CHILDHOOD: Wearable Suit for Augmented Child Experience

Jun Nishida
University of Tsukuba
1-1-1 tennodai
Tsukuba, Japan
jun.nishida@acm.org

Hikaru Takatori
University of Tsukuba
1-1-1 tennodai
Tsukuba, Japan
takatori@vrlab.esys.tsukuba.ac.jp

Kosuke Sato
University of Tsukuba
1-1-1 tennodai
Tsukuba, Japan
kosuke@vrlab.esys.tsukuba.ac.jp

Kenji Suzuki
University of Tsukuba
1-1-1 tennodai
Tsukuba, Japan
kenji@ieee.org

ABSTRACT

In this paper, we propose a novel wearable suit that virtually realizes a child's embodiment and experiences while preserving the user's interactions and perceptions. Virtualized child's embodiment through the user's own body provides opportunities to feel and understand a child's perceptions. Our suit helps users encounter inspirations in daily life and assess products and spaces, such as hospitals, public facilities, and homes, from the aspect of universal design. The suit consists of a viewpoint translator and passive hand exoskeletons. The viewpoint translator presents a child's point of view (POV) by using a pan-tilt stereo camera attached at the waist and a head-mounted display (HMD). The pan-tilt mechanism follows the user's head movement, and the passive hand exoskeletons simulate the grasping motion of a child's hand by using multiple quadric crank mechanisms and a small rubber hand. Through an user experience observation experiment, it is conducted that the proposed wearable devices can be used for evaluating the accessibility of buildings and products for children.

Categories and Subject Descriptors

H.5 [**INFORMATION INTERFACES AND PRESENTATION (e.g., HCI)**]: Multimedia Information Systems—*Artificial, augmented, and virtual realities*

General Terms

Design, Human Factors, Experimentation

Keywords

Kids, Universal Design, Augmented Human, Embodiment Transformation, viewpoint Translator, Passive Hand Exoskeleton

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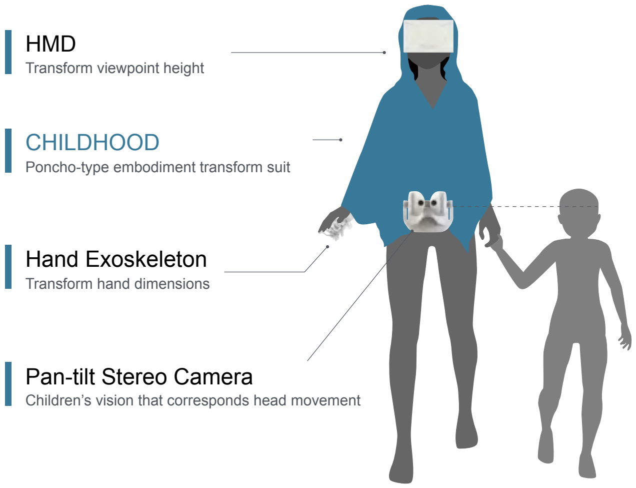

Figure 1: Conceptual representation of the proposed device

1. INTRODUCTION

Understanding and perceiving the world from a child's perspective is important for designing products, interior design and architectures from the aspect of universal design. The assumption is that observing objects and surrounding environments through a child's vision and haptic sensation will reveal new perspectives in designing and evaluating them.

Several studies have been conducted to assist in universal design for children. Ida et al. investigated the universality of devices and architectures in public spaces by recording videos through a hand-held camera positioned at a child's eye level[1]. They concluded that observing the world from a perspective different from that of an adult helped them realize that most construction in public spaces does not accord with universal design. Loup-Escandea et al. developed a simulation software that modeled a child's POV in a computer graphics space, such as in shops[2].

In this paper, we propose a novel wearable suit that virtually realizes a child's eye and hand movements using a

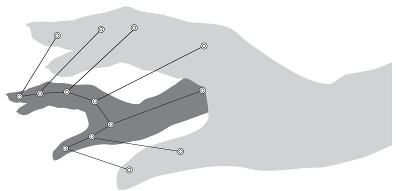

Figure 2: Concept representation of the passive hand exoskeleton

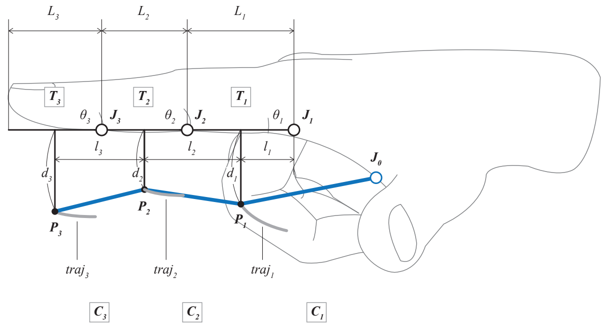

Figure 3: Link Mechanism of the passive hand exoskeleton

viewpoint translator and exoskeletons for the hands. We assume that virtualizing a child's body while preserving the user's embodied interactions with the actual surrounding environment will provide a virtualized child's POV as well as an insight into children's emotional experiences. This could help designers evaluate products, such as toys, family groceries, and home interiors, through real-time interactions.

2. METHODOLOGY

The suit consists of a viewpoint translator, two passive hand exoskeletons, and a rain poncho that holds both devices so that the user can easily attach these devices.

2.1 Passive Hand Exoskeleton

2.1.1 Design Principle

We describe here the design of the passive hand exoskeletons composed of multiple quadric crank mechanisms for simulating a child's hand through the user's hand. Fig. 2 shows the conceptual representation of the proposed exoskeleton. One of the ways in which humans interact with and understand the world is by touching, grasping, and/or throwing objects with their hands. Transforming the dimensions of the user's hands to a child's hands is important for reproducing the capability of the latter. The exoskeletons are divided into the following parts:

1. Finger sockets to attach the exoskeleton to the user's hand
2. A link mechanism to downscale the grasping motion
3. Child-sized rubber fingers to simulate skin-like haptic feedback
4. A thumbstall with a 4 cm wire to constrain the thumb's range of motion
5. A carabiner (spring hook) with a 70 cm wire to constrain the range of motion of the user's upper limbs

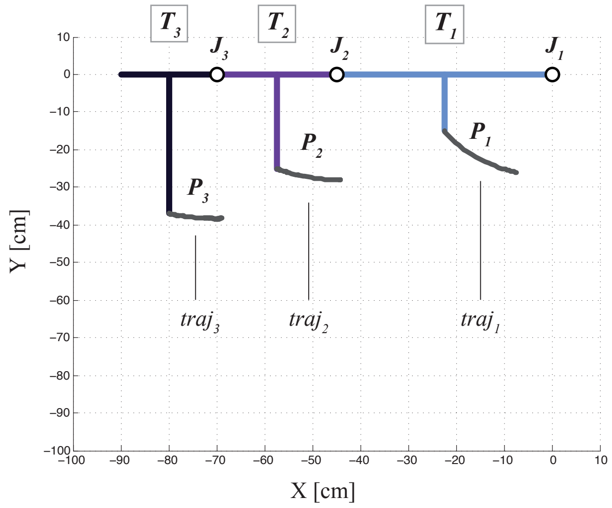

Figure 4: Simulation experiment results of the trajectory calculation

The proposed exoskeletons have no actuators or sensors and are passively manipulated by the user's actions. Users can thus receive complete and real-time haptic feedback from the exoskeletons, and can understand the difficulty encountered by a child in grasping objects in daily life.

2.1.2 Link Modeling

Fig.3 shows a link model of the proposed mechanism. The link mechanism consists of three T-shaped finger sockets with links (T_1, T_2, T_3), three small links that act as a child's fingers (C_1, C_2, C_3), a ball joint with two degrees-of-freedom (DOF), and a link that connects the small links to the ball joint. We calculated the trajectory $traj_{1,2,3}$ of points $P_{1,2,3}$ in order to ensure effective grasping capability, when attaching the exoskeleton to the palm of the hand. The length and shape of the joint slit for each trajectory was determined based on the angular displacement of each finger joint while grasping an object by using a motion capture system (V100: R2, OptiTrack Inc.). We then conducted a simulation to calculate each trajectory by using Eq. 1 from the acquired angle into $theta_i$:

$$\begin{aligned} P_i(x,y) \quad = \quad & \big(-\frac{1}{2} L_i \cos\theta_i + d_i \cos(\frac{\pi}{2} - \theta_i), \\ & -\frac{1}{2} L_i \sin\theta_i + d_i \sin(\frac{\pi}{2} - \theta_i) \big) + J_i \end{aligned} \tag{1}$$

L_i represents the i-th length between any two finger joints and d_i represents the distance between the i-th part of each finger and the mechanical joint, as shown in Fig.3. Fig. 4 shows the result of the simulation for each trajectory. Based on these results, we designed each link shape and joint slit, as shown in Fig. 5. Due to the small size of the links, the joint slit $traj_1$ for link T_1 was omitted. Instead, link C_1 and the 2-DOF ball joint were not attached together, hence resulting in a 3-DOF joint that complemented the joint slit function for $traj_1$.

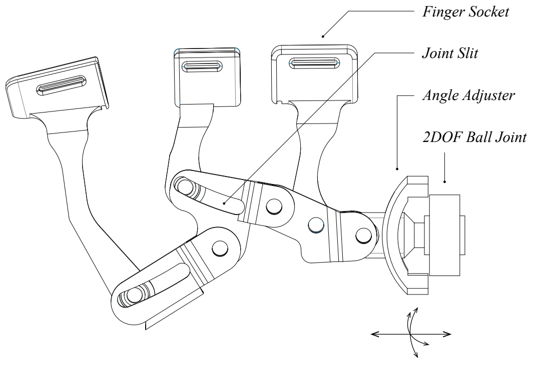

Figure 5: CAD Design of the link mechanism

2.2 Viewpoint Translator

2.2.1 *Design Principle*

We propose a novel viewpoint translator to implement a child's stature and eye level while preserving the user's embodied interactions, especially his/her head movement (Fig. 6). To this end, we implemented a robotic device. The viewpoint translator is divided into the following three components:

Stereoscopic camera
two cameras were used to generate a stereoscopic view. To expand the viewing angle, we attached a fish-eye lens to each camera. Furthermore, we designed a camera case and an adjustable slide-rail component to modify the distance of two camera lenses (i.e., the variable pupillary distance). The distance ranged from 45 mm to 120 mm.

Image display
The images from the cameras were processed on a laptop computer and displayed on the HMD.

Pan-tilt mechanism
We developed a wearable pan-tilt mechanism attached to the waist. Its velcro fastener was used as an adjustable belt. The pan-tilt mechanism consisted of two servo motors and an Inertial Measurement Unit (IMU) sensor controlled by a microcontroller. A gyroscope, accelerometer, and magnetometer were used to estimate waist orientation.

2.2.2 *Workflow*

The processing flow of our system is shown in Fig. 7. The stereovision processing and the head motion tracking were carried out on a laptop computer, and the waist motion tracking and the servo control were processed on a microcontroller. The stereovision processing was independent of any other software for maintaining the 60-Hz refresh rate. The images from each camera were processed using distortion correction methods and shown side-by-side on the HMD. To control the pan-tilt mechanism, the system acquired the orientation of the user's head using the sensors on the HMD. The microcontroller simultaneously acquired the user's waist orientation and subtracted it from the values obtained for his/her head orientation. The result was used to control the servomotors. These processes make it possible to reproduce a child's line of sight while preserving the user's head movement. Moreover, the entire control unit, including the computer and the battery, is packaged in a backpack. Therefore, the system is portable and the user can walk without any obstruction and interact with other users.

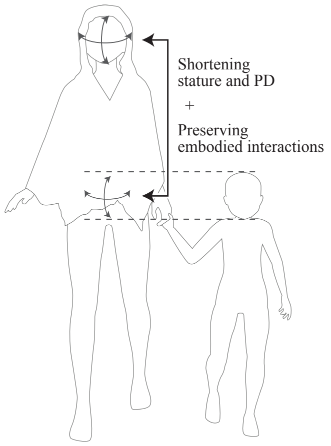

Figure 6: Conceptual representation of the viewpoint translator

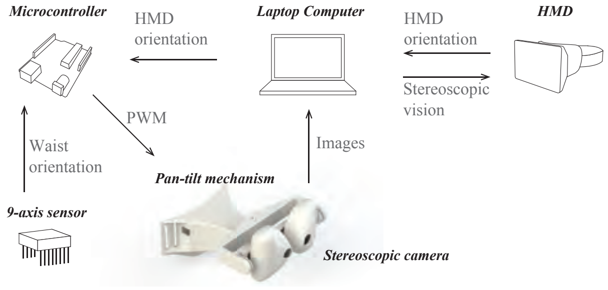

Figure 7: Workflow of the viewpoint translator

3. SYSTEM CONFIGURATION

3.1 Passive Hand Exoskeleton

Fig.8 shows the implemented passive hand exoskeleton. The links were manufactured by a 3D printer using an ultraviolet-hardened resin. The dimensions of the rubber hand were determined according to those of the hands of an average five-year-old based on data from the Japan Research Institute of Human Engineering for Quality Life[3].

3.2 Viewpoint Translator

Fig. 9 shows the implemented pan-tilt device. We used the micro-servomotor S3156 (Futaba Corp.). The specifications of the motor were: 9.3 g in weight, 2.4 kg · cm torque, which enabled a quick response at a 0.11 s-per-60 deg speed. The response of the motor was sufficiently fast to follow the speed of orientation of the user's head, which was measured by a motion capture system. An MPU-9150 (InvenSense Inc.) containing the the gyroscope, accelerometer, and magnetometer is used as the waist orientation detector, whereas Oculus Rift was used for HMD. It has 100-deg wide angle view, a nine-axis attitude detection sensor, and a 60 Hz refresh rate. We used the PlayStation Eye (PS Eye) camera at 60 fps to generate the stereoscopic view.

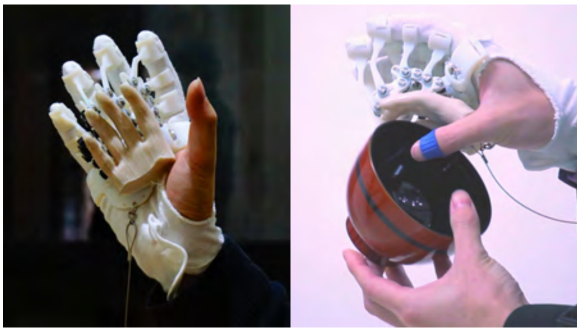

Figure 8: Overview of the passive hand exoskeleton

Figure 9: Overview of the viewpoint translator

4. EXPERIMENT AND RESULTS

4.1 User Experience Observation in Science Museum

From October 23 to 26, 2014, we exhibited our wearable suit at the National Museum of Emerging Science and Innovation in Tokyo, Japan. More than 400 visitors tried our system during this time. By observing them use our system and obtaining feedback from them, we gathered the following information.

With regard to visual perception, almost all of users mentioned that the difference in viewpoint height made them feel the enlarged magnitude of the surrounding space, as shown in Fig. 10. On the other hand, users reported feeling of pressure when surrounded by other people. Most participants found it easy to quickly familiarize themselves with the viewpoint translator. At the demonstration place, we had set up toys, dishes, and plastic bottles on a table at the exhibit, and asked the participants to try to grasp these objects, as shown in Fig. 11. The participants reported finding it difficult to do so.

Through this experiment, we verified that our system has the potential to be an assistive tools for universal design for children. For instance, a male participant in his forties indicated that the height of a handrail in the museum is same with five-year-old child's viewpoint height and they have risk to injure their eyes. A female participant in her fifties said that five-year-old children are not capable of grasping plastic bottles with one hand, and suggested an attachable handle in the design of such bottles so that children could easily hold them.

Figure 10: Overview of the demonstration

Figure 11: Overview of the demonstration

5. CONCLUSIONS

In this paper, we proposed a novel wearable suit that virtually realizes a child's embodiment and experience on our own body. To this end, we developed a viewpoint translator that transforms the user's viewpoint height into that of a child as well as passive hand exoskeletons that downscale the grasping motion of the palm of the hand. We placed emphasis on the user's embodied interactions and perceptions, such as head rotations in the viewpoint translator, haptic interactions, and temporal consistency in the hand exoskeletons. Observation experiments indicated that our system successfully provides a child's perspective and experiences, and demonstrated its potential for assisting product and/or spatial design by allowing the user to walk around and freely interact with other users. In future research, we plan to apply this system to an assessment device for public facilities, such as the children's ward in a hospital.

6. REFERENCES

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