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Next Generation Self-learning Style in Pervasive Computing Environments

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1. Introduction

With the great progress of technologies, computers are embedded into everywhere to make our daily life convenient, efficient and comfortable [10-12] in a pervasive computing environment where services necessary for a user can be provided without demanding intentionally. This trend also makes a big influence even on the education field to make support methods for learning more effective than some traditional ways such as WBT (Web-Based Training) and e-learning [13, 14]. For example, some WBT systems for educational using in some universities [1, 2, 9], a system for teacher-learners' interaction in learner oriented education [3], and real e-learning programs for students [7, 8] had succeeded in the field. However, a learner's learning time is more abundant in the real world than in the cyber space, and learning support based on individual situation is insufficient only with WBT and e-learning. In addition, some researches show that it is difficult for almost all learners to adopt a self-directed learning style and few of learners can effectively follow a self-planned schedule [4]. Therefore, support in the real world is necessary for learners to manage a learning schedule to study naturally and actively with a self-learning style. Fortunately, with the rapid development of embedded technology, wireless networks, and individual detecting technology, these pervasive computing technologies make it possible to support a learner anytime and anywhere kindly, flexibly, and appropriately. Moreover, it comes to be able to provide the support more individually as well as comfortable surroundings for each learner through analyzing the context information (e.g. location, time, actions, and so on) which can be acquired in the pervasive computing environment.

In this chapter, we address a next-generation self-learning style with the pervasive computing and focus on two aspects: providing proper learning support to individuals and making learning environments suitable for individuals. Especially, a support method is proposed to encourage a learner to acquire his/her learning habit based on Behavior Analysis through a scheduler system called a Ubiquitous Learning Scheduler (ULS). In our design, the learner's situations are collected by sensors and analyzed by comparing them to his/her learning histories. Based on this information, supports are provided to the learner in order to help him/her forming a good learning style. For providing comfortable

surroundings, we improve the ULS system by utilizing data sensed by environments like room temperature and light for the system, which is called a Pervasive Learning Scheduler (PLS). The PLS system adjusts each parameter automatically for individuals to make a learning environment more comfortable. Our research results revealed that the ULS system not only benefits learners to acquire their learning habits but also improved their self-directed learning styles. In addition, experiment results show the PLS system get better performance than the ULS system.

The rest of the chapter consists as follows. In the section 2, we propose the ULS system and describe the design of the system in detail followed by showing implementation of the system with experimental results. In section 3, the PLS system is proposed and we provide an algorithm to find an optimum parameter to be used in the PLS system. The PLS system is also implemented and evaluated comparing to the ULS system. Finally, section 4 concludes this chapter.

2. The ULS system model

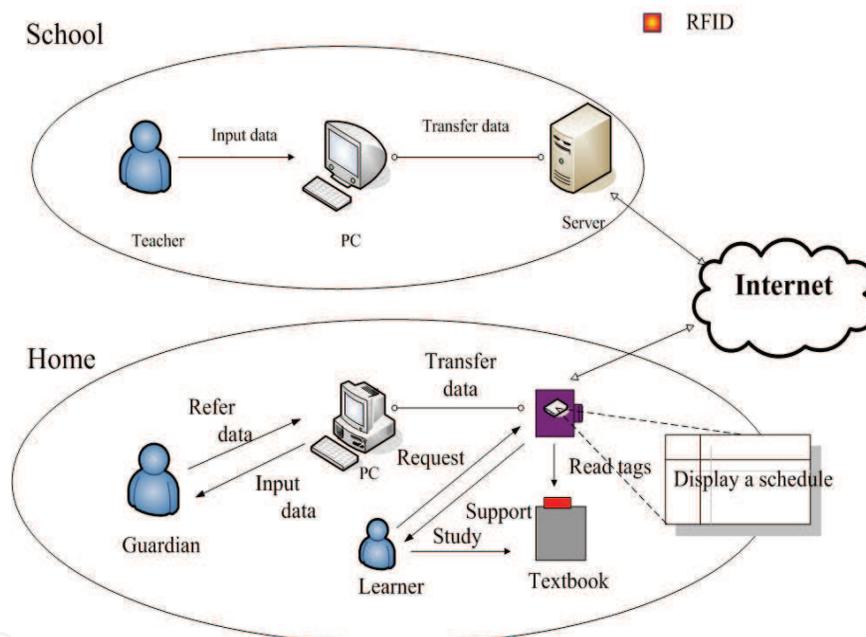


Fig. 1. A model of the ULS system

Figure 1. shows a whole model of a ubiquitous learning environment. The system to manage a learning schedule is embedded in a special kind of desks which can collect learning information, send it as well as receive data if needed, and display a learning schedule. In the future, it will be possible to embed the system in a portable device like a cellular phone. As a result, a learner will be able to study without choosing a place.

In Figure 1., there are two environments. One is a school area. In this area, a teacher inputs a learner's data, test record, course grade, and so forth. This information is transferred to the learner's desk in his/her home through the Internet. The other is a home area. In this area, a guardian inputs data based on his/her demands. This information is also transferred to the desk. When the learner starts to study several textbooks, his/her learning situation is collected by reading RFID tags attached to textbooks with an RFID-reader on the desk. Based on combination of teacher's data, parent's demand, and learner's situation, a learning

schedule is made by the system. A learning schedule chart is displayed on the desk. The learner follows the chart. The chart changes immediately and supports flexibly. The guardian also can see the chart to perceive the learner's state of achievement.

In this paper, we are focusing on the home area, especially learners' self-learning at home. We assume a learning environment is with the condition as same as Figure 1. To achieve the goal, we have the following problems to be solved:

1. How to display an attractive schedule chart to motivate the learner?
2. How to give a support based on Behavior Analysis?
3. When to give a support?
4. How to avoid failure during learning?

In order to solve the above problems, at first, a method which can manage a learning schedule is proposed. Its feature is to manage a learning schedule based on combination of the teacher's needs, the parent's needs, and learner's situation. Its advantage is that the learner can determine what to study at the present time immediately. Secondly, the ULS is implemented based on behavior analyzing method. Because behavioral psychology can offer students more modern and empirically defensible theories to explain the details of everyday life than can the other psychological theories [9]. The function of the ULS is to use different colors to advise the learner subjects whether to study or not.

2.1 Ubiquitous Learning Scheduler (ULS)

This paper proposes a system called Ubiquitous Learning Scheduler (ULS) to support learner managing their learning schedule. The ULS is implemented with a managing learning schedule method. It analyses learning situations of the learner and gives advices to the learner. This method solves the problems we mentioned above. Its details are described in following sections.

Subject Name	Mon.	Tue.	Wed.	Thu.	Fri.	Sat.	Sun.
Jpn.	Navy Blue	Navy Blue	Navy Blue	Green	White	White	White
Math.	White	White	White	Red	White	White	White
Sci.	White	Navy Blue	White	Green	White	White	White
Soc.	Navy Blue	White	White	Yellow	White	White	White
HW.	Navy Blue	Navy Blue	Navy Blue	Red	White	White	White

Fig. 2. An example of a scheduling chart

Figure 2. shows how to display a learning schedule chart in the ULS. Its rows indicate names of subjects and its columns indicate days of the week. For instance, a learner studies Japanese on Monday at a grid where Jpn. intersects with Mon. The ULS uses several colors to advise the learner. The learner can customize the colors as he/she like. Grids' colors shown in Figure 2. is an example of the scheduling chart. Each color of grids means as follows.

- Navy blue: The learning subject has been already finished.
- Red: The subject is in an insufficient learning state at the time or the learner has to study the subject as soon as possible at the time.

- Yellow: The subject is in a slightly insufficient learning state at the time.
- Green: The subject is in a sufficient learning state at the time.

As identified above, red grids have the highest learning priority. Therefore, a learner is recommended to study subjects in an ideal order: red→yellow→green.

The indications consider that accomplishments lead to motivations. There are two points. One is that a learner can find out which subjects are necessary to study timely whenever he/she looks at the chart. If a learning target is set specifically, it becomes easy to judge whether it has been achieved. The other is that the learner can grasp at a glance how much he/she has finished learning. It is important for motivating the learner to know attainment of goals accurately.

Basically, the ULS gives a learner supports when he/she is not studying in an ideal order. For example, when the learner tries to study a subject at a green grid though his/her chart has some red grids, the ULS gives a message such as “Please start to study XXX before YYY”, where XXX is a subject name at a red grid and YYY is the subject name at the green one.

2.2 Supports to avoid failure during learning

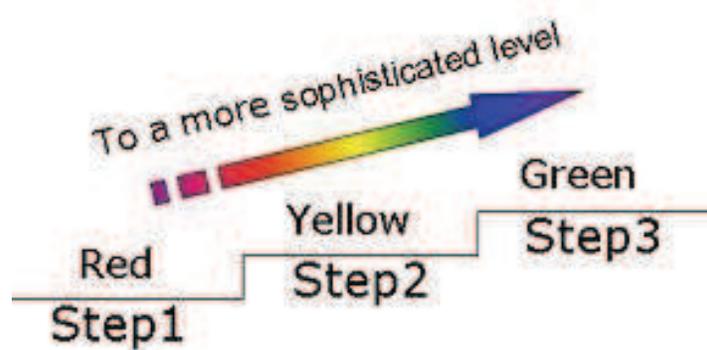


Fig. 3. Model of Shaping

	Red	Yellow	Green
Compliment Examples	Good! You've challenged this subject.	Quite good! You've done basic study for this subject.	Excellent! You've studied this subject quite enough.
Learning Time (Objective Time)	Regard-less of time	More than 10 min.	More than 20 min.

Table 1. Example of complements and learning time

The ULS also aims to lead the learner to a more sophisticated learning style than his/her initial condition. To solve this problem, we used the Shaping principle in Behavior Analysis [9]. When differential reinforcement and response generalization are repeated over and over, behavior can be “shaped” far from its original form [9]. Shaping is a process by which learning incentive is changed in several steps from their initial level to a more sophisticated level [9]. Each step results from the application of a new and higher criterion for differential reinforcement [9]. Each step produces both response differentiation and response

generalization [9]. This principle also makes sense in the learning behavior. By referring to Figure 3., this paper considers red grids as step 1, yellow ones as step 2, and green ones as step 3. Step 1 is the lowest level. The ULS gives the learner different compliments based on learning time according to each color. Learning time depends on a learner's situation. Table 1 shows an example of that. Learning time of yellow and green are based on average of elementary students' learning time in home in Japan [4].

2.3 Design of the ULS system

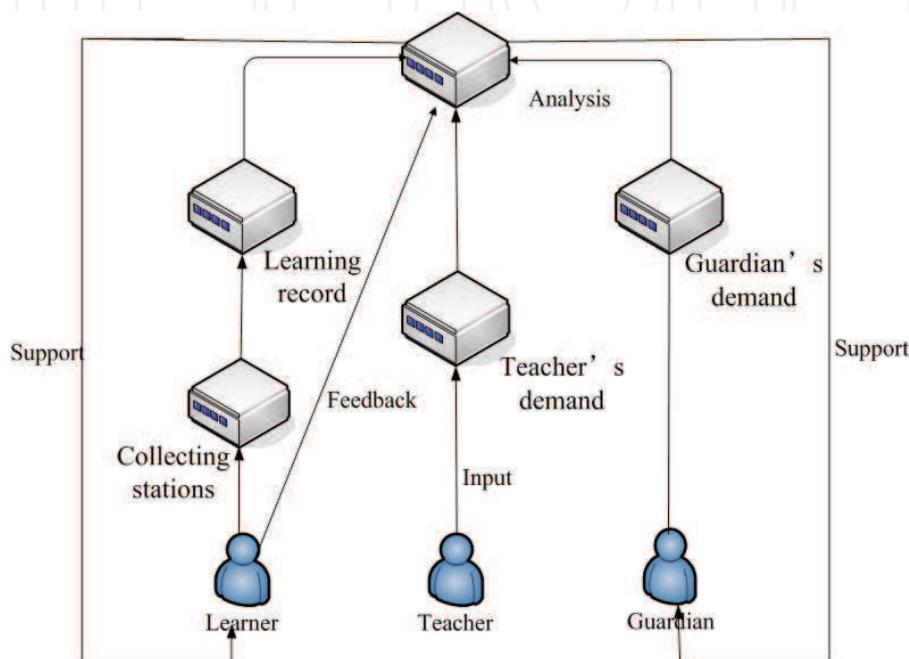


Fig. 4. Model of Shaping

Figure 4. shows a flow chart of the system in this research. A teacher and a guardian register each demand for a learner into each database, a *Teacher's Demand DB* and a *Guardian's Demand DB*. The demands indicate which subject the learner should have emphasis on. Each database consists of learning priorities and subject names. On the other hand, the learner begins to study with some educational materials. At the same time, the ULS collects his/her learning situations and puts them into a *Learning Record DB*. The database consists of date, learning time, and subject names. By comparing and analyzing the information of three databases, the ULS makes a scheduling chart such as Figure 2. and always displays it in learning. The learner pursues its learning schedule. The ULS gives him/her supports, depending on learning situations. The guardian can grasp the learner's progress situation of the schedule by the ULS supports.

Each grid's color is decided with calculating Color Value (CV). We define the following equation for determining CV.

$$CV = CV_0 * LAD + SAD \quad (1)$$

Each notation means as follows.

$$CV[2 \leq CV \leq 4] : Color Value \quad (2)$$

CV decides a color of the current grid and has some ranges for three colors such as red, yellow, and green. The green range is from -2 to 0, the yellow one is from 0 to 2, and the red one is from 2 to 4. Also, the value smaller than -2 will be considered as green and bigger than 4 will be considered as red respectively. For example, when CV equals to 0.5, the color is yellow. These ranges are not relative to RGB code and are assumed to be set by the teacher in this research.

$$CV_0[0 \leq CV_0 \leq 1] : \text{Initial Color Value} \quad (3)$$

CV_0 is decided with combination of the teacher's demand and the guardian's one. At first, the teacher and the guardian respectively input priority of subjects which they want the learner to self-study. Priority is represented by a value from 1 to 5. 5 is the highest priority and 1 is the lowest one. ULS converts each priority into CV_0 . CV_0 is calculated by the following equation.

$$CV_0 = (TP + GP) * 0.1 \quad (4)$$

In the equation (4), TP and GP mean Teacher's Priority and Guardian's Priority respectively.

	Jpn.	Math.	Sci.	Soc.	HW.
Teacher	5	2	3	4	1
Guardian	5	4	2	3	1
Sum.	10	6	5	7	2
CV_0	1.0	0.6	0.5	0.7	0.2

Table 2. An example of a relationship between ranks and CV_0

For an example, in Table 2, Math ranks the value as 2 by the teacher and the 4 by the guardian. Therefore the sum of their priority equals to 6 and CV_0 is decided as 0.6.

The learner's situation also affects CV. We express it as Long-term Achievement Degree (LAD) and Short-term Achievement Degree (SAD). Both of their values are fixed at the end of a last studying day.

$$LAD[0 \leq LAD \leq 100] : \text{Long-term Achievement Degree} \quad (5)$$

LAD indicates how much the learner has been able to accomplish a goal of a subject for a long term. In this paper, this goal is to acquire his/her learning habit. The default value is 100 percent. We assume that the learner has achieved his/her goal when all grids are green. Then, the LAD value equals to 100 percent. For example, if the number of green grids is 12 where the number of all grids of a subject is 15 at current time, the LAD value equals to 80 percent. The term period is assumed to be set by a teacher. For instance, the term can be a week, or a month. LAD values are initialized when the term is over.

$$SAD[1 \leq SAD \leq 1] : \text{Short-term Achievement Degree} \quad (6)$$

SAD indicates how much the learner has been able to accomplish a goal of a subject for a short term. In this paper, this goal is to study a subject for objective time of a day. The

default value is 0. SAD has particular three values, -1, 0, and 1. These values means as follows.

1. The learner has studied for no time.
2. The learner has studied for less than objective time.
3. The learner has studied for more than objective time.

Objective time depends on a grid's color. This idea is based on Section 4.4. For example, objective time is 10 minutes for red grids, 20 minutes for yellow ones, and 30 minutes for green ones. At a subject on a red grid, we assume that a learner is not willing to study it. Therefore, to compliment studying is important, even if the learner studies for only a fraction of the time. That is why objective time of red grids is less than one of others. If the learner takes 10 minutes to study a subject on a yellow grid, the SAD value equals to 0. In this paper, objective time is initialized by the teacher based on the learner's ability. Since the learner starts to use the ULS, the ULS automatically has set objective time. The ULS analyzes average learning time of the learner, and decides it as objective time for yellow grids. The ULS also analyzes minimum learning time and maximum one, and decides each them as objective time for red grids and green ones. Therefore, the objective time is flexibly changed with the learner's current ability.

Sometimes there are some relationships between the subjects. If the learner studies the subjects in a meaningful order, it will result a better understanding. Otherwise, the learning efficiency is down. For example, classical literature (Ancient writings or Chinese writing) witch is told in traditional Japanese class might require some pre-knowledge about the history to help learner understanding the contents and meaning well. In this case, it is clear that the priority of study the subject History is higher than the subject Japanese. Also, it is a common sense that rudimentary mathematics might be a prerequisites course before science study. Considering this characteristics, we also define an equation to improve the system,

$$CV'_i = CV_i + \left(\sum_{j=1}^n CV_j \right) * P_i \quad (7)$$

where, $P_i = \frac{X_i}{\sum_{j=1}^n X_j}$

We improve the CV' to apply the shaping principle. P means the priority of each subject. In this paper, we take the teacher's priority into this formula. Because teachers are more familiar with the relationships between each courses than guardian and it should has more weighted to influence the learner.

	Jpn.	Math.	Sci.	Soc.	HW.
TP	5	4	1	2	3
CV	1.8	1.2	-0.5	0.4	0.8
CV'	3.03	2.18	-0.25	0.89	1.54

Table 3. An example of relationship between CV and CV'

For example, in Table 3., the teacher set the priorities as (Jpn., Math., Sci., Soc., HW.), (5, 4, 1, 2, 3) respectively. Using the equation (7), we can earn the new priority, for example, Jpn. like:

$$CVJpn.' = 1.8 + (1.8 + 1.2 - 0.5 + 0.4 + 0.8) * \frac{5}{(5 + 4 + 1 + 2 + 3)} = 3.03$$

$$CVMath.' = 1.2 + (1.8 + 1.2 - 0.5 + 0.4 + 0.8) * \frac{4}{(5 + 4 + 1 + 2 + 3)} = 2.18$$

and the same to the other subjects.

2.4 Implementation and evaluation of the ULS system

We implemented the ULS system based on a specialized desk using a laptop PC, which is connected to a RFID-READER with RS-232C in this research. We use version 1.01 of DAS-101 of Daiichi Tsushin Kogyo Ltd for RFID-READER and RFID [10]. Programming language C# is used to develop the ULS system. We use Microsoft Access for a *Teacher's Demand DB*, a *Guardian's Demand DB*, and a *Learning Record DB*.

In this research, each class has its own textbook with an RFID-tag. The ULS recognizes that a learner is studying a subject of which an RFID is read by the RFID-READER. We assume that as learning time while the RFID-READER reads the RFID.



Fig. 5. Screen shot of ULS

Figure 5. is a screen capture of ULS in this research. It shows a learning scheduling chart for a student and his/her guardian. Marks indicate that the learning of the subject has been already finished.

The purpose of the evaluation is as follows:

1. Could the system provide efficient and effective learning style to the learner?
2. Could the system increase the learner's motivation?
3. Could the system improve self-directed learning habit of the learner?

Through verifying these points, we attempted to find several needs to be improved in this system.

The method of this evaluation is a questionnaire survey. 20 examinees studied five subjects with this system for a few hours. Based on their information such as liked or disliked

subjects, Color Value of each subject is initialized. After an examining period, they answered some questionnaires for evaluating this system. Contents of the questionnaires are as follows:

Q1: Did you feel this system makes your motivation increase for self-directed learning?

Q2: Did the system provide suitable visible-supports to you?

Q3: Do you think this system helps you to improve your learning habit at home?

Q4: Did you feel this system was easy to use?

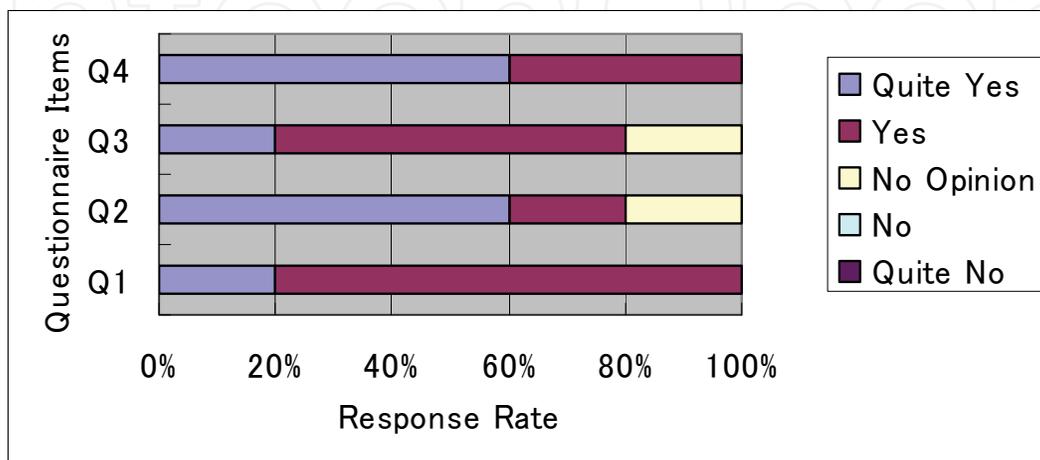


Fig. 6. Result of Questionnaire Survey (1)

Figure 6. shows statistical results of questionnaire survey of only using the equation (1). Positive responses, more than 80 percent of "quite yes" and "yes", were obtained from every questionnaire item. However, some comments were provided in regard to supports of this system. For example, "It will be more suitable if the system can support for a particular period such as days near examination." One of this reasons was the system was designed focused on usual learning-style.

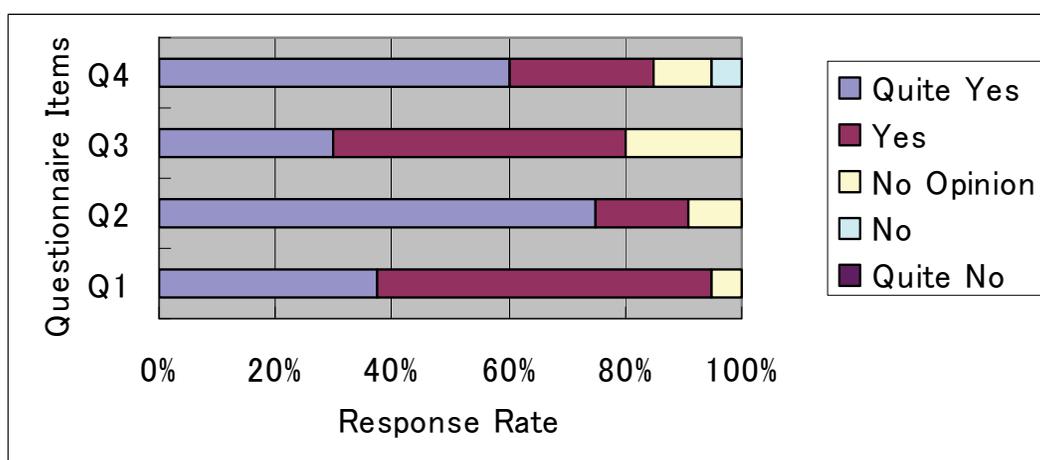


Fig. 7. Result of Questionnaire Survey (2)

Figure 7. shows statistical results of questionnaire survey with the equation (7) implemented in the system. We can see there is a progress especially on the answer "Quite Yes" comparing with the result only using the equation (1).

3. The new model of the ULS system

3.1 Pervasive Learning Scheduler (PLS)

So far, we propose a support method for self-managing learning scheduler using Behavior Analysis in a ubiquitous environment. Based on our method, the ULS is implemented. According to the experiment results, the contribution of the ULS can be summarized as follows: the ULS is effective to motivate a learner at his/her home study, and the ULS helps to improve his/her self-directed learning habit with considering his/her teacher's and his/her guardian's request.

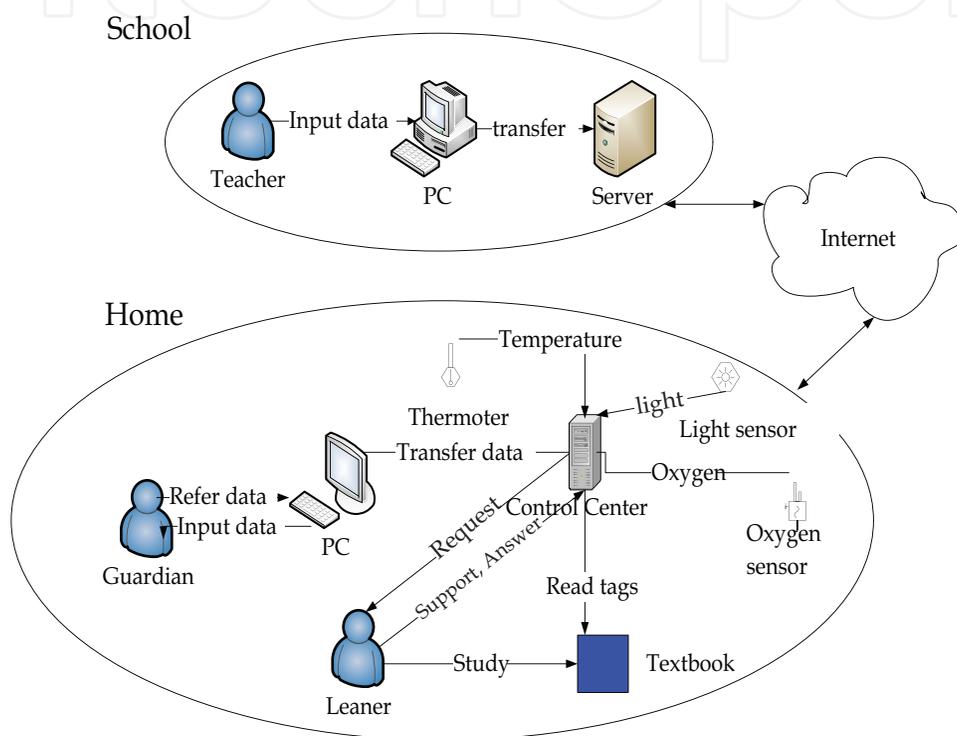


Fig. 8. The improved model: Pervasive Learning Scheduler (PLS)

We improve this ULS model with considering environments surrounding the learner since the learner could more effectively study in an environment comfortable for him/her. For example, intuitively it is better for the learner to study in a well-lighted area than in a dark one. Figure 8. shows the improved model and we call it as called a Pervasive Learning Scheduler (PLS). In this research, we only consider an environment at home where sensors are embedded as shown in Figure 8. These sensors collect corresponding data from the environment and send it to a control center. The control center decides whether the corresponding parameters are suitable for the learner and adjusts them automatically. For example, a learner accustoms himself to a temperature of 26 degree. The current temperature collected by the sensor is 30 degree. As the control center receives this data, it makes a decision on adjusting the temperature. We only show three kinds of sensors in the figure, however; the PLS also can include other several kinds of sensors as users need.

To this end, we have the following problem: how does the control center decide optimum values for each parameter? In order to solve this, we propose a data training method. Its feature is to select adaptive step to approach the optimum value.

3.2 Design of the PLS system

In the PLS system, sensors collect data from an environment and send it to the control center. Based on collected data from a learner's surroundings, the control center adjusts each parameter to the optimal value. A problem is how to decide the optimum values by the control center. As we take a temperature as an example, then the problem can be rephrased as: how does the control center know the suitable temperature for each individual learner.

You may think that a learner can tell the control center a preferred temperature as the optimal value in advance. More precisely, however, the learner can only set an approximate value not exactly optimal one on the system. We solve this problem to train the data based on the following algorithm.

1. A learner sets the current temperature with a preferred value and sets a step value.
2. The system increases the current temperature by the step value while the learner studies.
3. At the end of study, the system compares the studying efficiency with a previous one in a record. If the efficiency ratio increases, go to the phase (2).
4. If the efficiency becomes lower, it shows that the step value is too large, so we should deflate the value. Divide the step value by 2, then go to the phase (2). Stop after the step value is less than a threshold value.
5. After find an optimum temperature with the highest efficiency ratio, reset the step value to the initial one. Repeat the above phases from (1) to (4) except for the phase (2). In the phase (2), the system decreases the current temperature by the step value.
6. After find another optimum temperature by the second round, compare it with the optimum temperature we firstly found, and choose the better one according to their efficiency ratios.

The studying efficiency is derived based on CV' obtained by the equation (7) in subsection 2.3. The efficiency $E(t)$ is calculated at time t of the end of study with the following equation (8).

$$E(t) = \frac{n}{\sum_{j=1}^n CV'_j(t)} \quad (8)$$

Then, we can obtain the efficiency ratio comparing $E(t)$ with $E(t-1)$ which is the efficiency of the previous study at time $t-1$ in a record with the following equation (9).

$$\text{Efficiency Ratio} = \frac{E(t)}{E(t-1)} \quad (9)$$

Temperature	24	25	25.5	26	26.5	27	28
Efficiency ratio	0.8	0.95	1.4	1	1.3	0.96	0.85

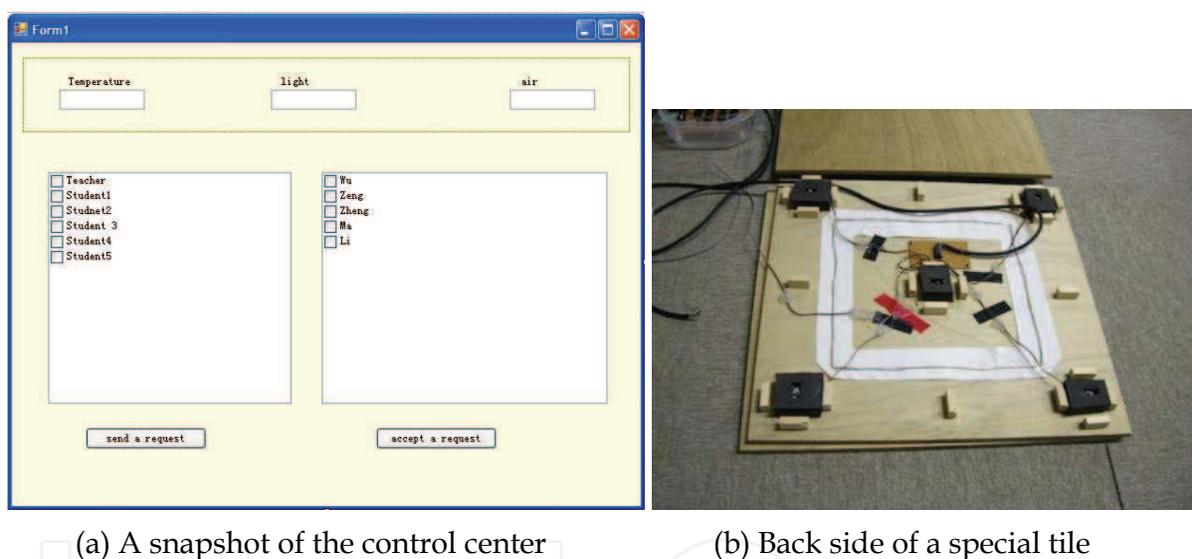
Table 2. An example of temperature values and efficiency ratios

Table 2. shows an example of how to decide the optimum temperature value when firstly the learner sets 26 degree as an approximate temperature which makes him/her comfortable. We can assume that the optimum temperature is around the approximate temperature 26 degree, then the optimum temperature can be in $[26-A, 26+A]$, where A is a positive number larger enough to find the optimum value. A is the step value and initially

set by the learner. We assume the learner sets it as $A=2$. According to our algorithm, we compare the efficiency ratio of temperature of 28 and 26. We can see that the efficiency ratio of 28 degree is lower than that of 26 degree. We decrease the step value and get a new step value: $A'=A/2=1$. Then, we compare the efficiency ratio of 27 degree with that of 26 degree. The efficiency ratio of 26 degree is still higher, so we decrease the step value again and get another step value: $A''=A'/2=0.5$. The efficiency ratio of 26.5 degree is higher than that of 26 degree. As a result of the first round, we find that the optimum temperature that is 26.5 degree. For simplicity, we generally stop when the step equals to 0.1. Then, we repeat the phases to obtain another optimum temperature. As a result of the second round, we find the optimum temperature that is 25.5 degree. Comparing the efficiency ratio of 25.5 degree to that of 26.5 degree, we finally choose 25.5 degree as the optimum temperature because its efficiency ratio is higher.

Each day, we only modify the temperature once, and we get the corresponding efficiency ratio. After several days, we can finally get the optimum temperature. In the same way, the control center finds an optimum value for each parameter.

3.3 Implementation and evaluation of the PLS system



(a) A snapshot of the control center

(b) Back side of a special tile

Fig. 8. Implementation of the PLS system

We implement the PLS system based on the ULS system. Figure. 8(a) shows a screen capture of the Control Center in the PLS system.

To improve performance of gathering sensory data, we develop special tiles as shown in Figure. 8(b). The special tiles are embedded with an RFID antenna and pressure sensors, which are spread all over the desk. Each book includes an RFID tag showing text information (e.g., English textbook). The dynamic information of a book put on the tile is acquired by the tile connected to a sensor network. We designed to solve the following problems; passive RFID reader only has a narrow range of operation and sometimes it works not well for gathering data of all books on the desk. 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. By using the special tile, accuracy of gathering learning information was increased.

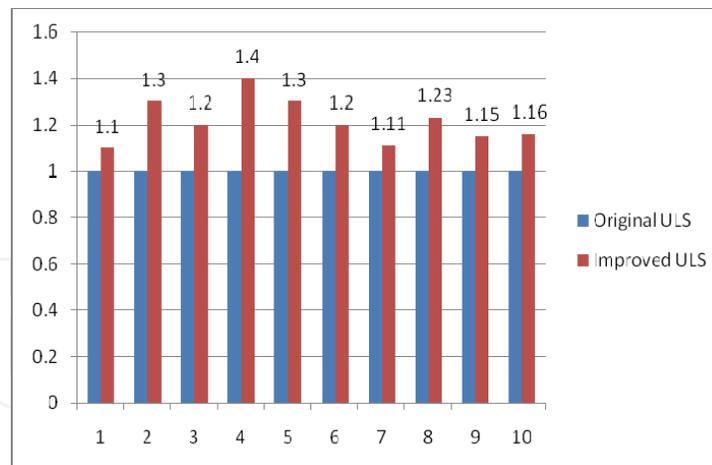


Fig. 9. Efficiency ratio comparison between the ULS and the PLS

We evaluate the PLS by involving 10 subjects of students. In order to evaluate learning effectiveness with considering environmental factors, they answer the following questionnaires, which is the same in subsection 2.4, after using the ULS system as well as the PLS system for some periods respectively.

Q1: Did you feel this system makes your motivation increase for self-directed learning?

Q2: Did the system provide suitable visible-supports to you?

Q3: Do you think this system helps you to improve your learning habit at home?

Q4: Did you feel this system was easy to use?

Then, we compare feedback scores of the PLS system with that of the ULS system and calculate efficiency ratio based on score averages. Figure. 9 shows every subject thinks that the PLS system is more efficient to study than the ULS system. We can conclude PLS system succeeds to provide comfortable learning environments to each learner with pervasive computing technologies, which leads to efficient self-learning style.

4. Conclusion

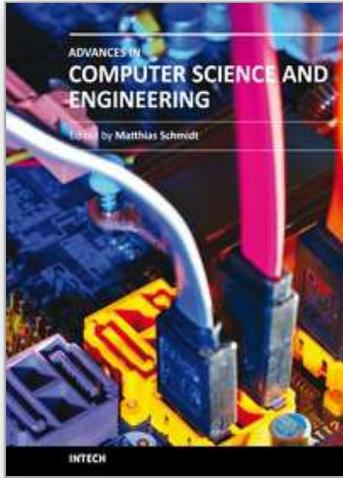
We address a next-generation self-learning style utilizing pervasive computing technologies for providing proper learning supports as well as comfortable learning environment for individuals. Firstly, a support method for self-managing learning scheduler, called the PLS, is proposed and analyzes context information obtained from sensors by Behavior Analysis. In addition, we have involved the environment factors such as temperature and light into the PLS for making a learner's surroundings efficient for study. The sensory data from environments is sent to a decision center which analyzes the data and makes the best decision for the learner. The PLS has been evaluated by some examinees. According to the results, we have revealed that improved PLS not only benefited learners to acquire their learning habits but also improved their self-directed learning styles than the former one.

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