OTOTONARI: Mobile Ad Hoc Pervasive Game that develops a regional difference

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Abstract : Mobile Ad Hoc network fits in with Pervasive Games as for entertainment computing. Pervasive Games, also known as Pergames are games based on real space and holds the features of both the traditional real space games before computers and computer games that use computer graphics and sound. We propose a Pergame content "ototonari" by defining the feature of the traditional real space games to be the simplicity in its introduction, physical factor and the regional difference. Ototonari creates a sound by users' collaboration and saves it as a sound data with the position information so that other users can refer to it even if they join afterwards, using mobile ad hoc network. Ototonari aims to develop a regional difference which the traditional games had, by handing over the users' experience as data to other users. We carried out an evaluation experiment at the site of Expo Aichi 2005 and studied its result.

1. Introduction

Researches of applications based on real space using mobile ad hoc network is being carried on in many fields. In the field of entertainment computing, pervasive games are remarkably used.

Pervasive Games, also known as "Pergames", are games based on real space and holds the feature of both the traditional real space games before computers and computer games that use computer graphics and sound[1][2]. The traditional games before computers are games such as tag and hide-and-seek. As Pervasive Games are based on real space, it fits in with mobile ad hoc network. But we rarely see games which consists of just mobile ad hoc network [3][4]. Also, there are some Pergames that use sensor network [5].

The feature of games before computers can be categorized into 3 categories as below.

a) Simplicity in its introduction
b) Reflection of its physical factor
c) Regional difference in rule and style

The first feature, the simplicity of its introduction, is the factor that one can start a game anywhere if they have the place and the players. It cannot be said that it has simplicity in its introduction, if it takes time to prepare and limits where to play.

The second feature, the reflection of its physical factor, means that the players' movement will differ according to the place they are playing that game. For example, when playing hide-and-seek, the players hide in a different place according to the field that the game is taking place, the physical factor.

The third feature is the regional difference. Originally, real space games such as tag and hide-and-seek have a difference in rules and style according to the country or region. The information that has been inherited in the environment surrounding people, therefore the culture, climate and history, brings out the regional difference.

There are many researches on Pervasive Games at present. But these researches do no more than playing games in real space based on computations [6][7][8][9]. There were not any cases where the game was designed with the feature of computation and have the 3 factors of traditional real space games. The third feature of regional difference was not considered at all in previous researches.

Regarding this state, we propose a Pergame content "ototonari" based on the above 3 factors. Ototonari has the points below.

1. Create a sound through users' collaboration using mobile ad hoc network based on the position, proximity and density.
2. Saves the sound created by the user as data and enables other users who play afterwards to refer to it using mobile ad hoc network.

The first point is based on the features of traditional games a and b. Ototonari has the specification which the game can be done only with mobile ad hoc network using PDAs with the application installed. It is preferable that the game can be done anywhere, without the condition of a specific network infrastructure, if a person has a PDA ready. There are some precedents that Pergames can immerse users in the game by using HMD [10][11]. Also, there is a trade off with the ability to immerse users into the game and the simplicity in its introduction by using HMD. In the application proposed in this thesis, we consider it to be faithful to the conditions of the traditional real space games. Therefore, we give priority to the simplicity in its introduction by attaching greater importance on its cost of introduction and the scalability of users. Also, regarding the feature b, we determine the physical environment, the users' position as the basis of creating sound. The aim of this is to reflect the physical environment by changing the sound created according to the position where the user is located.

The second point is based on the feature of traditional games c. In traditional real space games, there is a regional difference due to the inherited information. Based on this model, we aim to create a regional difference in ototonari by saving the users' experience to the location and inheriting it. User(X) saves the created sound to the location, then another user(Y) listens to the saved sound and created a new sound based on that sound. In this case, assume that Y's action is influenced by the sound X saved, the experience of X inherits to Y as information. If it does have an influence, we assume that it will have regional differences by inheriting continuously.

Ototonari which holds these features enables to offer the users a new game experience using computation with the features of traditional games. We consider that this will bring a big impact in the field of entertainment computing, Pergames, as the regional difference is not in the concept of recent Pergames.

In the next chapter, we state the game design and the system of ototonari, a Pervasive Game proposed in this thesis. Moreover, we evaluate and consider the experiment we did at Aichi World Expo.

2. Ototonari

Ototonari creates a sound based on the position, proximity and density of the user in real space using mobile ad hoc network. Then, it saves the created sound to the location as data through a particular terminal using mobile ad hoc network. This enables not only the current users that exist at that location, but also the users that appear afterwards at that location to share the sound.

Ototonari forms of multiple sub areas as the game area and the user plays a unique instrument at each sub area, then as the users get closer to each other, the number of instruments increase. The sound created by each user is merged and saved at each sub area. Users who play the game afterwards can listen to the sound that is saved at that location.

The game design and the system for ototonari is stated below.

2.1 Game Design

Here we state the game design for ototonari that is proposed in this thesis.

There are 2 types of games in ototonari and each is expressed as “term 1” and “term 2”. The game flow of each term is stated in Table 1. In term 1, the sound data created is saved to the game area. Then another user gets the data left in that game area and listens to the reconstructed sound based on that data in term 2 “2. Listening time”. The process of reconstructing the sound in the application based on the data left in that game area is called “remain”. Term 1 and term 2 can be rephrased as remaining term and non-remaining term.

However, there is no need for term 1 and 2 to be done continuously, and can be done at particular. Supposing that term 2 is played continuously, user (Y) listens to what user (X) left at that game area, and user (Y) creates a sound based on that. Y will leave the created sound to the location, and then X will listen to the sound Y created and saved based on what X created, when X plays the game again. An interaction model is formed if X changes the action due to listening to the sound [12].

Below, we state summarize each phase.

Moving Time: Users spread to a particular place in the game area.

Creating Time: A sound is created based on the users’ position, proximity of each user and density. The created sound is output in real time. In this creating time, communication is made easier by making it unable to create sound unless a user approaches another user. Also, the instrument differs for each sub area, so the users can enjoy the sound by moving from one sub area to another with other users. In ototonari, we adopted the style where the user does not create the sound from scratch, but by mixing the sound samples created based on the users’ position, proximity and density. This specification was made considering the perfection of the music and entertainment as a game. Of course, there is a method of putting the users’ position data in a virtual instrument parameter. But there are some problems such as the recognition of the change in sound being unclear and the dissonance when sounds are created. Therefore, we adopted the method where a sound sample, that is already a musical piece, is dismantled and is reconstructed due to the users’ movement in real space.

Mixing Time: The sound data created by each user is changed to a sound data for the particular area.

Mini Game Time: A mission is sent to the user from the agent in the application. There is a change in sound by clearing the mission. The aim of this mini game time is for the users to communicate with each other and clear the mission together.

Listening Time: The created sound can be listened to. Also, the sound saved in the area can be listened to. The aim of this is for the sound to have influence on the users’ action in the game by listening to the saved sound.

In the phase above, not only the sound but also a graphic is presented. To be concrete, (1) each user visualizes the instrument (refer 2.2.2) and (2) supports the progress of the game. The latter can be subdivided into presenting the left time in each phase, directing the user’s action in each phase and supporting the progress of the mini game time (refer 2.2.4).

Table 1. Game Flow

Term 1		Term 2	
Phase	Time line	Phase	Time line
1. Moving Time (1 min.)	00：00～01：00	1. Moving Time (1 min.)	00：00～01：00
2. Creating Time (3 min.)	01：00～04：00	**2. Listening Time (3 min.)***	01：00～04：00
3. Mixing Time (1 min.)	04：00～05：00	3. Creating Time (3 min.)	04：00～07：00
4. Mini Game Time (3 min.)	05：00～08：00	4. Mixing Time (1 min.)	07：00～08：00
5. Mixing Time (1 min.)	08：00～09：00	5. Mini Game Time (3 min.)	08：00～11：00
6. Listening Time (3 min.)	09：00～12：00	6. Mixing Time (1 min.)	11：00～12：00
		7. Listening Time (3 min.)	13：00～16：00

*phase”2. Listening Time” exists only in term 2. The sound data created and saved in term 1 can be listened to.

2.2 System

2.2.1 System Structure

The system structure for ototonari is shown in Fig. 1. The application of ototonari is operated in a PDA. The PDA used is the ai-MATE terminal developed by KDDI CORPORATION [13]. ai-MATE has Windows Mobile 2003 Second Edition for Pocket PC and enables communication functions such as wireless LAN (802.11b) and CDMA 1X WIN. Ototonari uses this ai-MATE as the mobile terminal that the user carries and also for the fixed terminal that is set in the game area.

Macromedia Flash is used for the interface of ototonari, and the game flow is shown graphically by this (Fig.3, Fig.4). The ototo player is descripted by C# and is taken a picture with a camera. Then the created sound is output within the hardware, the data is input and output, and then the communication log is output. Cast Service and JPEG Lib Wrapper are described in Native C++. Cast Service is a dll (dynamic link library) module using CCS (Contents Crusing System) developed by Murai Laboratory, Keio University [14]. In this proposal, as we use only the mobile ad hoc network, we omitted the corresponding module and use dll for the distributing function of the mobile node (=One Hop Neighbors), although the CCS as a communication architecture modules the communicative part with GPS.

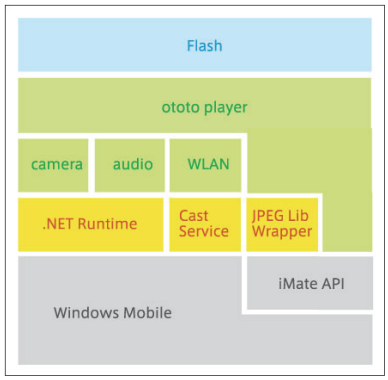

Fig. 1: System Structure

The file list used in ototonari is shown in Table 2. And the flow of the file movement between mobile terminals and fixed terminals are shown in Fig. 2. In the following sections after 2.2.2, only the file name is described.

2.2.2 Creating Time

We implemented 2 modules in ototo player to create sound in a mixing style.

First module, the base rhythm module, decides the type of music based on the sub area. Ototonari consists of a maximum of 4 sub areas (abcd) in a game area. Each sub area has a fixed terminal and casts an area message for each 5000 milliseconds to its coverage area. The mobile terminals that receive this area message plays the basic rhythm formed of bass and drums. Each sub area has a unique type of basic rhythms, Disco, Funk, Samba and Electro. These basic rhythms should be set to each sub area before the game starts.

The second module, instrument module, playas the instrument assigned to each sub area. Mobile terminals have an assigned instrumental set for each terminal ID corresponding to each sub area. For example, the user with ID{1} has an instrumental set of a-1, b-1, c-1 and d-1 in area abcd. Mobile terminals play an instrument corresponding to the ID in that area at the same time they receive an area message. In the present version, there are 10 types of instrumental sets for each sub area. These instruments sets should be set to each sub area before the game starts.

In creating time, the sound is created using these modules. The sound based on the position information is created by using the base rhythm module and the instrument module. The sound based on the proximity and density is created by the collaboration of the instrument module and the message casted by each mobile terminal. The mobile terminal {1} with ID {1} casts a created message to terminals in its coverage area. If mobile terminal {1} exists in area A, it casts a created message with the file name G-a-1, and all mobile terminals in mobile terminal {1}'s coverage area and also in area A play instrument 1 for type a for 5000 milliseconds. Here, the display on the terminal graphically shows the played instrument so that the user can distinguish which instrument is being played. The captured image of creating time is shown in Fig. 3. In creating time, a trapezoid corresponding to the instrumental set assigned to each user repeats expanding and reducing along with the played instrument (Fig. 3a). If a user receives a created message from another user, the trapezoid for that ID repeats expanding and reducing (Fig. 3b).

Also, if mobile terminal {2} exists in a different area from mobile terminal {1}, and receives a created message from mobile terminal {1}, errors are avoided by comparing the area ID of the final received area message and the area ID of the received created message in mobile terminal {2}. In connection

Table 2: Tasks and types of files in ototonari

File name	File structure	Sender	Function
Area message	Terminal MAC address –A- area ID (abcd)	Fixed terminal	Notify the area
Created message	Terminal MAC address –G- area ID (abcd) –terminal ID (0-9)	Mobile terminal	Notify the area and the instrument used for creating the sound.
Mix file	Terminal MAC address –M- area ID (abcd) –terminal ID (0-9)	Mobile terminal	Record data of the sound created by each player or recorded sound mixed at each area.
Remain file	Terminal MAC address –R- area ID (abcd)	Fixed terminal	Merges the mix file in term 1 and saves it for each area. Used in phase 2 of term 2.

* Record data in the file is recorded as high (=1) and low (=0)

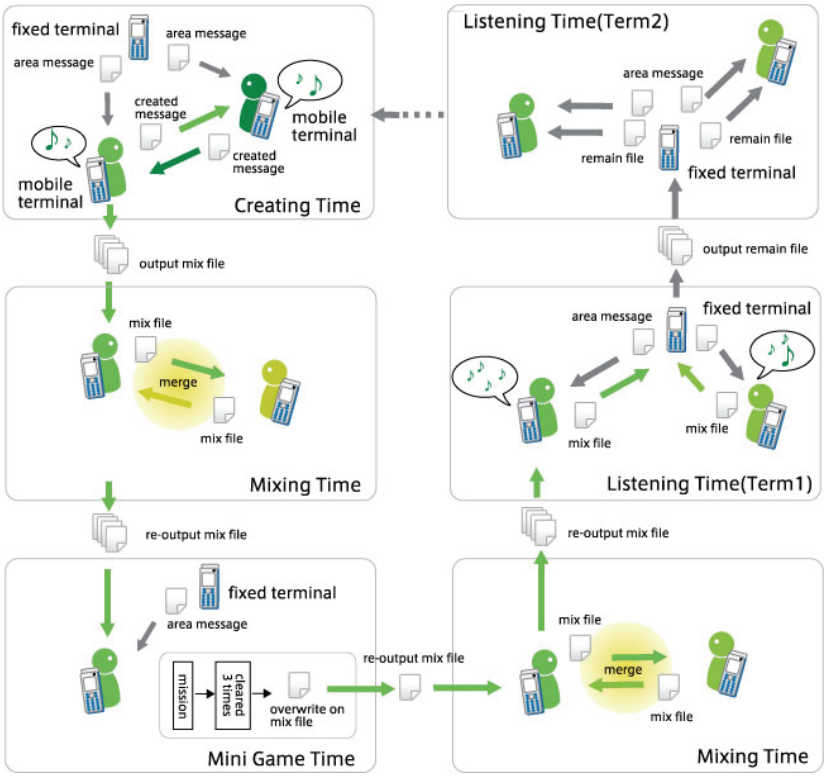

Fig.2: File movement flow

with this, referring to the error processing of the overlapping of coverage areas of fixed terminals in each sub area, the space between each fixed terminal should be decided considering the reception status of the fixed terminals before the game starts. If a mobile terminal exists in a blank area which is not covered by any fixed terminals area, the sound is created by processing uncertainty based on the last area message received [15].

The receiving record of the created message is output as a mix file by recording it as a matrix value consisting of "the corresponding instrument (10 rows: 0-9)* time (36 columns: 3 min/5000 msec)" as soon as the phase of creating time is over. However, the mix file is not output for areas where the user did not exist.

(a) (b)

Fig.3: Image of the display for Creating time

(a)State when instrument of only the user with ID8 is played

(b)State when instruments of users with ID1, ID8 are played

2.2.3 Mixing Time

In the mixing time, the mix files, that exists as many as the number of "mobile terminals*sub area" output in the creating time, are merged to change each users' sound into all the users' sound. It is merged by a logical sum of each cell in the matrix within the mix file. The merge is done only once to each file by enclosing the terminal MAC address, area ID and the terminal ID in each terminal's memory. The relevant memory is released as soon as the first mixing time is over. As the new data is overwritten its own mix file in this mining time, a new file is not output at the end.

2.2.4 Mini game Time

In mini game time, a mission is sent to each user from the ototo Player. In creating time, users can listen to the instrument played by other users if the mobile terminal exists in the same area as the sengding user and is in the same coverage area. On the other hand, all users in the corresponding area can listen to the user's instrument if that user clears the mission in the mini game. The mission is to follow the agent's instructions and take a picture of a real object that has the indicated color, red, blue and green. These colors are indicated randomly and if the user succeeds to clear this 3 times, they can clear the mission. Fig. 4 is an image of the mini game time. When the mini game time starts, the image on the display changes, and the image from the embedded camera is shown on the display. The display shows the current mission, left time and the position of the shooting button for the camera. When the game is

cleared, the data is enclosed in the memory and after the mini game time, a cast is done regarding that all the rows of the user's instrument has been played according to the mix file which has the area ID and the terminal ID to where the user is at present.

Fig. 4: Image of the display for mini game time

2.2.5 Listening Time

There are 2 ways for listening time, one is when the user participating at present listens to the created sound, and the other is when another user listens to a sound created and saved by participants before (Table 1, Fig. 2). The former is enabled by playing each instrument based on the data from the matrix cell in the corresponding mix file after choosing a mix file with the user's ID in the listening time regarding the area ID of the received area message. This is done after the second mixing time. The latter can be realized by the fixed terminals in each area re-merges the mix file in the terminal in the second mixing time in term 1 and the outputting the remain file. In the first listening time of term 2, each fixed terminal in each sub area casts a remain file with an area message, so it enables the users to listen to the sound data when the mobile terminals receive that message.

3. Evaluation Experiment

We carried out an experiment game to volunteers in EXPO 2005 Aichi, Japan using the proposed content ototonari. We confirmed the operation and the difference in the created and saved sound due to the area and the number of participants by operating the game to a large scale of participants using the log data and the questionnaire results. Also, we confirmed if a user changes their action due to listening to the saved sound, and if the other users' experience affects another user and inherits the information.

3.1 Experiment Environment

The experiment was done in the Ai-Chikyu open space in EXPO 2005 Aichi, Japan. This round open space's diameter was about 180m and about 25,000 square meters. It was a good location for it had no obstacles around to cut the reception. We used this area as a game area and divided it into sub areas abcd (Fig. 5). The fixed terminals were set close to the center of each sub area and one terminal covered about 45m radius regarding the packet loss confirmed in the experiment beforehand.

The experiment was done on July 8, 2005 with 50 volunteers. The volunteers were people from 18 to 55 years old who registered beforehand. There were 25 men and 25 women. The volunteers were randomly divided into two groups, group (A) with 20 people and group (B) with 30 people. The experiment was done in order, A (term 1) – B (term 2) – A (term 2) – B (term 1), without explaining the intention of the experiment but just explaining the game rule.

After each term, we asked the participants to fill out the questionnaire. The questionnaire for term 2 have some questions about the information left in the location. In this experiment, there are some overlapping instrumental sets which is assigned to each terminal ID as there are 20 or 30 people in each group. Therefore, users of terminal ID{1},{11}and {21} have the same instrumental set.

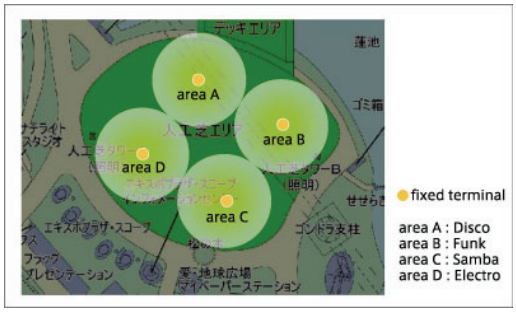

Fig.5: sub area setting

3.2 Log Data

The analyzed log data of term 1 and 2 is shown in Fig. 6.

Fig. 6 visualizes the matrix data of the remain files saved in the location for each sub area, in the first listening time in term 2. The horizontal axis has 3 minutes per 5000 msec and the total of 36 columns. The vertical axis has a total of 10 rows for each instrumental set. This visualizes the receiving status for files using 36 x 10 cell matrix. The remain file taken from the game area in group A's term 2 is the file that group B created and saved. The most number of harmonies made in each area seen in the remain file from group A was a:6, b:6, c:8 and d:6. The remain file taken from the game area in group B's term 2 is the file that group A created and saved. The most number of harmonies made in each area seen in the R file from group B was a:7, b:9, c:4 and d:7. The created and saved sound differs according to the sub area and the number of participants.

3.3 Questionnaire Result

The questions and the results of the questionnaire are shown in Fig. 7.

Here we state the questions in the questionnaire results where there was a notable difference in whether there was a remain phase or not.

In question a "Are you satisfied with the music you made?", compared to the positive answers from 30% of the users in term 1, there were positive answers

from 48% of the users in term 2. Therefore, we surmise that there was an effect on the user who creates the sound by listening to the saved sound in the location.

In question e "Did you listen to the music made by other players?", compared to the positive answers from 52% of the users in term 1, there were positive answers from 62% of the users in term 2. Therefore, we surmise that there was an increase in interest for not only the game experience of oneself but also for the game experience of other players by experiencing the remain phase.

We asked question f, "What did you think of the music made by other players?", to users who answered "Yes" to question e, to compare with question d. Compared to the positive answers from 81% of the users in term 1, there were positive answers from 87% of the users in term 2. There is a slight increase in positive answers by experiencing the remain phase. Also, there were more people who had good impressions to the sound that other users made than to their own music in both terms.

In question g "Did you make friends with other users through this game?", compared to the positive answers from 30% of the users in term 1, there were positive answers from 47% of the users in term 2. Therefore, there was an increase in positive answers by experiencing the remain phase.

Moreover, in question h "Did listening to the saved music saved in the game area affect your action?", only 22% of the users answered that they were affected. We surmise that there is an unconscious effect on the user as the 4 questions examined above clearly show a difference in their action by figures.

Furthermore, we asked these people who answered "yes" to question h, the next question i, "What kind of music did you think you would make compared to the saved music?". There were about 50% of each similar music and different music. This is a very interesting result for behavioral sociology that it has the same range.

Next, we state the notable comments on the free comment section of the questionnaire. There were some negative comments about the camera operation, such as "the response is bad" and "it doesn't recognize the color well". Users were asked to clear the mission using a camera during the mini game time, but the experiment was under a hot weather of 35 degrees C, so the color was not judged properly on the camera, which may have lead to this result. Also, there were some negative comments about the output of the sound, such as "I could have enjoyed more if the sound was bigger" and "I couldn't hear the sound because of the large noise from the surrounding area". We confirmed its output volume to be at an enough level at a pre-experiment, the open space at the time of the experiment had unexpected amount of noise. Therefore, we had some comments that it was dificult to listen to even though the PDA was set at its highest volume.

On the other hand, there were some positive comments, such as "I felt like I was communicating using the power of music", "It's interesting for we can talk to each other and have communication" and "we created a interesting sound when we moved around together in a group"

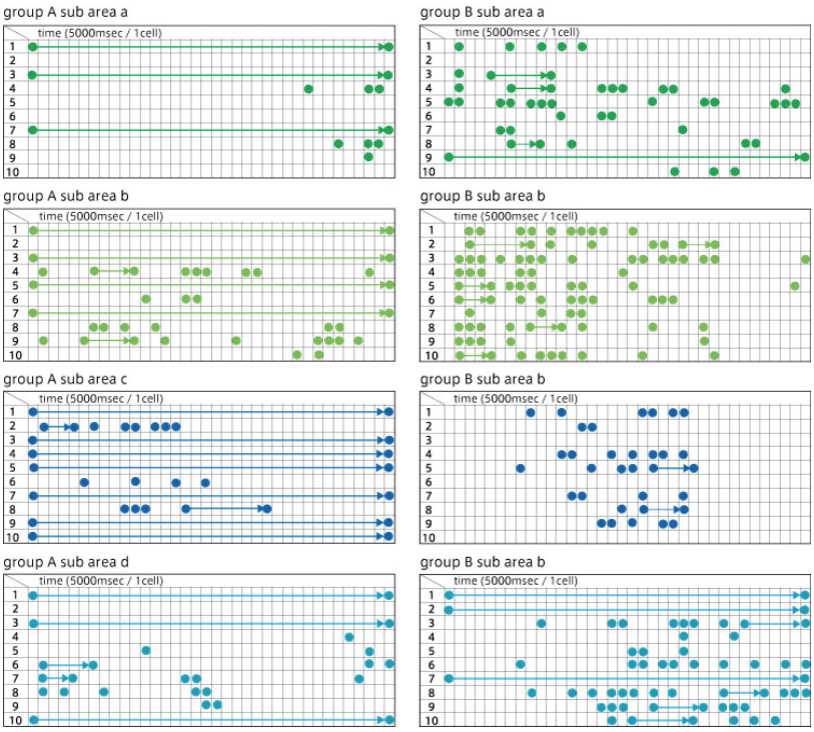

Fig.6: Visualization of remain files in term 2
(row: instrument ID, column: time transition per 5000msec)

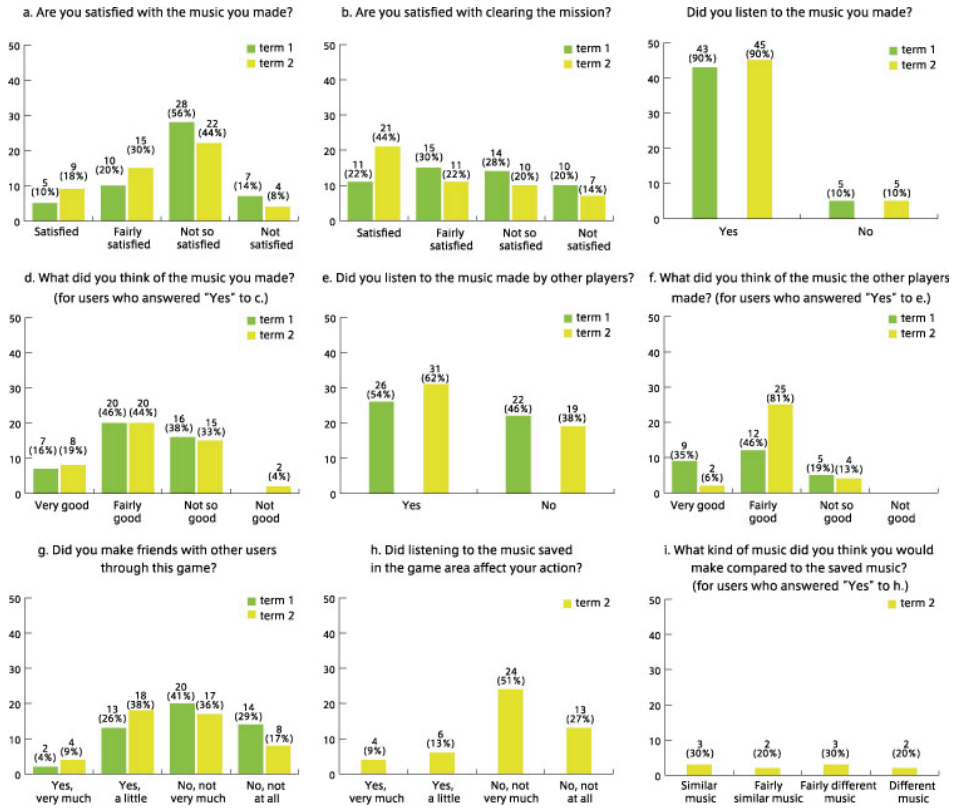

Fig.7: Questions and Results to the Questionnaire

4. Study

We study the 3 features of the traditional real space games that we adopted in this proposed contents. Also, we will state the development in the future.

Feature a: Simplicity in its introduction

In the proposed content, we designed the game by using only the mobile ad hoc network for PDAs with the application installed to realize simplicity in its introduction. Simplicity in its introduction close to the one for traditional real space games is realized by using only the mobile ad hoc network, in terms of being able to play wherever you want if a player and a place is ready.

But, there is a limit to designing games with only mobile ad hoc network. In the evaluation experiment, we isolated the public who are not participating in the game from the open space, so it is not an evaluation under an environment with many people and buildings. As long as 802.11b is being used, there is a need to design games considering the obstacles and communication failure by these obstacles.

Feature b: Reflection of its physical factor

In the proposed content, we adopted the method of creating sound based on the users' position, proximity and density to reflect physical factors. To be concrete, the creation of sound was made possible under the 2 conditions; 1) the area information agrees with each other and 2) can receive created messages between users. Also, we set a unique type of music for each area and gave each user a different instrumental set for each type of music to create sound. Therefore, the created sound is unique as users experience different areas each.

In 3.2, we examined and compared the remain files of each sub area which was taken from each groups' term 2. It is clear that a totally different sound is saved due to the number of users and their movement. From this result, it can be said that we realized feature b.

The limit of this method is that the reflection of physical factor is restricted to a macro factor of area. It can be much closer to the traditional real space games and realize a reflection of the physical factor more, if the micro factor, such as rocks, dents and hills existing in the area are reflected.

Feature c: Regional difference in rule and style

In the proposed content, we introduced the inheriting model of information in traditional real space games to create a regional difference. First the sound created by a user is saved in the location and this can be referred to by the users who participate afterwards. Then it can be said that the first user's experience was inherited to the next by changing the latter user's act by listening to the sound. Therefore, we assume that the experience is inherited if one changes their act due to listening to the sound.

In 3.3, we verified whether there is a difference in action. By examining the results of the questions a,e,f and g in each term, we came to a conclusion that there is a difference in the action between term 1 and 2. Also, according to question h, it can be said that it is an unconscious difference. As a result, a user's

experience affects other users' experience and changes their action unconsciously. Information is inherited as the action is different by listening to the sound. The repetition of this inheriting is assumed to create the regional difference.

The limit of this method is that the effect is indirect. This method can be stated as uncontinuous inheriting model. On the other hand, there is a direct inheriting model. This accelerates the creation of regional difference by playing the game which inherits continuously to one or all the attributes saved in the location.

Development in the future

As for the development in the future, a multilayer of interactions can be expected. In the present version, there is a problem that there are only 10 types of instrumental sets for each sub area, so if 11 or more people participate in the game, the assigned instrument overlaps. A multilayer of interaction can be realized by increasing the number of instrumental sets and improve it so that the users can create sound without overlapping.

Also, as a different method, the control of the coverage area of wireless LAN can be considered. In this experiment, we used the fixed and mobile terminals without controlling the wireless LAN. A multilayer interaction can be realized by changing the created sound due to the radio intensity or by adjusting the set up so that an interaction is made only when there is a fixed radio intensity.

5. Conclusion

In this thesis, we proposed a Pergame content ototonari which has the features of traditional real space games such as the simplicity of its introduction, the physical factor and the regional difference. In ototonari, we realized the simplicity of its introduction by designing the game using a PDA and its mobile ad hoc network. Also, we realized the reflection of the physical factor by creating sound through collaboration between users based on position, proximity and density of users in real space. Furthermore, we introduced a information inheriting model to realize the creation of regional difference. First, a user's experience was saved at the location as a sound data and was made possible for other users to refer to it afterwards. Then, a inheriting of information was confirmed as there was a difference in the users' action due to referring that information.

Ototonari is a Pergame that can offer a new game experience with computers by strictly adopting the features of traditional games. This creation of regional difference will especially bring a big impact in the field of entertainment computing called Pergames, as this concept was not seen in any of the existing Pergames.

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Reference

[1] Maerkurth, C., Cheok, A., Mandryk, R. and Nilsen, T.: Pervasive gaming: Pervasive games: bringing computer entertainment back to the real world. *Computers in Entertainment (CIE)*, Vol.3, No.3, ACM, 2005.

[2] Benford, S., Magerkurth, C., and Ljungstrand, P.: Bridging the physical and digital in pervasive gaming. *Communication of the ACM*, Vol.48, No.3, pp.54-57, ACM, 2005.

[3] Schneider, J. and Kortuem, J.: How to Host a Pervasive Game Supporting Face-to-Face Interactions in Live-Action Roleplaying. *Workshop on Designing Ubiquitous Computing Games, International Conference on Ubiquitous Computing (Ubicomp) 2001*, Atlanta, Georgia, Sept. 30 - Oct. 2 2001.

[4] Kaneda, Y., Minematsu, M., Saito, M., Aida, H. and Tokuda, H.: ANGEL: A Hierarchical State Synchronization Middleware for Mobile Ad-hoc Group Gaming. *International Workshop on Pervasive Gaming Applications at Pervasive (Pergames) 2004*, Linz / Vienna, Austria, April, 2004.

[5] Mount,S., Gaura, E., Newman, R.M., Beresford, A.R., Dolan, S.R. and Allen.M.: Trove: a Physical Game Running on an ad-hoc Wireless Sensor Network. In *Proceedings of the Conference on Smart Objects and Ambient Intelligence (SoC-EuSAI)*, pp.235-239,Grenoble, France, October, 2005.

[6] Bjork, S., Falk, J., Hansson, R. and Ljungstrand, P.: Pirates! - Using the physical world as a game Board. In *Proceedings of Interact 2001*, pp. 119-120, 2001.

[7] Benford, S., Seagar, W., Flintham, M., Anastasi, R., Rowland, D., Humble, J., Stanton, D., Bowers, J., Tandavanitj, N., Adams, M., Row- Farr, J., Oldroyd, A., and Sutton, J.: The error of our ways: The experience of self-reported positioning in a location-based game, *International Conference on Ubiquitous Computing (Ubicomp) 2004*, Nottingham, England, September, 2004.

[8] Chalmers, M., Barkhuus, L., Bell, M., Brown, B., Hall, M., Sherwood, S. and Tennent, T.: Gaming on the Edge: Using Seams in Pervasive Games, Second International Workshop on Pervasive Gaming Applications at Pervasive (Pergames) 2005, Munich, Germany, May, 2005.

[9] Smith, I., Consolvo, S. and LaMarca, A.: The Drop: Pragmatic Problems in the Design of a Compelling, Pervasive Game, *Computers in Entertainment*, Vol.3, No.3, ACM, 2005.

[10] Piekarski, W. and Thomas, B.: ARQuake: The Outdoor Augmented Reality Gaming System. *ACM Communications*, Vol. 45, No. 1, pp 36-38, ACM, 2002.

[11] Cheok, A., Goh, K., Farbiz, F., Fong, S., Teo, S., Li, Y., and Yang, X.: Human Pacman: A mobile, wide-area entertainment system based on physical, social and ubiquitous computing. *Personal And Ubiquitous Computing*, Vol.8, No.2, pp.71-81,Springer-Verlag, 2004.

[12] Norman,D.A.: The Psychology of Everyday Things. Basic Books, 1998.

[13] "ai-MATE". http://www.expo2005.or.jp/ml/fr/06/ (English)

[14] Ishida, T., Hisamatsu, S., Saito, S., Minami, M. and Murai, Jun.: Content Cruising System under Sparse Movements of Nodes. In *Proceedings of the 2004 International Symposium on Appplications and the Internet Workshops (SAINT2004 Workshops)*, pp.561-567. 2004.

[15] Flintham, M., Anastasi, R., Benford, S., Hemmings, T., Crabtree, A., Greenalgh, C., Rodden, T., Tandavanitj, N., Adams, M. And Row-Farr, J.: Where on-line meets on-the-streets: Experiences with mobile mixedreality games. In *Proceedings of The 2003 CHI Conference On Human Factors In Computing Systems,* pp.569-576, ACM, 2003.