Improvement of Immersion into a Virtual Game World: Using “Real Robot” as an Opponent’s Character

Shohei MIYABARA^{a,*}, Tao MORISAKI^a, Naohiro KOSHIJI^b

^a National Institute of Technology, Kurume College, Advanced Engineering School, Komorino Kurume 1-1-1, Fukuoka-ken 830-8555, JAPAN

^b National Institute of Technology, Kurume College, Komorino Kurume 1-1-1, Fukuoka-ken 830-8555, JAPAN

*Corresponding Author: syouhei.miyabara@gmail.com

Abstract

Immersion is one of the most important sensations a player experiences when playing a game. Virtual Reality (VR) is one gaming design method used to increase this sensation. However, VR usually requires the use of special, but often cumbersome devices such as goggles which foists a cumbersome burden on players. Therefore, the authors propose a new method to increase Immersion. The method entails bringing the game character into the real world. The authors developed an air hockey game that has two modes: “Virtual Robot Mode” and “Real Robot Mode”. In “Real Robot Mode”, a robot acts as the opponent’s character in front of the display. In “Virtual Robot mode”, the opponent’s character shows on the display as in the past. The authors prepared a questionnaire and analyzed the responses using the Semantic Differential method. 39 subjects responded to the questionnaire after playing the game in respective modes. The authors analyzed the results using Factor Analysis and found that the factors of the “Real Robot Mode” are significantly higher than that of the “Virtual Robot Mode” ($p < 0.05$).

Keywords: Immersion, Game, Robot, VR, SD method, Factor Analysis.

1. Introduction

Immersion is one of the most important sensations a player can experience in a game. VR is one gaming design approach to increase the sensation of Immersion. In addition, VR and Immersion are used for mental therapy⁽¹⁾. Thus, Immersion and VR have been studied by many researchers⁽²⁾⁽³⁾. However, VR games usually require players

to use cumbersome equipment such as oversized goggles. Also, There have been a number of speculative reports of many different types of side effect⁽⁴⁾. For example, many players report experiencing motion sickness when playing VR games.

The authors propose a new method to increase Immersion without relying on VR. The method involves getting the game character out of the virtual world and into the real world. The authors conjecture that a border between the real world and the virtual world becomes ambiguous by using this method. In this study, the authors developed an air hockey game in which the opponent character is a real-world robot. Then, the authors evaluated their Immersion approach surveying research subjects who played this game.

2. Experimental Equipment

2.1 Experimental Equipment

The authors used an air hockey game developed using Unity. Its rules are the same as that of commonplace air hockey. Players operate a mallet to hit a puck. Players earn a point each time the puck is deposited in the goal at the opponent’s end. The first player to score four points wins the game. Results are displayed after playing the game. This game has two modes: 1) “Virtual Robot Mode”; 2) and “Real Robot Mode”. Players select one of these modes in the title scene at the beginning to start the game. Fig. 1 shows the title screen, the air hockey field and the result screen.

2.2 “Virtual Robot Mode”

In “Virtual Robot mode”, the opponent character plays within the virtual world (within the display) as in the past. The character is a fashioned similarly after the real

(a) The title screen

(b) The air hockey field

(c) The result screen in when player lose

(d) The result screen in when player win

Fig. 1 The title screen, the air hockey field and the result screen in the game

robot in “Real Robot Mode”. The character operates a mallet by using its own arms in the display. Fig. 2 shows the “Virtual Robot Mode” character in play.

The game calculates the path of the puck by adding the movement distance per frame to the current mallet position. The game moves the opponent’s mallet and character close to the puck.

The character can say four different types of messages (through the computer speaker) depending on the game situation: 1) “Makenaizo!” (Never give up!) when the opponent gets a point; 2) “Yattazo!” (I did it!) when the character gets a point; 3) “Makechatta ...” (I lost...) when the character loses; and 4) “Kattazo ...” (I won!) when the character wins.

2.3 “Real Robot Mode”

In “Real Robot Mode”, the opponent character appears as a real robot in front of the display. There is no difference between “Virtual Robot mode” and “Real Robot Mode” other than real representation of the opponent character. Fig. 3 shows the “Real Robot Mode” robot in play.

This robot was made using Raspberry Pi3, actuators, a speaker, and plastic arms. The robot plays the game by actually using its arms via AirBar. AirBar is a tool that changes a normal display to a touch display. The game calculates a path of the puck by using the same method that is used in “Virtual Robot Mode”. The game sends data of the distance between the touch position and the mallet path to

Fig. 2 The “Virtual Robot Mode” character in play

Fig. 3 The “Real Robot Mode” robot in play

the Raspberry Pi3 via Wi-Fi. The robot moves to approach the puck path.

The robot speaks in the same voice as that used in “Real Robot Mode” through a speaker implemented in the robot. The situations when the robot speaks are the same as those when the virtual characters speak in “Virtual Robot Mode”.

3. Experiment

3.1 Experimental Method

The authors compared game users’ impressions relating to Immersion that players got from playing in “Virtual Robot Mode” and in “Real Robot Mode”.

The authors prepared a questionnaire using the

Table 1 Pairs of polar adjectives and their relation to Immersion

Immersion levels	Impressions	No.	Positive Adjectives		Negative Adjectives	
			Japanese	English	Japanses	English
Engagement	Preference	1	好きな	favorite	嫌いな	dislikable
		2	親しみやすい	friendly	親しみにくい	unfriendly
		3	感じのいい	decent	感じの悪い	rude
	Easy of use	4	分かりやすい	easy	分かりにくい	difficult
		5	単純な	simple	複雑な	complex
		6	早い	early	遅い	late
		7	すばやい	quick	鈍い	slow
	Rewards	8	楽しい	fun	つまらない	boring
		9	充実した	fulfilling	空虚な	emptiness
		10	達成感のある	satisfying	達成感のない	unsatisfying
		11	手応えのある	tough	物足りない	unsatisfactory
Engrossment	Visual	12	きれいな	clean	きたない	dirty
		13	かわいい	pretty	憎らしい	detestable
		14	癒しのある	soothing	落ち着かない	restless
	Want to continue	15	続けたい	want to continue	やめたい	want to quit
		16	興味深い	interesting	退屈な	uninteresting
	Intention	17	集中した	focused	気の散った	distracted
Total Immersion	Empathy	18	暖かい	warm	冷たい	cold
		19	打ち解けた	casual	堅苦しい	serious
		20	近づきやすい	approachable	近づきがたい	unapproachable
	Atmosphere	21	派手な	gorgeous	地味な	plain
		22	明るい	cheerful	暗い	gloomy
		23	優しい	kind	怖い	scary
		24	賢い	wise	愚かな	foolish
		25	積極的な	aggressive	消極的な	passive
		26	なさそうな	novel	ありそうな	common

Semantic Differential method. Kanda also used SD method to evaluate an interaction between humans and an autonomous robot⁽⁵⁾. The questionnaire has 26 evaluation items that each consist of a pair of polar adjectives. Respondents evaluated game impressions according to these evaluation items in 7 levels. The authors determined adjectives related to immersion with reference to Emily Brown's and Paul Cairns' study⁽⁶⁾. Immersion is divided into 3 levels. The first level is Engagement. The second level is Engrossment. The third level is Total Immersion. The authors have considered the possibility that the "novelty" of the game affects the results and, thus, added the polar pairing of "novel-common" to list of adjective evaluation items. Table 1 presents these adjectives and their relation to Immersion. The subjects were all Japanese speakers so the survey was conducted in Japanese. However, the authors have translated the adjectives from Japanese into English for the purpose of this paper. Therefore, the adjectives may have different nuances between Japanese and English.

Subjects of this experiment were 39 students from the National Institute of Technology, Kurume College (NITKC).

Subjects played the game and responded to the questionnaire after playing the game in respective modes.

3.2 Result and Evaluation

The authors assayed the results of the experiment using the Wilcoxon signed rank test. The analysis revealed that the results of "Real Robot Mode" were significantly higher than that of "Virtual Robot Mode" ($p < 0.05$).

Fig. 4 presents the average of results for each adjective. The authors predicted that these adjectives would have stepwise differences among the Immersion levels. However, the analysis showed that this was not the case. The authors conjecture that the reason for a lack of stepwise differences may be because of a mis-selection of the polar adjectives. Therefore, the authors analyzed the results using Factor Analysis and classified the factors into the immersion levels.

Using Factor Analysis to better understand the results of the experiment, the authors removed adjectives with communalities less than 0.3. This criteria removed four polar adjective pairs: "early-late", "quick-slow", and "gorgeous-plain". The authors determined a number of factors to 8 by using eigenvalues and assayed that the number is adequate using the Chi-squared test. The cumulative contribution ratio of these factors is 70.4%. Table 2 presents loadings and proportions of variance and communalities after varimax rotation. The authors regarded loadings greater than 0.5 as high loadings. The high loadings are shown in bold in Table 2.

The authors calculated the factor scores and compared them between "Virtual Robot Mode" and "Real Robot Mode". The authors assayed the averages of the factor scores using Wilcoxon signed rank test. The authors found that the factor scores of "Real Robot Mode" are significantly higher than those of "Virtual Robot Mode" ($p < 0.05$). Fig. 5 presents a comparison of the factor scores between "Virtual Robot Mode" and "Real Robot Mode". This means the "Real Robot Mode" has the effect of giving the player a better impression than the "Virtual Robot Mode".

The authors considered respective factors and classified these into the immersion levels. Factor1 has high loadings in the adjectives of "Preference", "Empathy" and "Atmosphere". The reason for this may be because of a mis-selection of adjectives in Total Immersion. For example, "casual-serious" are similar to the adjective "Preference". Therefore, Factor1 may relate to "Preference" in

Fig. 4 The average of results for each adjective

Table 2 Loadings

No	Positive adjectives	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Communarity
1	favorite	0.776	0.347	-0.004	0.285	0.049	0.009	0.177	-0.098	0.848
2	friendly	0.533	0.547	0.273	0.009	0.240	-0.214	-0.079	0.291	0.852
3	decent	0.386	0.594	0.344	0.095	0.272	-0.142	0.020	0.158	0.749
4	easy	0.081	0.108	0.061	0.031	0.779	0.013	0.087	0.042	0.640
5	simple	0.099	-0.044	0.077	-0.060	0.870	0.066	-0.246	-0.050	0.846
8	fun	0.379	0.636	0.091	0.303	0.111	0.012	0.080	0.059	0.671
9	fulfilling	0.325	0.507	0.149	0.391	-0.008	0.050	0.056	0.190	0.580
10	satisfying	0.317	0.572	-0.062	0.307	-0.096	0.208	-0.014	-0.117	0.593
11	tough	0.099	0.896	0.105	0.156	-0.004	0.359	-0.062	-0.115	0.995
12	clean	0.188	0.373	0.555	-0.006	0.107	0.026	-0.231	0.120	0.562
13	pretty	0.174	0.090	0.917	0.003	0.161	0.018	0.062	-0.292	0.995
14	soothing	0.041	-0.017	0.750	0.260	0.004	0.130	0.048	0.163	0.679
15	want to continue	0.371	0.327	0.071	0.837	0.005	0.030	-0.005	-0.210	0.995
16	interesting	0.093	0.215	0.190	0.674	-0.021	0.287	0.069	0.177	0.663
17	focused	0.368	0.240	0.172	0.192	0.245	0.311	-0.159	-0.133	0.459
18	warm	0.456	0.068	0.452	0.111	-0.028	0.385	-0.047	0.330	0.690
19	casual	0.662	0.292	0.263	0.130	0.136	0.141	-0.145	-0.045	0.670
20	approachable	0.778	0.047	0.041	0.108	0.259	0.174	-0.245	0.044	0.781
22	cheerful	0.484	0.251	0.434	-0.009	0.005	0.107	-0.189	0.169	0.561
23	kind	0.629	0.218	0.233	0.132	-0.024	0.041	-0.140	0.114	0.550
24	wise	0.310	0.199	0.171	0.286	0.118	0.607	0.201	0.035	0.671
25	aggressive	0.531	0.216	0.063	0.141	0.014	0.348	0.089	-0.057	0.485
26	novel	-0.134	0.001	-0.024	0.051	-0.088	0.078	0.780	-0.004	0.643
	variance explained	4.038	3.227	2.581	1.880	1.728	1.151	1.005	0.569	
	propotion of variance	17.555	14.031	11.221	8.173	7.512	5.004	4.370	2.473	

Engagement. Factor2 has high loadings in the adjectives “Preference” and “Rewards”. Therefore, Factor2 may relate to “Preference” and “Rewards” in Engagement. Factor3 has high loadings in the adjective “Visual”. Therefore, Factor3 may relate to “Visual” in Engrossment. Factor4 has high loadings in the adjective “Want to continue”. Therefore, Factor4 relates to “Want to continue” in Engrossment. Factor5 has high loadings in the adjective “Easy of use” in engagement. Therefore, Factor5 may relate to “Easy of use” in Engagement. Factor6 has a high loading in only “wise-foolish”. The authors consider that a number of high loadings is not enough to conjecture a relationship between Immersion and Factor6. Therefore, Factor6 may not relate to Immersion. Factor7 has a high loading in only “novel-common”. Therefore, Factor7 may relate to “Novelty”. This adjective is added by the authors to study an influence of “Novelty”. An influence of Factor7 is low except for

“Novelty”. Therefore, the authors conjecture that “Novelty” doesn’t affect the result of the experiment. Factor8 has no high loadings. However, Factor8 has relatively high positive

Fig. 5 Comparison factor scores

Table 3 The classification of the factors.

Immersion Levels	Impression	Factors
Engagement	Preference	Factor1
		Factor2
	Easy of use	Factor5
Engrossment	Rewards	Factor2
	Visual	Factor3
Total Immersion	Want to continue	Factor4
	Empathy	Factor8

loadings in “warm-cold” and has relatively high negative loadings in “pretty-detestable”. Factor8 may relate to the opponent character since about 60% of the subjects lost when playing the game. When players are immersed in a game and lose, they feel frustrated against their opponent. The frustration doesn’t detract from the warmth of the game. The authors conjecture that the player’s impression of the opponent relates to the feeling of “Empathy”. Therefore, Factor8 may relate to “Empathy” in Total Immersion.

The authors assayed the averages of the factor scores related to Immersion by using the Wilcoxon signed rank test. The authors found that the factor scores of “Real Robot Mode” are significantly higher than those of “Virtual Robot Mode” ($p < 0.05$). Therefore, the authors conjecture that players get more of a feeling of Immersion in “Real Robot Mode” more than in “Virtual Robot Mode”.

4. Conclusions

In this study, the authors attempt to improve the sensation of Immersion in games by placing the virtual game opponent character in the real world as a robot.

Firstly, the authors developed an air hockey game which has two modes: “Virtual Robot Mode” and “Real Robot Mode”. In “Virtual Robot Mode”, the opponent character exists within the screen; Whereas in “Real Robot Mode”, the opponent character exist “in front” of the display in the real world as a robot.

Secondly, the authors experimented with 39 adjectives using the SD method. Subjects played the game and responded to a questionnaire after playing the game in respective modes. The questionnaire has 26 evaluation items that consist of 2 polar adjectives related to Immersion. Table 1 presents these adjectives.

Thirdly, the authors assayed the results of the experiment using the Wilcoxon signed rank test. The authors found that

the results of the “Real Robot Mode” are significantly higher than the results of “Virtual Robot Mode” ($p < 0.05$).

Fourth, the authors used factor analysis to better understand the results of the experiment. As a result, 8 factors were found.

Fifthly, the authors assayed the averages of the factor scores using Wilcoxon signed rank test. The authors found that the factor scores of “Real Robot Mode” are significantly higher than those of “Virtual Robot Mode” ($p < 0.05$).

Sixthly, the authors classified respective factors into the immersion level. Table 3 presents the classification of the factors.

Seventhly, the authors assayed the averages of the factor scores related to Immersion using the Wilcoxon signed rank test. The authors found that the factor scores of “Real Robot Mode” are significantly higher than those of “Virtual Robot Mode” ($p < 0.05$).

However, there are three problems. Firstly, the authors only found one factor of Total Immersion. The authors conjecture that the reason is a mis-selection of adjectives in Total Immersion. The authors have to change the adjectives to find factors related to Total Immersion.

Secondly, the factor of Total Immersion doesn’t have high loadings. Therefore, the authors conjecture that the subjects couldn’t immerse in the game until Total Immersion. Players may have to play the game for a long time in order to immerse until Total Immersion. Moreover, players may have to like the game in order to immerse until Total Immersion. The authors have to develop an enjoyable game. Moreover, the subjects have to play for a longer duration.

Thirdly, because the number of subjects was too few, the results couldn’t be analyzed using factor analyses. Moreover, the subjects belonged to the same group. Therefore, the result of factor analysis may be not accurate. The authors have to not only increase the number of subjects, but select a more diverse group of subjects.

Therefore, the authors will experiment again after resolving these problems.

Acknowledgment

The authors are grateful to 39 students of NITKC who cooperated the experiment in this paper.

References

- (1) M. Krijn, P.M.G. Emmelkamp, R.P. Olafsson and R. Biemond : “Virtual reality exposure therapy of anxiety disorders: A review”, *Clinical Psychology Review*, Vol. 24 , pp. 259-281, 2004
- (2) Randy Pausch, Dennis Proffitt and George Williams : “Quantifying Immersion in Virtual Reality”, *SIGGRAPH*, Vol. 24, pp. 13-18, 1997
- (3) George Robertson, Mary Czerninski, and Maarten van Dantzich : “Immersion in Desktop Virtual Reality”, *UIST*, Vol. 10, pp. 11-19, 1997
- (4) John R. Wilson, “EFFECTS OF PARTICIPATING IN VIRTUAL ENVIRONMENTS: A REVIEW OF CURRENT KNOWLEDGE”, *Safety Science*, Vol. 23, No. 1, pp. 39-51, 1996
- (5) Takayuki Kanda, Hiroshi Ishiguro, Tetsuo Ono, Michita Imai and Ryohei Nakatsu : “An evaluation on interaction between humans and an autonomous robot Robovie”, *The Robotics Society of Japan*, Vol. 20, No. 3, pp. 315-323, 2002
- (6) Emily Brown and Paul Cairns : “A Grounded Investigation of Game Immersion”, *CHI EA*, Vol. 4, pp. 1297-1300, 2004