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An RFID-Based Reminder System for Smart Home

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***Abstract*—Some people tend to forget things when they leave home for work or school. It is desired that there would be a reminder system to automatically remind people what they might have forgotten to bring along just when they step outside their home. In this paper, we present a reminder system that uses the RFID technology to detect the objects that a user brings along. The system then provide a reminder object list to the user based on the history data collected from the same user and the events in the user's calendar on that day. The list is to remind the user objects he/she might have forgotten at home. A feedback mechanism is also designed to lower the possibility of unnecessary reminding. The user can mark the objects that are not needed from the reminder object list such that these objects will not appear in the list again in the same situation. A prototype system is introduced in this paper.**

Keywords-RFID; reminder systems; smart home; smart environment; ambient intelligence

I. INTRODUCTION

To provide people with a comfortable and convenient living environment, smart home has become an important research issue. Automatic and intelligent technologies are applied to the home environment to improve the quality of life. Sensors are the basic components needed to detect the contextual needs of the users. In recent years, sensor network research has been a hot topic [1][2]. In a smart home, sensors are deployed at home to collect user-centered information in the environment. The collected information is then processed by the server to provide suitable services to the user. This is also a part of *ambient intelligence*. Future Home is a real environment built by Microsoft [3]. It includes the front door, the entry/foyer, the kitchen, the family room, the dining room, the entertainment room and the bedroom. In Japan, Toyota also built a future home called PAPI [4]. The research combined automatic cars and IT facilities produced by Toyota. In Taiwan, Farglory Realty used advanced IT technologies for home security, such as face recognition and finger vein identification. RFID (Radio Frequency Identification) technologies have been widely used in these researches as well as other applications like anti-theft security, ticket systems, logistics, medical care, library and… etc. According to the survey of IDTechEx, the applications of RFID will reach the highest demand from 2015 to 2020. Although the current RFID software market is not so big, with the growing popularity of RFID the RFID software market will have a potential high growth in the near future [5].

This research aims at providing a reminding mechanism for the user in a smart home environment. We focus on objects that the user would bring along when he/she goes out. The RFID technology is used to sense the objects the user brings along at the front door. In the object database, an object is recorded not only by its name along with a unique RFID number, but also its class. The taxonomy has two levels: classes and objects. For example, both the June issue and the July issue of Scientific American have the same class – Scientific American. Furthermore, both classes and objects are classified into three different levels according to the frequencies the user took them out. The three levels are *daily*, *weekly* and *non-regular*. The reminder system is also connected to the user's calendar. Objects related to events on the calendar are also recorded in the database. An event object list can be built by the user or automatically detected and recorded by the system.

When the user leaves home, the reminder system checks the objects in his/her bags and pockets, and compares the objects with a list of objects generated by the system according to the date of the week and the events on the calendar. The system then sends a reminder object list to the mobile phone or PDA (Personal Digital Assistant) of the user. The user can quickly browse the list and take any objects he/she might have forgotten to bring along. There is also a feedback mechanism for the reminder list. If any objects mistakenly appear on the list, the user can give a feedback to the system. The user can simply mark the unneeded objects on the reminder list. Those objects will not be included in the reminder list in the same situation next time. In this research, we have implemented a prototype system for the ideas. The preliminary tests show that this approach is promising for real applications.

In Section II, related work in RFID applications and smart environment is discussed. The proposed reminder system is introduced in Section III. System implementation is then presented in Section IV. Finally, a brief conclusion and future work are given in Section V.

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II. Related Work

In this section, RFID applications and smart environment researches are reviewed.

A. RFID applications

There are three major components of an RFID system: the reader, the antenna, and the tags [6]. Each tag is associated with a unique number. When a tag is in the detection range of the reader, the number is read. Two types of tags can be found: active tags with a longer detection range and passive tags with a shorter detection range [6]. An RFID tag is usually attached to an object and the information of the object along with the RFID number are recorded in the database. Whenever the RFID tag is sensed, the object can thus be identified.

The papers to be discussed here are more advanced applications. One of the papers deploys a large amount of RFID tags in an office, a conference venue or other public places. The user can use mobile devices to receive desired information like locations or maps, also the user can leave a message to a certain person. Besides, the maps can be retrieved by the rescue crew in emergency through a tag [7]. RFID was also applied to home cooking. First, RFID tags are attached to ingredients and utensils. The system can automatically provide video instructions to the user according to the detected movements of the user. The user needs not check the cook book step by step [8].

Another paper proposed a client-server architecture that can remotely control home appliances via mobile devices. Massive RFID tags are distributed in the environment for location awareness. The advantages of this system are less power consumption and design complexity [9]. In medical care, there is an RFID application related to medicine taking. RFID tags are attached to medicine bottles and the reader is placed in the drawer storing the medicine. The system can help the elderly people to record their medicine-taking data and determine whether they have taken the right medication with right dosage [10]. On the other hand, the assessment of independent living ability for the elderly can also be done by the RFID technology. RFID tags are attached to the tools used in our daily life. Readers are placed on different body parts of the elder. Home activities of the elder can thus be recorded [11][12]. Above-mentioned researches were keen to use the RFID technology to provide the users with convenient services. Although the RFID tags deployed in the public areas can help reach the goal, the tag price is still too high to make it feasible in real applications. In addition, using RFID to detect user's activities requires the user to carry RFID readers. This is very inconvenient to the user. Hopefully, the RFID reader can become much smaller and light-weighted in the near future.

B. Smart environment

According to Mark Weiser, there would be many invisible sensors, actuators, computers and displays, embedded into our daily lives and contacted each other via the Internet in the real world. Smart environment is defined to be a small world with numerous smart devices constantly working to provide comfort to the inhabitants [13][14][15]. This concept is commonly used in residential. Researchers hope to use machine learning methods to learn the living habits of each inhabitant, and intelligent agents to provide services to each user. Generally speaking, these studies have to collect enough information/data first to train the machine learning system. For example, inhabitant behaviors at home can be recorded with a time stamp. The relationship of the behaviors in time can thus be analyzed [16][17][18]. Another issue is that people's behavior and demand usually change with time. Therefore, the system must also adapt to each user. A research used cameras, microphones and other wearable sensors to track the inhabitant. The support vector machine (SVM) was then used to determine the user's behavior change and hence different environment settings [19]. A good system not only can changes with the user, but also can predict the next user activity. Another research focused on patients with dementia and loss of short-term memory. A system was designed to remind the patients if a certain action has been taken (such as having tea, brushing teeth, and etc.). When the patient forgets the next action, the system can give tips through LED lights, images or text to remind the patient [20].

III. An RFID-Based Reminder System

A reminder system is designed to remind the user what he or she has forgotten to bring along with when he or she leaves home for work or school. The user can thus takes the needed objects before he or she goes far from home. The RFID technology is used in this system to sense the objects. There are two ways to determine the list of objects a person needs for his/her daily work. First, if the events on that day are known, objects for those events should be in the list. Secondly, if the objects that the user used to bring along with on that certain date of the week, they should also be in the list. In this work, we tried to combine these two sources of information to construct the reminder list for the user when he/she goes out for work or school on a certain day.

The background setting of this system is in a general home environment. An RFID reader is installed near the front door and RFID tags are attached to the objects the user would take out. Whenever the user goes out, the objects he/she brings along with are detected by the reader and saved in the database. In general, the objects are strongly related to the date in a week. For example, Mary is a student and she has English classes on Tuesday. Therefore, she usually brings the English textbook with her on Tuesday. John plays tennis with his friends on Saturday morning. He brings his tennis racquet with him on Saturday.

Fig. 1 illustrates the workflow of the reminder system. When the front door is open, the RFID reader is triggered to read the nearby tags and send their ID numbers to the server. The maximum detection distance should be set at around 1 meter. The server compares the list with the object list generated by a number of rules following the historical data and the calendar events. The missing objects are arranged in a reminder list. When the door is closed, the server sends the list to the mobile phone or PDA of the user. The functions of the reminder server and the PDA client are discussed in the following.

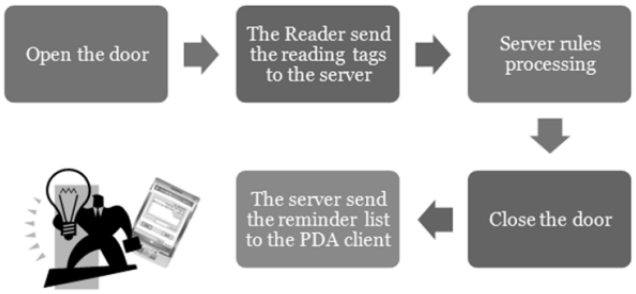

Figure 1. Workflow of the reminder system.

A. *Reminder server*

There are three main functions of the reminder server.

1) Collect tag IDs from the RFID reader.
2) Process the rule sets.
3) Generate and send the reminder list to the PDA client.

The user needs to initiate the system by inputting the object data including the object name, its RFID tag ID, and its class to the object database in the server. Recall that the objects are placed in a two level taxonomy: classes and objects. When the server received the tag IDs from the reader (detected when the user leaves home), it records the date along with the tag IDs. The tag IDs are associated with the objects and their classes in the database. The object/class use records for a week are then processed by the rule sets discussed in the following.

There are three sets of rules: the object rules, the class rules and the event rules. The object rules are used to classify all objects into one of the three frequency levels: *daily*, *weekly* and *non-regular* (Table I). *Daily* means that the object is taken out by the user every day, e.g., keys and wallet. *Weekly* means that an object is needed on certain dates during a week, e.g., English textbook on Monday and Wednesday because there are English classes on the two dates. The dates can be found from the use records in the previous week and they are recorded with the object in the database. As for *non-regular*, the objects have not been detected in the past seven days. The rules also define the conditions for object level change. An object can be upgraded or downgraded in the three levels. The adjustment periods of upgrade and downgrade can be made daily or weekly. For daily checks, the system makes adjustments right after the user leaves home every day. For example, if a non-regular object is brought by the user today, it is upgraded to a weekly object right away. If a weekly object is not brought by the user today, it is downgraded to a non-regular object. For weekly checks, the rules are performed every seven days. For example, if a weekly object was taken every day in the past week, it is upgraded to a daily object. If a daily object was not taken in any days in the past week, it is downgraded to a weekly object.

TABLE I. THE RULE TABLE.

Frequency of using objects	Satisfied conditions	Level up condition	Level down condition
Daily	Object is taken every day	---------	Object is not taken one day(check every week)
Weekly	Object is taken less than seven times a week	Object is taken every day next week(check every week)	Object is not taken next week(check every day)
Non-regular	Object is taken no regular	Objects is taken next week(check every day)	---------

The second rule set is called class rules. A class is a collection of objects with similar features. For example, different issues of the same magazine are of the same class. Classes are also classified into daily, weekly and non-regular and the rules in Table I are applicable to the classes. Therefore, the reminder list generated by the server includes not only the objects, but also the classes. For example, if a user takes Business Week with him/her every day, it is certain that the system will remind him/her whenever he/she forgets to bring *any* issue of Business Week on that day. Moreover, for the same medicine, every bottle has its unique tag ID. The user might need the medicine every day, but he/she might bring different bottles. If all the bottles are set to the same medicine class, the system can remind the user by the medicine class, not a particular bottle. The upgrade and downgrade rules also apply to the classes, but they are processed only in a weekly basis.

The third rule set is event rules. The rules help record the objects a user needed for a certain event. The objects for an event can be determined by the historical data and adjusted by the user through the feedback mechanism or they can be input directly by the user. When there is an event today and the event objects do not exist in the database. The event objects can be determined by subtracting daily and weekly objects from the objects that the user brings with him/her today. The server will automatically add the objects to the event. This can be illustrated by the following equation: *Event_Objects = All_Objects – Daily_Objects – Weekly_Objects*. If there are more than one unknown events, this might cause incorrect event object lists. However, they can be corrected with the user feedback at a later time. This process is shown in the first half of the flowchart in Fig. 2. The object rules and the class rules are performed in the second half of the flowchart.

Finally, a reminder list is sent to the user's PDA or smart phone before he or she goes far. The objects in the reminder list are ordered as follows: 1) event objects, 2) daily objects, 3) weekly objects, 4) daily classes, and 5) weekly classes. Meanwhile, level upgrade and downgrade rules are applied and related records are updated.

B. *PDA Client*

A PDA is used in our research as the client. A smart phone is another possibility. There are three main functions of the client.

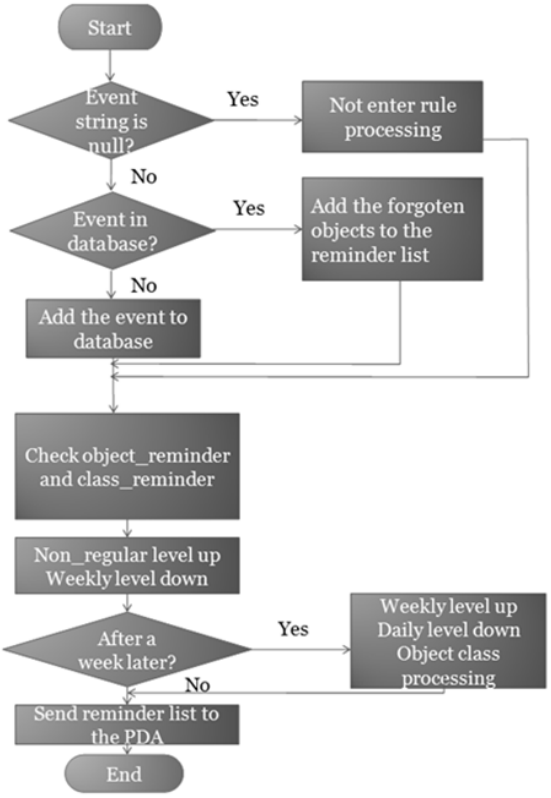

Figure 2. The flow chart of rules processing.

1) Reminder: When the user leaves home, the system automatically compares the taken objects with the object list generated by the system. The system then sends the reminder object/class list to the user's PDA. The PDA client is responsible for displaying the list to the user.
2) Calendar: The user can manage events in his/her personal calendar on the PDA. The system will automatically update the calendar of the user on the server.
3) User feedback: If the user is not satisfied with the reminder list, he/she can decide whether to ignore some of the objects in the reminder list and give a feedback to the system. The object/class frequency levels are then adjusted accordingly. Also, the user can modify the event objects for each event. With this feedback mechanism, the reminder system can provide a better service to the user with a more accurate reminder list.

IV. System Implementation

In the implementation of our prototype system, passive tags are attached to the objects. They are used, rather than active tags, because detection range is more appropriate for this application. Also, passive tags are smaller and lighter than active tags. Fig. 3 shows a few examples. In the application scenario of our system, the detection range should be from 0 to 100 cm or so. However, the RFID tags we used have a maximum detection distance of 10 cm. Thus in our tests, we have to put all the object tags close to the reader one by one. This should be corrected in real applications. The object data along with their corresponding RFID tag IDs are saved in a database built by MS SQL Server 2005. The RFID reader used in this implementation is a reader with a CF (Compact Flash)-card interface, which is attached to a PDA (Fig. 4). With this setting, the objects taken by the user can be automatically detected. The PDA then transmits the detected RFID tag IDs to the reminder server via a wireless LAN. After a reminder list is generated, the server sends the list to the client PDA carried by the user (Fig. 5).

On the server side, there are three user interfaces for system administration. The first one is for rule testing. The system administrator can select objects from the database for testing the correctness of the rules. Tag IDs from the reader PDA are not needed. The second one is for database management, including user data, object data and rule sets. The third one is for server management including initialization of the server and the communication between the server and the two PDAs (the reader PDA and the client PDA).

Figure 3. Objects attached with an RFID tag.

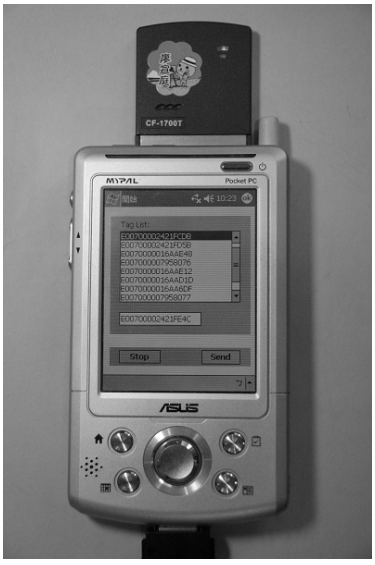

Figure 4. The CF-card RFID reader mounted on a PDA.

Figure 5. The reminder list sent by the server is displayed on the PDA client. The first three items are objects (crayons, badminton racquet, and English textbook); the last two are classes (sports goods and English books).

Experiments have been carried out with our prototype system. The user was assumed to be a school kid. A class schedule and some events were input into the system. Objects related to the classes as well as other personal belongings for daily activities were attached with an RFID tag. We then simulated the "going out" actions for one week. With the collected data, the objects are classified into one of the three frequency levels. The system then started to generate the reminder list to the user in the subsequent tests. Fig. 5 shows one of the reminder lists on the client PDA in our tests. Three objects and two object classes are displayed.

Generally speaking, our system could provide personal service in reminding the user what he/she had forgotten. The system is adaptive to the user's need. When the class schedule is changed for a new semester, it can be updated in the calendar. Also, the user can use the feedback mechanism to improve the system performance in reminding. However, in our tests, if the user brought things in an irregular manner, the system would not be able to provide useful reminder. Further tests by different types of users in real use cases are certainly necessary. The effectiveness of the reminder list in terms of *precision* and *recall* should also be analyzed.

V. Conclusion and Future Work

People forget things when they go out for work or school in the morning. In this paper, we present a prototype reminder system based on RFID and wireless technologies. The RFID makes it easy to detect and record the objects that the user takes out. Through the analysis on these records, the system would know what the user should bring along every day and what objects the system should put in the reminder list. Furthermore, the event calendar of the user is another source of information for constructing the reminder list. We think with some improvements the system can be used in real life.

In our experiments, the user was assumed to be a school kid. For the further tests, people of different backgrounds and working professions should be included. Next, in the current system, it can provide reminders to the user at weekends, but national holidays are not considered. Holidays probably can be treated as special events in the calendar. Also, the user may go out more than one time during a day. Time stamps can be added to the records of each "going out" and the system can analyze the user behavior not just based on the date of the week, but also the time of the day. Finally, the system can combine with weather forecast and event news from the Web. If the weather forecast says that the possibility of rain is very high this afternoon, the system can remind the user to take an umbrella with him/her. For example, if there are special discounts for members in a department store, the system can remind the user to bring the membership card.

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