Improvement of Immersion into a Virtual Game World: Using “Real Robot” as a Player Character

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Abstract

Immersion is an important sense for a virtual game world. Moreover, Virtual Reality (VR) is an effective method to improve immersion. However, VR requires wearing some devices such as a goggle which can be cumbersome of users. Therefore, an alternative method to improve immersion other than VR is proposed. In this study, the authors propose using a real robot as the player’s character. At this stage, the authors developed a game for experiment called “Catch Apple” in which players can use a real robot. The authors then surveyed 39 research subjects regarding the effect using a real robot had on them. The data was processed using Factor Analysis in order to find factors relating to immersion. The authors compared their factor scores. The results show that the factor scores of the “Real Robot” were significantly greater than the factor scores of the “Virtual Robot” ($p < 0.05$). In the future, the authors will develop new games and conduct similar experiments to confirm the correctness of the factors relating to immersion.

Keywords: immersion, robot, virtual reality, game, virtual world.

1. Introduction

Recently, many virtual world games have been commercially released. Immersion is an important element of these games⁽¹⁾, and using Virtual Reality (VR) is an effective method to improve it. In addition to gaming, VR is used for medical therapy⁽²⁾. Using VR, patients are rehabilitated in each suitable virtual world. Thus, much research is undertaken to improve immersion⁽³⁾⁻⁽⁴⁾. However, VR requires wearing devices which are oftentimes have noxious aspects⁽⁵⁾. Therefore, the authors propose a method

to improve immersion in a virtual world game without the use of VR. The method is the materialization of a virtual player character, in other words, using a real robot to act as a player’s character. At this stage, the authors have developed a computer game system to realize this method and have evaluated the abilities of this system. This paper provides validation of our method of improving immersion.

2. Development of A Game for Experiment

2.1 Foundation of A Game

For this study, the authors developed and used a computer game system called “Catch Apple”. The opening scene of “Catch Apple” is illustrated in Fig. 1. In “Catch Apple”, images of apples fall from the upper part of the computer display, and players aim to get ten of them in 20 seconds. To start the game, players choose either “Real Robot” or “Virtual Robot” for their player character. “Real Robot” and “Virtual Robot” are shown in Fig. 2.

The “Real robot” is simply constituted, having two wheels, a ball caster, two arms, an active speaker and a web camera (although this study doesn’t use the web camera). The wheels and ball caster correspond to the character’s feet.

Fig. 1 Opening scene of “Catch Apple”

Fig. 2 “Virtual Robot” and “Real Robot”

Two arms are moved by servo motors, and all the robot’s devices are controlled by Raspberry Pi 3. Moreover, “Real Robot” is similar to “Virtual Robot” in appearance.

2.2 Case of “Virtual Robot”

A game scene is shown in Fig. 3, and a flow of the game in this case is as follows (illustrated in Fig. 4): 1) The game starts after three counts; 2) The apples fall from above; 3) In order for a player to “get” an apple, the “Virtual Robot” must touch it. “Virtual Robot”, which moves only left or right, is controlled by using the left and right arrow keys on the computer keyboard; 4) After getting an apple, “Virtual Robot” waves its arms jubilantly while an audio cheer “Yattazo!” -- Japanese for “I got it!” -- plays in the background; 5) If a player gets 10 apples in 20 seconds, the game shows victorious scene for the winner. If a player fails, this game shows a scene for the loser.

2.3 Case of “Real Robot”

In this case, players “get” an apple when “Real Robot” overlaps the apple on the screen. Therefore, it is necessary to detect the horizontal position of “Real Robot” in the real world and convert it into the position in the virtual world in the game. The authors do this by putting a QR code on “Real Robot” and detecting it using a web camera. “Catch Apple” receives the center position and converts it into the corresponding position in the game world. A picture of playing this game is shown in Fig. 5.

The detection system hardware consists of a Windows 10 computer and a web camera. A breakdown of the process is as follows: 1) The web camera takes a picture of “Real Robot”; 2) The computer detects the position of the four corners of the QR code in this picture and finds the center position by calculating the average of the 4 positions; 3) “Catch Apple” receives the center position and converts it into the position in the game world through the following expression:

Fig. 3 Playing scene

Fig. 4 Flow of the game in case of “Virtual Robot”

$$x3 = \frac{(x2 - x1)(X3 - X1)}{X2 - X1} + x1 \quad (1)$$

where $x1$, $x2$ and $x3$ are respectively left end position, right end position and the position of the transparent game object in the game world. Moreover, $X1$, $X2$ and $X3$ are respectively left end position, right end position and the center position of QR code in the picture. This is illustrated in Fig. 6. $x1$ and $x2$ had been previously confirmed in the development environment (In this study, the authors used Unity). $X1$ and $X2$ are previously measured by processing pictures of which there is QR code at left and right end.

A flow of the game in this case is as follows: 1) The game starts with a message showing “Waiting ...” until the web camera detects the QR code. When detected, a 3-second timer starts after which the game immediately begins; 2)

Fig. 5 Picture of playing game

Fig. 6 Description of each coordinate

Apples begin falling from above; 3) The player controls “Real Robot” by using the same method of “Virtual Robot”; 4) A transparent game object which is formed to match the size of “Real Robot” moves to the position where the QR code is detected. In other words, this game object tracks the horizontal motion of “Real Robot”; 5) When the game object touches an apple, the player “gets” the apple; 6) The computer sends information via Wi-Fi every time an apple is “got”. Corresponding to a “got”, “Real Robot” plays the sound of “Yattazo!” from its speaker while waving its arms; 7) The rest is the same as 5) in the case of “Virtual Robot”.

3. Experiment

3.1 Method

Our research design was to use a Semantic Differential questionnaire to confirm the effects of “Real Robot” in “Catch Apple”. The authors used 26 two-polar adjectives

Table 1 26 two polar adjectives

No.	Japanese	English	Japanese	English
1	好きな	favourite	きらいな	dislikeable
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
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
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
12	きれいな	clean	汚い	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
15	続けたい	want to continue	辞めたい	want to quit
16	興味深い	interesting	退屈な	uninteresting
17	集中した	focussed	貴の散った	distracted
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
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	ありがちな	common

which were decided according to Brown’s study⁽¹⁾. They are shown in Table 1. However, this questionnaire was conducted in the Japanese language. The list of adjectives translated from Japanese into English is shown in Table 1.

The adjectives are rated by 7-grade evaluation. Brown says “immersion is indeed used to describe the degree of involvement” and proposes that involvement is divided into three levels: 1) Engagement; 2) Engrossment; and 3) Total Immersion. Moreover, Brown proposed that each level has some barriers. The authors conjecture that immersion can be evaluated by using them. Therefore, the adjectives are defined according to those barriers. This relationship is shown in Table 2. However, it may be novel to control “Real Robot” for most people which could affect their questionnaire response. Therefore, “Novel” was added to these adjectives to survey its effects.

In this study, 39 students in National Institute of Technology, Kurume Courage (NITKC) are selected as research subjects. “Catch Apple” has two modes. Firstly, a research subject selects and plays one of the two modes and immediately afterwards answers questions related to that mode. After this, the research subject plays the other mode and follows up by answering its corresponding questions. The answered questionnaires are processed by Factor Analysis. Then, the results for each mode are compared with

Fig. 7 Result of the questionnaires

each other. The method is referred to Kanda's study⁽⁶⁾. Kanda evaluated interactions between a robot and human.

3.2 Result and Discussion

Results of the questionnaires are shown in Fig. 7. This is average of scores. Firstly, the authors evaluated this data by Wilcoxon signed-rank test which showed that that the scores of "Real Robot" are significantly greater than the scores of "Virtual Robot" ($p < 0.05$). Moreover, the 26 two-polar adjectives are defined according to three levels of involvement. Therefore, scores should rise in the order of Engagement, Engrossment, and Total Immersion. However, the scores didn't reflect this (Fig. 7). The reason may be that the determinations of the adjectives was mistaken. Therefore, the authors confirmed the validity of the polar adjectives and reclassified them into three levels after Factor Analysis.

Secondly, the authors processed the results of the questionnaires by Factor Analysis in order to find factors relating to immersion and to evaluate them. The authors found 9 factors by chi-square test, and its loadings are shown in Table 3. The authors evaluated the average of the factor scores by Wilcoxon signed-rank test. This evaluation shows that factor scores of "Real Robot" are significantly greater than the factor scores of "Virtual Robot" ($p < 0.05$). The

Table 2 Relationship between Levels and adjectives

Levels	Barriers	Adjectives	
		No.	Name
Engagement	Preference	1	favourite
		2	friendly
		3	decent
	Easy of use	4	easy
		5	simple
		6	early
		7	quick
	Rewards	8	fun
		9	fulfilling
		10	satisfying
		11	tough
Engrossment	Visual	12	clean
		13	pretty
		14	soothing
	Want to continue	15	want to continue
		16	intresting
	Intention	17	focussed
Total Immersion	Empathy	18	warm
		19	casual
		20	approachable
	Atmosphere	21	gorgeous
		22	cheerful
		23	kind
		24	wize
		25	aggressive

Fig. 8 Difference of Factor Score

authors subtracted factor score of "Virtual Robot" from factor score of "Real Robot". The result is shown in Fig. 8.

Thirdly, the authors classified the factors into Engagement, Engrossment and Total Immersion by using only loadings greater than or equal to 0.5. Factor1 affects adjective 2(A2), 3, 12, 13, 14, 17, 18, and 19. However, A18 and A19 is similar to A2, A3. Therefore, A18 and A19 did same work as A2 and A3. Tus Factor1 was classified into Engagement and Engrossment. Factor2 affects A9, A10 and A11, thus was classified into Engagement. Factor3 affects

Table 3 Loadings

No.	Adjectives	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7	Factor8	Factor9	Communality
1	favourite	0.259	0.185	0.699	0.119	0.085	0.099	0.141	0.045	0.177	0.675
2	friendly	0.771	0.186	0.194	0.094	0.109	-0.012	0.217	0.046	-0.006	0.737
3	decent	0.705	0.089	0.291	0.148	0.347	0.147	0.080	0.140	0.113	0.793
4	easy	0.194	0.075	0.306	0.086	0.145	0.105	0.539	-0.320	0.145	0.590
5	simple	0.211	0.061	0.089	-0.030	0.162	0.014	0.950	-0.089	0.047	0.995
6	early	0.277	-0.048	0.056	0.063	0.133	0.931	0.127	0.025	-0.083	0.995
7	quick	0.055	0.012	0.095	0.156	0.082	0.619	-0.044	0.059	0.184	0.465
8	fun	0.116	0.419	0.870	0.135	0.021	0.119	0.093	-0.087	-0.022	0.995
9	fulfilling	0.061	0.692	0.456	0.129	0.042	0.025	0.040	-0.005	-0.104	0.722
10	satisfying	0.217	0.857	0.092	0.040	-0.080	-0.096	0.055	0.160	0.032	0.837
11	tough	0.245	0.713	0.206	0.201	-0.088	-0.011	-0.009	-0.019	0.006	0.660
12	clean	0.588	0.058	0.099	0.081	0.079	0.181	0.104	-0.068	0.209	0.464
13	pretty	0.595	-0.008	0.133	0.151	0.129	0.145	0.167	0.057	0.542	0.757
14	soothing	0.543	-0.023	0.085	0.088	0.179	0.142	0.102	-0.001	0.789	0.995
15	want to continue	0.315	0.396	0.458	0.449	-0.051	0.020	0.196	0.130	-0.022	0.726
16	intresting	0.161	0.294	0.052	0.634	0.143	0.239	0.214	0.221	0.178	0.720
17	focussed	0.584	0.291	0.216	0.224	0.048	0.089	0.078	-0.145	-0.007	0.560
18	warm	0.695	0.072	-0.163	-0.057	0.158	0.056	-0.066	-0.150	0.208	0.616
19	casual	0.664	0.207	0.152	0.155	0.205	0.065	0.137	-0.056	0.008	0.599
20	approachable	0.208	-0.061	0.275	0.295	0.273	-0.016	0.134	-0.496	0.183	0.582
21	gorgeous	-0.020	0.393	0.038	0.227	0.333	0.253	0.069	0.062	0.129	0.408
22	cheerful	0.320	0.058	0.071	0.120	0.736	0.095	0.102	-0.080	0.131	0.710
23	kind	0.298	-0.182	0.003	0.074	0.732	0.130	0.145	-0.014	0.020	0.701
24	wize	0.035	0.040	0.134	0.597	0.067	0.048	-0.109	0.001	0.065	0.401
25	aggressive	0.307	0.286	0.033	0.565	0.114	0.159	0.087	-0.156	-0.108	0.578
26	novel	-0.031	0.106	0.080	0.121	0.034	0.093	-0.125	0.852	0.080	0.791
contribution		16.008	10.208	8.4273	6.631	6.371	6.1155	5.9549	4.9994	4.7911	
cumulative contribution		16.008	26.215	34.643	41.274	47.645	53.76	59.715	64.7147	69.506	

Table 4 Result of classification

Levels	Factors
Engagement	Factor1
	Factor2
	Factor3
	Factor6
	Factor7
Engrossment	Factor1
	Factor4
	Factor9
Total Immersion	Factor4
	Factor5
none	Factor8

A1 and A8, thus was classified into Engagement. Factor4 affects A16, A24 and A25, thus was classified into Engrossment and Total Immersion. Factor5 affects A22 and A23, thus was classified into Engagement. Factor6 affects A6 and A7, thus was classified into Engagement. Factor7 affects A4 and A5, thus was classified into Engagement. Factor8 affects only A26. A26 is the additional adjective and doesn't relate to immersion. Therefore, Factor8 may not relate to immersion. Moreover, "Novel" doesn't affects result of this experiment."Factor9 affects A13 and A14, thus was classified into Engrossment. This resulting classification is shown in Table 4. The result shows that the factors classified into Engagement are a majority. However, there were no factors classified into Total Immersion. The reason for this is that Engagement is the lowest level and Total

immersion is the highest level. Therefore, the authors conjecture that the classification is correct. Moreover, players couldn't reach Total Immersion when they played "Catch Apple".

Lastly, the authors evaluated the scores of factors relating to immersion by Wilcoxon signed-rank test. The results show that the factor scores of "Real Robot" are significantly greater than the factor scores of "Virtual Robot" ($p < 0.05$). Therefore, the authors conjecture that using "Real Robot" as a player character improves immersion of games.

4. Conclusions

In this paper, the authors verified a method to improve immersion into games. Firstly, the authors developed the game "Catch Apple" in which a player can use "Real Robot" as a player character. The game is shown in Fig. 1 and Fig. 3 and "Real Robot" in Fig. 2. Secondly, the authors designed a questionnaire based on Brown's study of immersion⁽¹⁾ and administered it to 39 students at NITKC. The adjectives tested in the questionnaire are shown in Table 1 and the results in Fig. 7. Thirdly, the authors processed the survey responses using Factor Analysis in order to find factors relating to immersion. The resulting factors are shown in Table 4. Fourthly, the authors evaluated the resulting factors. The results show that the factor scores of "Real Robot" is significantly greater than the factor scores of "Virtual Robot" ($p < 0.05$). Lastly, the authors conjecture that using "Real Robot" as player character improves the sensation of immersion of games.

However, there are fore problems. Firstly, the research subjects are few to implement Factor Analysis. Moreover, they belong to the same group. Secondly, the authors found the factors relating to immersion instinctively. Therefore, the correctness of the founded factors is not certain. Thirdly, the players couldn't reach Total Immersion. One reason may be that players may not like the game "Catch Apple" because the authors developed it only for the experiment. Because of this, the authors may not find all factors relating immersion. Fourthly, if players look the computer display from except the front, players may not able to play correctly the game using "Real Robot" as a player's character. Because, in this case, players can't recognize correctly location relationship between "Real Robot" and apple in the virtual game world. Generally, players look the computer display from the front. However, this restriction may have bad influences on immersion.

Therefore, the authors will follow-up with three tasks:

Firstly, the authors will develop a new game which reference existing popular games such as air hockey in order to be liked by players. Secondly, the authors will conduct similar research on the new game in order to confirm the correctness of the factors relating to immersion. Thirdly, the authors will survey influence of changes of player's viewpoint on immersion.

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