ambiguity-free interaction with 3D objects. Oh et al [6] propose an interaction method where users can conveniently manipulate a virtual object with touch interaction recognized from the inertial measurement unit (IMU) attached to the index finger's nail and head movements tracked by the IMU embedded in the HMD.

To enhance the virtual environment, game controllers are usually used in VR. Strasnick et al [3] present a novel design of linkage, electro-mechanically actuated physical connections capable of rendering variable stiffness between two commodity handheld virtual reality (VR) controllers. Cho et al [4] utilizes a spindle and wheel to present the interaction technique where users can twist or roll a button ball within his/her fingers simultaneously with other hand motions. For the haptic feedback, Heo et al [8] uses a single 6-DOF force sensor and a vibrotactile actuator to render grain vibrations to simulate the vibrations produced during object deformation based on the changes in force or torque exerted on a device. Tokuyama et al [9] proposed a torque display method for free-form deformation (FFD) with a 6-DOF haptic device which combines bending and twisting operations to extend the editing capabilities of the constructed shape deformation system by means of screw-motions. Tamaki et al [10] achieves this by placing the Photo-reflectors over specific muscle groups on the forearm to detect hand gestures as input. For output, electrode stimuli pads are placed over the same muscles to control the user's hand movements. Both sensors and electrode stimuli pads target main muscle groups responsible for controlling the hand.

While these approaches effectively provide specific spatial interaction and 3D object manipulation and interaction with people between real-world and virtual environment, most researches need many expensive peripherals or deliver the haptic feedback from outside stimuli actuator which unafforded to the user and doesn't integrate well with virtual reality. The aim of the research in this paper was to develop an inexpensive intuitive game controller that can simultaneously provide the intuitive manipulation for VR applications.

3. Implementation

The system structure is shown in Figure 1. In the physical environment, people usually do most things by their hand motions. The controller digitalizes the hand motions through wireless transmission protocol into a virtual environment. In the virtual environment, players are able to interact with the virtual object in an intuitive way by their daily hand motions.

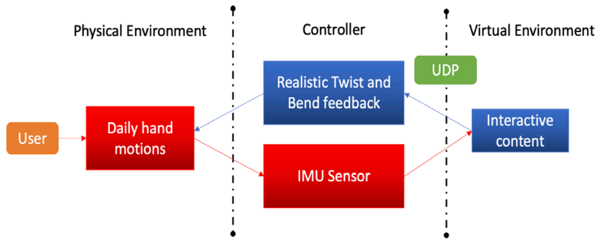

Fig. 1. This is the system structure of the research. Physical Environment include the daily hand motions. Controller is equipped with a 3D printed soft bar, IMU sensor and one MCU. Virtual Environment were the two created scenarios for the user to interact.

1.1. *Intuitive Control*

We explored how to integrate technology into the human experience by the development process of the game controller. It is interesting when a device becomes so natural that it is almost like a daily real activity in the virtual environment. Simultaneously, there are many advanced approaches in the user interfaces that aim to make the game controller more natural and intuitive, however, systems that achieve a truly integrated experience where the interface becomes part of a person's experience of themselves remains rare. At the forefront of this integration of technology and humanity, sensors and customized 3D printed components were designed specifically to integrate with the game controllers. A device like Tactical haptics [1] and Drag:on [2], transform the way a person can interact with the virtual environment. A common thread emerges when reviewing the game controller technologies that successfully integrate into the human experience, which is that it must provide an intuitive experience. In our project, it quickly became clear that it would be vital for our controller design to deliver a realistic and intuitive experience during gaming. As game controllers become wireless and more related to realistic manipulation, it becomes possible to embed them into a customized game application.

1.2. *Hardware Design*

The development of the game controller utilized a rapid prototyping methodology with various features trialled and refined to produce the final design. In particular, the prototyping involved considerable experimentation with different types of shape and mounting for the case and other electronic components. One of the early test prototypes is shown in Figure 2. The controller was printed by the 3D printer with soft material to provide customized joints for a variety of game scenarios. The IMU sensor was embed in the controller to deliver the bend and twist angle from the player to the Wemos D1 mini which is like an Arduino interface but provides WIFI with a small size all for a great price. Then Wemos D1 mini through the UDP protocol transmits the data to Unity virtual environment.

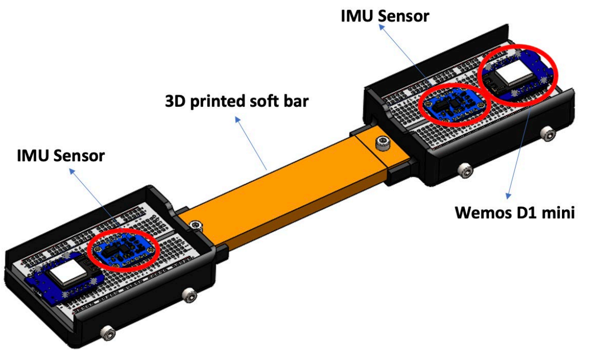

Fig. 2. This is prototype CAD of the HaptWarp controller.

1.3. *Wireless Data Transmission*

Wireless Communication is the fastest growing and most vibrant technological area especially integrated with game controllers. Wireless Communication is a method of transmitting information from one point to another, without using any connection like wires, cables, or any physical medium. Apart from mobility, wireless communication also offers flexibility and ease of use. We chose the UDP protocol since the situation in our research is a real-time data transmission case when the controller is delivering data that can be lost because newer data coming in will replace the previous data under a high frequency.

1.4. *Virtual Content*

When considering what application can be enhanced by Haptwarp controller, VR games came to our minds first. In this game, players can do daily activities from certain scene objects with the Haptwarp controller as shown in Figure 3 and Figure 4. While doing different natural activities, the player can perceive different tactile sensations from the controller. For example, while opening the door in a virtual environment, the user will receive the visual and haptic feedback of feeling the force from the 3D printed bar. When the user twists the controller, the screwdriver will lock the screw in the virtual environment. By combining those actions, the player needs to explore the virtual world by moving around himself, using the controller to trigger the game event, receiving the new clue, and figuring out how to escape from the chamber.

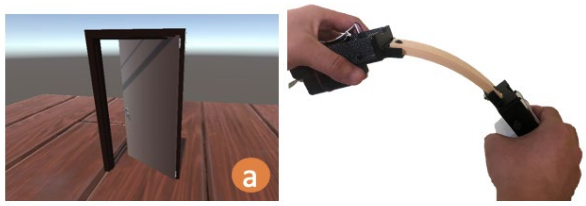

Fig. 3. Users can bend the controller to simulate the open-door activity in virtual environment.

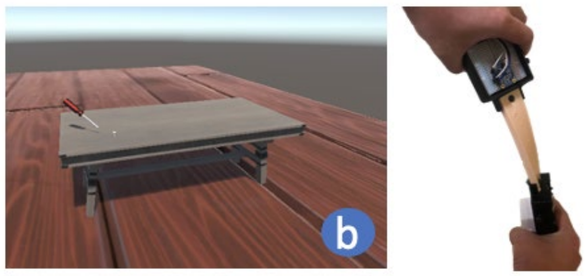

Fig. 4. Users can twist the controller to simulate the activity of locking a screw.

4. Conclusion

In summary, this paper has performed an intuitive game controller that can provide the user with the act of interacting and controlling virtual objects with sensors. This system approaches the unique capability of delivering the human hand motions and haptic sensations with wireless communication, as compared to conventional techniques. Furthermore, to validate the efficacy of this approach, we developed two interactive contents in the virtual environment for the user to experience the intuitive manipulation with the HaptWarp controller.

In our future work, we will optimize the controller. For the 3D printed soft bar, we focus on enhancing the immersive feeling by designing a variety of shapes of linkage able to bring more daily hand motions that can be applied to multiple events in the virtual environment. For the sensors, we focus on setup variety bio-sensor to acquire user body information which will be applied into virtual environments to activate different content to enhance the immersive experience. Finally, we will conduct further studies to investigate the complementary effect and the tactile illusions in VR for both partial and full body experiences.

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