Ubiquitous Laboratory: A Research Support Environment for Ubiquitous Learning Based on Sensor Networks

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Abstract. With the great progress of technologies, computers are embedded into everywhere to make our daily life convenient, efficient and comfortable. In the learning field, ubiquitous technologies make it possible to provide services to learners anytime and anywhere in the real world. In this paper, we present an 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 detected by sensor networks and analyzed to provide 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) to prove our proposal is useful and practical.

Keywords: Ubiquitous Computing, Context Aware, Sensor Network, RFID

1 Introduction

In recent years, many researchers have extensively studied on WBT (Web-Based Training) and E-learning to collect learner's study histories and give him/her study advice [3] [4] by using the internet. Some universities have already offered e-learning programs for students [1] [2]. However, in the real world a learner's study time is abundant, and study support which based on individual situation is insufficient by only using WBT and E-learning. Therefore, ubiquitous technology is applied to the learning field to meet this challenge. 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, etc) 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 are used in offices to manage employee’s entering leaving information or to assist conference attendants. The others are systems for tourist guiding assisting. Almost all of them are for enterprises.

In this research, we mainly focused on the educational field. Laboratory is a central place for college students to study and research. Students usually spend a lot of time in the laboratory to do their research activities such as doing exercises, writing papers, making presentations, and implementing systems. However, because the life styles and schedules of students are different, it is not easy to share information and have communications among students and teachers. Furthermore, following the trend of the current times, there is a demand to open laboratory for a regional contribution, university-business innovation and international exchange. To answer these demands, Ubiquitous Laboratory (U-Lab) is presented in this paper. Then we propose a method to analyze the similarity and the difference between objects and/or persons based on data from sensor networks by using Euclidean Distance. This method is the base of several services in 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 the laboratory. If the similarity becomes clear, the system can give certain advice which book is the best for the student. We also implemented a ubiquitous environment; U-Corner, as a test case of the Ubiquitous Laboratory. Through this implementation, we stepped out as a first step of the whole design of U-Lab. U-Corner is a partial space of the laboratory. It 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 people who are visiting U-Corner useful support.

Some works have been done 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 is mainly aiming at managing learner’s lifestyle and study custom. The other research has proposed to utilize mobile and ubiquitous computing technology such as access points, iPAQs, tablet PCs, and RFIDs in the field [12]. It aims to support and improve academic activities in an original model of learning environment and especially focuses on learning in the field of Computer Engineering. In [11], not only for schools, but also for kindergartens’ learning support method has been proposed. With the progress of researches of ubiquitous computing, network hardware and infrastructure have been going to be completed. The field of sensor networks is one of the most important and necessary parts for ubiquitous computing. Three kind of wireless sensor nodes such as wearable, portable, or embeddable nodes have been developed from the viewpoint of hardware [13]. By embedding computers, several sensors, RFID tags, cameras, and so on in almost all objects around elderly users in home, the users can be supported kindly and received services friendly [7]. With the high cost to realize the proposed environment, it 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 minimizing introducing the additional investments.

The remainder of this paper is structured as follows: In Section 2, our basic idea is presented. After giving the details of our method in Section 3, implementation of our system is described in section 4. We present our result and experiment in section 5. Finally, we have conclusion and discussion in Section 6.

2 Basic Ideas and the Outline of the System

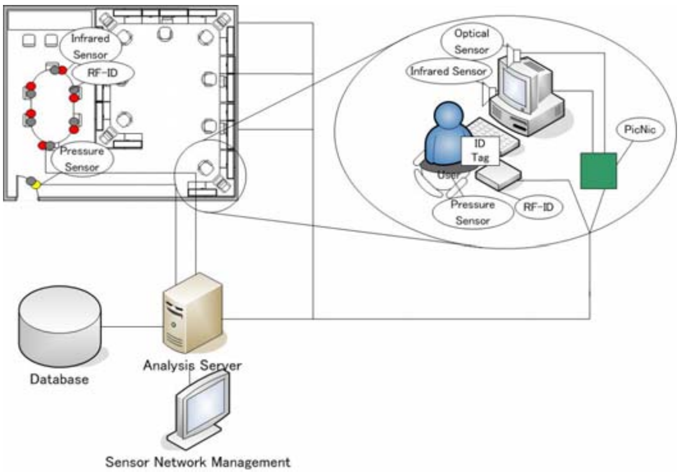

Fig. 1. The Model of the U-Lab

The model of U-Lab is shown in Fig 1. We assumed everywhere in U-Lab is the detectable area of research, study, and the other activities. The laboratory is embedded a number of infrared sensors, RFID readers, and so forth. These devices cooperate with each other and compose one sensor network. By using this sensor network, actions of every people in the laboratory are grasped and recorded into database server. Moreover, a research progress which each student is currently doing, for example, presentation documents for a seminar, a submission status of a thesis draft, and so on, is collected by the system. The system systematically analyzes data of activities and progress state caught during a period and guess a student's life style, research effect and efficiency. Based on the results, the student receives proper supports according to one's own status by the system. Then, the system shows the results of analysis as reference to let professors know the progress of the student's research. And also, for visitors, the system provides services such as introducing the laboratory and the presenting the research achievements based on visitors' interests and visitors' level of knowledge by fully using the sensor network.

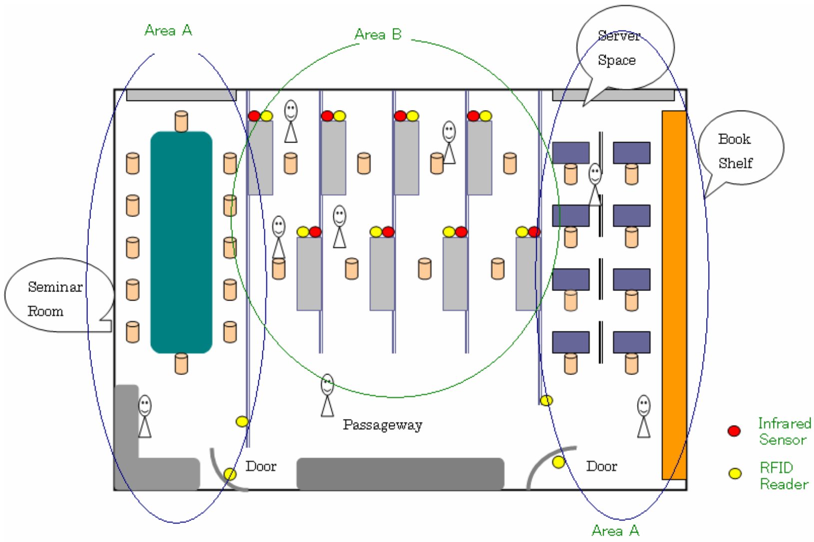

Fig. 2. An Example of Areas and Sensors Layout in U-Lab

- How to set areas

As you can see in Fig, 2, the laboratory is divided by two areas according to detectable ranges 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 which is assigned area A. For example, a seminar must be held if the user is in a seminar room, and the user must be reading books or some documents if the user in a room having a book shelf. The system does not consider unexpected actions such as taking a nap in a seminar room and chatting in a room having a book shelf. Like this, area A includes common spaces such as a seminar room, a room having a book shelf, and an experiment room. The other area, say area B, is a space where a 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.

- How to set sensors

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

To collect activity information of each user more and more appropriately, the system uses infrared sensors which only need a few meters to detect objects and can recognize whether or not a user is present. Infrared sensors are set in each user's desk and wall of each user's space (see Fig. 2), and the system collects 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. When a user passes around a detectable range of RFID readers set in boundaries (doors) of each area, readers send the server the location where the user is entering/leaving and the time when the user is entering/leaving. 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 a user sensed by an RFID reader are one and the same. The server saves received data into a database and uses it for users' behavior analysis.

- How to analyze efficiently

If the system keeps collecting, saving, and analyzing users' information for a long period, each user's life style will become clear. Including 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 log files of a server, checks each user's status like submission of thesis drafts and submission of presentation documents, and 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 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 of the user and also 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 extra effort for it. However, the more specified a schedule, the better to accomplish a goal [8]. Therefore, it 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 keeps to the schedule or runs ahead of the schedule, the system gives encouragement through praise. Moreover, each user and the professor share the data stored in the database for a long period. Even though every user is sure to know what they have done 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 introduction of the laboratory and the announcement of the research achievements though moving images, sounds and texts.

- How to manage resources and documents in a 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 search who uses these resources, when and where users returned them, and so on. 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 get it. In our research, RFID tags are attached to the items which is shared and also used frequently in a laboratory. By grasping the current location where these items are put, users can find an item they want whenever they access the system. This service also helps to prevent losing resources of a laboratory.

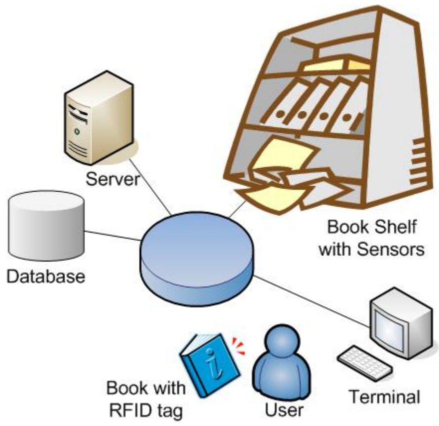

Fig. 3. Network Link of Book Shelf

In particular, to manage books on book shelves, we will apply the method of [9]. 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 with 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 Fig. 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 book shelf. 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 book shelf or 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 a one's PC warns the student to return the book as soon as possible.

3 Comparing Method

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

Our method analyzes a similarity and a difference between objects and/or persons based on data 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) which introduces achievements of a laboratory to visitors. (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 them as well as shows each visitor a suitable order to visit exhibitions.

At first, we set several parameters for a vector to every exhibition to decide the suitable path for a visitor. 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. The relationship goes closer the number becomes larger. For instance, Ubiquitous School Bag is an exhibition in the U-Corner. Considering its attribute, the vector will be set as (5, 3, 1, 3). 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, at the entrance, the system provides some simple questions to the visitor. These questions include several keywords related to those four parameters. Also, the system asks how long the visitor will stay in the U-Corner for coordinating the path and the number of exhibition should 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 has the same meaning to 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, semantic visiting course for the visitor in the most interesting order. Following are some definitions and a formula for Euclidean distance calculation.

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

The above denotes an attribute vector of an exhibition and a characteristic vector of a visitor respectively. Note that each component of the vectors is from one to five.

Let *dij* denotes the Euclidean distance between a certain attribute vector and a certain characteristic vector which is calculated by the following.

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

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. Also, the system will generate a boundary value from the question, limitation of the tour time, we mentioned above to adjust how many exhibitions should be shown to the visitor.

4 Implementation

4.1 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 a 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 based on 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 occupation, interests, visiting history, visiting path. It is supposed that the tag is attached to the visitor when he/she is in the ubiquitous corner. The following section will describe the definition of the U-Corner and classify the results of research achievements.

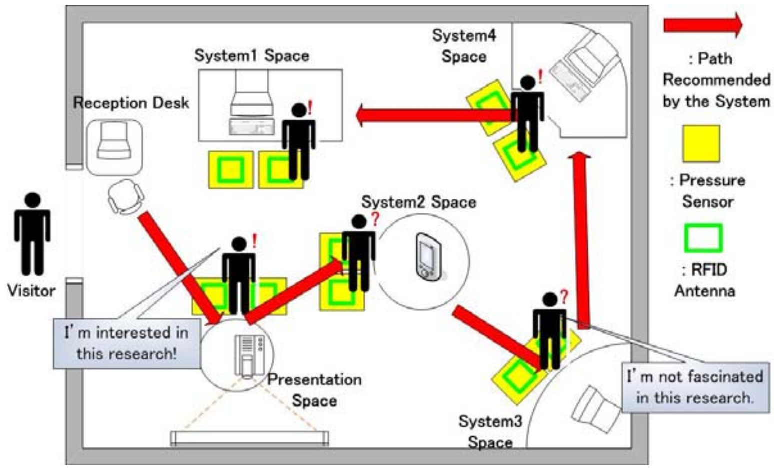

Fig. 4. The Model of the Ubiquitous Corner

Fig. 4 shows a floor plan of the U-Corner. There are many exhibitions in it. Each exhibition shows one of the research achievements. The floor of the ubiquitous corner is filled with some special tiles which includes pressure sensors and RF-ID antennas. RF-ID antennas can detect the identity of the visitor and pressure sensor can know the current place of the visitor. The antennas and pressure sensors are controlled by a relay circuit (a logical disjunction circuit) because each tile has more than one antenna and pressure sensor. Through the circuit, the system can know the identity and location information of the visitor. When a visitor enters in 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. Then, the system will show a suitable visit path to the learner based on the result of an analysis of his/her input information.

4.2 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 find the exhibition is interesting, he/she can step the right tile to let 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 next seeing. As we explained in the section 4, our idea is to adjust the characteristic vector to bring the two vectors more closely or more far. If the visitor shows interesting in the exhibition, the system will reinforce the similarity in current direction. If not, the system will reduce the parameters. The system will compare every parameter between two vectors.

- Interesting Case

```
for(k=-0; k<=n; k++){
   If(Aik < Cjk)   Cjk = Cjk – 1;
   If(Aik == Cjk)  Cjk = Cjk;
   If(Aik > Cjk)   Cjk = Cjk + 1;
}
```

- None Interesting Case

```
for(k=-0; k<=n; k++){
   If(Aik > Cjk)   Cjk = Cjk – 1;
   If(Aik <= Cjk)  Cjk = Cjk + 1;
}
```

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. Suppose a certain exhibition’s attribute vector is (1, 3, 5, 2) a certain visitor’s characteristic vector is (4, 1, 2, 3). Based on the algorithm, if the visitor shows interesting on 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 one to give a next guidance.

4.3 Difficult points of development

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

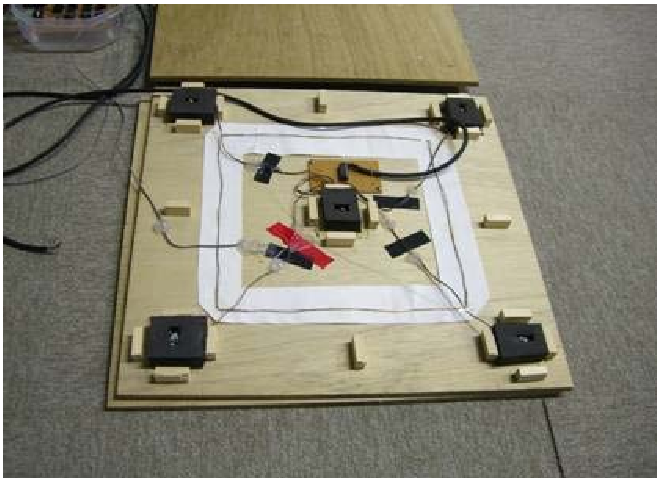

Fig. 5. A Tile for Gathering Visitor's Action

To solve this problem, we proposed a tile to detect visitor's action (See Fig. 5). It is composed of a RF-ID antenna and pressure sensors. Passive RF-ID reader [10] only has a narrow range of operation. The antenna and reader are combined by default. Sometimes it works not well for gathering visitor's action. We separated the antenna from the reader and created a RF-ID antenna with coil to broad the operation range of it. As the result, with a relay circuit 16 antennas can control by only one reader. The tile also has five pressure sensors. Each one is buried in a sponge and some chips are around the sponge to protect the sensor from weight of the visitor. By using the special tile, accuracy of gathering visitor's movement was increased.

5 Experiment and Verification of the System

The purpose of experiment shows the followings.

1. Could the system know the visitors interesting?
2. Is the support suitable for visitors?
3. Is the system useful for LAB introducing?

These three points are examined through the experiment.We got 15 students' corporations to execute this experiment. First, they registered at the entrance to initialize their personal information. Also, each one 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 to answer several questions.

- 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?

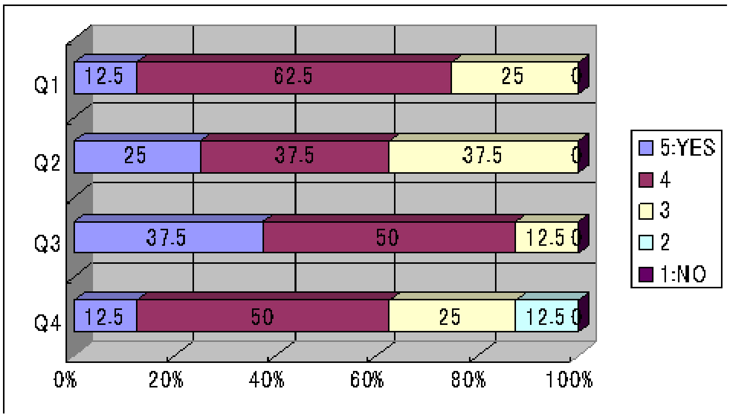

Fig. 6. The Result of Experiment

The result of experiment can be explained as follows. 75% people feel the guide is done according to their interesting. 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, 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. 62.5% of visitors think they experienced a ubiquitous environment in the U-Corner. This can be progressed by changing the way to collect visitors' interesting not by asking question but by analyzing their action. Also, the interaction with the tile can have more variation.

6 Conclusion and Future Work

In this paper, we designed a ubiquitous environment based on an existing laboratory to support college students, professors, and visitors using sensor network. To provide flexible and friendly service, we proposed an analyzing method by using the Euclidean Distance. As the case study of the whole U-Lab, we implemented a ubiquitous corner which provides a guide system to laboratory visitors based on their interesting. Through the experiment, the results show it is useful for laboratory introduction with a ubiquitous environment. Our proposal is revealed useful and practical.

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, acceleration sensor can be added to the tile to get more information about people.

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