An Educational Schoolbag System for Providing an Object Reminder Service

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Embedding educational functions into devices in the everyday environment is an important task for advocates of ubiquitous learning. In this paper, we discuss how to add a reminder service to a schoolbag. An educational function would be added to the device to help pupils remember belongings. Reminding oneself of things is a difficult task and reminder services have been an important subject of computer applications. However, most reminding tools are used for business, not education. Most such services use PDAs as terminals and require the user to create the reminder list by him or herself, making it too complex for some pupils to use. The systems also seldom pay attention to helping users learn how to avoid forgetting. In this research, a ubiquitous learning support system that makes use of schoolbags is presented to assist pupils in managing their personal items. With RFID and infrared sensors, a microcontroller embedded in a schoolbag can monitor what has been put in or taken out of the schoolbag and automatically maintain a schoolbag's items list. Such a bag also enables teachers to make up a schedule that specifies required items for given days. The microcontroller then compares the schedule with the items list in the schoolbag and provides a reminder service for the pupil. In addition to the reminder service, which is based on principles of behavior modification, the paper also proposes a series of methods to help pupils form good personal management habits and reduce their dependence on outside machines.

1. Introduction

With the development of computing technology, ubiquitous learning has come within researchers' horizons. It can be viewed as a combination of ubiquitous computing and e-learning¹⁾. Ubiquitous computing advocates have described a vision of a ubiquitous computing environment in which devices can understand a user's environment and proactively provide context-aware services $^{(4),10,11)}$. With the advent of ubiquitous learning devices, though proactive services are not yet available, some educational function is desired. Since users tend to rely on tools and lose ability related to those tools, ubiquitous learning tools that can help users improve their ability would be a great improvement. This paper presents a ubiquitous learning tool in the form of a schoolbag that provides a reminder service for pupils. Educational functions such as helping pupil remember things more often are also discussed. There are benefits from two viewpoints. One is organization: going to school serves multiple functions, one of which is that children learn to organize themselves. The other is parenting: having a device that helps and reminds may be beneficial for parents who will not need to remind their children as often.

There are already commercially available schoolbags that incorporate security devices into schoolbags to protect pupils. Dai Nippon Printing Co., Ltd. and DoCoMo Systems developed "KIDS SAFETY PASS" ¹⁰). Using IC tags, the system can inform a pupil's family whether he or she is going to school or coming back home. SECOM has developed a smart schoolbag with a GPS function 11). A GPS terminal is attached to the schoolbag, and the system can notify the parents of the pupil's location. These systems are lightweight and can enhance security. But it is hard to add new functions to these systems. Since a pupil can take a schoolbag almost anywhere, schoolbags could be powerful tools for recording the pupil's rhythm of life and for providing educational support. Moreover, when ubiquitous computing devices become small enough, the architecture used in the schoolbag can be incorporated into other smaller learning tools (pencil boxes and pens, for example). This could be the basis of a very useful ubiquitous learning

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environment.

Dozens of reminder devices have been invented, such as alarm clocks, calendars, Post-it notes, and Personal Information Management (PIM) devices. These reminder devices usually provide service in a static context. For example, an alarm clock can wake a user up at the time set by the user; a $PIM^{2),3}$ can alert a user to deadlines set by the user. In contrast to this kind of reminder, a context-aware reminder would provide a reminder service in a dynamic context. CyberMinder⁶) is an early context-aware reminder system that takes account of location, time, user ID, sound level, and even stock prices. For example, it can alert a user to changes in his or her stock prices. Although the system can grasp many contexts, it can only remind a user of the event and not of needed objects.

Recently, accompanied by the development of RFID technology, some research has managed to create an object reminder service. Borrielo⁷) presented a reminder system that makes use of RFID tags and RFID readers to identify each object. GateReminder⁸) is a family-shared home appliance located by the front door that can remind users of things they need to take and know before leaving home.

Like the two studies mentioned above, our schoolbag system also makes use of RFID technology to provide an object reminder service. However, taking into account RFID limitations, such as sensible space, the relative positions of **RFID** antennae and **RFID** tags, different **RFID** antenna deployment methods will be required. For example, both the front door area⁷) and the hallway⁸⁾ are roomy, open spaces. Accordingly, multiple readers and antennas would need to be applied to improve reading accuracy. In contrast, the space inside a schoolbag is small and items are close to sensors. Multiple readers would make the bag heavier and reduce its portability. Multiple antennae in such a space would interfere with each other and decrease reading accuracy. Therefore, our research has paid a lot of attention to the design and placement of antennae. The contexts a schoolbag must take into account are different from those taken into account by existing context-aware reminder systems. For example, the contexts the GateReminder must take into account include which direction the user is heading in - to the front door, or to the living room, whether the door opened or closed. The motion detector and door sensor are used to determine these contexts. The contexts a schoolbag must take into account include what objects are taken out of or put into the bag in the real time. Hence, our system uses infrared sensors and the Real Time Clock (RTC).

Creating an object reminder service is the main purpose of our research. Another purpose is to evaluate the feasibility of integrating educational functions into the schoolbag, thereby improving the pupils' personal management skills. People tend to depend on services provided by outside machines, allowing important skills to atrophy. The reminding function is the first step of our research. The second step is processing how to help pupils learn to arrange their lives by themselves using the schoolbag. In this paper, we present an educational support module and discuss the potential for enhancing the ability to remember things.

The remainder of the paper is organized as follows. In Section 2, the system model and the problems that must be solved are discussed. Then, in Section 3, the system design details are presented. In Section 4, we present how we will implement and test the system. Finally, Section 5, summarizes the paper and discusses future work.

2. Model and Problems

The Educational Schoolbag for Pupils is our first attempt to create a working prototype of a ubiquitous educational aid for pupils. The main users of the system are pupils. From the pupil's point of view, the system should provide interfaces that enable him or her to easily know what items will be needed on a given day and to check what is inside his or her schoolbag. The pupil should also get a reminder service and educational support at the proper time and in the proper way. Since pupils often need teachers or parents to help them manage their items, the system also should provide interfaces that enable others (such as teachers and parents) to draw up a schedule that includes a required objects list and an alarm time. The final goal is to enable a pupil to manage personal items correctly by him or herself without reminders.

Server/Client architecture was designed for the system with the above criteria in mind. **Figure 1** is a conceptual model of the schoolbag system. The teachers and parents of the pupil can make up a schedule on their PCs and send the schedule to the schoolbag via a server.



Fig. 1 Model of schoolbag system.

The objects list and the schedule will be displayed on an LCD on the schoolbag so the pupil knows what he or she needs to put in the bag. Then the schoolbag will monitor what is being put in or taken out. If, by the deadline of an alarm time, some items on the items list have not been put into the bag, an alarm will alert the pupil of the needed items. The data flow is specifically described as follows.

- 1. Teachers or parents make up a schedule and a list of required items. The schedule is sent to the schoolbag by the server via a wireless network.
- 2. The schoolbag uses the RFID reader and other sensors to detect what personal items have been taken out or put in.
- 3. Information on the required personal items can be checked by the pupil on the schoolbag's LCD.
- 4. If a deadline has passed and some required items have not been put into the bag, then an alarm will sound to remind the pupil not to forget needed items.
- 5. Meanwhile, information about items and a timestamp will be sent back to the server and stored in the database to improve future support.

To implement the system described above, the following problems must be solved.

1) How to enable the schoolbag to know what is being put in or taken out, which is the important raw data for the whole system. We try to make use of the pupil's actions putting in and taking out items as the implicit input.

2) How to set schedules.

Two problems have to be clarified concerning

the schedules. The first is who should make up the schedules. Pupils are not mature enough to make schedules by themselves, so the system provides an interface for teachers and parents to make up the schedules. The second is what contents should be included in the schedule. Although an events list including items such a test next Friday can be added to the schedule as well, one of our main purposes is to illustrate the feasibility of providing an object reminder service based on a pupil's implicit input. So in this paper a schedule includes warning times, an items list of the needed objects, and a reminding method.

3) How to set warning times

From our observation, if the warning message is sent out only once, it may not successfully remind the pupil. Alerts and the interval between two alerts must be optimized for effective reminding.

4) How to support a pupil. Two kinds of support need to be provided to pupils. One is a reminder service to help pupils remember needed objects. The other is educational support to help a pupil to learn to remind him or herself. 5) How to keep the schoolbag as portable as possible. Obviously, wireless communication is necessary for the schoolbag. Most other reminder systems use PDAs or cell phones $^{2),3),6)}$. However, PDAs are not appropriate for the schoolbag system because they are difficult for pupils to use due to their many unnecessary extra functions, and because the schoolbag system has special needs such as low power operation. So, a circuit board must be designed to meet the needs of the schoolbag system.



Fig. 2 Deployment of RFID antenna of a RFID reader. (a) Front View, (b) Side View.

3. The Schoolbag System

3.1 Outline

The schoolbag, as a client in the Server/Client architecture, is the main part of our schoolbag system. By combining RFID and infrared sensors, the schoolbag can monitor what is put in or taken out of it and maintain an objects list. It also has a clock. When it reaches the warning threshold, which is sent to it as part of the schedule, the schoolbag will check whether all the objects on the schedule's objects list are in the bag. If any items are not in the bag, the proper reminder method will be adopted to remind the pupil.

3.2 Design of the Schoolbag Client

3.2.1 Deployment of the RFID reader and RFID tags

This paper mainly focuses on how to provide a reminder service about objects (such as text books, notes, pencil box, and so on), so the schoolbag system has to know what it contains. An RFID reader is used to identity objects. A RFID tag is attached to the center of each object. The deployment of the RFID antenna and the controller, which includes an RFID reader module, are shown in **Fig. 2**. The controller (the controller architecture is presented in Section 4) is a rectangular box consisting of control modules, including the RFID reader module.

A loop shaped RFID antenna is placed at the top of the schoolbag. If it is placed at the bottom or middle of the schoolbag, the RFID reader will read an object's tag, repeatedly. Lots of the CPU time would be wasted dealing with useless queries and the logic complexity of the system work flow would increase because the system would need to add methods of picking up valuable data from the duplicated data set. Putting the antenna at the top can avoid the above two problems.

3.2.2 Deployment of Infrared Sensor

Infrared sensors are integrated into the system for two reasons. First, although the RFID is good at understanding what the item is, it is not good at judging whether items are being put in or taken out. Second, it is difficult to confine the RFID reader to reading only the RFID tags that are in the schoolbag. If a book with an RFID tag is taken out of the bag within range of the RFID reader, it will falsely record that book. To solve the above two problems, infrared sensors are integrated into the system.

The system can judge whether an object is put in or taken out of the schoolbag from the reactions of two infrared sensors. The infrared emitter (infrared LED) and two infrared receivers (the top receiver is labeled "T", and the bottom receiver is labeled "B") are placed as shown in Fig. 3. Each receiver has two statuses: signal receiving status and no signal status. When there are no objects between the infrared LED and the infrared receiver, the receiver can continuously receive the signal from the emitter. This status is called signal status, and is denoted X (X could be either T or B). When there are objects between the infrared LED and the infrared receiver, the receiver cannot receive the signal from the emitter. This status is called no signal status, and is denoted



Fig. 3 Deployment of RFID antenna of an RFID reader and infrared sensors. (a) Front view, (b) Side view.

Table 1	Putting in and taking out judgment
	patterns.

	An object is being put into the		
$(1) \to (B) \to (1) \to (B)$	schoolbag (IN)		
	An object is being taken out of		
$(B) \to (T) \to (B) \to (1)$	the schoolbag (OUT)		

as $\overline{\mathbf{X}}$.

Table 1 shows the in/out patterns of the two infrared sensors: T and B. When an object is going past the two infrared sensors into the schoolbag, it will first block the signal between the emitter and the top receiver; then it will block the signal between the emitter and the bottom receiver; next it will pass over the top receiver; finally it will pass over the bottom receiver. Conversely, when an object is going through the two infrared sensors out of the schoolbag, it will first block the signal between the emitter and the bottom receiver; second it will block the top receiver; third it will pass over the bottom receiver; finally it will pass over the top receiver.

3.2.3 Personal Items Monitoring Module

The function of this module is to determine an object's identity and IN/OUT (Table 1) status. The object's identity is determined by the RFID reader. The IN/OUT statuses of the object are monitored by the two infrared sensors. Procedure 1 shows the process module for monitoring personal items.

Procedure 1

If the top infrared sensor is in no signal status or the bottom infrared sensor is in no signal status

To make a judgment on the pattern based on the Table 1 If the pattern is IN Get RFID tag's ID If the ID is on the items list Set the status of the item to IN If the pattern is OUT Get RFID tag's ID If the ID is on the items list Set the status of the item to OUT

3.2.4 Forgotten Items Checking Module

The module's main function is as a timing system for the reminder service (Procedure 2). **Procedure 2**

If current time has arrived at any schedule's warning threshold

Compare the items list in the schedule with the items list maintained by the schoolbag

If any items listed in the schedule are OUT Activate reminder service

Otherwise Show encouraging message

3.2.5 Support Module

This module mainly focuses on how to provide the reminder service properly and how to

 Table 2
 Table of reminding time patterns.

Reminding Pattern (RP)	Alarm time
RP1	20:00, 8:00
RP2	19:50, 20:00, 7:50, 8:00
RP3	19:40, 19:50, 20:00, 7:40, 7:50, 8:00





help a pupil reduce his or her reliance on the reminder system.

3.2.5.1 Reminding Component

Based on the observation that a pupil may often be reluctant to pack his or her schoolbag even if he or she hears the alarm message, three kinds of reminding patterns (RPs) are defined in **Table 2**. The frequency of reminders increases as the system moves from RP1 to RP3. The reminding module will remind a pupil at least two times (RP1), for example at 20:00 and the next morning at 8:00. As shown in **Fig. 4**, if the reminders do not succeed in getting the pupil to put items in the schoolbag, the system will move to RP2.

3.2.5.2 Behavior Modification Component

The purpose of this component is to help pupils form good self-management habits and reduce their dependence on the external system.

B.F. Skinner's stimulus-reinforcement (S-R) theory is integrated into this component design. Reinforcement is the key element in Skinner's S-R theory. A reinforcer is anything that strengthens the desired response. It could be verbal praise, a good grade or a feeling of increased accomplishment or satisfaction. In this component, the audio device on the schoolbag gives verbal praise to a pupil when the pupil's performance improves. Moreover, to enhance the pupil's sense of accomplishment, each



Fig. 5 Schoolbag system Server/Client architecture.

Friday at 20:00, if the pupil's performance is one of the five best in his or her class, his or her rating will be displayed on the LCD of the schoolbag.

4. Implementation and Evaluation of the System

4.1 Schoolbag system's implementation architecture

The implementation architecture for the whole system is shown in **Fig. 5**. The system has four parts: a server, a database, PCs, and schoolbags.

- 1. The server deals with queries from the PCs and schoolbags, transmits the schedule from the PCs to the schoolbags directly, and stores the data from the schoolbags in the database.
- 2. PCs make the schedule and send it to the server.
- 3. The schoolbag maintains an items list that specifies the objects in the bag and receives the schedule from the server. At alarm time, it compares the items list with the schedule and provides reminding support and sends the compared result, that is, the status of the each item in the schedule, back to the server.
- 4. The database stores the historical data about the status of the objects in the



Fig. 6 Diagram of the controller in the schoolbag.

main modules.		
Atmel 89S52		
RF-MOD10H2		
WiPort		
ZJM12864BSBD		
DS1302		
ISD4004		
24LC64		

 Table 3 IC list for main modules.

schoolbag.

All schoolbags can communicate with the server through wireless access points (APs). The wireless communication protocol is the widely used IEEE 802.11b. The schoolbag is portable and, as long as there is wireless AP nearby, the schoolbag can exchange data with the server.

4.2 Implementation of the schoolbag

The hardware of a schoolbag consists of a micro-controller, an RFID reader, a wireless module, an LCD display, two infrared sensors, a system clock module, a voice record/playback module, a speaker, and a ROM module (**Fig. 6**). The IC list is in **Table 3**.

The schoolbag's software has four components: data management, communication, sensor control, and pupil support. The componentized design is flexible, and reusable since data such as a schedule from the server and a local items list, are usually stored in the RAM. If it powers down or resets the system, the data will be lost. The data management component responds by reading data from or writing data into the ROM through the I2C bus. The



Fig. 7 Picture of ubiquitous schoolbag.

data, including the schedule from the server and the local items list, are all backed up by the data management module. The communication component is used to communicate with the server. The RFID reader and the infrared sensors are controlled by the sensor control component. At an alarm time, the pupil support component provides the reminder service and educational support.

Two languages, Java and C, have been selected to develop the system. The server side program and the teacher's client side program were developed in SUN J2SDK1.4.2. The pupil's side program, which runs on the embedded hardware, was fabricated at Keil C51.

Figure 7 is a picture of the whole system.

4.3 How the schoolbag system is used

A teacher can use the ScheduleMaker (**Fig. 8**) to make up the schedule for his or her pupils. A schedule includes the date, alarm times, and needed objects. For example, in Fig. 8, a schedule is made that specifies that on Sep. 18th, the math book, nature book, and social studies book are required. The alarm time is

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Fig. 8 Sample schedule.



Fig. 9 (a) Putting a textbook into schoolbag,(b) Check object status on LCD.

8:30. Then when the "Send Schedule" button is pushed, the schedule is sent to the schoolbag via the server.

When an object is put into/taken out of the schoolbag, the object's ID and in/out status is automatically recorded by the schoolbag (**Fig. 9**). A user can check the in/out status of the objects displayed on the LCD.

At an alarm time, if the status of some objects is out, then a voice message from the speaker tells the pupil what has been forgotten.

4.4 Experiment

4.4.1 Object monitoring accuracy

We tested the accuracy of the system's monitoring of in/out status by experiment. Three objects were used to test the system: an A4-size book, an A6-size notebook, and a 13×6 cm RFID tag card. Three speeds were used to test the system: slow, or about 15 cm/s, normal, or about 30 cm/s, and fast, or about 50 cm/s. Each item was taken out and put in at each speed twenty times. The RFID reader that we use is non-anticollision, so it is a prerequisite of this experiment that we take objects in and out one by one. The results of this experiment are shown in **Table 4**.

The results in Table 4 show that the size of the object has a relatively big effect on the accuracy only when the object is moving fast. This is because an RFID reader needs 200–300 ms to read the tag's data. So when the object is moving too fast, it is difficult to judge the item's identity.

4.4.2 Experiment on system usability by users

In our second experiment, ten pupils (grades of the pupils are displayed in **Table 5**) were invited to test the schoolbag system by using it. Six guardians monitored the whole process of the experiment. After the experiment, each of the pupils and guardians filled out a questionnaire. The questionnaire for the guardians is same as the form for the pupils, but the guardians were asked to answer the questions from a parents' point of view.

Through the questionnaire, we tried to find out how future users (pupils and their guardians) think about the following problems:

- a. Frequency with which pupils forget things in daily life. (Q1)
- b. Need for a schoolbag with a reminding function. (Q2, Q3, Q4)
- c. Propriety of the supporting methods of the schoolbag system. (Q5, Q6)
- d. Effectiveness of the schoolbag reminding function. (Q7)
- e. Probability that the schoolbag will modify the user's behavior. (Q8)

Concretely, the questionnaire form is as follows. (The form consists of eight multi-choice questions and one open-ended question. For Q2 through Q8, there is a five point rating scale with A being the most positive and E the most negative.)

Q1 Could you tell us how often you forget personal belongings in your daily life?

- A. Every day
- B. More than once a week
- C. About once a week

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 Table 4
 Accuracy of schoolbag at each speed.

	A4	A6	Tag card
Slow 15cm/s	90%	95%	95%
Normal 30cm/s	95%	95%	90%
Fast 50cm/s	90%	85%	55%

Table 5 Grades of pupils.

	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Total
Number of	2	3	1	2	2	10
participants	2	,	1	2	2	10



- D. Not less than once a month
- E. Never forget (include less than once a month)
- Q2 To avoid forgetting, would you like a schoolbag like this one to help you?
- Q3 If you could buy such a schoolbag in a shop, would you like to have one?
- Q4 Would you like the schoolbag rather than your parents to help you to pack your bag?
- Q5 Do you feel the message displayed on the LCD is easy to understand?
- Q6 Do you feel the voice message is easy to understand?
- Q7 By using such a schoolbag, do you think you would stop forgetting things?
- Q8 By using such a schoolbag, do you think you would gradually forget things less frequently?
- Q9 Open question: Please write your feelings, comments, and any ideas about the schoolbag.

The statistical results are shown in **Fig. 10** (pupils) and **Fig. 11** (guardians).

Frequency of forgetting: For Q1, 60% of pupils answered either A, B, or C, indicating that they forget things at least once a week. In



response to the same question, more than 80%of guardians say their children forget things at least once a week. This difference can be interpreted to indicate that guardians usually pay more attention to their children's forgetfulness. **Necessity**: For Q2, Q3, and Q4, more than 70% of pupils answered either A or B, and almost all of the guardians would like to have such a schoolbag. Some guardians reported that repeatedly urging their children to pack their schoolbag tends to irritate their children and sometimes results in outright disobedience. From this point of view, if a schoolbag can do such things automatically and in a less nagging way, it would solve this problem.

Propriety: Object status is displayed on the LCD to help pupils check what's in the schoolbag. More than 60% of pupils say they had no problems reading the message on the LCD, and only two pupils (grade two) choose "not easy". They complained that there were Kanji (Chinese characters) on the LCD that they had not yet learned. So we found out that for first and second graders, Hiragana is a better choice than Kanji. This issue can be resolved by adding a display pattern button that allows the

user to choose from Hiragana and Kanji. Answers to Q6 showed that voice support received the highest score for providing user-friendly interface. Eighty percent of pupils thought it was easy to understand. One pupil said the volume was too low and she could not clearly hear the voice.

Effectiveness & Potential: Eighty percent of pupils and 100% of guardians (counting A and B) believe that the schoolbag can help them avoid forgetting necessary objects. Ninety percent of pupils and 100% of guardians (counting A and B) believe that such a schoolbag can gradually help the pupils to form good personal management habits.

In response to the open-ended question, both pupils and guardians expressed valuable feelings and advice. Some pupil said they were amazed to have a schoolbag that could speak. Moreover, several pupils said that using our schoolbag is almost as natural and convenient as using a traditional schoolbag. Based on the feedback from the pupils, the main problem of the current schoolbag is that the embedded devices make it heavier. In response we are designing a schoolbag that will be much lighter. Some guardians said that the present system can only monitor the status of objects in the schoolbag and that it would be better if a system could provide a reminder service for objects that are not put into a schoolbag, such as a sports outfit, sports shoes, glasses, etc. Finally, almost all guardians expressed worry about whether pupils will become too dependent on such a schoolbag and lose their ability to think and manage for themselves. This is a problem of concern to us that we are trying to solve by integrating behavior modification techniques into the system. This idea was introduced in Section 3.2.5.

5. Conclusion and Future Work

We developed a smart schoolbag system that can check whether all needed objects have been packed. It also provides a reminder service to prevent pupils from forgetting objects and educational support methods to improve pupils' self-management skills so they will forget less frequently.

The results of the experiment prove that users' behavior (packing and unpacking objects) in a relatively small space (schoolbag) can be changed using different sensors. This method can be generalized and applied to some other applications.

The present schoolbag cannot monitor more than two objects at the same time. Anticollision type RFID reader and RFID tags should be used in fabricating the schoolbag so that pupils will be able to use the schoolbag as they do regular schoolbags.

Since the system makes few assumptions about the environment, it has great potential in real life applications. It can be used to collect data about a pupil's daily behavior. In future work, a ubiquitous schoolbag system which can apply into pupils' daily life will be developed. Then the behavior psychology principles can be integrated into the system to help pupils to form a good habit. And all of these ideas can be evaluated by inviting dozens of pupils to use our schoolbag in their real life.

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