Music Recommendation System for Public Places Based on Sensor Network

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Summary
Recently, there have been several studies about personal music recommendation system on the internet and personal computer environment, but the music recommendation system for public places has not been studied. In this paper, we study a music recommendation system based on a sensor network in public places such as highway rest places, parks, huge marts, etc. The proposed system includes five modules consisting of sensor nodes, sink nodes, host, music database, and remote control module. Sensor nodes are installed at places where people are coming and going frequently. The information sensed by sensor nodes is transmitted to the host through sink nodes using RF communication, and then the host computes the density of people from this information. In order to choose a music that best matches the current situation from our music database, several variables such as the density of people, season, weather, and time are used as main parameters. We also evaluate and analyze the accuracy of this system through an experiment environment.

Key words:
Music Recommendation System, Sensor Network, Bayesian Network, Music Recommendation Algorithm.

1. Introduction

Recently, the evolution of ubiquitous technologies has been spreaded progressively into our life, and we think that even a person who has no concern in this area may listen this term. The technologies such as RFID and wireless sensor networks have been used in order to implement the ubiquitous environment. For example, these technologies are used in the area of home automation, office automation, building management, military application, etc. Currently, a variety of applications using such a technology have been absorbed quickly in our life.

With the development of information technology and data compression, musics with high quality are stored on various medias, and then provided through the internet and personal devices (MP3, iPod) according to the choice of users. However, it is very difficult for users to remember and know a location in their computers where the music is stored at. They also have difficulties in choosing their favorite musics. There have been several researches about a music recommendation system so that users can choose music items that best meet their needs and preferences [1,2]. Microsoft's Windows Media Player and Apple's iTunes are an example of commercial music software. A search engine on most music recommendation systems depends on how users are frequently listened their favorite musics [3-5]. In addition to the number of frequencies listened by users, several researchers recently proposed algorithms which recommend a music considering the current situations such as the age and sex of users, season, weather, time, etc [6,7].

This paper considers a music recommendation system based on a sensor network in public places where people are coming and going frequently. The proposed system is to purpose what best meets the satisfaction of a lot of people than an individual when we compare the previous results with ours. For example, public places include highway rest places, parks, huge marts, etc. In these places, there are many people coming and going frequently in a short time. If we play a music that best matches the current situation such as the number of people, season, weather, and time, we hope that the place will be satisfied by most of the visitors. However, most public places are to play a music chosen by an operator randomly not considering its surrounding environment. Therefore, such places are not giving a good mood and high quality service to the visitors on account of the above reason.

This paper proposes a music recommendation system for public places based on a sensor network. The proposed system consists of the following five modules: sensor node, sink node, host, music database, and remote control module. A sensor node is installed at a place where many people are coming and going frequently. The information sensed by the sensor node is transmitted to the host through a sink node using RF communication. The host computer computes the density of people using the information collected from all of the sensor nodes. The host also plays a music that best meets the current situation considering season, weather, and time in addition to the density of people. This procedure is repeated automatically at regular intervals adapting the surrounding environment. The remote control module supervises various operations of the host computer using hand-held devices at a remote place. It includes remote operations such as monitoring the current music status, playing a new music, stopping the current music, etc.

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The remainder of this paper is organized as follows. In section 2, we review the previous results about music recommendation system, and the concept and algorithm of the proposed system are described in section 3. The implementation and evaluation of the proposed system are explained in section 4. Finally, we conclude with some final remarks.

2. Related work and background

In the previous music management software, a user can manage and retrieve efficiently musics by meta data including artist, the name of music, and genre. There have been several studies in order to recommend a music to users in addition to these items. Commercial softwares such as Window Media Player and iTunes recommend a music to users based on the frequency and time of a music users already listened. However, these softwares have a disadvantage it is difficult for users to satisfy fully because they recommend a music using simple items. The Bux Music site in Korea recommends musics to users according to age, time, and theme [8]. The Last site in America recommends a music that users want to listen based on a profile collected from users [9].

The techniques such as collaborative filtering, content-based recommendation, and hybrid approach combining two methods have been considered a mainstream for recommender systems for a long time [10-12]. In [13], a music recommendation system is proposed considering the situation information on a home network. In the paper, a music that users want is recommended reflecting the tendency and situation information of users based on content-based recommendation technique. Korpipaa et.al proposed a method for recommending a music based on fuzzy Bayesian network [14]. A music replay device is developed using a sensor that can sense the heat of human body, but this device is not a music recommender because it plays a music as only the device senses someone [15].

As mentioned above, the previous music recommenders are based on personal tendencies on the internet and personal computer environment. The main factor out of personal tendencies is the frequency of a music that users listen, and in addition to this item, the surrounding information such as sex, age, weather, season, etc are considered. There exist some kind of music devices with only play and replay operations as a sensor is detected, but these devices can not be seen as some parts of a music recommender. We study a music recommendation system for public places where many people are coming and going frequently in a short time, and our music recommender uses the concept of sensor network. To the best of our knowledge, the proposed system is to be considered as the first music recommender for public places.

3. The proposed music recommendation system

3.1 The architecture

This section describes the architecture of an adaptive music recommendation system based on a sensor network. The proposed architecture is shown in the figure 1. As shown in the figure, the proposed system consists of sensor module, sink module, host module for recommending and playing a music, music database management module, and remote control module. A sensor node transmits sensed information to a sink node using RF communication as the movement of people is detected. The sink node collects the information transmitted from sensor nodes, and transmits it to the host computer. The host computer computes the total number of people using the information received from the sink node, and then chooses a music that best meets from music database considering the number of people, season, time, and weather.

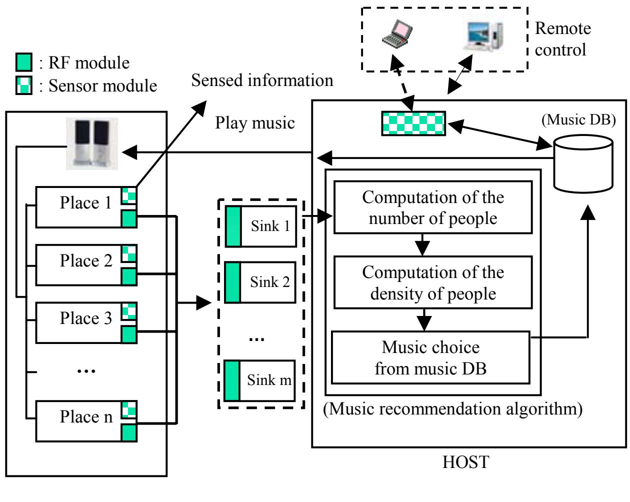

Fig. 1 The architecture of the proposed system

The details of the algorithm will be explained later. The definition of each module is as follows.

◦ Sensor module: a sensor is installed at a place where people are coming and going frequently. This module is used for sensing people, and RF device is attached to each sensor.

◦ Sink module: a sink module is an interface between a sensor and the host computer. That is, a sink module collects the information received from sensor nodes, and transmits it to the host computer.

◦ Host computer: this module computes the number of people using the information received from sensor nodes,

and chooses a music from music database that best meets the current situation considering the number of people, season, weather, and time.
◦ Music database: this module includes the musics of a variety of genres, and a music has the following attributes: the number of people, season, weather, and time.
◦ Remote control: this module monitors the status of the host computer using hand-held devices such as PDA, and has various operations for manipulating the host computer. The module uses the interface such as RF communication and wireless network.

The figure 2 shows briefly an operation flow about the proposed music recommendation system. If there are no people at the places where sensors are installed, the system do not play a music and will be waiting. In this system, a sensor can be deployed more than a place according to application area. The information of people sensed from the sensors is transmitted to a sink node using RF communication, and then the sink node transmits the collected information to the host computer. The host computer computes the density of people in the public place based on the number of people collected from each sensor. The density of people is represented by a value between 0 and 1, and it means the density about the total number of people coming and going at a place for a given time. The more the value is near 1, the more the density of people is higher.

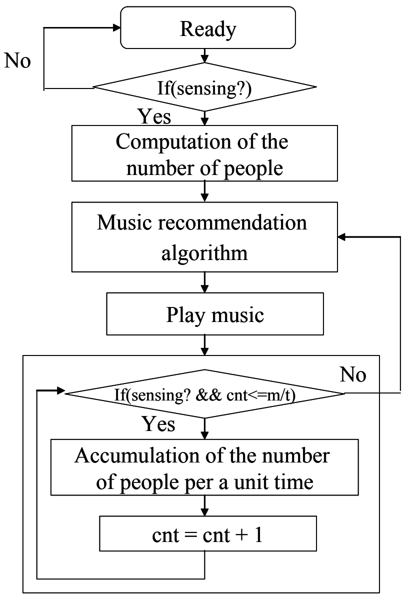

Fig. 2 The flow diagram of a music recommendation

The proposed system uses the density of people per a unit time, season, time, and weather as the parameters in order to choose a music from music database that best matches the current situation. We define a period as *m* and a unit time as *t*. The proposed system collects the status of people *m/t* times at intervals of a unit time for a period in order to increase the accuracy of the number of people. It also computes the density of people using the average and standard deviation of data collected for a period. Each music item in our music database has the following attributes: the file name and title of the music, season, time, and the density of people. In this paper, we assume that the values on the attributes of each music item in music database are already given by professional music artists.

The figure 2 shows the flow diagram for playing a music in the proposed system. As shown in the figure, the current density of people is compared to the previous density. If two values are equal to each other, the current music is played continuously, and otherwise a music is chosen considering the current situation according to the parameters. When a music is playing, the music have to keep for a given time in order to minimize the frequent retrieval of database due to the density of people.

3.2 The algorithm

3.2.1 The density of people

It is very important to compute efficiently the density of people because the proposed system is used at a place where people are coming and going frequently. This paper considers two situations to compute the density of people. First, we consider a situation in which all of the sensors are deployed independently each other. In this case, the summation of the number of people collected from each sensor is the total number of people as a sensor is independent to another sensor. Second, we consider a situation in which there exists a dependency among sensors. For example, if there are two sensors with a dependency and a person who already detected by a sensor goes through another sensor, the total number of people will be counted two times.

Let *S* be a set about the number of people collected from each sensor node. If we have *n* sensors, the set *S* is denoted as $\{s_1, s_2, \ldots, s_n\}$. Where, s_i means the number of people received from the *i-th* sensor for a unit time. We first consider a situation in which all of the sensors are independently each other. Then, the total number of people can be computed by equation 1, which divides total summation into 2 because a sensor can not identify that a person is coming and going.

$$Total\_people = \frac{1}{2}\sum_{i=1}^{n} s_i \qquad (1)$$

We next consider a situation in which there exist dependencies among sensors. For example, we suppose that there are two sensors at a rest room and a restaurant at a highway rest place. In this case, some people can stop by the restaurant after visiting first the rest room, and some people can do it in the other way. Because a person is sensed by two sensors at this situation, the equation 1 can not be applied directly. This paper uses a Bayesian network inference for solving this problem with a dependency. The Bayesian network consists of directed acyclic graph(DAG) with multiple nodes [16]. In DAG, a node represents the status of an event, and a link denotes a dependency relation. If there exists a link from a node *x* to a node *y*, *x* is called parents of *y*, and *y* is dependent to *x*. The Bayesian network is based on probability. If we define random variable as $\{x_1, x_2, \ldots, x_n\}$, the joint probability can be computed by equation 2 [17].

$$P(x_1, x_2, \ldots, x_n) = \prod_{i=1}^{n} P(x_i \mid Parents(x_i)) \qquad (2)$$

If there are dependencies among sensors, the equation 1 and 2 is applied simultaneously to compute the total number of people. The dependencies among sensors depend on application area of the proposed system. As mentioned above, let *S* be the set on the number of people collected from sensors that are at the difference places, and let *E* be the set of links representing a dependency among nodes. The following example shows a situation in which there are five sensors and there exist two dependencies among sensors. An element in *S* corresponds to a node.

$$S=\{s_1, s_2, s_3, s_4, s_5\},\ E=\{<s_2, s_4>, <s_3, s_5>\}$$

In the example, s_4 and s_5 are dependent to s_2 and s_3, respectively, and the others are independent each other. If there is no dependency among sensors, the total number of people can be computed by equation 1. However, because this example has two dependencies, $<s_2, s_4>$ and $<s_3, s_5>$, the total number of people must be computed considering two conditional probabilities as follows: $P(s_4|s_2)$ for $<s_2, s_4>$ and $P(s_5|s_3)$ for $<s_3, s_5>$. The equation 3 shows an expression in order to compute the total number of people at this situation.

$$Total\_people = \frac{1}{2}\{\sum_{i=1}^{5} s_i - (s_2+s_4)P(s_2,s_4) - (s_3+s_5)P(s_3,s_5)\} \qquad (3)$$

Where, $P(s_2, s_4) = P(s_4|s_2)P(s_2)$, $P(s_3, s_5)=P(s_5|s_3)P(s_3)$

The sensor used in this paper detects just a time when several people pass it through together at the same time. Also, as only the sensed information per a unit time is considered, the before and after information is ignored. We now will explain how to compute the total number of people considering this problem. Let *m* be a period, and let *t* be a unit time. The proposed system collects the number of people from all of the sensors repeating *m/t* times per a period. *m* can be chosen as an integer that is divisible by *t*. The following algorithm computes the total number of people considering all of the situations explained above.

<Algorithm : Counting people>

1. For *k=1* to *m/t*
   IF (all the elements in *S* are independent) THEN
   // p_k is the number of people in the *k-th* unit time
   Compute $p_k = \frac{1}{2}\sum_{i=1}^{n} s_i$
   ELSE
   Compute p_k considering dependencies among elements in *S*
   // p_k can be computed in the way like the equation 3
   End for

2. Compute the average(*avg*) and standard deviation(*sd*) for $p_k (1 \le k \le m/t)$
   $avg = average\ (p_1, p_2, \ldots, p_{m/t})$,
   $sd = standard\_deviation\ (p_1, p_2, \ldots, p_{m/t})$

3. Compute the average of p_ks such that p_k is $(avg - sd) \le p_k \le (avg + sd)$ in $\{p_1, p_2, \ldots, p_{m/t}\}$. This value is used as the total number of people for a period.

Let *T_person* be the total number of people for a period computed in the above algorithm. This paper uses the density of people instead of the number of people. We define *max_person* to the maximum number of people in order to compute the density of people. The value of *max_person* depends on an application area, and can be set by a system manager. Let *P_density* be the density of people. This value can be computed by the following equation 4. The table 1 shows the density distribution according to the number of people. This table can be changed depending on application area. The density of people has a value between 0 and 1, and the more the value is near 1, the more the number of people increases.

$$P\_density = \min\{\frac{T\_person}{max\_person},\ 1\} \qquad (4)$$

Table 1. The density distribution

Density	Meaning
$0 \le P\_density \le 0.2$	Very small
$0.2 \le P\_density \le 0.4$	Small
$0.4 \le P\_density \le 0.6$	Normal
$0.6 \le P\_density \le 0.8$	Large

$0.8 \le P\_density \le 1.0$	Very Large

3.2.2 Situation information and music database

In this paper, the density of people is a very important parameter in recommending a music to users, and several parameters such as season, weather, and time are used in addition to the density of people. The information of season and time can be obtained directly by the host computer without the help of additional devices. The season is classified into spring (Mar.～May.), summer (Jun.～Aug.), autumn (Sep.～Nov.), and winter (Dec.～Feb.). The time is divided into morning (6:00～12:00), afternoon (12:00～18:00), evening (18:00～24:00), and midnight (24:00～6:00). The time can be divided in more details according to the surrounding environment. The weather can be obtained directly by the weather forecast center.

The structure of our music database consists of the fields such as music file name, season, time, weather, and the density of people. The field of "music file name" means a path including a file name that a real music is stored, especially MP3 file. The field of "season" includes the information suited to this music such as spring, summer, autumn, and winter. In the same way, the fields of "time" and "weather" include the information of the current time and weather suited to this music. The density of people is represented by a value between 0 and 1. If this value is 1, it means a maximum density. We suppose that the related data of fields in our music database is already given by a music artist.

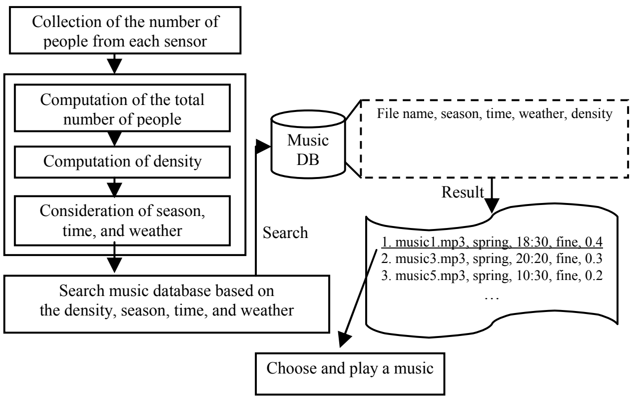

Fig. 3 The procedure of choosing and playing a music

The figure 3 shows a procedure for looking up our music database using these parameters, and playing a music that best matches them. For example, let us consider the following situation: the density of people (0.4), date and time (21/05/2006, 18:30), and weather (fine). Then, our music recommender searches the music database based on the set of the following parameters, (the density of people, season, time, weather) = (0.4, May, 18:30, fine), and chooses music items having information similar to these parameters. Finally, the best matched music out of these music items is chosen and then played.

3.2.3 The algorithm for playing a music

```
Procedure Music_Paly_Based_on_Sensor

// m means a period, and t means a unit time.
1. Initialize the communication environment between the host
   and sink nodes.
2. Choose and play a  music considering the current situation.
3. Wait until sensors are operated.
4. while (1) {
5.   units = 0;
6.   Initialize the timer.
7.   do {
8.     if (a people is sensed) {
9.        if (music player is not operated) {
10.         Prevent music player from playing a music.
11.         Play a music that best meets the current situation.  }
12.       else {
13.         if (the value of the timer is equal to a unit time) {
14.           Save the number of people sensed.
15.           Initialize the timer.  }
16.           units = units + 1;  }
17.    else {
18.         Decrease the timer if there is no a sensed value.
19.         if (the value of timer is equal to 0) {
20.           Initialize the timer and sensing counter.
21.           Stop music player.  }
22.    }
23.    Increase the value of the timer.
24.  } until (units == m/t)
25. Compute the total number of people for a period using the
    algorithm <counting people> described in the section 3.2.
26. Compute the density of people using the total number  of
     people, equation 4, and table 1 in the section 3.2
27.  If (the density computed above is equal to the current one)
28.       Keep playing the current music.
29.  else {
30.       Choose and play a music that best meets the current
          situation using the following parameters: the density of
          people, season, weather, and time.  }
31. }
```

Fig. 4 The music recommendation algorithm based on a sensor network

Our music recommendation algorithm based on a sensor network is shown in the figure 4. In the algorithm, the line 1 initializes the communication between the host and a sink. The lines 3～24 show a procedure for operating our music player when one of sensors is operated. In these lines, several variables such as the timer and sensing counter are used, and then the music player is operated and stopped according to the current situation.

The lines 13～16 check and store the number of people sensed by all of the sensors for a unit time, and a unit time is denoted as 30 seconds in this paper. The lines 25～30 collect data about the number of people for a period, and compute the density of people using these data. Finally, a music is chosen and played.

4. System implementation and evaluation

4.1 Experiment environment

The table 2 shows the list of hardware and software used to implement and evaluate the proposed system, which consists of sensor node, sink, host, music database, and remote control module. Two Embedded boards [18] are used to compose the host and remote control module. The communication between the host and remote control module is done by RF devices attached to the embedded board. The infrared sensors with RF communication also are used, and the information collected from sensor nodes is transmitted directly to a sink node. We used Arm Cross compiler in order to implement a program performing to the host computer, and the music player is implemented by Bash Shell. The EZ_esto tool is used to develop a program performing to a sink node and a sensor node.

Table 2. The list of hardware and software

Hardware	Software
- Infrared sensor module: 3 - Sink node : 1 - LETOK-X255 board : 2 - Speaker	- cdt-arm-binutils-2.14-2 - cdt-arm-linux-headers-1.0-2 - hdparm-5.2-4 - cdt-arm-glibc-bootstrap-2.3.2-2 - cdt-arm-glibc-target-2.3.2-2 - cdt-arm-gcc-3.3.3-2 - redhat 9.0(kernel 2.4.20) - EZ-esto v1.0

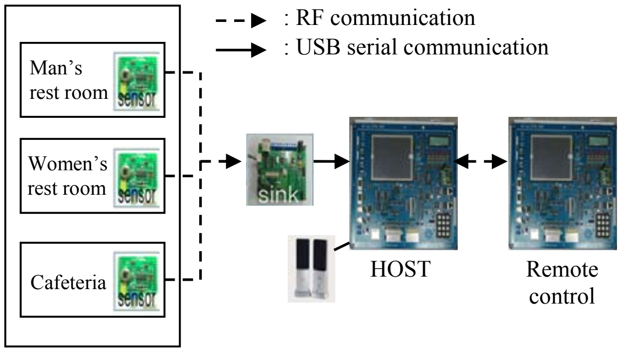

Fig. 5 The experiment environment

In order to evaluate our system, we implemented an environment like a highway rest place as shown in the figure 5. The experiment is performed considering the following two situations. First, two sensors are installed at a men's rest room and a women's rest room, and we also suppose that the two sensors are independent each other. Second, three sensors are installed at a men's rest room, a women's rest room, and a cafeteria. In this case, we suppose that there are dependencies among sensors located at two rest rooms and the cafeteria. As shown in the figure 5, RF communication is used between a sensor node and a sink node, and the communication between the host and a sink node uses USB communication interface. The host computer includes music database and speakers. In this experiment, we used an embedded board with RF device as the remote control module.

4.2 Communication protocol

4.2.1 Communication protocol between a sensor and a sink

The ZigBee standard, IEEE 802.15.4 MAC [19, 20], is used as the communication protocol between several sensors and a sink node, and a sensor transmits an information sensed to a sink node using RF device. The ZigBee communication is a low-power, short-distance wireless standard that has great possibilities in applications from home automation to industrial. This paper uses the frequency bandwidth of 2.4 GHz.

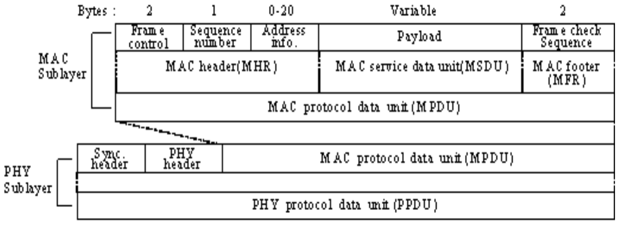

Fig. 6 The packet structure of IEEE 802.15.4

The figure 6 shows the packet structure of IEEE 802.15.4 used in PHY Layer and Mac Layer. This paper uses MSDU (MAC Service Data Unit), Payload field. A sensor makes a packet as shown below, and puts it into Payload field. Then, RF device attached to the sensor sends MPDU to a sink node.

1byte	1byte	1byte	1byte	1byte	1byte	variable	1byte
Node ID	Packet Type	Length	Sensor ID	ADCH	ADCL	…	Padd -ing

Node ID : ID of a sensor node
Packet Type : The information of packet type
Length : The number of sensors
Sensor ID : A sensor type
ADCH : ADC value of a sensor(High byte)
ADCL : ADC value of a sensor(Low byte)

For example, if the sensor ID at men's rest room is 32 and the sensor detects a people, the sensor puts 32 into sensor ID field and stores the detected data into ADCL field. Then, the packet made by the sensor is sent to a sink node by RF communication. The sink node checks if the received packet has the format of sensor packet, and converts it to the pMsdu stream of a byte. The sensor ID is stored in pMsdu(2), and the detected data are put into ADCL field using pMsdu(5).

4.2.2 Communication protocol between a sink node and the host

A serial communication is used between a sink node and the host. The sink node and host are connected by USB devices, and FDTI for a serial communication is used. The serial communication among two devices is set up by 8,400 baud, 8 data bit, 0 parity bit, 1 stop bit, no flow control. The sink node adds the value received from a sensor to the previous value with the same ID. This procedure is repeated for a unit time, 30s, and then the accumulated value is transmitted to the host.

4.2.3 Communication between the host and remote module

Two embedded boards, LETOK−X255, are used for the host and remote module, and RF communication device is attached to each board. The embedded board uses a serial interface for RF communication. In the embedded board, RF device is connected to STUART of the host computer, and its speed is set up by 9600bps. The operator of the proposed system can request the current status of the host using the remote module. The remote module can show up the information through the screen, and can perform various control functions for handling a music.

4.3 Evaluation

As explained in the previous section, we consider two situations in order to evaluate the proposed system. The two situations are as follows:

☐ Situation 1: two sensors are installed at a men's rest room and a women's rest room, and there is no dependency among the sensors.

☐ Situation 2: three sensors are installed at a men's rest room, a women's rest room, and a cafeteria. In this situation, we suppose that there is a dependency between the men's rest room and the cafeteria, and also there is a dependency between the women's rest room and the cafeteria.

4.3.1 The experiment result of situation 1

The figure 7 shows the experiment result on the situation 1. In this paper, we tried to do the experiment in different methods considering the following factors: speed going through sensing area, passing distance, going through over 2 peoples at the same time. In the figure 7, we compared the number of people obtained by the experiment with the number of real participants. The result shows the accuracy of 85% compared to the number of real participants. The reason is because we get rid of unreliable data which are out of standard deviation range from the average value. Specially, if all of the data are included, the accuracy of the proposed system is increased over 92%. However, if two peoples or above go through a sensor together, the accuracy is a little decreased because the sensor detects just a time in such a case.

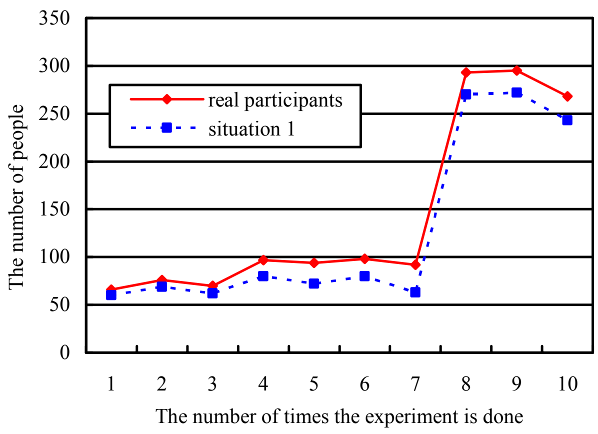

Fig. 7 The experiment result of situation 1

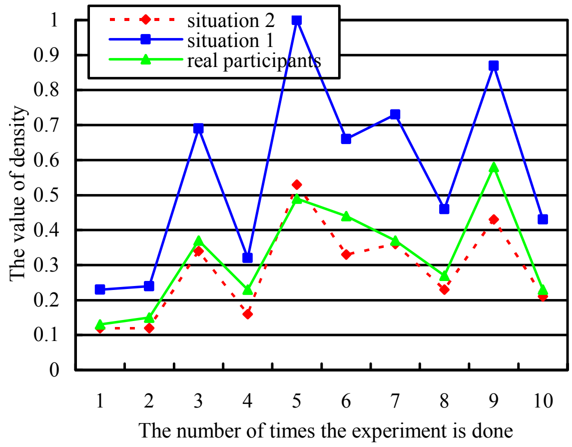

Fig. 8-a The comparison according to the density of people

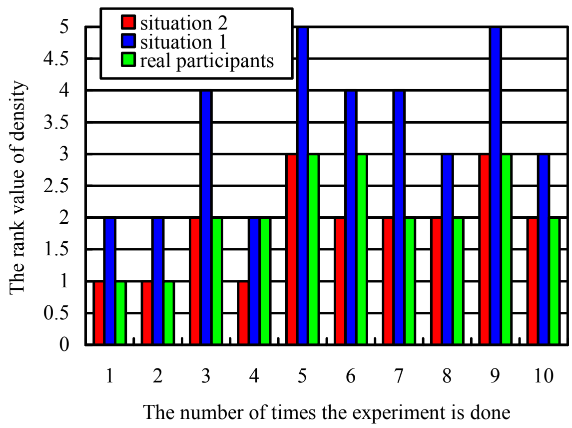

Fig. 8-b The comparison according to the rank value of density

Fig. 8 The experiment result of situation 2

4.3.2 The experiment result of situation 2

The figure 8 shows the experiment result on the situation 2. In this situation, we supposed that the sensor at the restaurant is dependent to sensors at the men's and women's rest rooms. The experiment is done by using the equation 3 in the section 3.2. In order to apply this equation, we assumed that the probability a person stops by one of the rest rooms is 0.93 and the probability a person stops by the restaurant after coming by one of the rest rooms is 0.48. We obtained these values through a questionnaire. The figure 8-a shows a comparison result on the density of people in the trials of 10 times, where the green line means the density of real participants, and the red line means the density of people in the situation 2. In addition to these lines, the blue line shows the density of people not considering dependencies like the situation 1. The experiment result shows that the density of people considering dependencies is very close to that in real data, but the density of people not considering dependencies is of much difference compared to that in real data.

The figure 8-b shows another result. The experiment was performed by classifying in five ranks according the number of people as shown in the table 1. This result also shows that as dependencies among the sensors are considered, the rank value of density of people is very close to that of real data. Therefore, we can reduce the number of times in order to retrieve frequently music files according to the change of density when a method considering dependencies is used.

5. Conclusion and further research

In this paper, we proposed a music recommendation system for public places based on a sensor network. The public places mean a place where people are coming and going frequently such as highway rest places, parks, huge marts, etc. The proposed system consists of five modules: sensor nodes, sink, host, music database, and remote control. This paper used the density of people as the most important factor in order to choose a music, and in addition to this factor, weather, time, and season are used. In the proposed system, sensor nodes are installed at several places where people are coming and going frequently, and the density of people is computed by using the information collected from sensors.

The proposed system is implemented as an experiment environment and evaluated through real participants. The experiment was done by two cases considering and not considering a dependency among sensors. The experiment result shows that the number of people is very close compared to the number of real participants. In the future, we think that in order to develop the proposed system as a commercial product, it will be improved several kinds of things such as stability of system, distance among sensors, and management of music database.

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