Experimental methods and natural player analysis for sensory-motor interaction using pressure sensors

Taisuke YAMASHITA Akihiko SHIRAI Motofumi HATTORI

Kanagawa Institute of Technology
yamashita @ shirai.la

Abstract
This report is on a new experimental method and natural player analysis for sensory-motor interaction using pressure sensors like balance board. The methods are implemented into an experimental game system and its companion agent which have various voices without any visual feedback interactions and agents were examined by summarizing the output of evaluation functions (A) threshold based and (B) frequency spectrum based to obtain the virtual emotion of companion player. The study also has developed a dynamic frequency recognition algorithm with more applicative implemen tation for game system than post complex frequency spectrum analysis using FFT library. As a result, a conventional model (A) could have an interaction with 50% of players but it could be completely and easily controlled by players. Model (B) could have an interaction with at least 58% of players but the model fails to be controlled by the will of most players. A mental model has also been constructed by applying (A) and (B) into a companion player to realize realistic human-agent physical communication as an exercise entertainment system instead of a boring skill training machine.

1 Introduction

An Exercise Entertainment System (EES) like Nintendo 's Balance Board in a consumer platform can engage strong motivation of whole body exercise activities complete with sweating and attractive techniques. The software developments using such EES can enlarge value-added contents on existing devices with less risk than owned development of special devices.

However, its difficulty level adjustment and normalization of reaction feelings are more challenging in EES than a mouse, touch panel, or other input devices because its interaction handles different inputs by different game players who have different "sensory-motor play" and physical properties like human weight and other physiological aspects.

EES, which uses human weight, especially requires calibration of players 'weight before playing to normalize players ' behavior to a standardized signal. But it is an inconvenience in natural game play and more difficult in a casual game because it must share privacy data for a short time.

From such a background, EES has been used in this study and devised a design of a casual massage exercise game "LovePress" that includes companion agents program to realize a sense of massaging experiments as a subject in virtual and physical input by sensory-motor interaction. It was then found that the importance of modeling of companion agents difficult to control and in maintaining player motivation in interactive exercise game play.

This article has reported player experiment comparisons of two evaluation models which have a frequency spectrum analysis with a band path filter for player inputs and conventional threshold-based pressure intensity analysis. It used an experimental game system of " LovePress " that has no visual feedback but various voice reactions by special companion agent algorithms as evaluation functions with an emotion value.

The expressions in the exercise game can be increased if various companion agents in EES can be designed. In addition, it may realize a game system that can maintain the player motivation by their motion by establishing an evaluation technique to evaluate a physical experience of various players in real time.

2 Motivation and Purpose

The current digital game platform may isolate to least three domains in near future which are (1) whole body interaction entertainment in next generation 's consumer set top device, (2) conventional video game on PCs and Web browsers, (3) SmartPhone and portable game machine with rich interfaces such as multi-point touch panel, camera, acceleration sensor and GPS. That means that in the future the conventional consumer platform will shift to a whole body entertainment system that is currently represented by Nintendo Wii[14] and Microsoft Kinect[13].

A lower layer unconscious "sensory-motor interaction" is being focused on that provides a more principled, natural and freeform play than conventional "logical play". It includes developing companion player agent sensors and recognitions that can dynamically recognize physical continuous inputs from players. Furthermore, its upper layer "Emotion feedbacks" are being applied between the player and game system [1, 2].

This concept is not a singular point of view from current video game industry and academic research. Isra reports layered brain architecture for simulated autonomous and semi-autonomous creatures that inhabit graphical worlds [10]. And Valve, the most famous FPS game studio reports their player testing and empiricism in "Left 4 Dead" [3, 6] in GDC2009. This issue, controlling agents from measuring player 's motivation, is one of the most interesting topics in current video game research.

Here are also some previous studies in physical computing entertainment systems from both of videogame industrial and academic activities. SEGA and Konami developed some game titles using a touch panel on a DS platform to express a lover 's physical interactions. Tsujita 's "SyncDecor" had applied metaphor interaction to a set of furniture like a dustbin in the distance. Inami 's "RobotPhone"[9] had applied voice communication into a robotic teddy bear using tangible link connections in the distance.

Konami 's "LovePlus" had realized a visual companion agent that emulates their emotion from physical inputs using touch panels like DS and iPhone. However this system design is not suitable as an exercise because of small momentum. Moreover, this emotion model is difficult to apply into EES, fighting game and immersive FPS/TPS.

Because of these backgrounds, the purpose was set to develop a next generation's game system that can keep a player's motivation via an interactive companion agent to naturally move a player's own body in a daily living space.

3 System

The experiment system consists of four pressure sensors of BB as an input and headphones as an output (Figure 1).

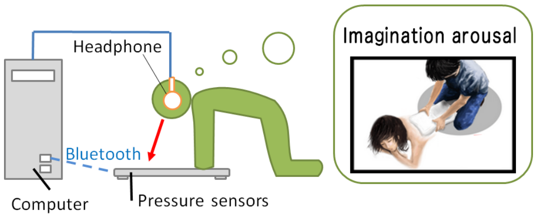

Fig. 1: Hardware configure of our experiment system

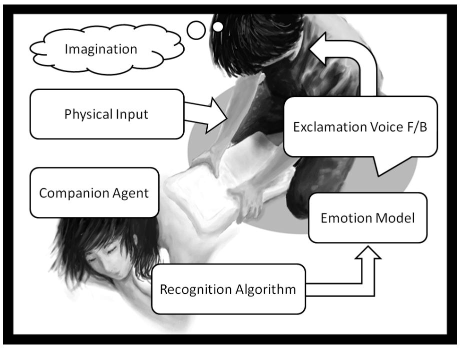

Fig. 2: [Concept visual] Sensory-motor interaction on EES with imagination arousal by exclamation vioce feedback

3.1 Prototype game design

The new EES game design in this study had only massaging by pressure sensors. The concept of this design avoided depending on specific culture and/or languages then it did in using an exclamation voice feedback instead of a narrative feedback. It concentrated to motivate "imagination arousal" using a metaphor as BB for a companion's back then it eliminated any buttons or mouse inputs. The player could tell their desire to the companion agent only with a sensory-motor interaction by continuously pressing the pressure sensors in BB.

3.2 Algorithm

Agents were examined by summarizing the output of the evaluation functions: (A) threshold based, and (B) frequency-spectrum based in order to obtain the virtual emotion of companion player. A dynamic frequency recognition algorithm was developed with more applicative implementation for game system than post complex frequency spectrum analysis using the FFT library.

3.3 Evaluation Functions

The virtual emotion of the companion player is implemented by an evaluation function, i.e. a good feeling or a bad feeling are expressed by an output value of the evaluation function. If the output value of the evaluation function increases, a good feeling of the virtual emotion increases. If the output value of the evaluation function decreases, a good feeling of the virtual emotion decreases (i.e. the bad feeling of the virtual emotion increases).

This article reported on two types of evaluation functions, (A) a threshold based evaluation function, and (B) a frequency spectrum based evaluation function.

3.3.1 (A) A threshold based evaluation function

The value of the evaluation function (A) is determined by basing it on the intensity of the massage pressure. The intensity of the massage pressure is computed as the sum of the outputs of 4 pressure sensors of the BB. If the intensity is greater than 10kgF and less than 25kgF, the value of the evaluation function (A) is increased. If the intensity is otherwise, the value of the evaluation function (A) is decreased.

3.3.2 (B) A frequency spectrum based evaluation function

The intensity of the massage pressure is defined as described in the above. The intensity is measured by 60 fps from the BB. By checking the increase and the decrease of the time evolution of the intensity values, the maximum values and the minimal values of the intensity are obtained. By judging the maximal value, the minimal value and

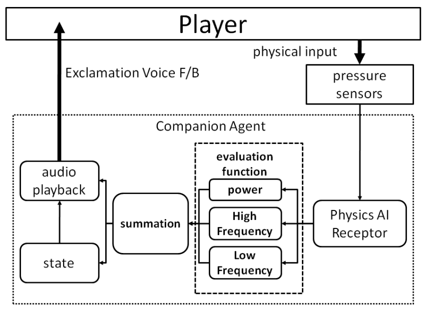

Fig. 3: Block diagram of experimental system

Model Type / f(t)	Type A	Type B
+1	10 – 25kgF	2 – 0.85Hz
−1	Under 10kgF or Over 25kgF	Over 25kgF

Fig. 4: Evaluation Functions: Type A detects pressure intensity, type B is a band path filter for frequency of player input. Each function have penalty to avoid unrealistic value.

the next maximal value, a period of the intensity is computed and a frequency is obtained as the reciprocal number of the period. If this frequency is higher than 0.85Hz and less than 2Hz, the value of the evaluation function (B) is increased. If the intensity is greater than 25kgF, the value of the evaluation function (B) is decreased.

4 Experiment and results

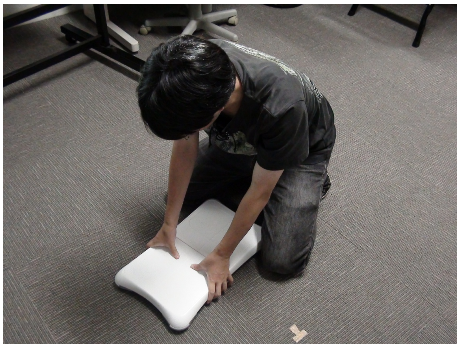

Fig. 5: [Photo] Experiment using EES

4.1 Experiment protocol

As to the future theme mentioned in the motivation, there are a few interaction systems with whole body exercise activities as mentioned in the examples of previous research and development. In order to design the interaction systems with whole body exercise activities, a Wii Balance Board (whose maximum weight is 136kgF) was used that has 4 pressure sensors acting as a pressure sensor device.

Each player (herein referred to as subjects) massages, for 5 minutes, two companion agents that have the evaluation functions (A) and (B) adhering to the following: The 12 subjects are young men approximately 22 years old and with a weight range of greater than 44 kg and less than 88kg. The 12 subjects are divided into the 1st group and the 2nd group. The 6 subjects in the 1st group massage the companion agent (A) before they massage the companion agent (B). The 6 subjects in the 2nd group massage the companion agent (B) before they massage the companion agent (A). By this arrangement, the so-called learning effect will be avoided.

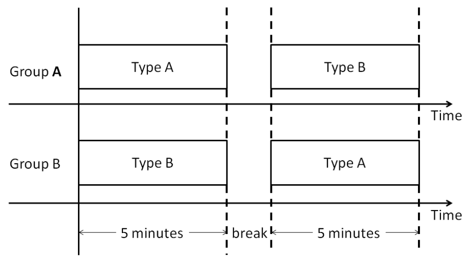

Fig. 6: Experiment protocol to control the comparison conditions

When a subject massages the companion agent, he hears her voice which expresses her positive feeling and negative feeling. The subject never knows the output of the evaluation function.

After each subject finishes to massage, he reported the answers for the following questions.

- Which time do you think longer between the massage for (A) and the massage for (B)?
- Which companion agents do you like more between (A) and (B) ?
- Do you notice the algorithm how the feelings of the companion agents are determined?

4.2 Results

The intensity of pressure values and the output of the evaluation functions for the subjects 1 and 2 and the companion agents (A) and (B) are shown in figures 7, 8, 9 and 10.

By the massage of subject 1, both companion agents (A) and (B) had positive feelings (figure 7, 8). By the massage of the subject 2, the companion agent (B) had positive feelings (10), and the companion agent (A) had negative feelings (9). It may be understood as a misunderstanding of cognitive model between player and agent.

Furthermore, subject 2 made a pause to massage the companion agent (A) from 150 second to 160

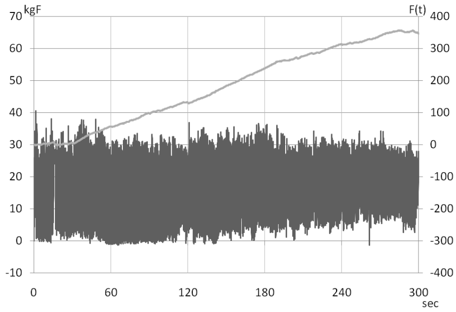

Fig. 7: Subject 1 - Function A

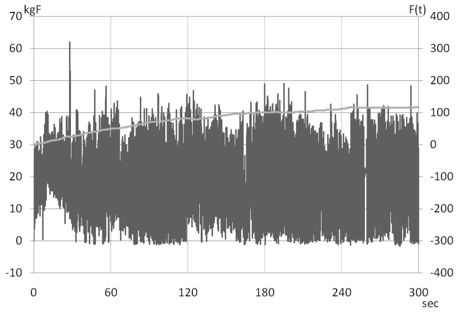

Fig. 8: Subject 1 - Function B

seconds. It may be understood as abandoning or getting tired by misunderstanding.

Figure 11 and 12 is a summary of all subjects for each evaluation functions.

The variance of the output of the evaluation function (B) between all subjects is less than the variance of the output of the evaluation function (A) between all subjects. It means (B) could get communicate with various players but (A) may give different impressions.

The negative feeling of the companion agent (A) is greater than the negative feeling of the companion agent (B). It can be described as a different penalty between different algorithms but (B) shows roughly 3 groups at 5 minutes of playing.

As players' impression, 66% of subjects preferred (A) because of it could be completely and easily controlled by players. And they reported as "5 minutes was too long. The suitable playtime is about 2 minutes". But it is within the scope of the assumption.

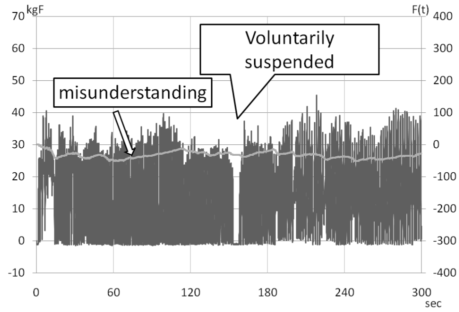

Fig. 9: Subject 2 - Function A, Player made a pause from 150 second to 160 seconds.

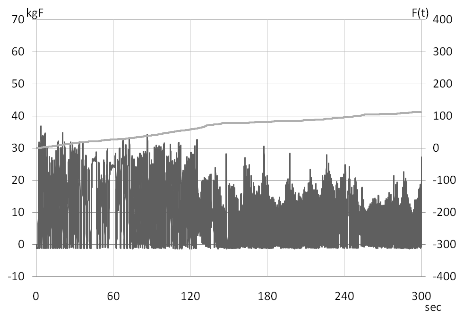

Fig. 10: Subject 2 - Function B, same player could take a point continuously.

5 Discussions and Applications

5.1 Discussions

Here are discussed are the application of the result and models to an EES game content. Model A and B were rearranged to a cutaneous mechanoreceptor in perception psychology similar to Pacinian corpuscles and Meissner's corpuscles in human skin [12],[17]. With this metaphor, it could be understood that a frequency for stimulation and intensity characteristic for the transformation are different and rational. In addition, we can set sensitivity and the rate of these receptors as individual personality of actors in a game system. Therefore three character settings were developed as companion agents which a player could choose as a partner of the massages (Figure 13).

Each character had different threshold and contribution ratio of evaluation functions A and B.

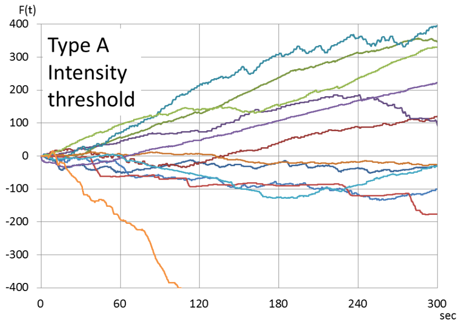

Fig. 11: A summary of all subjects for each evaluation function A, some player could get win, but some player had complete defeated.

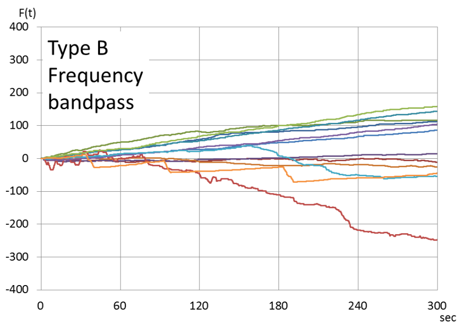

Fig. 12: A summary of all subjects for each evaluation function B, most players could made interact with the agent.

And dynamic emotion can be explained as summation of the evaluation functions in a character. Supplemental visuals and voice feedback were also assigned to express plural stages of character emotions.

5.2 Application

In this paper, we had reported our evaluation model from cognitive simulation method of artificial intelligence and with some experimental methods of perception psychology. Its acquired results have various application fields to enlarge current interactive techniques like virtual reality entertainment or tele-existence communication entertainment systems in near future.

As an example, our system can obtain player's characteristic by natural playing using favorite frequency and intensity from unselfconscious repeti-

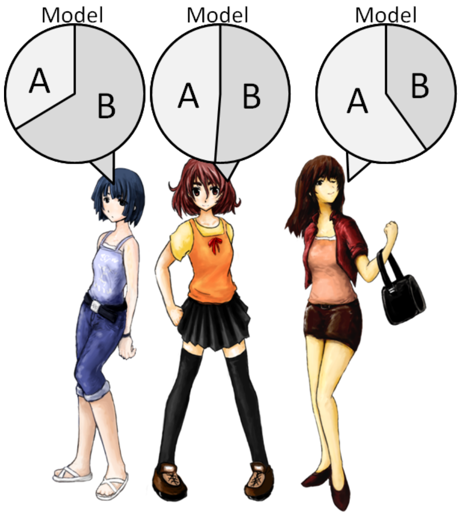

Fig. 13: Character design and examples of contribution ratio of receptor models

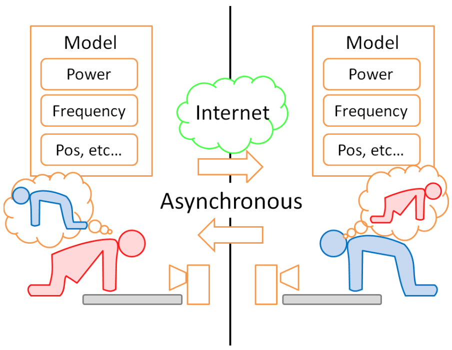

Fig. 14: [Concept]Application for tele-existence

tion. Then we can configure a new companion agent who can give a suitable feedback to represent him if we could get his exclamation voice samples. This player emulation can configure a new asynchronous physical communication game system from a long distance using a set of EES through a narrow band width connections.

6 Conclusion

We had reported a new experimental method and natural player analysis for sensory-motor interaction using pressure sensors like balance board in this paper.

Our methods were implemented into an experimental game system and its companion agent which have various exclamation voices without any visual feedback interactions and we have examined agents by summarize the output of evaluation functions (A) threshold based and (B) frequency spectrum based analysis to obtain the virtual emotion of companion player from natural play condition. Especially, our implementation of dynamic frequency recognition algorithm had worked well as a robust system.

As a result from player experiments and impression, conventional model (A) could made interaction with 50% of players but it could be complete controlled by players easily.

Model (B) could made interact with at least 58% of players but model had not controlled by most players will.

And we have also constructed a mental model by applying (A) and (B) into a companion player to realize realistic human-agent physical communication as an exercise entertainment system instead of a boring skill training machine.

We also think our model can be applied onto the next generation's entertainment systems like a tele-existence entertainment system that has a extend of current exercise entertainment system to keep higher quality of human life by computer enhanced sensory-motor playings.

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