Intelligence@Lab: A Smart Space for Researchers Based on Sensor Networks in Pervasive Computing Environment

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Abstract

With the rapid progress on the Internet Technology, many projects have been proposed in terms of remote education system such as WBT (Web-Based Training) and E-learning. Such systems can help learners for studying by themselves based on their own learning history in a virtual world. However, learners usually spend time in the real world during studying, exercising, and the other activities. It seems the systems do not give enough support to learners in the real world. Ubiquitous technologies make it possible to provide services to learners anytime and anywhere in the real world. It means learners can receive more meticulous, individually-targeted support in ubiquitous environments. In this paper, we propose a ubiquitous environment to support college students, professors, and visitors in a laboratory to encourage positive research activities. Actions of people in the Ubiquitous Laboratory (U-Lab) are individually recorded by sensor networks and analyzed to provide suitable supports. Based on these collected information, U-Lab provides services such as to grasp a precise research progress and share research information among students and professors. We also propose a method to advise students to improve their research activities.

As a case study, we implemented a ubiquitous corner (U-Corner) in order to prove our proposal is useful and practical.

1. Introduction

In recent years, many researchers have extensively studied methods like WBT (Web-Based Training) and E-learning by using the internet to collect learner's study histories and to give him/her study advice [3] [4]. Some universities have already offered e-learning programs for students [1] [2]. However, in the real world, each learner has his/her own study style and individually decides time to study so that study support based on individual situation is insufficient by only using WBT and E-learning. Therefore, ubiquitous computing is applied to the learning field, which is called as ubiquitous learning. In a ubiquitous learning environment, service required for a user can be provided without demanding intentionally. Moreover, it comes to be able to provide the study support more individually through context information (e.g. location, time, actions, and other persons nearby) corresponding to individual data which can be acquired in the ubiquitous environment. So far, many context-aware applications are developed by some research laboratories or some universities [5]. Some of them exploit context information very well. However, almost all of them are used for enterprises. Some are applied in offices to manage employee's entering/ leaving information or to assist conference attendants. The others are systems to assist tourist guiding. In Our research, we mainly focus on the educational field.

On the other hand, a laboratory is a central place for college students, especially in the science and engineering majors, to study and research. Students usually spend a lot of time in the laboratory to do their research activities such as writing theses, making presentations, implementing systems, and even doing homework. However, because the life styles and schedules of students are individually different, it is not easy to share information and have communications among students and instructors. Furthermore, by following the trend of the times, there is a demand to open the laboratory for a regional contribution, university-business innovation, and international exchange. Some projects have been proposed on support methods in the ubiquitous learning field, such as a proposal of a personalized ubiquitous education support environment [6]. This research gives priority to lower class students, like elementary school students rather than college students. And it mainly aims at managing learner's lifestyle in order to make the student acquire the habit of studying by himself/herself. The other research has proposed to utilize mobile and ubiquitous computing such as access points, iPAQs, tablet PCs, and RFIDs [12]. It aims to support and improve academic activities in an original model of a learning environment and especially focuses on learning in the field of Computer Engineering. Not only for schools, but also for kindergartens learning support method has been proposed [11].

With the progress of researches in ubiquitous computing, network hardware and infrastructure have been going to be completed. People from all over the world accept benefit from the use of network technologies such as the Internet, wireless networks, Gigabit Ethernet, and so on. The field of sensor networks is one of the most important and necessary parts for ubiquitous computing. Some kinds of wireless sensor nodes such as wearable, portable, or embeddable nodes have been developed from the viewpoint of hardware [13]. Elderly users can be supported kindly and be received services friendly by embedding computers, several sensors, RFID tags, cameras, and so on in almost all objects around the users in home [7]. This research mainly focuses on supporting older persons in daily life and constructs the whole electric house to realize it. Our research aims to utilize our existing laboratory as long as we can without constructing new equipments.

In this research, Ubiquitous laboratory called U-Lab is proposed. Then we develop a method to analyze a similarity and a difference between objects and/or persons based on data from sensor networks by using the Euclidean distance. This method is the base of several services in the U-Lab. For example, the system should grasp a similarity between books and a student‘s interest when the student borrow some books from a book shelf in a laboratory. If the similarity becomes clear, the system can give certain advice which book is the best for the student. We also designed a ubiquitous environment: U-Corner, as a test case of the ubiquitous laboratory. Through this implementation, we stepped out as for implementing the whole design of the ubiquitous laboratory. U-Corner, which is a partial space of the laboratory, is filled with a lot of special tile. These tiles can collect the activity data of people based on a sensor network. By using these data, we can get semantic information subsequently and give useful support to people visiting U-Corner.

The remainder of this paper is structured as follows: In Section 2, a model of U-Lab is shown and problems are formally defined. Our basic idea is presented in Section 3. After giving the details of our method and some case studies in Section 4, implementation of our method is described and the result of our system is shown by an experiment in Section 5. Finally, we have conclusion and discuss future work in Section 6.

2. Model and problem definition

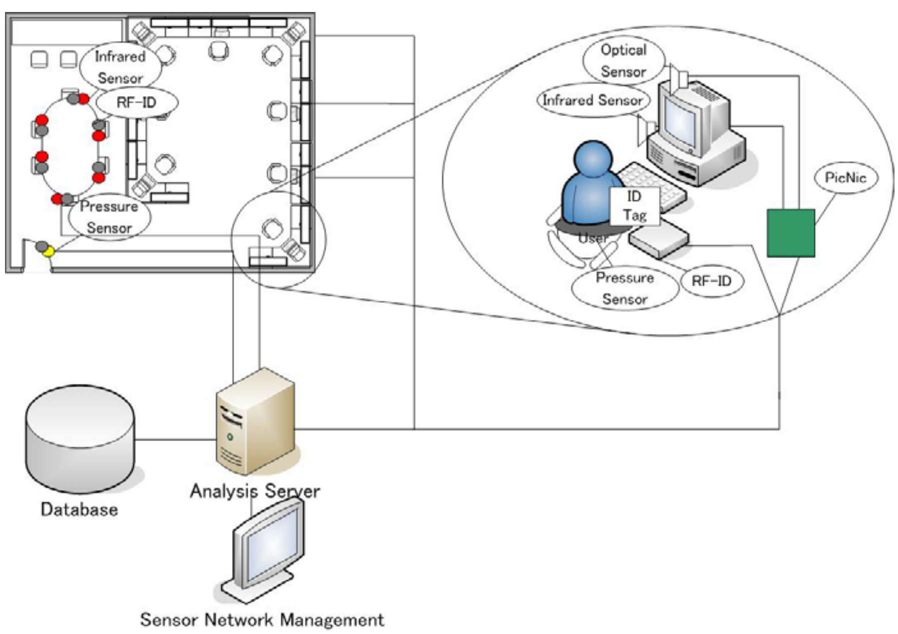

Figure 1. The model of the U-Lab

In this research, a laboratory contains a professor's room, a students' room, a seminar room, and a personal computer (PC) room as shown in Figure 1. A professor works and stays mainly at his/her room. At the students' room, a desk and a PC is given for each student. It is assumed that each student researches and studies in each one's space of the student's room. There are some shared rooms like the PC room and the seminar room. Students' activities in these rooms include having a seminar, using PC, discussing, and reading books. Furthermore, some sensors are embedded in each room and they can collect entering/leaving information and detect behavior of people in the room. Research is considered as the main activity in the laboratory. For instance, the research activities include professor's own investigation, group seminar, discussion between the professor and students, a regular colloquium, surveys, design and experiments based on individual level and so on. Therefore, to support these activities, it is necessary to manage individual schedule for the professor and students and grasp the state of equipments, books, and resources in the laboratory. Also for visitors, the laboratory provides information about the laboratory such as ongoing projects, research achievements, and objectives of the laboratory if they want.

To realize this model, the problem is formally defined as follows.

1. How to know the schedule of each member belonging to the laboratory.
2. How to collect the location data of resources, equipment, and books in the laboratory.
3. How to get a semantic result of people's behavior.
4. What kind of supports the laboratory should provide for users.

3. Basic ideas and the outline of the system

In this research, we assume anywhere in a laboratory is a detectable area of research, study, and the other activities by some sensors. A number of infrared sensors, RFID readers, and so forth are embedded in the laboratory as shown in Figure 2. These devices cooperate with each other and compose one sensor network. By using this sensor network, actions of every people in the laboratory are sensed and recorded into some databases in a server. Moreover, the system also collects a research progress: what each student is currently working on, a status of preparing presentation documents for a seminar, a submission status of a thesis draft, and so on. The system reasons each student's life style, research effect and efficiency, and so forth by systematically analyzing data of activities and the research progress gathered over a period of time such as one day, one week, or one month. Based on the results, the student receives supports and/or advice suitable for his/her current situation by the system. Then, the system shows the professors the results of analysis as reference in order to let them know the accurate progress of the student's research. And also, for visitors, the system provides services such as providing information about the laboratory (i.e. ongoing projects and research achievements) based on visitors' interests and visitors' level of knowledge by fully using the sensor network.

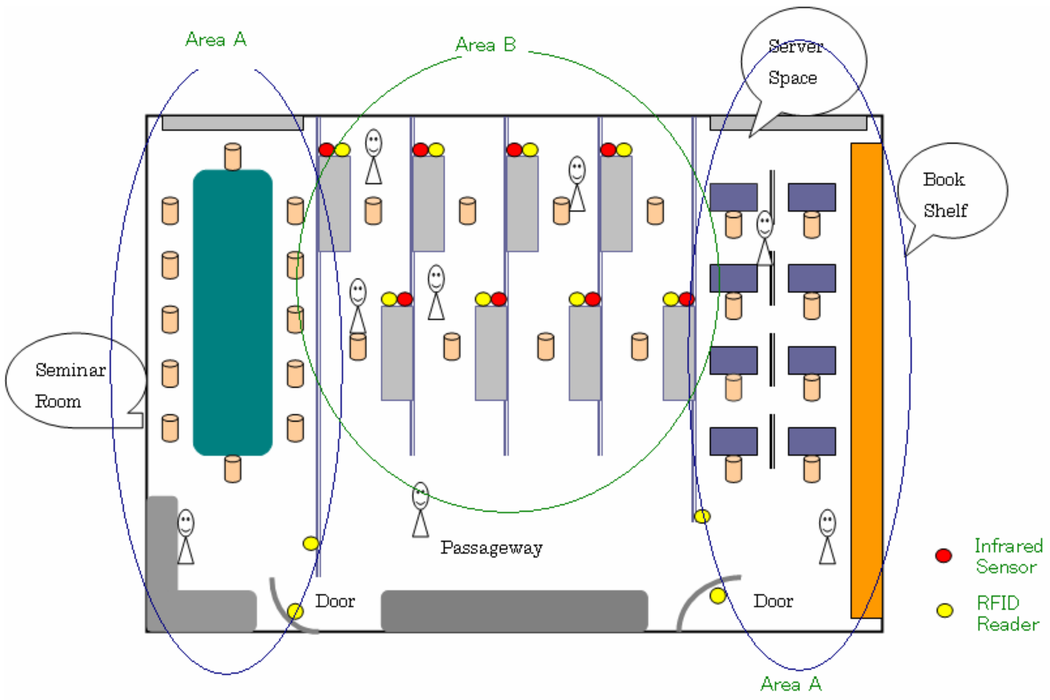

Figure 2. An example of areas and sensors layout in U-Lab

- **How to categorize areas in the laboratory**

As you can see in Figure 2, the laboratory is divided into two areas according to detectable ranges by sensors and features of each sensor. The one area, say area A, detects whether or not a user is present in area A. If the user is present in area A, the system assumes the user does a specified activity assigned in area A. For example, the user must attend a seminar if the user is in a seminar room and the user must be reading books or some documents if the user is in a room having bookshelves. The system does not consider unexpected actions such as taking a nap in the seminar room and chatting in the bookshelf room. Like this, area A includes common spaces for all members in the laboratory, such as a seminar room, a bookshelf room, and an experiment room. The other area, say area B, is a space where each user works individually. Area B includes a personal space such as a research room having the user's desk and one's computer. Every user has one's own computer in one's own space and we assume that every user spends almost all time in one's own space. Therefore, to analyze data of activities of each user, the system should collect not only location information, but also activity information in area B.

- **How to set sensors**

RFID readers and tags are used to grasp a user's location approximately. The RFID readers are set in both area A and area B (see Figure 2). We assume that every user has an RFID tag wherever and whenever they are in a laboratory. However, because the receivable rage of the RFID readers is limited, the RFID readers are set at boundaries (i.e. doors) of each spaces included in area A. On the other hand, for area B, the RFID readers are set in each desk because information is collected mainly from desks.

To collect activity information of each user more and more accurately, the system uses infrared sensors which only need a few meters to detect objects and can recognize whether or not a user is present around the sensors. Infrared sensors are set in each user's desk at each user's space (see Figure 2) so that the system can collect data of users' activities within a few meters around desks.

- **How to share information among sensors**

Data collected by every sensor is managed by a server in the system. When a user passes around a detectable range of the RFID readers set in boundaries (doors) of each area, the readers send the server time and a location where the user enters in/leaves from. When an infrared sensor detects a user's actions, this data is related to information grasped by an RFID reader nearby this infrared sensor. In this case, the system assumes that the user detected by the infrared sensor and sensed by the RFID reader are the same one. The server saves received data into a database and uses it for users' behavior analysis.

- **How to analyze collected data efficiently**

If the system keeps collecting, storing, and analyzing users' information for a long period, each user's life style will become clear. Log files of a server include time when a user comes to or leaves from a laboratory everyday, attendance rate of seminars, and behavior patterns in the laboratory. The system periodically accesses the log files, checks each user's research progress like the status of submission of thesis drafts and presentation documents, and finally reasons research effect and efficiency of each user. Specifically, each user's history of activities can be got by storing data of location and time detected by the RFID readers to a database. As we mentioned before, when a user is in area A, the system reasons that the user is working, studying, or reading books in a common space. When a user is in area B, the system reasons that the user is studying currently only if an RFID reader set in the user's desk senses an RFID tag attached to the user while an infrared sensor detects the user's action. And, visitors have particular RFID tags so that the system can distinguish them from laboratory members.

- **How to support effectively**

At first, each student makes one's own learning schedule with a professor's consent. It includes a seminars' schedule, time of group activities, a research schedule, time of thesis submission, and so on. Some people might think that making a schedule is a waste of time because they will take much time and need extra effort for it. However, the more specified a schedule, the more is a goal accomplished easily [8]. Therefore, making a research schedule is one of the most important parts in students' works for their research. Then, the system compares the schedule to data detected by sensors, and then the system gives some advice/notices to the user if the user falls behind on the schedule. If the user catches up with the schedule or runs ahead of the schedule, the system gives encouragement with praise. Moreover, each user and the professor share the data stored in the database for a long period. Although every user is sure to know what they have done by themselves so far, it is common for people to realize a fact how lazy their life style was after they look at their history of activities. Based on this history, the professor can also give proper advice to students. In addition, the system constantly monitors users' presence in each room so that laboratory members can grasp a situation of each member at real time. Therefore, the system can help smooth communication among students and between each student and a professor. And also, for visitors, to make them enjoy and feel convenience of a ubiquitous environment, the system provides services such as providing information about laboratory though moving images, sounds and texts.

- **How to manage resources and documents in the laboratory**

In a laboratory, there are a lot of resources such as books, journals, papers, hardware, software (i.e. CD-ROM), and the other things. However, it is hard to find out a member who uses resources you want, to search when and where he/she will return them, and so on if a number of students can use and borrow these resources in the laboratory. As is often the case, when a student wants to borrow a book or a device, the student can not find where it is. As a result, the student has to contact some of laboratory members to find and get it. In our research, RFID tags are attached to the items shared and also used frequently in a laboratory. By localizing these items, users can find an item they want whenever they access the system. This service also helps to prevent losing resources of a laboratory.

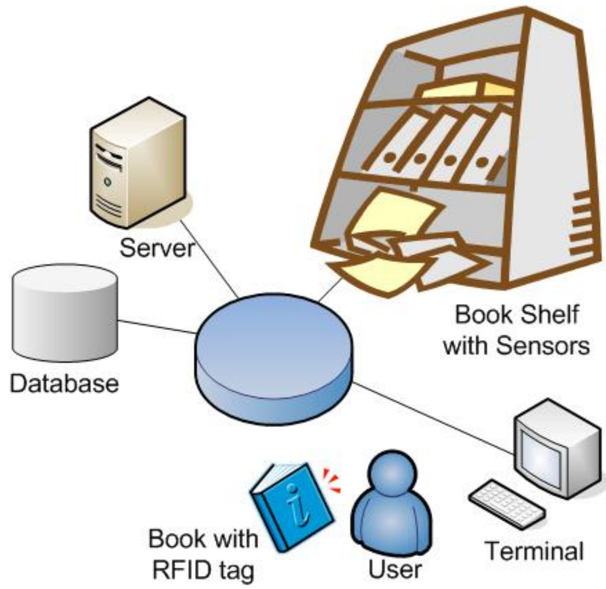

Figure 3. Network link of book shelf

In particular, we will apply the method of [9] in order to manage books on bookshelves. This research uses two infrared sensors to check whether a textbook is in or out from a school bag, and one RFID antenna to recognize which textbook is in/out. Each textbook is attached to a RFID tag containing unique ID and book information. In our research, we embed two infrared sensors and one RFID antenna to one rack of a book shelf (see Figure 3). Sensing a book by the infrared sensors and reading a RFID tag on the book, the system can immediately grasp which book is pulled out (borrowed) and which book is put on (returned) from the bookshelf. The system saves a name of a book with time and a name of a person who borrows/returns the book to a database. Basically, the system gives support and advice through a terminal near the bookshelf or/and an each user's PC. For example, if a student borrowing a book has not returned it for a quite long time, the system through his/her PC warns the student to return the book as soon as possible.

4. Comparing method and case study

4.1. Comparing method

To provide flexible and user-friendly service, the system should compare one data to the other data such as comparing a personal schedule to one's history of activities obtained from a sensor network as we mentioned in the previous section. Such a comparison of visible information is relatively easy. Meanwhile, a comparison of vague and invisible information like interests, knowledge levels, and preference is awkward. However, such a comparison is required for the system to give users detailed support in this research.

Our method analyzes a similarity and a difference between objects, persons, and an object and a person based on data collected from sensor networks by using the Euclidean distance. One example is to compare a similarity between an object and a person. U-lab includes ubiquitous corner (U-corner) where visitors can get information about a laboratory such as research achievements and ongoing projects. (Details of U-corner will be shown in the following section and also U-corner is implemented.) U-corner displays several exhibitions for visitors. Then the system introduces each exhibition for a visitor at his/her own level of knowledge as well as guides him/her in a suitable order to visit exhibitions based on his/her preference.

At first, we set several parameters for a vector to every exhibition in order to decide the suitable path for a visitor and pick up some keywords for the parameters. As an example, they can be “education”, “hardware”, “matching”, and “difficulty level”. The values of these parameters are preset according to their research attribute. The range of each parameter is from one to five. As the value of a parameter (keyword) becomes larger, a research is more related to the parameter (keyword). For instance, Ubiquitous School Bag is one of exhibitions in the U-Corner. When the parameters are (education, hardware, matching, difficulty level), the vector of the exhibition will be set as (5, 3, 1, 3). For another example, a research of Matching between University Students in a Laboratory and Laboratory’s OB/OG is an exhibition closely related with the education field, matching algorithm. Therefore, the vector may be set as (4, 1, 5, 2).

On the other side, the system has a simple questionnaire to the visitor at the entrance before entering into U-Corner. This questionnaire includes several keywords related to those four parameters. Also, the system asks how long the visitor will stay in the U-Corner in order to coordinate the path to visit exhibitions and the number of exhibitions to be shown to the visitor. Based on these questions, we can get a visitor’s characteristic vector like the attribute vector of the exhibition. The range of the characteristic vector is also from one to five and each parameter (keyword) are set as exactly same as the attribute vector. By calculating the Euclidean distance between the characteristic vector and the attribute vector, we can get a result of their similarity. With these Euclidean distances, the system will generate a suitable and semantic visiting course in the most interesting order for the visitor. Equation (1) and Equation (2) are some definitions and a formula for Euclidean distance calculation respectively.

$$\vec{A_i} = \begin{pmatrix} A_{i0} \\ A_{i1} \\ \vdots \\ A_{in} \end{pmatrix} \text{ And } \overrightarrow{C_j} = \begin{pmatrix} C_{j0} \\ C_{j1} \\ \vdots \\ C_{jn} \end{pmatrix}. \quad (1)$$

Equation (1) denotes an attribute vector of an exhibition and a characteristic vector of a visitor respectively. Note that each component of the vectors is set from one to five.

Let *dij* denote the Euclidean distance between a certain attribute vector and a certain characteristic vector which is calculated by Equation (2).

$$d_{ij} = \sqrt{\sum_{a=0}^{n} (A_{ia} - C_{ja})^2} \; . \quad (2)$$

The system will sort the distances in a shortest path first algorithm and guide the visitor to the exhibition which is most matching with the visitor.

4.2. Case study

In addition to the abovementioned example, our method can be applied to the other two services as follows.

- **Case 1: Analysis of similarity between students' interest on their researches**

The system also supports communication among laboratory members as we mentioned in the section 3. If there are a lot of members belonging to a laboratory, it is slightly hard to exactly grasp contents of research which each member works on currently. The system can figure out progress of research conducted by each member in the laboratory by constantly monitoring a file server. As we mentioned in the section 3, each student submits documents, such as thesis drafts and presentation materials, to the server every week/month. These documents are saved into a database so that the system can compare the one student's research to the other student's research. Based on such a comparison, the system reasons a similarity/difference among students' research. Then, a member is informed about whose research is the closest to his/her research by the system if the member wants. As a result, the member could find a research "fellow" and they could actively discuss their research more than before. It also encourages members to study positively because the system always updates information about a relationship among researches. Thus, if some members change topics/fields of their researches, automatically and immediately a previous relationship among researches would be modified.

- **Case 2: Analysis of similarity between a student's knowledge level and a book's difficulty**

The U-Lab has an area where there are bookshelves. The system manages books in the laboratory as well as recommends books to students. As we mentioned in the section 3, the system records every user's history of book rental. Based on the data recorded by the system for a long period, the system gives users advice related to books. For example, when a user borrows a book from a bookshelf for the first time, the system provides nothing to the user except saving his/her rental history into a database. Then, when the user returns the book to the bookshelf, the system through a terminal asks the user whether or not the book was easy for him/her to understand. If the user answers "yes", his/her parameter of knowledge level is incremented. Otherwise, the parameter is decremented. The system saves the information about the book such as the name, the author, and the field. The next time the user borrows another book, the system suggests some suitable books for the user's level of knowledge based on his/her history of books. These recommended books are selected by using our method comparing the user's knowledge level to books' difficulties. Because the system grasps both the user's knowledge level and the user's interest, the system can give the user appropriate and helpful support to select a book to read.

Moreover, by incrementing the user's knowledge level gradually, it becomes closer and closer to the high level in small steps. According to behavior analysis [8], to achieve a big goal, we need to accomplish small goals on the way of the final goal. After we clear the all of obstacle in the way, finally we can get an ideal result. Therefore, the user can understand complicated books and absorb knowledge well at last by assistance of the system.

5. Implementation

5.1. Model of ubiquitous corner

In recent years, national and public universities are turned into independent administrative entities in Japan. Under the influence of this trend, business-academia collaboration takes an important role more and more than before. In that way, an open laboratory would be a key event of all in a university. In this research, as we mentioned in the previous section, we implemented ubiquitous corner (U-Corner) as a representative example of the ubiquitous laboratory. U-Corner is a space which introduces achievements of the laboratory to visitors. The ubiquitous corner is included in the ubiquitous laboratory.

In this research, the whole space of the corner can detect people's actions through a sensor network. The sensor network is composed of two or more pressure sensors, infrared sensors, and RF-ID readers. Every visitor will be given a RFID tag at the reception desk to enjoy the ubiquitous environment. The tag stores his/her information, such as personal data (i.e. occupation and interests) and data regarding U-Corner (i.e. visiting history and visiting path). We assume the tag is attached to the visitor when he/she is in the U-Corner. The following section will describe the definition of the U-Corner and classify the results of research achievements.

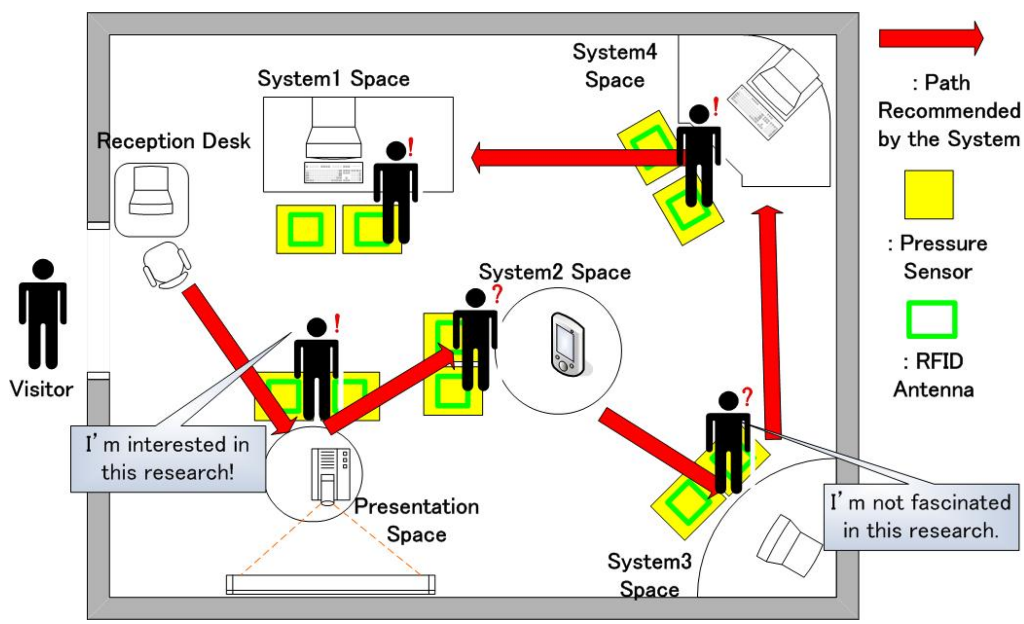

Figure 4. The model of the ubiquitous corner

Figure 4 shows a floor model of the U-Corner where there are many exhibitions to show visitors. The floor of the ubiquitous corner is filled with some special tiles including pressure sensors and RF-ID antennas. The RF-ID antennas can detect the identity of the visitor and pressure sensor can grasp the current place of the visitor. The antennas and pressure sensors are controlled by a relay circuit (a logical disjunction circuit) as each tile has more than one antenna and pressure sensor. Through these tiles, the system can identify and localize the visitor wherever he/she is in the U-Corner. When a visitor enters into the U-Corner, he/she will be given support to experience a ubiquitous environment. At first, the visitor will be asked some questions about his/her interesting, occupation, and so on through a questionnaire provided by the system. Then, the system will show a suitable visit path to the learner based on the result of an analysis of his/her input information.

5.2. Interaction with the special tile

After the visitor entered the U-Corner, the system always checks the position where the visitor is. When the visitor watches an exhibition, he/she can have some interaction with the tiles. If he/she is interested in the exhibition, he/she can step the right tile to let the system know his/her feeling. If not, he/she can step the left tile. Then, based on our method, the system will recalculate the path for the next exhibition to visit. As explained in the section 4, our idea is to adjust the characteristic vector in order to bring the two vectors more closely or more far. If the visitor shows his/her interest in the exhibition, the system will reinforce the similarity in current direction. If not, the system will change the parameters in the characteristic vector of the visitor according to the attribute vector of the exhibition. The system will compare every parameter between two vectors and modify the parameters in the characteristic vector subject to the visitor's interest as follows.

- Interesting Case
```
for(k=-0; k<=n; k++){
  If(A_ik < C_jk)   C_jk = C_jk – 1;
  If(A_ik == C_jk)  C_jk = C_jk;
  If(A_ik > C_jk)   C_jk = C_jk + 1;
}
```
- Non-Interesting Case
```
for(k=-0; k<=n; k++){
  If(A_ik > C_jk)   C_jk = C_jk – 1;
  If(A_ik <= C_jk)  C_jk = C_jk + 1;
}
```

Note that each component of the vectors is supposed to be set from one to five.

Table 1. **An example of two vectors**

Attribute Vector	A_{i0}	A_{i1}	A_{i2}	A_{i3}
$\overrightarrow{A_i}$	1	3	5	2
Characteristic Vector	C_{j0}	C_{j1}	C_{j2}	C_{j3}
$\overrightarrow{C_j}$	4	1	2	3

Table 1 is an example to explain the algorithm to change the parameters in the characteristic vector. Suppose a certain exhibition's attribute vector is (1, 3, 5, 2) a and certain visitor's characteristic vector is (4, 1, 2, 3). Based on the algorithm, if the visitor shows his/her interest in the exhibition, the visitor's characteristic vector will replaced by (3, 2, 3, 2). On the other hand, it will be (5, 1, 1, 4). After the calculation, the system will use a revised characteristic vector in order to guide the visitor to the next exhibition to visit.

5.3. Outline of the system

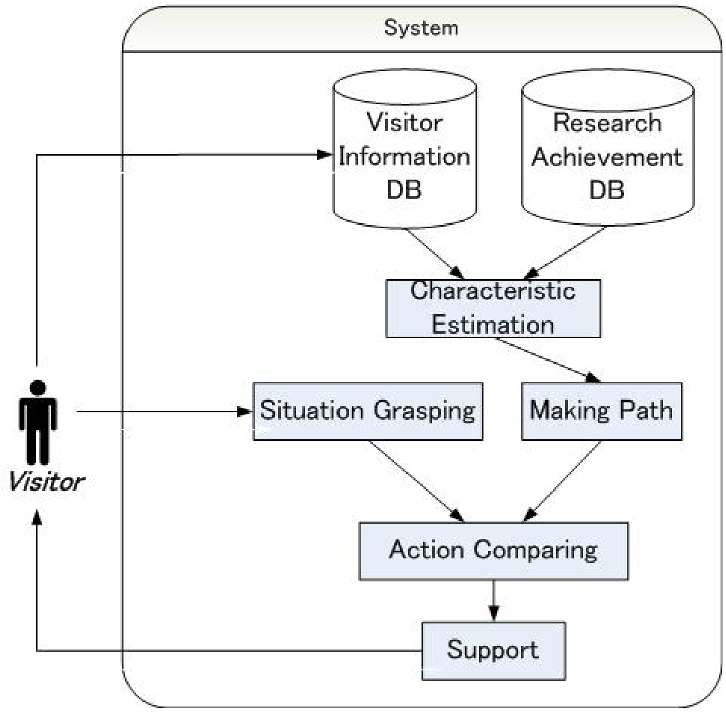

Figure 5. Outline of the U-Corner system

Figure 5 shows an outline of this system and it has five modules: characteristic estimation, path making, situation grasping, action comparing, and support modules.

- **Characteristic estimation module**

Attributes of exhibitions are preset by a system manager. The system can obtain visitor's characteristic from his/her inputs through a questionnaire..

- **Path making module**

By using the abovementioned algorithm, the suitable visiting path is made and will be shown to the visitor.

- **Situation grasping module**

The visitor's location information is gathered from some tiles with RF-ID readers and pressure sensors. That means, the module identifies an exhibition where the visitor is looking currently. And also the identification of each visitor is detected.

- **Action comparing module**

The interaction from visitors is analyzed. The result will be used in the path making module to give a next guidance.

- **Support module**

The module provides some guidance and information to visitors with voice and pictures.

5.4. Environment of development

The abovementioned idea and applications were verified by implementing a system, which was developed by Microsoft Visual C# .NET programming language. We used Microsoft Access to construct the database for visiting records. We set S2000 Microreader (RF-ID Reader) of Daiichi Tsushin Kogyo Ltd [10] to each exhibition. Every visitor in the U-Corner is required to wear a RF-ID tag.

5.5. Challenges of development

The most challenging point of development was how to capture the visitor's action; where they are? and which exhibition are they watching?

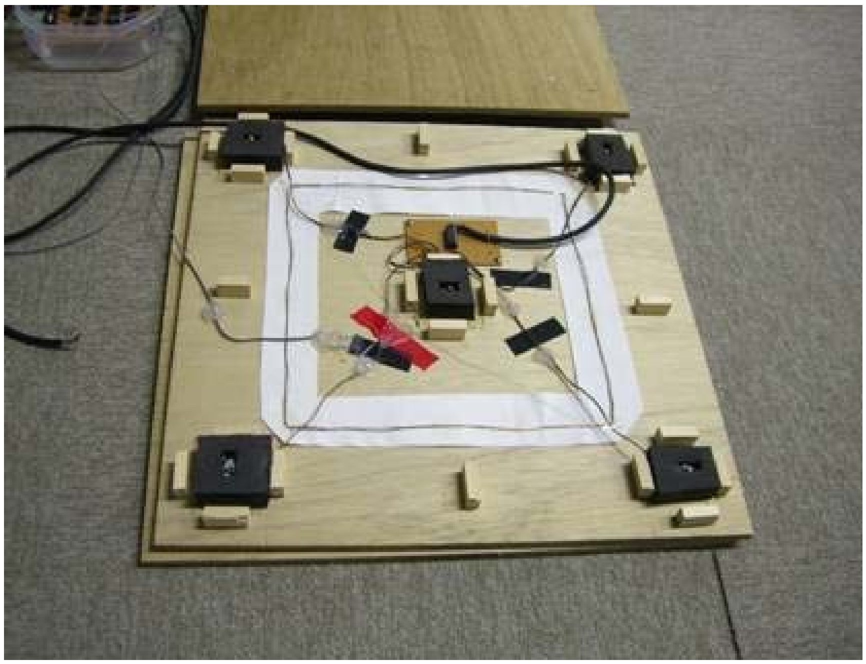

Figure 6. A tile for gathering actions of a visitor

To solve this problem, we proposed a special kind of tile to detect visitor's action (See Figure 6). A RF-ID antenna and pressure sensors are embedded in the tile. Generally speaking, a passive RF-ID reader only has a narrow range of operation and is combined with a antenna by default. Sometimes it does not work well for gathering visitor's action. Therefore, we separated the antenna from the reader and created a RF-ID antenna with coil to broad the operation range of it. As a result, a relay circuit allows only one reader to control 16 antennas. The tile also has five pressure sensors buried in a sponge surrounded by some wood chips to protect the sensor from weight of the visitor. By using the special tile, accuracy of gathering visitor's movement was increased.

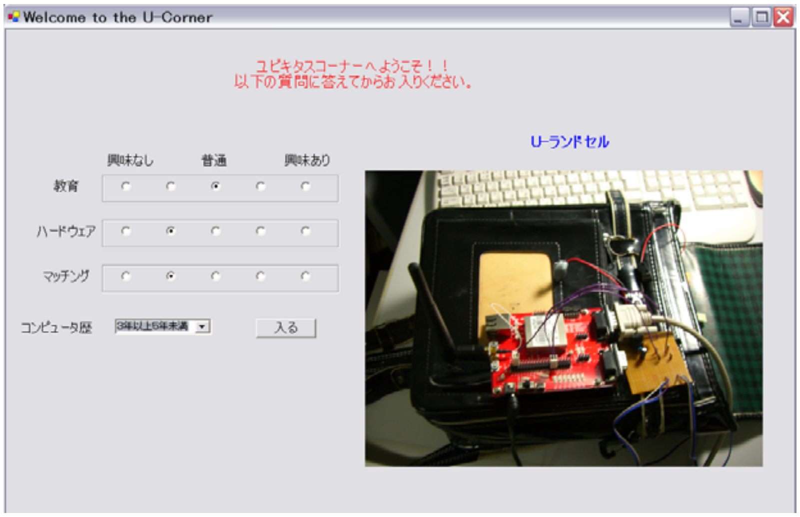

Figure 7. The GUI of the system

Figure 7 shows a screen shot of a questionnaire given by the system before the visitor enters in the U-Corner.

6. Experiment and verification of the system

The purpose of experiment is to verify the followings.

1. Could the system figure out the visitors’ interest?
2. Is the support provided by the system suitable for visitors?
3. Is the system useful for LAB introducing?

These three points are examined through the experiment.

We got eight students’ corporations in the University of Aizu for this experiment. First, they registered at the entrance of the U-Corner to initialize their personal information through a questionnaire. Also, each examinee held a RF-ID tag in this experiment. During their visiting, they interacted with the special tile and experienced some support. After the experiment, we asked them the following several questions for performance measurement of the system.

– Q1. Could this system have guided exhibitions according to your interest?
– Q2. Was the support of this system appropriate?
– Q3. Was the system useful for introducing the laboratory?
– Q4. Was a ubiquitous environment able to be experienced through this system?

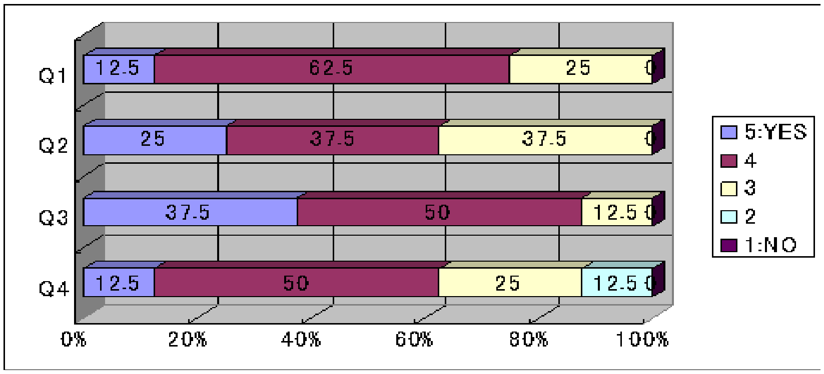

Figure 8. The result of experiment

As shown in Figure 8, 75% people feel they were guided according to their interest. This data indicate the path making algorithm still leave room for improvement. In contrast, about 40% visitors think the support provided by the system is not so appropriate. The timing of support and the way of support should be discussed in the future. The result of Q3 shows that it is a useful way to guide a visiting path for laboratory introduction. Only 62.5% visitors think they experienced a ubiquitous environment in the U-Corner. This can be progressed by changing the way to collect visitors' interest not by asking question but by analyzing their actions. Also, the interaction with the tile can be considered have more variation.

7. Conclusion and future work

The present work is intended to construct a ubiquitous environment in a laboratory for ubiquitous learning based on a sensor network. We implemented a ubiquitous corner as a model of the ubiquitous laboratory. The tile having RF-ID readers and pressure sensors functions as sensor network to detect peoples' action. U-Corner provided a guide system based on visitors' interest. Through the experiment, the results show it is useful for laboratory introduction with a ubiquitous environment.

In the next step, we will implement the whole ubiquitous laboratory. Also, some problems found in the experiment will be solved. More sensors, such as light sensor, temperature sensor, and acceleration sensor can be added to the tile to get more detailed information in order to figure out users' actions.

Acknowledgements

The authors would like to thank all members in the Computer Network Laboratory, the University of Aizu, specially Mr. Tosa and Mr. Ichizawa for their technical supports. This work was supported by National Natural Science Foundation of China (Grant Nos. 60533040, 60773089 and 60725208), 863 Program of China (Grant Nos. 2006AA01Z199 and 2006AA01Z172), Natural Science Foundation of Shanghai Municipality of China (Grant No. 05ZR14081) and Shanghai Pujiang Program (Grant No. 07pj14049)."

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