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Research paper

Development of a Smart Hold to Provide Realistic Feedback for Screen Climbing Contents

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Abstract

Background/Objectives: Screen Climbing requires additional feedback that can overcome the limitations of the climber being aware of what is going on because the content is using only projected images.
Methods/Statistical analysis: Smart hold was designed to provide two realistic types of feedback. One is the visual feedback provided through the three-color light-emitting diode (LED) and the other is the haptic feedback felt by the hands through the vibration actuator. These are both provided by a single control board. Two screen climbing contents were developed to utilize the visual feedback using LED smart holds with haptic feedback via vibration actuators.
Findings: The evaluation of usability was conducted for the screen climbing contents that utilized the smart hold. The average and lowest scores in the immersion element were 4.16 and 3.08, respectively, which indicated that high satisfaction scores were obtained for realistic feeling, concentration, and interest viewpoints compared to existing indoor climbing results. The average and lowest scores of the interaction element were 4.18 and 3.63, respectively, which showed high satisfaction levels in terms of immediacy, intuitiveness, and reward viewpoints with regards to the interface of the screen climbing content. Finally, the average and lowest scores of the physical activity element were 4.07 and 3.75, respectively, which showed high satisfaction levels in terms of the movements and safety viewpoints of screen climbing.
Improvements/Applications: The evaluation results showed high satisfaction levels since the average score was 4.13. However, this evaluation was limited somewhat because the usability evaluation was conducted with independent single players only.

Keywords: *Screen Climbing, Smart Hold, AR Feedback, Screen Sports content, Sportainment*

1. Introduction

In recent years, outdoor activities have been increasingly discouraged due to environmental factors, such as fine dust and global warming, in many countries, including China and Korea. As a result, the demand for screen sports that can provide realistic experiences indoors for the purpose of entertainment has increased rapidly[1,2]. Accordingly, certain sport types are more commonly made for screens, including screen golf and baseball. Among them, many attempts have been made to create augmented reality indoor climbing (bouldering), an urban style sport that induces whole body movements and a high quantity of motion in a short period of time.

Screen sports consist of a screen that visually provides a sporting environment and related circumstantial elements as well as the equipment interface used in sport activities. For screen climbing, screen and equipment interfaces are integrated as one body in the wall. Content is projected via an existing indoor climbing wall being used as a screen, as provided by Randori and ValoMotion[3,4]. In addition, it is made to be interactive by recognizing the climber's movements, but it requires additional feedback that can overcome the limitations of the climber being aware of what is going on because the content is using only projected images when a climber is hanging on the wall[5,6,7,8].

This study aims to introduce the development of smart hold that can provide haptic feedback, increasing the feeling of immersion, interaction, and concentration on physical activities with regards to screen climbing content that utilizes a wall as a screen as well as an interface.

2. Materials and Methods

2.1. Design and Fabrication of Smart Hold

The proposed smart hold was designed to provide two realistic types of feedback. One is the visual feedback provided through the three-color light-emitting diode (LED) and the other is the haptic feedback felt by the hands through the vibration actuator. These are both provided by a single control board.

The control board of the smart hold that provides realistic feedback is shown in Figure 1. The vibration actuator was mounted inside the holder module to receive a vibration command from the content server, thereby producing vibration to the holder. The LED was also mounted inside the holder module to output color according to the emitting command delivered by the content server. The control board was arranged to have 1:N parallel control based on RS485 (19200 Baud Rate) communication.

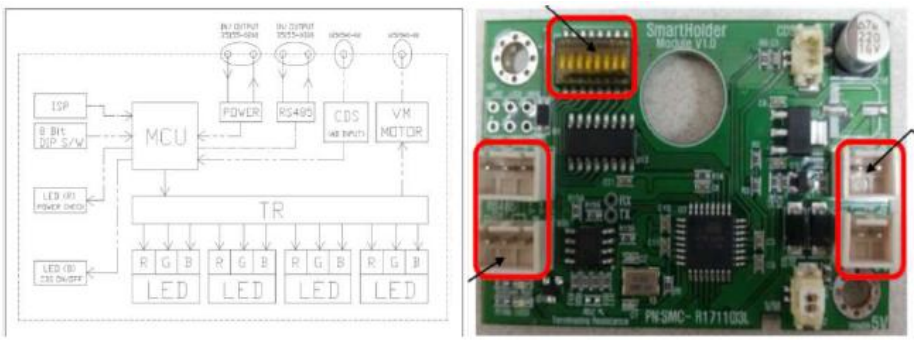

Figure 1: Control board for single smart hold control

The smart hold, including the control board, is shown in Figure 2. The handle of this hold was fabricated using a translucent material to express LED light easily, and the rough surface was provided to prevent slippage of the hand. Each hold has a unique independent ID assigned through an 8-bit dual in-line package (DIP) switch. The dimensions of the hold were 109.7 mm (4.3") x 65 mm (2.5") x 69.3mm (2.7") and its weight was 0.6 kg. The power consumption, including that of the vibration actuator and LED module, was 5 V, 440 mA, and 2.2 W.

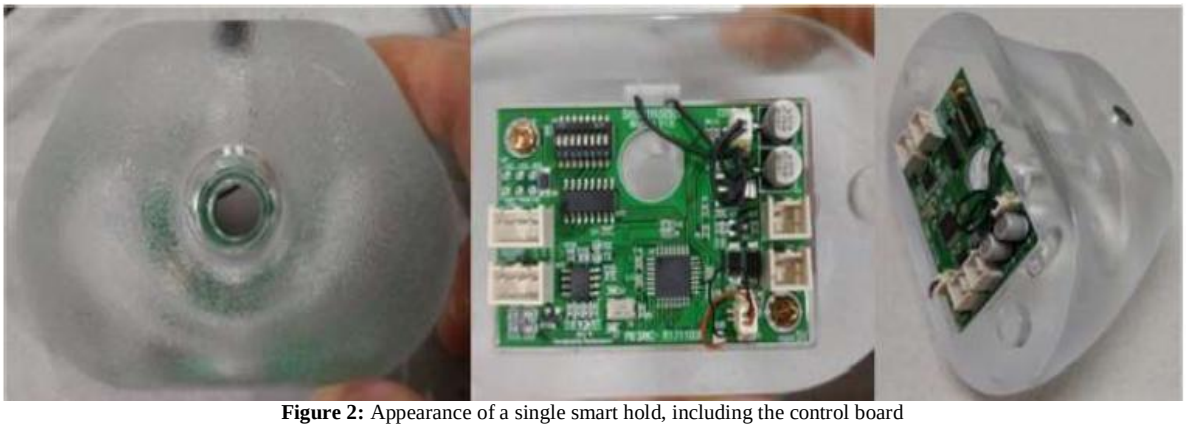

Figure 2: Appearance of a single smart hold, including the control board

The smart hold-mounted climbing wall was fabricated as a module 1 m x 1 m (horizontal/vertical) in size, is shown in Figure 3. Each module had a total of 16 holds (four holds horizontally and four holds vertically). The standard model using the above basic module was a wall that was 4 m long in the horizontal direction and 3 m long in the vertical direction. Thus, a total of 196 smart holds were attached to the standard model.

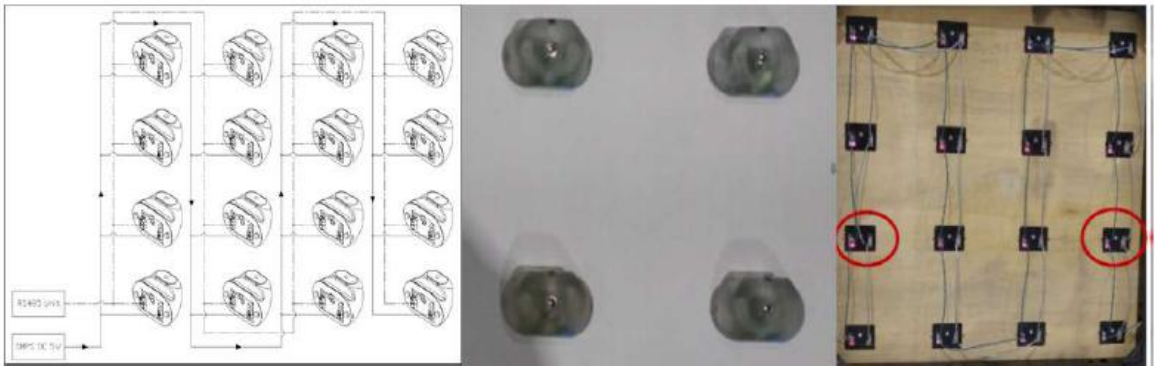

Figure 3: Climbing wall module, including the smart holds

2.2. Development of Content Utilizing the Smart Hold

A total of two screen climbing contents were developed to utilize the visual feedback using LED smart holds with haptic feedback via vibration actuators. Since screen climbing content is a type of serious "sportainment" that involves mobility, it was designed to have not only entertainment value but also exercise benefits. Both contents were made for children aged 5–12 years[9,10]. Each consisted of three stages with different user interactions, and each stage was composed of sub-stages with three different difficulty levels. The difficulty level of the game was controlled by extending the experience time from 30 sec up to 30 min depending on the user's ability. A graphic interface was provided so that users could see the time limit, current status, and acquired score quickly and intuitively to enhance the content experience.

The first content was titled "Sea Story" and was designed to represent the underwater world of the sea, is shown in Figure 4. The concept was to explore various oceans (the Pacific, Atlantic, and Indian Oceans) and to catch and understand distinctive fish in each, thereby creating an illustrated book (scrapbook) and competing with other users. The LED feedback was provided by a hold where an item is generated in order for the user to recognize the newly generated item as soon as possible. The vibration feedback was provided by a hold when a user was successful in acquiring an item.

Figure 4: Screen shot of the "Sea story" content

The second content title was "Space Crash," which was designed to portray space, is shown in Figure 5. The concept was as follows: a spacecraft was attacked critically by extraterrestrial life during interstellar space travel, and the broken spacecraft was recovered and arrived at K-280. More specifically, it consisted of defending against attacks from a robot with artificial intelligence and saving crew members after breaking into the damaged part of the spacecraft. The LED feedback was provided by a hold where an item was generated in order for the user to recognize the newly generated item as soon as possible. Vibration feedback was provided by a hold when a user was successful at acquiring an item.

Figure 5: Screen shot of the "Space Crash" content

2.3. Evaluation on the Smart Hold-Applied Content

The evaluation of usability was conducted for the screen climbing contents that utilized the smart hold, is shown in Figure 6. The purpose of this evaluation was to check the appropriateness of the realistic sportainment content and to identify necessary improvements.

The evaluation subjects were four children (two male and two female) aged seven years. To facilitate the usability evaluation smoothly, two groups were created: the two male children, who were friends, and the other two female children, who were also friends, composed each separate group. The evaluations were conducted independently. During the evaluation process, the content was explained and how to play was demonstrated. Each child played the game separately, and a survey was conducted on the subjects with their parents.

Regarding the evaluation method, since the children may not able to answer the survey questionnaire by themselves, the parents of the children observed verbal and nonverbal behaviors experienced by the children in response to the content and recorded in interviews with the children. The survey questionnaire consisted of 10 questions presented in Table 2 with five point scales for immersion, interaction, and physical activity, and the children answered these questions. The scale's scores were as follows: 1 was strongly disagree, 2 was disagree, 3 was neutral, 4 was agree, and 5 was strongly agree. The evaluation questions are presented in Table 1.

Table 1: Questionnaire to evaluate the usability of the screen climbing content

Element	Detailed element	Question item
Immersion	Realistic feeling	It was so similar to actual climbing that it seemed like real climbing.
	Concentration	I was able to concentrate on the content while playing.
	Interest	It was so fun to experience the content that I wanted to keep playing the game.
Interaction	Immediacy	The items, LED lights, and vibration effects were appropriate during the game.
		The item buttons reacted correctly according to the movement (touch) taken.
	Intuitiveness	The rules of the content were easy to understand.
		The items and buttons were quickly understandable according to movements (touch).
	Reward	There was a reward system, such as a score, to motivate users to participate in the content actively.
Physical activity	Movements	One's body can move freely while playing the content.
	Safety	There was a safety device to prevent dangerous situations.

Figure 6: Evaluation site of usability

3. Results and Discussion

The evaluation results on usability are presented in Table 2. The average and lowest scores in the immersion element were 4.16 and 3.08, respectively, which indicated that high satisfaction scores were obtained for realistic feeling, concentration, and interest viewpoints compared to existing indoor climbing results. The average and lowest scores of the interaction element were 4.18 and 3.63, respectively, which showed high satisfaction levels in terms of immediacy, intuitiveness, and reward viewpoints with regards to the interface of the screen climbing content. Finally, the average and lowest scores of the physical activity element were 4.07 and 3.75, respectively, which showed high satisfaction levels in terms of the movements and safety viewpoints of screen climbing.

Table 2: Evaluation results on usability of the screen climbing content

Element	Detailed element	Average of the two male children		Average of the two female children		Overall average	
		Average score of the sub-element	Average score of the element	Average score of the sub-element	Average score of the element	Average score of the sub-element	Average score of the element
Immersion	Realistic feeling	3.08	4.11	3.83	4.19	3.46	4.16
	Concentration	4.25		4.58		4.42	
	Interest	5.00		4.17		4.59	
Interaction	Immediacy	3.63	4.23	3.92	4.1	3.78	4.18
	Intuitiveness	4.63		4.63		4.63	
	Reward	4.42		3.83		4.13	
Physical activity	Movements	3.75	3.88	4.50	4.25	4.13	4.07
	Safety	4.00		4.00		4.00	

4. Conclusion

The current screen climbing content is installed in a number of exhibition halls and virtual reality sport experience zones, including the event hall of the 2018 PyeongChang Winter Olympic Games. A large number of individuals and group players visited the experience zone and provided constant feedback for content usability improvement.

The evaluation of the usability of the screen climbing content was conducted with 10 questions consisting of three elements. The evaluation results showed high satisfaction levels since the average score was 4.13 and the lowest score was 3.08. However, this evaluation was limited somewhat because the usability evaluation was conducted with independent single players only. For a future study, the usability evaluation will be extended to the concept of cooperation and competition experienced by two or more players in multiplayer mode.

Acknowledgment

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