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Gamification based Participatory Environmental Sound Collection Framework for Human Activity Recognition

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Abstract: Environmental sound has been considered as an efficient data source for human activity recognition during daily life. However, to collect a large amount of sound data for training from people is not easy work even smart phones that are usually used to execute programs responsible for the collection tasks have become ubiquitous devices nowadays. In this paper, we propose "Sonic Home," a participatory environmental sound collection framework based on gamification techniques to make it easy and efficient to collect training data of guaranteed acoustic fidelity and appropriate type labeling. This game will encourage users to record and upload environmental sound and evaluate the quality of sound data uploaded by others in order to obtain in-game money and sound related objects that are essential to continually build their houses. With sound data collected by this framework we can carry out some further work for sensing human's various activities with higher accuracy and more diversity.

Keywords: Environmental sound, training data collection, activity recognition, gamification, Sonic Home

1. Introduction

One of the general ways for us to recognize human activities is to speculate from sound. As we know, a person's daily life is surrounded by various kinds of sound. The types of sound related to a person's activities can be classified into speech sound, sound generated by human's activity (crowd noise, engine sound, water sound, appliance sound, etc) and that comes from the background of the person's location. Under normal circumstances, we can infer not only the activity but the thinking of a person from speech sound. However, in the other circumstances, we are only able to make it using the sound of activities directly or that related to the background information indirectly. For instance, we can say a person may be doing cleaning work when we hear noise generated by a vacuum and we can also guess he is inside a railway station and may be going to take or getting off a train as there is background sound of a train going by. Among these three types of sound, activities sound and background related sound are called the environmental sound, which we are trying to make use of to recognize human activity.

To apply machine learning for recognition, one of the most critical tasks is to collect as many labeled training samples as possible. In order to obtain robust recognition model with high accuracy, the method to collect training samples should satisfy three main requirements highlighted as high collection efficiency, good diversity and guaranteed quality of collected data. In old times, this task was usually depending on wearable devices [1] with sensors or some hand held devices such as a PDA (Personal digital assistant) [2]. As a result, the data collection task was often executed by few volunteers as collaborators [3] and this sort of collection mechanism might not be efficient enough taking the three requirements mentioned above into consideration. Fortunately, we are on the brink of a new era in the development of the ubiquitous mobile phones [4], which has made things changed by not just integrating various ubiquitous sensors inside, but also powerful enough computing capability to run even programs with complicated processes. Even though, the data collection is still not easy work. On one hand, different from the previous mechanism that has volunteers as collaborators, in some new open distribution platforms known as "App Stores," we have to find out ways to keep users continuing participating the data collection mechanism provided by us. On the other hand, we also have to work out methods to evaluate these collected data to ensure the data quality. In a word, we have to give the users reasons and motivation to perform quality guaranteed collection task for us without getting boring, which means a mutual benefit mechanism is in need. To implement such mechanism in our research, we utilize methodologies of gamification techniques for constructing a participatory environmental sound collection framework.

In this paper, we propose "Sonic Home," a social game with Android smart phones as clients, in which players are encouraged to record and upload environmental sound during their daily life to get in-game money or items to decorate their houses. At first, a user will just get an initial house frame with little stuff and if the user records and uploads a piece of labeled sound data, for instance, the sound of toilet flush, he will earn some "money" and a new "toilet" object that can be decorated in his bathroom. Though, the user is able to record and upload sound data with the same label for more than one time but will get less money, which means it is profitable for him to upload various sound data with different labels to make his house become a "real" house by pay-

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ing for lots of decorations such as a bed in living room or a shoe rack in the entrance room. Another way to get money or items is to make use of the social functions, such as making friends or another function that is more meaningful for us, evaluating the quality of the sound data uploaded by other users with respect to acceptable acoustic fidelity and appropriate sound type labeling. In addition to the core game design, we will also provide rankings and irregularly release some events such as promotions to provide more attractive contents to make users enjoyable and data collection efficiency.

As another topic apart from game contents, there are several issues, which we mentioned before, worth paying attention to:

- The continuity of game playing for users, noted as efficiency.
- The diversity control of collected sound data, noted as diversity.
- The mechanism for ensuring data quality, noted as quality.

As a convention, we will call them "The Three-Issues" during the following parts of this article.

In this paper, we introduce approaches to tackle the game playing continuity issue and sound data diversity control issue through gamification methods and a data reliability scoring method based on inter-users evaluation against the data quality issue.

The remainder of this paper is organized as follows: In section 2, we introduce the background of this work including related work of different training data collection methods introduced in some environmental sound based human activity recognition researches and those about gamification techniques. In section 3, we describe the approaches including how to apply gamification concepts in "Sonic Home" and methodologies to handle the previously mentioned three issues in detail. Section 4 introduces the architecture of the whole sound data collection framework with descriptions of application prototypes. Then in section 5, we try to discuss some potential research points not included in our approach currently. At last, we present the conclusion and some remarks of future work.

2. Related Work

2.1 Training Data Collection of Environmental Sound

Many research works have been concentrating on recognizing human activity by using environmental sound. For instance, in [4], Lu et al. proposed a general purpose scalable framework for modeling sound events on mobile phones called "SoundSense." "SoundSense" is powerful to be able to recognize not only environmental sound but also speech and music. However, as it is a standalone application just work locally on a smart phone, thus, this solution is not a participatory one, which means the environmental sound collected is usually from the daily life of one single user. Square up "The Three-Issues," "SoundSense" does not provide an ideal framework for training data collection because of the lacking of efficiency and diversity. Another example introduced in [5] showed an efficient way to collect training data by downloading audios from a professional audio sharing web site called "FreeSound" [6]. This method perfectly cleared issues of ensuring collection efficiency and diversity. Nevertheless, the evaluation of quality as the third issue depends on the equivalent mechanism provided by "FreeSound" of downloaded data. We can also assume that, if it is true that the difference between recording devices integrated in smart phones and others may result in some unexpected errors on acoustic fidelity, the use of data from third party may have potential quality risks. Other details we concern are that the "Freesound Open API" [7] with which to access data of the web site has several restrictions including the scope of access, credential limitations, possibility of termination of use and possible charge in future, etc that has a chance to make negative impact on long-term research. At last, context-specified researches like [8], which focus on recording environmental sound of a bathroom to recognize the human activities inside it, have the issues of efficiency and diversity as well.

2.2 Gamification Techniques Related Research

To construct a collection framework that satisfies all of "The Three-Issues," we became to take gamification techniques into account as many examples have been turned out to be successful attempts. In [9], an orientation guidance mobile application was introduced to help new students complete all of the orientations opened in the campus where the location information is unfamiliar to them. The application was integrated with a Google Map that described the overall location information of the campus and highlighted specified buildings where the students should get to attend orientations. This whole application was driven by an "**Achievement**" concept that a student completed an achievement meant to complete a task such as successfully arrived the building for orientations. As the game playing motivation, to accomplish the list of all achievements will not only help students attend orientations efficiently but also get familiar with locations in the campus quickly with fun. Another attractive example focus on monitoring noise pollution in urban environments mentioned in [10] introduced the way to use concepts following gamification techniques in order to continuously collect pollution information. With special attention to some general gamification concepts defined in [10], we list them as follows:

- **Status**: Users usually like to compare or share their progress and achievements with other users, to see who is in a better or worse position than others. To do this, it is necessary to split game progress in stages or levels, from easiest to hardest ones.
- **Access**: This concept encourages allowing users to unlock new features depending on their contribution or participation in the game. It is important to make these features exclusive enough to engage the user who achieves them more attached to the application.
- **Power**: With the transference of some power to some users, it is possible to encourage them to keep using the application. The power can be represented by letting them to do actions that are not allowed to users who have used less the application.
- **Stuff**: In addition to all functional concepts stated above, it is important to provide a set of free rewards, badges or gifts for users as an incentive to keep playing. Those items are attractive to users because they can make the difference with others.

As a summary, the listed concepts above including "**Achieve-**

ment" are in fact partially revealing some basic mentalities such as sense of accomplishment, curiosity, self-expression, competitive consciousness, etc of players in social games.

To describe these basic mentalities systematically, we made a brief study of **Bartle Test of Gamer Psychology** [11], in which players of multi-player on line games are classified into four characters based on Bartle's character theory [12]:

- **Achievers**: Players who prefer to gain "points," levels, equipment and other concrete measurements of succeeding in a game. They will go to great lengths to achieve rewards that confer them little or no game-play benefit simply for the prestige of having it.
- **Explorers**: Players who prefer discovering areas, creating maps and learning about hidden places. They often feel restricted when a game expects them to move on within a certain time, as that does not allow them to look around at their own pace.
- **Socializers**: There are a multitude of gamers who choose to play games for the social aspect, rather than the actual game itself. These players are known as Socializers or "Hearts." They gain the most enjoyment from a game by interacting with other players, and on some occasions, computer-controlled characters with personality. The game is merely a tool they use to meet others in-game or outside of it.
- **Killers**: They thrive on competition with other players, and prefer fighting them to scripted computer-controlled opponents.

As a conclusion, it is one of the keys to apply gamification techniques appropriately in a social game by figuring out our own concepts and methodologies that are capable of satisfying different types of players.

3. Approaches

3.1 "Sonic Home" In A Nutshell

"Sonic Home" attempts to implement environmental sound data collection for training, a common task in the way of gamification following game design concepts. One of the basic activities of players during the game playing is to record and upload environmental sound from their daily life to obtain items to decorate rooms that compose their houses. Another activity of users is to visit others' houses and evaluate the quality of sounds associated with items inside. Both of these two basic activities are contributing to the users' further game playing by obtaining in-game money, items or other resources, which will give users motivation to move forward under the mechanism of game systems. The basic outline is illustrated in Fig 1.

In order to keep users feeling exciting from different aspects during the game playing, which will meanwhile contribute to our sound data collection task, we propose some gamification concepts to achieve this objective. The following parts of this chapter are going to describe the concepts put forward in "Sonic Home" concerning the various types of players and "The Three-Issues."

3.2 Gamification Concepts

Before describing gamification concepts in "Sonic Home" in detail, we will at first elaborate the thinking contained in the game

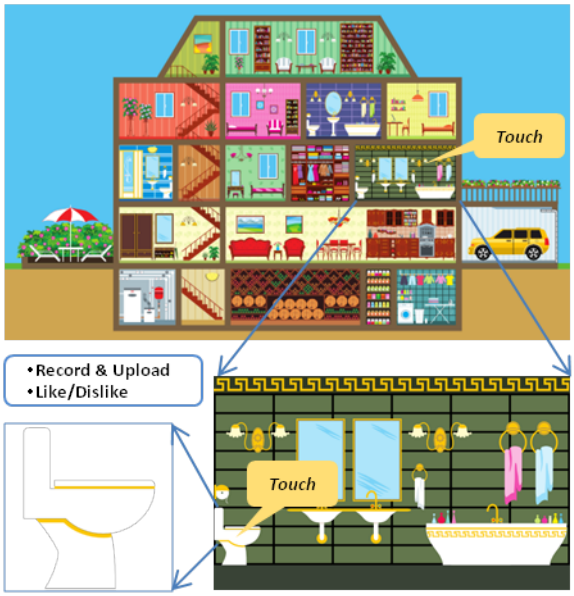

Fig. 1 "Sonic Home" in a nutshell.

design to illustrate an overview of it for giving better comprehension of the following parts. The basic thinking of "Sonic Home" is to provide mechanisms that fulfill "The Three-Issues" by making all of the four types of players enjoyable to keep their game playing motivation, which is meanwhile our expectation for it. In spite of some general gamification concepts summarized by related researches [9, 10], we think it is better for us to review these concepts' direct use in "Sonic Home" to recognize that some of them are appropriate for our case while others may not suit our vision in the current research. For instance, we prefer to implement achievements system to stimulate the mood of users to enjoy forward moving process and relaxed game playing without too much pressure caused by differentiation of status, which means few should have to feel frustration during the play. In addition, there are also some context specialized contents such as room decoration sense, that should be regarded as some specific concepts. Therefore, the concepts we put forward may be different from the general ones and described with some concrete examples instead of abstractions.

We classify gamification concepts of "Sonic Home" into two different types noted as "context specified concepts" and "common game playing concepts," of which the former is about most of the context specified features of the game design while the latter is about some common approaches widely used in most of other social games.

3.2.1 Context Specified Concepts

With the main target types of players rounded in parentheses, our context specified concepts are defined as following:

- **Collectors Temperament (Achievers, Explorers)**: One of the most important motivations of "Sonic Home" is to collect more in-game money and items to construct a splendid house of yourself. The initial house frame assigned to players is a small one with empties rooms that a scene of moving to into a new home. To enrich the decoration and design of each room and obtain various items as many as possible, players who have potential of **Achievers** and **Explorers**

may enthusiastically participate in the mechanisms provided by the game to satisfy their desire of temperament as collectors. As a case in point, a bottle of spices in kitchen or an umbrella hanging on the wall of an entrance room may not attract the attention of other players except for those called "collectors."

- **Pursuit of Degree of Completion (Achievers, Killers)**: Start from a small initial house frame, players who have pursuit of degree of completion may enjoy themselves by building up a super deluxe mansion eventually. The sense of accomplishment and honor inherent in this process is another important motivation for players who have potential of **Achievers** and **Killers**. "The richer content there is, the better" is a principle for us in game design with respect to not only players' satisfaction but diversity of sound we can collect. And what's more as the future work, in order to enable players to experience the building-for-completion process for more than one time without refactoring the existing finished house, we provide a "Works Garage" for keeping completed works. As we assume that people are always having the trends to create something new, we can say that the more players make use of the "Works Garage," the more sound data we can collect with both quantity and diversity.
- **Relationship Building (Socializers)**: The relationship building part, i.e. the social part, as the motivation of **Socializers** of a social game is undoubtedly important. Some basic functions such as making friends or visiting friends' houses are provided as well as the others social games. Furthermore, the relationship building in "Sonic Home" focuses on simulating how to make the event that friends as guest visit your house an interesting experience. When visitors represented by avatars are visiting others houses, the owner of the house will see them inside the rooms and interacting with objects, for instance, if someone is interacting with a toilet, suppose playing the sound of it, his action in the other players' eyes is a scene that avatar on the top of the toilet with a piece of message "He is enjoying this toilet." In addition, users can also evaluate the sound by touching "like/dislike" just like what they do during watching a video on YouTube. The evaluation made by players is quite important for us to build the reliability scoring mechanism that will be introduced in chapter 3.4 to determine the quality of collected sound. And Of course, players who make evaluation will receive rewards from the game system for appreciating their participation.
- **Virtual Reality (All)**: The feature that players are enabled to move objects in their rooms freely is the key to implement virtual reality to some degree. We prefer not to fix all of the objects in a room to predefined locations but allow players to customize the interior as they like not just to provide more flexibility but also the create the possibility to implement virtual reality, which means uses are able to decorate their rooms just like rooms of themselves in real life.
- **Sense of Beauty (All)**: The design or color theme of houses is another attractive point for all types of players. We try to prepare as more as possible design of house, room and objects with different color themes. One example of color themes is that some houses and the interiors may be designed with pretty pink color, which may be popular for female players.
- **Personality of Objects (All)**: In "Sonic Home," every single object (including house, room, item and even the background) can be named by players or upgraded to different advanced designs. Each object has an individual set of attributes including the name and description of design and a player with the nickname, for instance, "Takuya," can name his house "Takuya's Superb Castle" and the kitchen "Great Canteen of Maekawa" and even the toilet "Star Gate" without any limitation for personality. As extras, players can upgrade objects to some exciting designs such as changing the background of house to customized pictures from newly taken or existing photos in the device. We expect the personality function may make great contribution to interesting game playing for all types of players.

3.2.2 Common game playing Concepts

Besides the context specified concepts, those we call them common game playing concepts are efficiency with ability for enhancement of game playing. Some of these common concepts we use in "Sonic Home" are defined as following:

- **Achievements (Achievers, Explores)**: Achievement system as an elementary but essential element of game systems has a lot of efficacies. For new players, a tutorial like achievement system is capable of guiding them to get familiar with the basic game systems and commonly used options or menus in a step by step manner. Another case is to design some challenging achievements or quests for relatively veteran players who are interested in completing their achievement list or obtaining great rewards. A special case that we think of is whether to make some feature-unlock like achievement systems in which players have to stand for game feature limitations until they finally complete some achievements regarded as the key to unlock the next stage or function. This strategy is widely used in many games (not just social games) but some tips are needed to be taken into consideration before starting the design. One is not to lock up too many core features which will make players feel frustrate easily before they successfully unlock them but do it to extension features. This is important to make sure that both new players and veteran players will find the right ways to enjoy themselves with different expectation to the game system. Another tip is to ensure that the process to complete achievements is not some repeated work that will soon make all the players get boring. The last tip is not to make the whole achievements system visible under guidance but provide some hidden while interesting achievement events that should be fired in different ways illustrated as setting the location of toilet paper roll somewhere near to the flush toilet will complete a small achievement like "Good location setting for usability!"
- **Rankings (Achievers, Killers)**: The reason why we provide rankings in the game is based on several ideas. The aim of rankings is usually to give honors to active players who have made lots of contributions to the game and can also encourage players outside the list to perform better game playing

than before. In "Sonic Home," in addition to these purposes, we hope the high ranked players' works will give some inspirations to the others to improve the average level of works of the game.

- **Promotions (All)**: Promotions are able to stimulate enthusiasm of users to concentrate on the game playing in various ways. For new players, we present some long-term provided promotions of basic items used to help these users to get familiar with the game playing quickly with some easily reachable results. For veteran players, the promotions contain some special items usually expensive with discounting prices. Even more, promotions are commonly related to the real life such as festivals, which means players can decorate pumpkins on their houses during the Halloween promotion and get the dishes of turkey that can be put on their tables from Thanksgiving promotion.
- **External SNS Access (All)**: Some most popular Social Network Framework (SNS) have open Abstract Programming Interface (API) for developers to access resources of these frameworks like Facebook [13] and Twitter [14]. We can use these open APIs to implement a lot of functions such as user login with external registration authentication and uploading game playing information (game states or images of houses) to their personal profile of SNS, which may be regarded as an important point not only for **Socializers** but all other types of players as SNS sites have become such inseparable parts of the life of almost everyone.

We have taken great lengths to introduce each gamification concept of "Sonic Home" in detail. These concepts have shown almost all of aspects of the game design that how to satisfy different types of players and have illustrated the outline of how to meet "The Three-Issues." To explain and give deep analysis of why our concepts are able to make this social game a collection framework capable of high collection efficiency, good diversity and guaranteed quality of sound data with more details during implementation, the last three subsections of this chapter to complete this work.

3.3 Game Playing Continuity

Almost all of the concepts described in the previous subsection are defined with concern to the issue of game playing continuity. It is not the ultimate objective we try everything to satisfy of the four types of players but the means to keep their motivations of continuing game playing to be stable collaborators of our sound data collection. It is noteworthy that the access of external SNS that can share game contents with players' friends on SNS sites like Facebook and Twitter will not only increase the loyalty of active players but raise the popularity of "Sonic Home" to their friends who may be potential users of us in future. Another principle that game providers should keep in mind is that updating functions and contents of game irregularly is an efficient way to keep fresh feeling of veteran players that is applicable for both off-line and social games. Keeping game playing continuity is the basic while most important objective for social game designers and in our research, it is the direct way to ensure high sound data collection efficiency as well.

3.4 Diversity Control

We have several ways to implement diversity control of collected sound. One method is described in subsection "Pursuit of Degree of Completion," players will be encouraged to try to collect as many different types of items with various environmental sounds as possible, which will result in good diversity of sound data. However, it is possible that not all players will follow the right way we pointed to them but to record and upload some common sound many times for more in-game money and items. As to this case, one easy solution is that we will decrease the rewards for the same sound each time it is uploaded. Another issue is how to collect sounds not that popular for players. A possible way to solve the issue is to create promotions for items with these sounds, with which we are able to encourage players who are eager to earn large amount of in-game money and precious items to concentrate on collecting these sounds during a period of time. And what's more, we can list the collection of these sounds as the achievements so that players not need so much money but desire to complete more achievements for honor or sense of completion will help as well.

3.5 Reliability Scoring for Ensuring Quality

3.5.1 Overview

Recognition model built with low quality training sound data is likely to result in failure when judging the label of input sound for test. One case is that some data with low quality of acoustic fidelity may even confuse human to recognize the sound type let alone machine learning. Another case is that errors of labeling may easily lead to a recognition error.

Because we cannot evaluate a large quantity of sound data by ourselves, in "Sonic Home," we propose a mechanism called "Reliability Scoring" to ensure the quality of sound data collected by players with respect to acceptable acoustic fidelity and appropriate sound type labeling leveraging the subjective judgment of players. As a notice, we present players as "users" in this section for generality.

The basic reliability scoring mechanism is made up of three reliability factors that are based on some assumptions:

- **User Reliability Factor (URF)**: We assume that sound data collected by reliable players who are attempting to upload sound of acceptable acoustic fidelity and appropriate sound type labeling is reliable as well.
- **User Evaluation Reliability Factor (UERF)**: Suppose a piece of sound is evaluated as "good" by other reliable players is reliable.
- **Data Reliability Factor (DRF)**: A sound data segment that is apparently an sample of outliers compared to others with the same label will be considered not reliable.

In practice, however, the accuracy of reliability scoring factors may be affected by social relationships between players. As a case in point, the "friends" of a player have the trends to "like" sounds uploaded by him and the evaluations given by strangers are likely to be of objectivity and we name this case the result of "Relationship Impact." To obtain more reliable evaluations, we propose an extra factor for adjustment called "Relationship Impact Adjustment Factor" shorten for **RIAF**. The other parts of

this chapter will give the description of definition and calculation of each factor and show how to apply reliability scoring to training data used for building recognition model.

3.5.2 User Reliability Factor (URF)

As mentioned in "Relationship Building" concept previously, players are able to give "Good" or "Bad" ("Like" or "Dislike" in the game) evaluation to sounds of others to gain more in-game money or items. The evaluation is in fact the essential operation for our mechanism of reliability scoring. Based on the assumption of URF, we try to create a method to calculate the reliability factor of each user taking

- The evaluation from one player to another.
- The accuracy of evaluation of a player.

Consider $user_i$ has evaluated partial or all sounds belonging to $user_j$. For convenience, we define expression w_{ij} the evaluation from user "i" to "j" and illustrate "◯" for "Like" and "×" for "Dislike" in Fig 2.

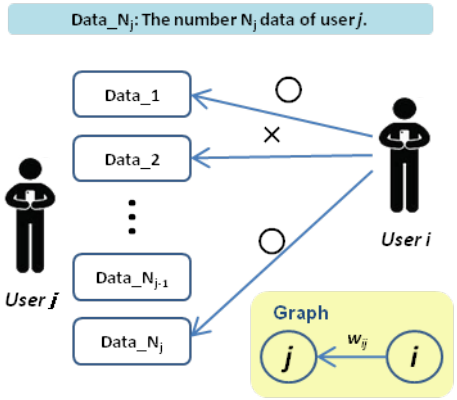

Fig. 2 The evaluation from user "i" to "j."

Suppose the number of "Like" from user "i" to "j" is n while that of "Dislike" is m and the **RIAF** is r_{ij} (the definition of r_{ij} will be described in subsection 3.5.5), then we can get $w_{ij} = \frac{n*(1-r_{ij})}{n+m}$. If we define the relationships between all users make up a directed graph E with users as nodes and evaluations as directed edges, then we can also calculate the evaluation accuracy (noted as y_i) of $user_i$ with the formula: $y_i = \frac{1}{S_i} \sum_{j:e_{ij} \in E} exp(-(w_{ij} - \overline{w_j})^2)$, in which S_i stands for the number of successor nodes of $user_i$ and $\overline{w_j}$ stands for the average evaluation from all users to $user_j$. The calculation means the more the evaluation from $user_i$ differs from the average, the more possibility that the evaluation accuracy of him is low. Furthermore, we define the URF_i of $user_i$ with the formula: $URF_i = \frac{1}{P_i} \sum_{j:e_{ji} \in E} w_{ji} * y_j$, in which P_i stands for the number of precursor nodes of $user_i$.

3.5.3 User Evaluation Reliability Factor (UERF)

Different from URF, UERF concentrates on the evaluation of every single sound data based on the evaluations from all other users to it. Follows the definition, we can calculate the UERF with the formula: $UERF_{i\_x} = \frac{1}{U_{i\_x}} \sum_{j:e_{ji} \in E} w_{ji} * y_j$, in which $UERF_{i\_x}$ stands for the UERF value of number x sound data of $user_i$ and U_{i_x} stands for the number of other users who have evaluated this sound. Another case that some sound data have not received enough evaluations to calculate efficient UERF, the URF of the user who is the owner of them can be regarded as the estimated UERF. We will also encourage players evaluate those have not been fully evaluated sound data through some gamification methods such as providing more rewards than usual.

3.5.4 Data Reliability Factor (DRF)

If there are still too few users available for providing efficient evaluations or even the number of users and evaluations are enough, it may not be reasonable to depend on users' subjective judgments completely. In addition, we define DRF that is able to evaluate data's quality from the view of outliers detection for the original sample set. This process is to make sound data with the same label a training set and perform leave-one-out cross-validation (LOOCV) by picking out one sample once and calculate the likelihood of it to the recognition model as GMM (Gaussian Mixture Model [15, 16]) built by the others. Thus, the likelihood is the DRF value of the picked out sample.

3.5.5 Relationship Impact Adjustment Factor (RIAF)

We hope that players will evaluate the sound data of whomever objectively all the time, however, the reality is something else like the saying "Love me, love my dog" that people are always trending to "Like" everything of their friends and show more objectivity to strangers, which may lead the evaluations between players and their "friends" to some errors. We define this case the "Relationship Impact" and to rectify the potential errors due to it while $RIAF \in [0, 1]$ is the factor to adjust effects caused by relationship impact. In the ideal circumstance that all players have objective adjudgement, the RIAF will always be 0, which means no relationship impact exist that will affect the reliability of evaluations. If a player trends to give different evaluations to his "friends" and "strangers," we will give a higher RIAF to his evaluations to make them be as accurate as possible but a penalty may be given to him that will decrease his URF. Of course, both of the RIAF and penalty of URF are dynamically calculated and users may make changes to them by giving more objective evaluations. Another solution as a game function is to recommend sounds waiting for evaluation that belong to strangers to players with higher rewards to encourage them perform more objective evaluations. In practice, we can create a public marketplace that shows sound items have not yet been evaluated to evaluators who are interested in obtaining rewards. To erase RIAF between items providers and evaluators in this marketplace, items will be provided and evaluated anonymously.

3.5.6 Applying Reliability Scoring to Training Samples

In the last subsection of the topic of reliability scoring, we introduce how to apply it to training samples to achieve the objective that increase accuracy of recognition model. To calculate the reliability score of each sample sound data, we simply multiply URF, UERF and DRF: $score = URF * UERF * DRF$. We then normalize all of the scores of samples with the same label and assign a weight to each feature vector as MFCC (Mel-Frequency Cepstral Coefficients as feature, which is designed to mimic human perception [17]) of a sound: $weight_i = normalized(score_i)$, in which the $weight_i$ stands for the weight of number i sample of the training set. At last, we will build a GMM as the recognition model for this subset of training data with these weighted samples.

4. Architecture & Prototype Implementation

4.1 General Architecture

This subsection will introduce the general architecture of "Sonic Home" as a Client/Server architecture with Android smart phones as client devices, the outline and all of the modules of which are illustrated in Fig 3.

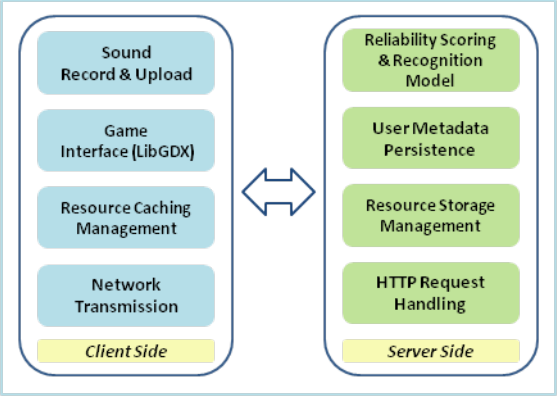

Fig. 3 General architecture of "Sonic Home."

Most of the game logics are included in the client side that is responsible for recording and uploading of sound, rendering of game interface and handling user action, management the caches of resources (PNG texture images, MPEG sound clips, etc) in the device's external storage (i.e., usually a secure digital card) and perform network transmission to send HTTP requests to the remote server. Users are able to touch objects to fire events that with different functionalities while they need to input some text instead of just touching something in some cases such as naming objects as they like which is a function introduced in the concept of "Personality of Objects." To render the game interfaces, we use an open source cross-platform game engine called "LibGDX" [18], which has powerful libraries and useful tools for creating 2D/3D games for almost all of the popular platforms including smart phones (Android, iOS), desktops (Windows, Mac, Linux) and HTML5. For the remote server, we put the code of server side in one of the servers managed by our laboratory. The server side is capable of creating users graphs for reliability scoring and building recognition model (i.e., GMM) for uploaded environmental sound data, persistence of users' metadata to the database, management of the storage of resources and HTTP request handling.

4.2 Prototype Implementation of "Sonic Home"

The prototype implementation of "Sonic Home" is still under progress currently with some infrastructures completed while game interface, reliability scoring mechanism and recognition model building are under construction illustrated in grey color in Fig 4.

After a user launched the game client application from Android device, the game at first loads locally stored meta data of user information such as a user ID, then send a request with an action called "load user info" to load all of the user's meta data including the definition of his house represented in the format of JSON

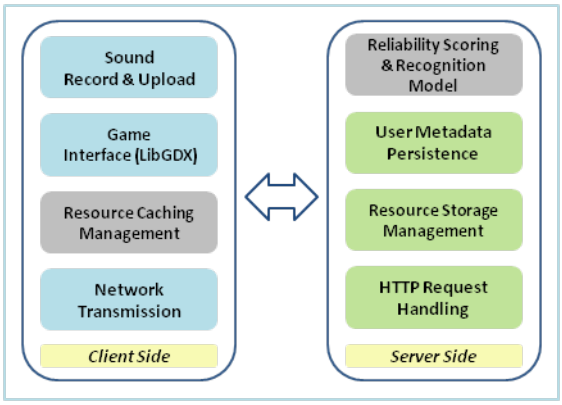

Fig. 4 Current implemented modules.

(JavaScript Object Notation), which contains all of the essential information for rendering the house such as offset coordinates, scaling rate, definitions of rooms, etc. The texture image ID and sound clip ID of each item in the rooms are also contained in the house definition. Then the game controller will have a check of whether the resources (image and sound) needed to be loaded exist in the local caches. If not, send extra HTTP requests to load these resources from the remote server and store the downloaded data into caches for later loading, otherwise, just load them directly from caches. All of the loading processes are finished during the several seconds' display of the splash image. After all of the resources loading are completed, the screen will change to show the house of user shown in Fig 5.

Fig. 5 Game interface of house.

In the rendering screen of house, users are able to touch whichever room to display the room individually shown in Fig 6, in which users can perform further operations such as recording environmental sound related to the corresponding type of object. If the current rendering screen of room belongs to someone else, users can then play the environmental sound of an object and choose to "like" or "dislike" it.

As the next part of current development, we will implement all of the gamification concepts introduced in this paper to make "Sonic Home" playable and carry out exhaustive evaluation methods for our approach.

5. Discussions

In this chapter, we mainly discuss the possible extensions of "Sonic Home" in future in order to increase the diversity of collected sound data as indoor sound is just part of all environmental

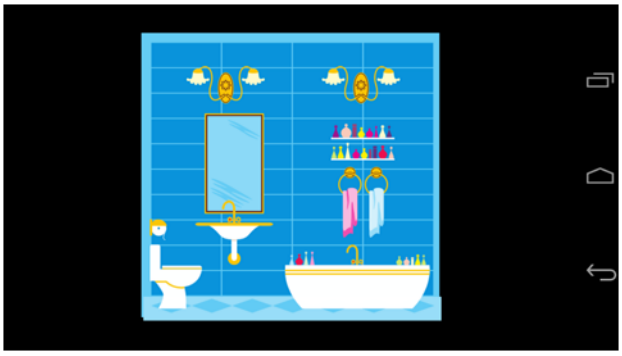

Fig. 6 Game interface of room of toilet.

sound we can hear in real life. To enable our sound data collection framework to handle more general cases. We are planning to extend the contents of the current social game to include transportation sound such as engine sound of vehicles, sound of passing train and that of aircrafts. In addition, we also plan to enable the game to collect nature sound of waterfall, sea waves, wind, rain, thunder, jungle, etc. Moreover, sound of animals such as dogs, cats, birds, insects, etc are also listed as part of future work.

Of course, to add more outdoor sound into the game we have to prepare designs and scenes for the corresponding contexts as well such as bus/train stations in a town or different sceneries of wild. Another point need to be taken into consideration is that during outdoor sound collection, location information may be useful, with which we can power some location based event or social functions. For instance, players may be curious of sound from places that near to him or he hope to go.

As the scope of the game including outdoor contents will largely exceed the current indoor version, we prefer to rename the extension that comes in future from "Sonic Home" to "Sonic Life" at last.

6. Concluding Remarks

In this paper, we presented an approach to create a mechanism leveraging gamification techniques for the collection of environmental sound data for human activity recognition by proposing a social game called "Sonic Home," which is designed to solve problems caused by what we called "The Three-Issues" that should pay attention to during a sample data collection task. To keep the motivation of different types of players of this social game, which is equivalent to ensuring stable collaborators for the collection task, we defined various gamification concepts with respect to both context specific circumstances and general game playing. To obtain sound data of not just large quantity but guaranteed quality, we described our method to evaluate collected sound data that called "Reliability Scoring" in detail with special attention to potential errors may be caused by "Relationship Impact," an issue that is prevalent in social networks. We also described the general architecture of our solution and the current status of implementation of the prototype which is still under progress. At last, we discussed some possible extensions of "Sonic Home" which may largely increase the diversity of sound data that the game can collect in future.

Developing gamification based solutions for general task is a new and interesting topic including issues of both researches related and game playing related. According to our experience during this research, we think the key point to successfully making gamification contribute to the research lies in applying game design elements to accomplish the main task of research without being addicted to game development excessively that may result in deviation from the main purpose.

As for the future work, we will at first complete a fully functional prototype as the trial version with users of small groups such members of our laboratory. During this early trial, we will collect as many as feedbacks as possible for the next stage of development and work out methodologies for the evaluation of the whole approach. As the next phase of research, we will concentrate on implementation of newly added functions and extensions for the preparation to release this game on "Google Play" in order to engage large scale experiment with users from the entire world.

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