Supporting Ubiquitous Learning Using Life-log Camera

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Contents

List of Papers

Main Papers

(1) "PACALL: Supporting Language Learning Using SenseCam",
Bin Hou, Hiroaki Ogata, Toma Kunita, Mengmeng Li and Noriko Uosaki.
International Journal of Distance Education Technologies, Vol.11, No.1, pp.14–30, 2013, Published.

Secondary Papers

(1) "JAMIOLAS 3.0: Supporting Japanese Mimicry and Onomatopoeia Learning Using Sensor Data",
Bin Hou, Hiroaki Ogata, Masayuki Mitaya, Mengmeng Li, Yuqin Liu and Yoneo Yano.
International Journal of Mobile and Blended Learning, Vol.2, No.1, pp.40–54, 2010, Published.

(2) "Passive Capture for Ubiquitous Learning Log Using SenseCam",
Bin Hou, Hiroaki Ogata, Mengmeng Li, Noriko Uosaki.
Proceedings. of the 19th International Conference on Computers in Education (ICCE 2011), pp.396–400, Chiang Mai, Thailand, 28 Nov.– 02 Dec. 2011.

(3) "PACALL: Supporting Language Learning Using SenseCam",
Bin Hou, Hiroaki Ogata, Toma Kunita, Mengmeng Li, Noriko Uosaki, Yoneo Yano.

Proceedings. of the 7th IEEE International Conference on Wireless, Mobile, and Ubiquitous Technologies in Education (WMUTE 2012), pp.127–131, Takamatsu, Japan, 27 Mar.– 30 Mar. 2012.

(4) "Supporting Daily Reflection for Ubiquitous Learning Log Using SenseCam",
Bin Hou, Hiroaki Ogata, Mengmeng Li and Noriko Uosaki.
Proceedings. of the 6th International Conference on Collaboration Technologies (CollabTech 2012), pp 2–7 Sapporo, Hokkaido, Japan, 27 Aug.– 29 Aug. 2012.

(5) "Using SenseCam for Capturing Ubiquitous Learning Log",
Bin Hou, Hiroaki Ogata, Mengmeng Li, Noriko Uosaki, Kousuke Mouri.
Proceedings. of 1st IIAI International Conference on Learning Technologies and Learning Environments (IIAI LTLE 2012), pp. 267–272, Fukuoka, Japan, 20 Sep.– 22 Sep. 2012.

List of Figures

List of Tables

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Chapter 1

Introduction

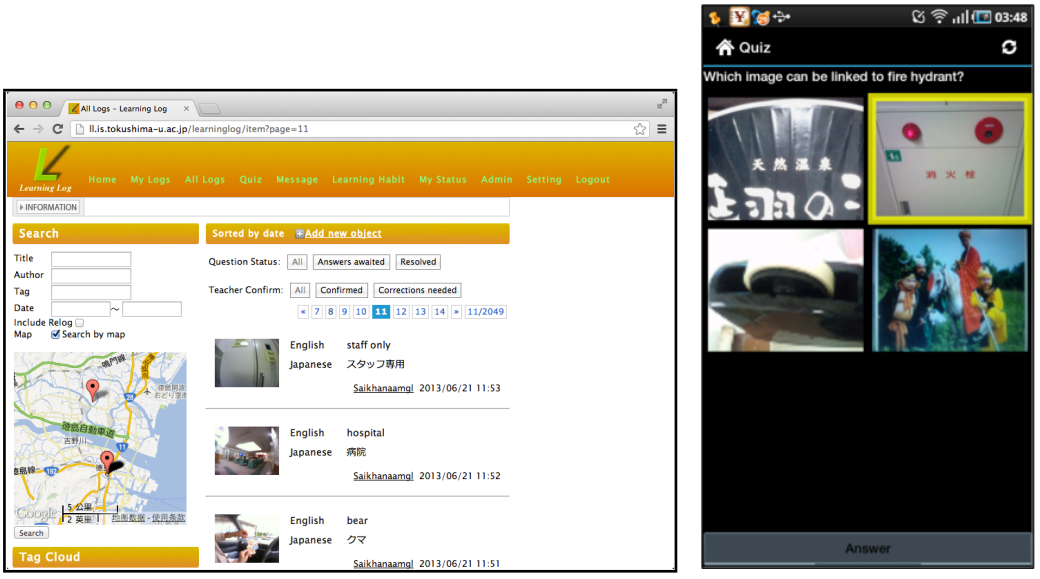
1.1 Background

April 4, 2012, Google announced a new project called "Project Glass" and released a product "Google Glass" in the year 2013 (*Google Glass*, n.d.; Starner, 2013). This device is a wearable device with a head-mounted display (Figure 1.1). It can help people in their daily-lives such as navigation, recording their daily-lives, video chatting finding information on Internet, etc. Such activities turn to be easily at anytime anyplace and anywhere. This is the mission of this project - producing a mass-market of ubiquitous computer (C. C. Miller, 2013).

This paper introduces a research on supporting ubiquitous learning with life-log camera. It is a part of our project – "Ubiquitous Learning Log for You" (*Learning Log for You Project*, n.d.; Ogata, Li, Hou, Uosaki, El-Bishouty, & Yano, 2010). The Ubiquitous Learning Log for Your project started from October 2009. Learning Log was originally

Figure 1.1: Google Glass

designed for children as a personalized learning resource (*Learning log - Wikipedia, the free encyclopedia*, n.d.). It was set by teachers to help their students record their thinking and learning (Beck, 1998). In this learning log, the logs were usually visually written notes of learning journals.



(a) Web Side (b) Mobile Side

Figure 1.2: Web side and Mobile side of SCROLL

We defined a ubiquitous learning log (ULLO) as a digital record of what a learner has learned in the daily life using ubiquitous technologies and proposed a model called LORE (Figure 1.3) to show the learning processes in the perspective of the learner's

activity (Ogata, Li, Hou, Uosaki, Moushir, & Yano, 2010). We developed a system SCROLL (System for Capturing and Reminding Of Learning Log) (*Learning Log - Learning Log*, n.d.) in order to helps learners log their learning experiences with photos, audios, videos, location, QR-code, RFID tag and sensor data and share ULLOs with others. Also, learner can receive personalized quizzes and answers for their question. This system is implemented both on web (Figure 1.2(a)) and android smartphone platforms (Figure 1.2(b)). With the help of built-in GPS and camera on smartphone, learners can navigate and be aware of past ULLOs by augmented reality view.

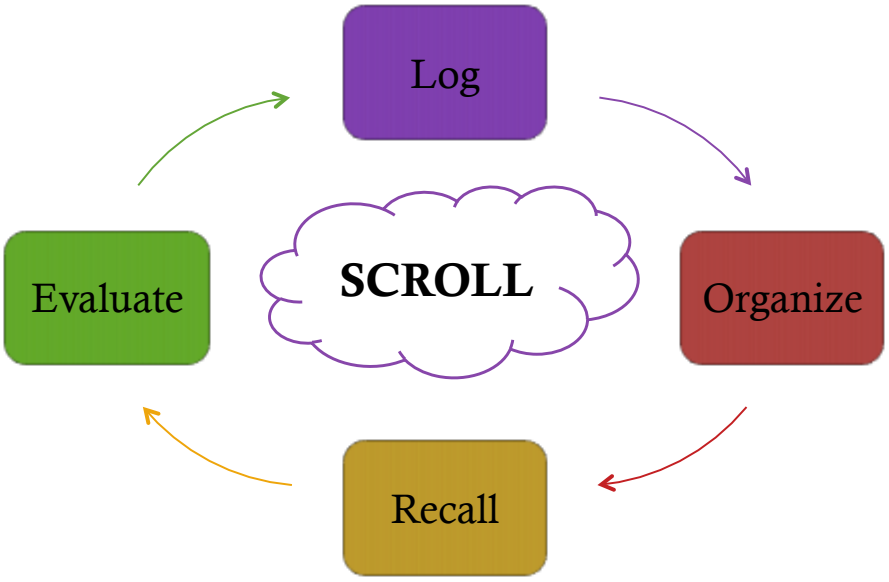


Figure 1.3: LORE Model

As it shown in Figure 1.3, there are 4 processes in LORE model, that is to say there are 4 main functionalities in SCROLL – Log, Organize, Recall and Evaluate.

Log Log what a learner has learned, when the learner faces a problem in the daily life, s/he may learn some knowledge by her/himself, or ask others for help in terms of questions. The system records what s/he learned during this process as a ULLO. We designed two modes to record learning materials – active and passive. Here

is a typical scenario of active mode – when a foreign student in Japan walks into a supermarket, there are a lot of food that he/she does not know how to speak it in Japanese. Then he/she can take a photo of this food by Smartphone and ask someone how to speak it in Japanese, then logs the learning materials as a ULLO including photo, names of the food both in Japanese and his/her mother language, location and time, etc. However in the passive mode, device such as life-log camera can take photos of foods and record the contextual information such as location and time automatically and waits learner to review the recorded contents before logging them as ULLOs.

Organize When the learner tries to add a ULLO, the system compares it with other ULLOs, categorizes it and shows the similar ULLOs if exist. There are a lot of ways for categorizing. For example, a foreign student in Japan learned a new word "Tofu" in a supermarket and logged this process as a ULLO. This ULLO can be categorized into "Japanese", "Food", "Supermarket", etc. It is difficult to have it categorized all by system. In the designed system, user can add their ULLOs into multiple categories and add several tags to each ULLO. After that, he/she can review the learned contents by categories/tags. Similar objects can be found by matching titles, content of photos, locations and categories, and then the knowledge structure can be regulated and organized.

Recall The learner may forget what s/he has learned before. Rehearsal and practice in the same context or others in idle moments can help the learner to recall past ULLOs and to shift them from short-term memory to long-term one. Therefore, the system assigns some quizzes and reminds the learner of her/his past ULLOs.

Evaluate It is important to recognize what and how the learner has learned by analyzing the past ULL, so that the learner can improve what and how to learn in future. Therefore, the system refines and adapts the organization of the ULLOs based on the learner's evaluation and reflection.

Miller and Gildea (G. A. Miller & Gildea, 1987) compared the way that children are taught words from dictionary definitions and a few exemplary sentences with the way vocabulary is normally learned outside the school. They noted that people generally learn words outside school. It suggests that using mobile devices is a good way for people to remember the vocabulary since people can use mobile devices anywhere and anytime.

Therefore, in our project, the traditional method we used is using mobile devices such as smartphone and tablet PC with the aim of registering ULLOs anytime and anywhere learners want to log. In other words, learners have to take photos and registering ULLOs manually. It means that learners must record their learning experiences consciously. This is an active mode to record the learning experiences. However under this active mode, learners cannot record all of the learning experiences in the system. For example they may forget to take some pictures when they learned some new words, or although they wanted to take photos but they are could not because they were too busy. As a result learning chances will be lost and forgotten.

A passive mode can be a solution of these problems. In this mode, learners are not required to record learning experiences actively, but some devices will record all the learning activities automatically. Therefore, we attempt to introduce the concept of life-log into this system to record learning experiences in a passive way. The notion of

life-log can be tracked back at least 60 year (Bush, 1945). It means to capture a person's entire life or large portions of life. It usually uses digital devices to record life-log such as wearable cameras or video recorders. For example, in the early 1980s Steve Mann captured his life using a wearable computer and streaming video. He captured his everyday life 24 hours a day in order to see what he was looking at (Mann, Picard, & Section, 1995). The life-log brings us the data of whole life of not only learning but also other activities. However, if there is any way that we can extract the learning part from it, the learning will be more significant and more sufficient. Besides, our system captures the learning log beyond their consciousness and learners' burden will also be reduced. Microsoft's SenseCam (Hodges et al., 2006) is an effective way to capture life-logs. It is a wearable camera equipped with a number of sensors. The SenseCam is a device to record a series of images and capturing logs of sensor data. As an important part of our project, we used the product of SenseCam named Vicon Revue (*Vicon Revue | Memories for life*, n.d.) with the mission of providing a passive way to record learning logs in learners' daily lives. We attempt to use this learning model to solve the problem of "missed learning experiences".

1.2 Objectives

In the project Ubiquitous Learning Log for You, we have developed a system named SCROLL to implment the model LORE (Figure 1.3), however as one of main functionalities in LORE, Log needs further improvements. This research focuses on Log in

LORE to improve Log. The learning that happens in this research are informal learning only.

First, this research makes an approach to complete the Log part of the ubiquitous learning log with passive mode. The traditional way to log the ULLO is record the learning material consciously in active mode. However, active mode is not the only method to log the ULLO but also a passive mode. This dissertation discusses the feasibility of passive mode, and uses the life-log camera to record life-log passively, and proposes a system named PACALL to build a ubiquitous learning environment.

Secord, this research attempts to introduce the concept of Life-log to the ubiquitous learning log. As mentioned above, ubiquitous learning log is defined as digital record of what a learner has learned in the daily life. However, in the previous works, all the logs are record by learners manually. In this research, we attempts to record the life-log firstly, and then extract learning materials from life-log.

Third, this research discusses the method of analyzing the life-log photos. Everyday, it may takes thousands of life-log photos normally. Looking through all the life-log causes a workload problem for learners. Therefore, this research proposes a method to analyze a large amount of life-log photos and reduce workload for learners. It is significant to further research.

Finally, this research also surveys the usability of SenseCam in learning. Although the SenseCam is just one kind of the life-log cameras, we think the role of SenseCam in learning and method when using it is almostly the same. Therefore, in this research,

we discusses the usability of SenseCam and find out how the SenseCam can support ubiquitous learning.

1.3 Dissertation Outline

This dissertation is organized as follows.

- Chapter 1 is introduction. The background and objectives of this research are introduced in this chapter.
- Chapter 2, learning theoretical foundation and related works. Before introducing this research in detail, theoretical background of this research and the related works must be overviewed. This chapter introduces all of the learning theories of this research including several learning and cognitive theories, and especially the ubiquitous learning theory, life-log and wearable computing. This chapter also introduces some related works.
- Chapter 3 introduces our project - Ubiquitous Learning Log for You in detail. This research is a part of this project, and in order to build a ubiquitous learning environment, this research uses most of the learning functionalities of our previous work - SCROLL (System for Capturing and Reminding Of Learning Log), so it is necessary to introduces the whole project.
- Chapter 4 explains the design and implementation of this research. Also, the user interface is also introduced in this chapter.

- Chapter 5 Evaluation. We have conducted 3 evaluations during this research. The effectiveness of our system is investigate in this chapter.

- Chapter 6 concludes this dissertation.

Chapter 2

Learning Theoretical Foundation and Related Works

2.1 Learning and cognitive theories

2.1.1 Authentic learning and situated cognition

We are learning from what happened in the real world, so-called, from the authentic environment (*Learning log - Wikipedia, the free encyclopedia*, n.d.). Especially, we learn a lot of vocabularies from our conversations, TV, and other daily activities. Therefore, it is very important to capture what we learned and recall them to enhance learning.

Herrington (Herrington & Oliver, 2000) designed a situated learning framework for authentic learning environments. The finding of this research suggests that the use of the situated learning framework provided effective instructional design guidelines for the

design of an environment for the acquisition of advanced knowledge. According to (Lombardi, 2007), Lombardi suggested that Authentic learning may be more important and more common than ever in a rapidly changing world. He also concluded technological support for authentic learning environments (Lombardi, 2007):

1. High-speed Internet connectivity for provision of multimedia information.
2. Asynchronous and synchronous communication and social networking tools for the support of teamwork.
3. Intelligent tutoring systems, virtual laboratories, and feedback mechanisms that capture rich information about student performance and help students transfer their learning to new situations.
4. Mobile devices for accessing and inputting data during field-based investigations.

In our previous works - Ubiquitous Learning Log for You. We have used high-speed Internet connectivity for learners to register the ULLOs and developed a social networking system - SCROLL. We also use this system to help learners transfer their learning to new situations. Besides, in this research, we use the wearable life-log camera to record learning data.

2.1.2 Encoding specificity principle

The same context reminds us of the things that we have experienced there (Tulving, 1985). This is a principle suggests how the contextual information affects memory and recall (Tulving & Thomson, 1973). Godden (Godden & Baddeley, 1975) suggests that

location and environment in which learner learned something would effects learner recall it. For example, if s/he is in the upstairs and wants to bring something from the downstairs, s/he may forget in the downstairs. However, if s/he goes back to the upstairs, s/he recalls the thing that s/he wanted.

Therefore, in this research, we use a system to help learners have a reflection of what they have seen and help them find out learning materials.

2.1.3 Picture superiority effect

This concepts suggests that learning material are much more likely to be rememebered if it is presented as pictures rather than as words (Shepard, 1967; Defeyter, Russo, & McPartlin, 2009; Childers & Houston, 1984; Curran & Doyle, 2011). People can remember vocabularies with their pictures more than those without their pictures (Nelson, Reed, & Walling, 1976). Paivio (Paivio, 1990) proposed a dual-coding theory in order to explain this effect. According to this theory, memory exists verbally or imaginally. While Nelson (Nelson et al., 1976) also proposed a sensory semantic theory to explain this phenomenon. It suggests that pictures are more access directly than words.

Therefore, our previous works - SCROLL shows the picture of ULLO for a quiz. In this research we also capture photos of life-log to help learner have a reflection of what they have learned in the daily life, and register learning materials to SCROLL.

2.1.4 Repetition with increasing intervals

This is the learning method that uses increasing intervals of time between successive reviews of previously learned knowledge (Pimsleur, 1967). Forgetting curve (Ebbinghaus, 1913) also suggests that memory would be lost without repetition.

Based on this theory, SCROLL sends a quiz to the learner. In this search, we also use this functionality of SCROLL as a part of constructed ubiquitous learning environment.

2.2 Ubiquitous Learning

2.2.1 Ubiquitous Computing

The word "ubiquitous" means being everywhere especially at the same time. Ubiquitous computing is post-desktop model of human-computer interation in which information processing has been thoroughly integrated into everyday objects and activities (*Ubiquitous computing - Wikipedia, the free encyclopedia*, n.d.).

Ubiquitous computing makes it possible to have people interact with everything around them because the computing devices are integrated into the surrounding environment. In the ubiquitous computing environment, everything around can be accessed by ubiquitous technology including identification technology and sensor technology and other technologies (Figure 2.1).

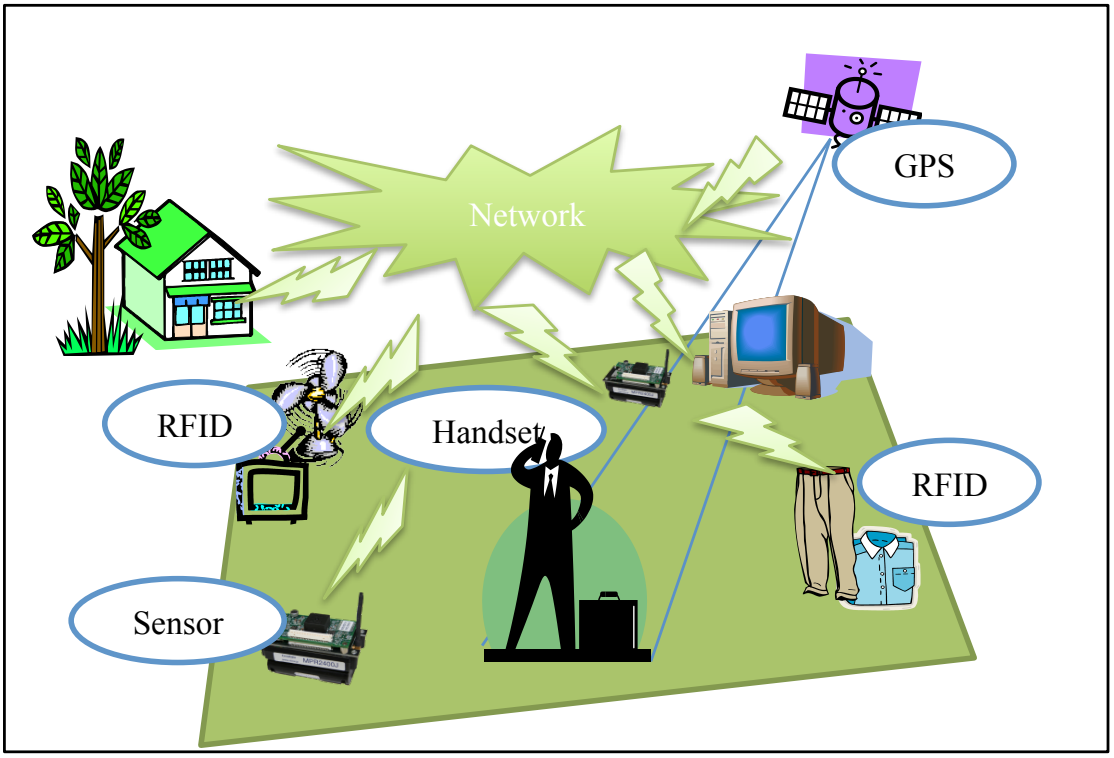


Figure 2.1: Ubiquitous computing

2.2.2 Ubiquitous Learning

When the ubiquitous technology is used in learning area, it is usually called Computer Supported Ubiquitous Learning (CALL) or Ubiquitous Learning (or u-learning, ULearning). The ubiquitous learning has integrated high mobility with embedded computing environments (Chen, Kao, Sheu, & Chiang, 2002; Ogata & Yano, 2004). Ogata compared the ubiquitous learning with other learning environment (Ogata & Yano, 2004) (Figure 2.2). In this comparison, we can see that the ubiquitous can provide a learning environment with high level of embeddedness and high level of mobility.

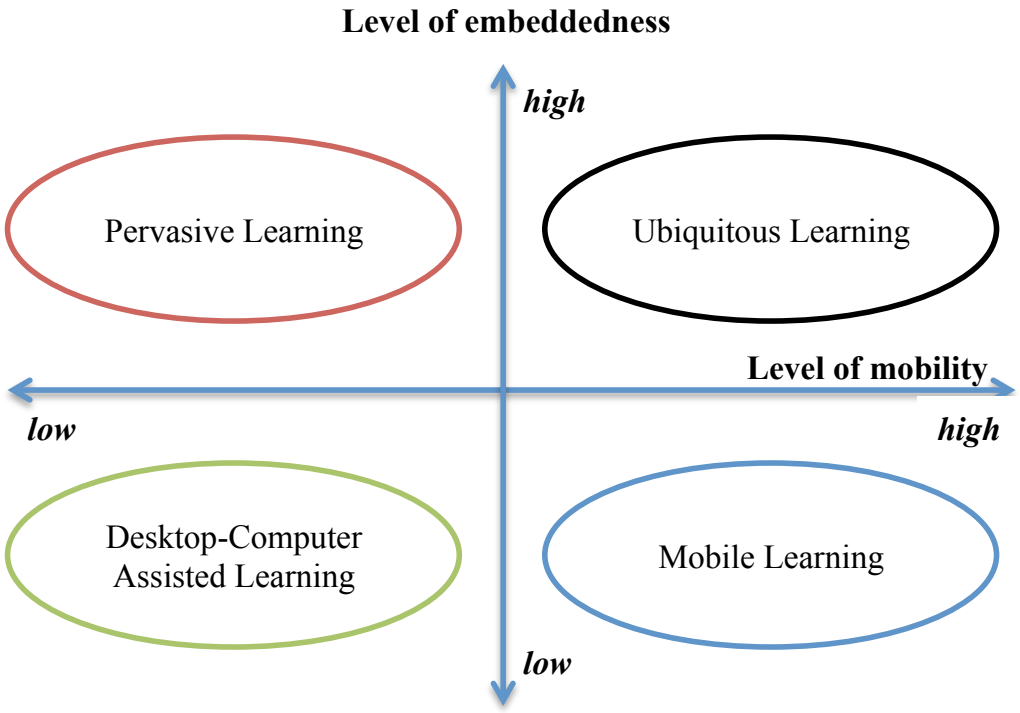


Figure 2.2: Comparison of learning environments

The main characteristics of ubiquitous learning are (Ogata & Yano, 2004):

Permanency Learners never lose their work, unless it is purposely deleted. In addition, all their learning processes are recorded continuously every day.

Accessibility Learners have access to their documents, data, or videos from anywhere. That information is provided based on their requests. Therefore, the learning involved in this system is self-directed.

Immediacy Wherever learners are, they can get any information immediately. Thus, learners can solve problems quickly. Otherwise, the learner can record questions and look for answers later.

Interactivity Learners can interact with experts, teachers, or peers in the form of synchronous or asynchronous communication. Hence, experts are more reachable and knowledge becomes more available.

Situatedness The learning can be embedded in our daily lives. The problems encountered as well as the knowledge required are all presented in their natural and authentic forms. This helps learners by notifying them about contextual features of a problem and provides relevant actions.

2.3 Life-log

Rawassizadeh (Rawassizadeh, 2012) defines life-log as pervasive tools or systems which sense and capture contextual information from the user's environment in a continuous manner. There are many researches on life-log. With the development of ubiquitous

computing and compression technology, it gets easier to save large data of life-log into storage devices (Aizawa et al., 1997).

Life-log can be recorded manually or automatically. When it happens manually, user is able to record what he/she want to record and the format of data is free so that it can be described in detail. Also, the subjective data from user can be recorded. However, it causes the problem of workload and user may be overburdened.

In contrast to this, when it happens automatically, the workload is low. Life-log can be recorded unconsicously. Life-log data such as photos and locations can be recorded continuously. However, the objective data cannot be recorded most of the time.

MyLifeBits (*MyLifeBits - Microsoft Research*, n.d.) is one of the famous service that provide life-log service. This project will be introduced in section 2.5.1.

Life-log does not record all the data during daily life, but only the important part. Several devices are produced to record life-log. The typical branches of life-log are introduces as follows.

2.3.1 Learning Log

In general learning log is life-log in learning. It records what a learner learned during the daily life. When we learned something, we usually record the learning content by memo or other tools instantly. However, if we record learning content without well organized, after a while, we usually forget whether we have record this learning content or not. When we meet this learning content next time, we have to learn it again.

Whereas, the life-log is well organized. If we use life log to record learning content, it turns to be learning log. Also, this learning log can help us reflect what we have learned at any time.

Learning log is life-log on learning. It depends on learner's motivation of learning. As long as learner has motivation of learning, the life-log will be recorded for long period.

2.3.2 Food Log

Food log is used to record what people have eat in the daily life. Few people can answer what they ate 10 years ago. However, with food log, this can be answered easily.

Foodlog (*FoodLog*, n.d.) is a online web service that let people record food log. By using this service, users are not only able to record what they have eaten, but also able to share their food log, and it is useful to health management.

Food log is life-log on food life. It can be also recorded for long period because it is necessary for everyone.

2.3.3 Diet Log

Diet log is also one type of life-log. Smartphone is able to used to record diet log at present. It can be used at any place and any time and makes it possible to have a ubiquitous diet. There are also several devices to record diet log (Mault et al., 2003). However, diet log is usually useful for people in a short term and cannot be record for long period.

2.4 Meta-Knowledge Model

Meta-knowledge is "knowledge about knowledge", that is the knowledge about what we know and what we don't know (Carver, 2002). Figure 2.3 explains this process and shows how to support learning in passive mode by meta-knowledge model. We classify all the objects surrounding us into 4 groups – there are "(I) I know what I know", "(II) I know what I don't know", "(III) I don't know what I know" and "(IV) I don't know what I don't know". For example, for non-English speaker, when a learner walk outside and see a fire hydrant, if he notice it and remember how to speak it English that is the status (I). If he does not know how to speak it in English and that is status (II). Since he have notice it, and does not know how to speak it, he can learn it by dictionary or ask for someone else. Then this knowledge will be transferred from (II) to (I). This is the process C – learning. It only happens consciously that is to say active mode.

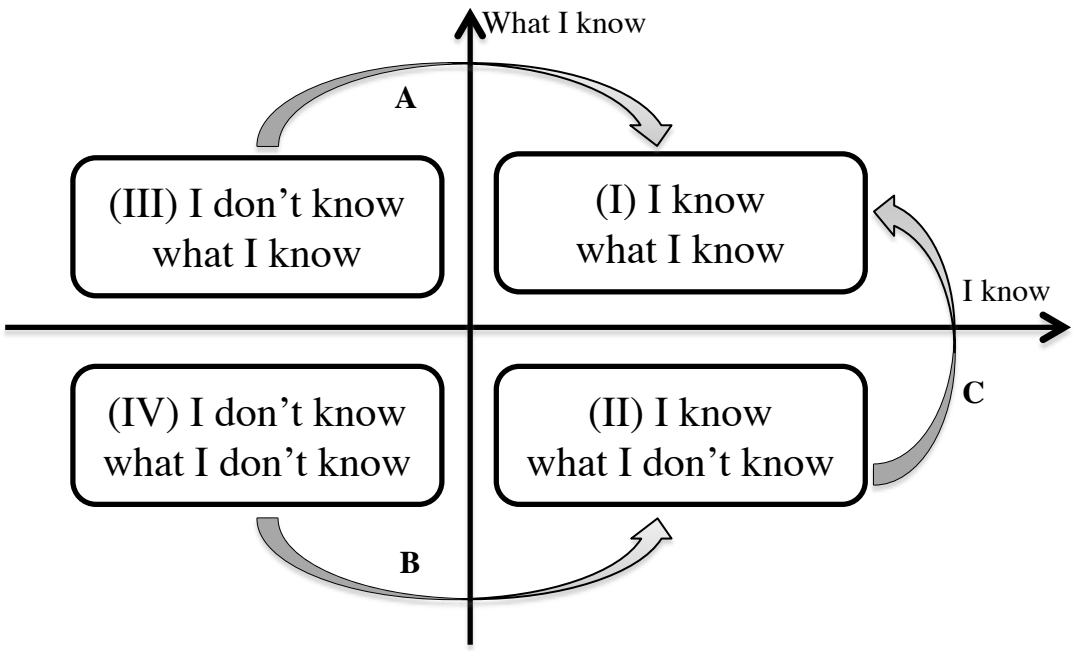


Figure 2.3: Meta-Knowledge Model: How passive mode supports learning

Another situation, if he has not noticed the fire hydrant how can he learn it? The answer is no way without any assist method. Therefore, we want to use life-log as a passive way to support it. There are also two situations. First is he have already known how to speak it in English (status III). In this case, captured life-log photos can help him notice this fire hydrant and let me revise it. In another case (IV), captured life-log photos let him know there is an object that he does not know, and then he can have a chance to learn this object (B to C). This is a good way to help a learner know what he/she does not know if he/she does not know what he/she does not know.

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2.5 Related Works

2.5.1 MyLifeBits

MyLifeBits (*MyLifeBits - Microsoft Research*, n.d.) is a Microsoft's project. The aim of this project is to implement Bush's Memex model (Bush, 1945) by which he proposed

to store everything that you saw and you heard.

MyLifeBits has a large amount of storage that can store email messages, web pages, books, photos, sounds, videos, etc. It also has a full-text search function to supply users with searching text, audio annotations and hyperlinks. In addition, the MyLifeBits project team is also using SenseCam to have the passive capture of life-logs and to upload the sensor information along with the photos to the MyLifeBits repository (Gemmell, Williams, Wood, Lueder, & Bell, 2004).

We have learned a lot from this system. In our previous works, we had made it possible to store the learned materials such as photos, sounds, videos and pdf files into the system repository. Besides, we have also implemented recall functions that use quizzes and contextual information to help learners to remember what they have learned. However, all works that we have done are using active logging mode, not passive logging mode. It means that learners must record their learning experiences as learning material consciously. Comparing to the passive mode, in the active mode we are more likely to miss learning chances since we are not necessarily able to record what we have learned or sometimes we just forget to record it. Therefore, we planned to introduce passive capture in our project with SenseCam.

2.5.2 SenseCam Browser

SenseCam browser (Doherty & Smeaton., 2008; Doherty, Moulin, & Smeaton, 2011) is a photo browser for SenseCam that supports users reviewing and organizing their life-log photos. This SenseCam browser uses a series of automatic content analysis techniques

to classify all the life-log photos into several events and select representative images for each.

In the PACALL, we use the sensor data to analyze at the present and we plans to use image-processing techniques in the future to classify and filtering all the life-log photos. The classification and filtering function in our system is similar with SenseCam browsing. Besides, we also designed several other functions for ubiquitous learning log system such as uploading as learning losg and finding similar logs in the future.

2.5.3 Collaborative Reflection with SensorCam

Fleck and Fitzpatrick (Fleck & Fitzpatrick, 2006) used SensorCam to support collaborative reflection. In their research, the students were asked to wear SenseCam when they played arcade games. After that, they did a reflection on their learning experiences. They found that SenseCam images were not only used to support memory aids but also can be used as resources for supporting the collaborative reflective discussion. The research also suggests SenseCam has potential to support reflection and that it is more appropriate in learning situation than videos.

Chapter 3

Ubiquitous Learning Log for You

3.1 Overview

As mentioned above, this research is part of our project - Ubiquitous Learning Log for You. In order to understand this research, the previous works must be introducted firstly.

Our previous works has developed a system named SCROLL(*Learning Log - Learning Log*, n.d.). This system provides several basic functionalities to implements the LORE model (Figure 1.3) and help learners to record, organize, recall and evaluate ULLs. Also, there is a Quiz system, and learners can receive personalized quizzes and answers for your questions. Learners can also navigate and be aware of your past ULLs supported by augmented reality view.

This chapter introduces our previous works in detail. Moreover, this chapter helps reader understand how learners learn by this research, because this research is just provides a

logging functionality to SCROLL to some extent. The learning activities especially RECALL usually happens when learners use SCROLL.

3.2 The Design of SCROLL

We designed SCROLL as a model of system to implement to implement the following types of learning:

1. Self-directed and personalized learning
2. Reflective learning
3. Collaborative learning
4. Situated learning and experiential learning
5. Seamless learning

3.2.1 Self-directed and personalized learning

The first one is self-directed and personalized learning.

The traditional learning is teacher directed learning, and this learning assumes that teacher has theresponsibility what and how the learner shouldbe taught. However self-directed learning (SDL)(Knowles, 1975) is different from teacher directed learning. Brookfield(Brookfield, 2009) defined self-directed learning as learning in which the conceptualization, design, conduct and evaluation of a learning project are directed by the learner. Knowles in

his book "Self-Directed Learning" (Knowles, 1975) proposed 4 features of self-direct learning that different from teacher directed learning:

1. Assumes that the human being grows in capacity(and need) to be self-directing as an essentialcomponent of maturing, and that this capacityshould be nurtured to develop as rapidly aspossible.

2. Assumes that the learner's experiences becomean increasingly rich resource for learning, which should be exploited along with the resources ofexperts.

3. Assumes that the students natural orientation istask or problem centered and that thereforelearning experiences should be organized as taskaccomplishments or problem solving learningprojects (or inquiry units).

4. Assumes that learners are motivated by internalincentives, such as the need for self-esteem, thedesire to achieve, the urge to grow, thesatisfaction of accomplishment, the need to knowsomething specific, and curiosity.

Personalized learning means the tailoring of pedagogy, curriculum and learning environments to meet the needs and aspirations of individual learners. Typically technology is used to facilitate personalized learning environments (*Personalized learning*, 2013).

We design SCROLL based on these two objectives that adopt self-directed and personalization:

(1) By being aware of a learner's current context. Currently, the context includes location and time. For the location information, the system can detect whether a learner

is near to the place where he uploaded a learning log and whether there are location-based learning logs recorded by other learners close to him. If either requirement is met and the availability of the device is high, the system will show him a quiz based on the knowledge he gained around there or notify him the surrounding learning logs added by others.

(2) The system can record the context data when a learner uses the system to study as his context history and then catches his learning habits by making use of the context history. If the learning habits exist and the circumstance meets the learning habits, the system will show a piece of recommendation message to encourage him to review what he has learned.

3.2.2 Reflective learning

An important goal of SCROLL system is to help learners recall what they have learned after they archived their learning logs. When a learner captures his learning log, besides the location based property mentioned above, a number of things are designed for learners to encode as retrieval cues. For instance, according to the picture superiority effect (Defeyter et al., 2009; Shepard, 1967), the learning logs with pictures are much more likely to be remembered rather than those without pictures. In addition, according to the basic research on human learning and memory, practicing retrieval of information (by testing the information) has powerful effects on learning and long-term retention. And compared with repeated reading, repeated testing enhances learning more.

For these two reasons, the quiz function taking advantages of the pictures, locations and so on is proposed. Three types of quizzes can be generated automatically by the system, which are yes/no quiz, text multiple-choice quiz and image multiple-choice quiz.

Usually, learners can examine themselves by practicing the quizzes. But two more ways that are provoked by the system are provided. One is that when a learner moves to the place where he took down knowledge, the system can show quizzes about the learned knowledge for him. The other one is that if a learner has his learning habits, the system will prompt him to review what he learned in quizzes. In the rest part of this paper, we will talk about them in detail.

3.2.3 Collaborative learning

We design SCROLL also as a collaborative learning. Learning log is a log that a learner has done, therefore for collaborative learning in SCROLL is asynchronous model.

Any learner in this system is able to share ULLOs, and system will show the shared ULLOs to others. Besides, they can also ask for others questions when they share ULLOs. In reflective learning, shared ULLOs can also be used to generate quizzes in order to help learners learn more objects.

3.2.4 Situated learning and experiential learning

According to (Lave & Wenger, 1991), situated learning is learning that takes place in the same context in which it is applied. (Itin, 1999) also defined experiential learning as

"learning from experience". We design a concept called task in SCROLL to implements the situated learning and experiential learning. It simulates same context for learning and helps learner learning from past experiences. Tasks are referred as the activities that the knowledge can be used. They are related to the learning contexts like school, hospital, post office and so on. For instance, if the system recommends a learner a Japanese word "トマト (tomato)" in a supermarket, the learner can talk with the staffs in the supermarket using the word "トマト (tomato)", such as asking its price, location, recipe and so on. And it has been proved that by talking with the Japanese native speaker using the recommended word, learner can master the word well (Jonassen & Grabowski, 2012). The activity of asking about the information is a kind of the so-called task. Basically, the learners who saved the learning log are responsible for providing what kinds of tasks the knowledge can be utilized. And one learning log can be used in several tasks. Moreover, the system provides some predefined tasks in different contexts in order to reduce the learners' burden of designating tasks when they save their learning logs. Table 1 shows part of the predefined tasks in different contexts. What's more, the tasks can be defined by the learner and designated by the administrator of the system.

The system assigns the appropriate task for a learner based on the difficulty of the task and the learner's ability. For example, asking the price of the production is easy for learners to finish while asking about the recipe of the vegetables is quite difficult for most learners. And when the learners received the recommended the learning log and the task, they are also asked to provide feedback for the system. For example, they are asked to take the photos of the object if they are asked to inquire the location of it. And if they are asked to learn about the place of the production, they need to accomplish

this information on the system. Only providing the feedback can prove that they have really used the knowledge. And if the learner meets new problems when he carries out the tasks, he can record them in photos, videos, audios or texts and upload them to the system in order to ask for help. Such accumulated data is also meaningful for the other learners.

3.2.5 Seamless learning

Recent progress of mobile and wireless technologies offers us a new learning environment, namely "seamless learning". It allows learners to learn anytime, anywhere, and provides them with multiple ways of learning throughout the day. By seamless learning, we mean learning which occurs with seamless transitions between in-class and out-class learning as "American College Personnel Association (1994) stresses the importance of linking students" in-class and out-of-class experiences to create seamless learning and academic success. (Wong & Looi, 2011). The basis of our seamless learning idea is cyclic model of learning, proposed by (Takeuchi, 2007), that there are four processes of learning: preview, in-class lesson, review, and expanded self-learning, where 'class', in a broad sense, means not only learning in-class but also learning out-class and it allows teachers to incorporate students self- learning into classroom activities (Sumi & Takeuchi, 2008).

Based upon the above ideas, we design the following Seamless Mobile-Assisted Language Learning Support System (hereafter we call it SMALL System) as a sub-project. It contains following parts:

1. Textbook Data: consists of the whole units of the textbook to be learned through one semester. A teacher uploads PDF file textbook data to the system in advance.

2. Learning Log System: or SCROLL is a system developed by our team. Users register what they have learned, which we call "learning log objects (LLO) to the system and view LLOs uploaded by themselves and others, then it supports recalling of their learning logs by giving them quizzes.

3. Quiz: The students register textbook target words and their newly acquired words during their self-learning and the system gives them quizzes. It generates quizzes based on the LLOs registered and viewed by the students.

4. Message: Users can send messages to other users in this system. When a viewer clicks the author name of the LLO, new window will be popped up and can send a message to him. This function will promote the students interaction or discussion and will lead to collaborative learning which will be inevitable where the teacher in not there outside-class self-learning.

3.3 Functionalities

We implemented SCROLL both on web and smartphone platforms. It contains following functionalities:

3.3.1 ULL Recorder

This component facilitates an easy way for the learners to upload their ULLOs to the server whenever and wherever they learn. As shown in Figure 3.1(a) and Figure 3.2, in order to add a ULLO, the learners can take its photo, ask questions about it and attach different kinds of meta-data with it, such as its meanings in different languages.

(a) Add ULLO (b) ULLO List (c) Quiz

Figure 3.1: SCROLL interface of Android mobile phone

3.3.2 ULL Finder

If learner registers a new ULLO, the system checks whether the same object has been already stored or not by comparing the name fields of each object using a thesaurus dictionary. Also, the learner can search ULLOs by name, location, text tag and time. Using this function, learners can understand what, where and when they learned before. Figure 3.1(b) and Figure 3.3 show the list of the learner's ULLO, which helps him to recall all his past ULL. Besides, it allows him to be aware of the others' learning objects and to

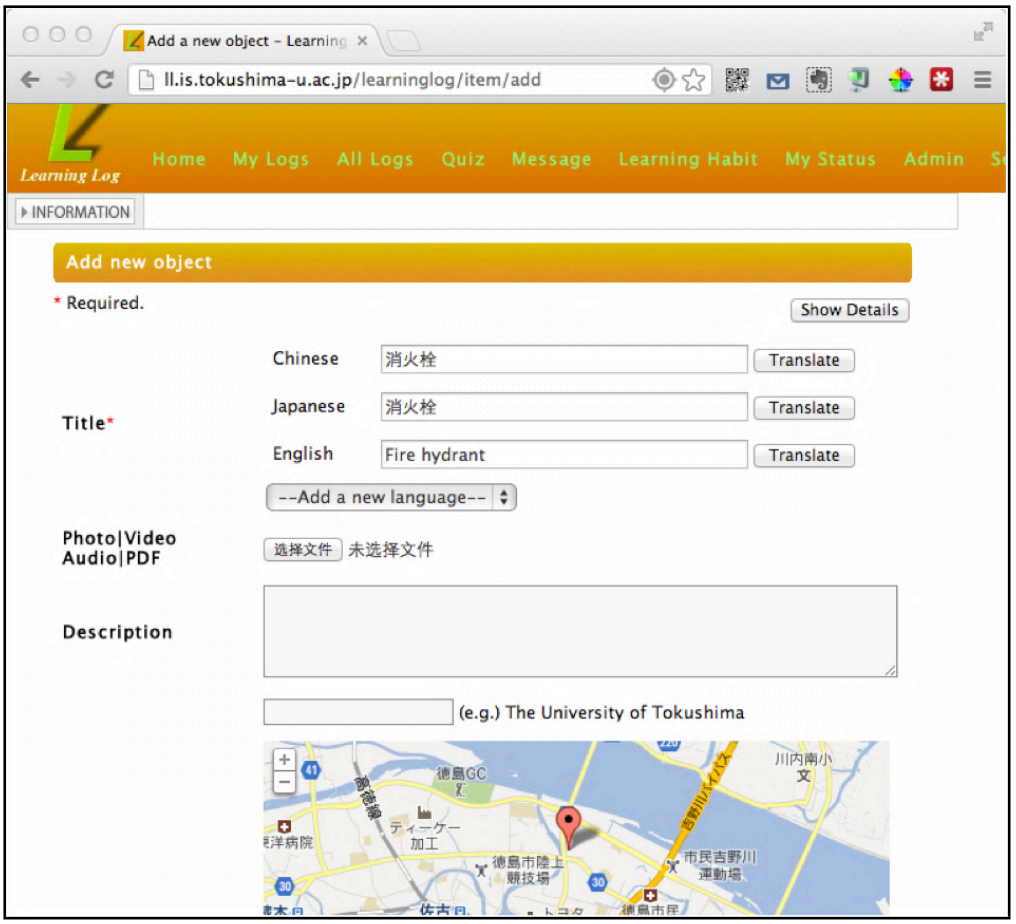

Figure 3.2: SCROLL interface of Web (Add a new ULLO)

re-log them; it means that the learner can make a copy of them into his log. Therefore, the learner can obtain a lot of knowledge from the other learners even though he has not experienced that knowledge by himself. By sharing ULLOs with other learners and relogging the other learners' ULLOs, the acquisition of the knowledge is enhanced.

3.3.3 ULL Reminder

As shown in Figure 3.1(c) and Figure 3.4, the system generates simple multiple-choice quizzes based on the meta-data of the stored ULLOs. For example, the idea of "quiz with image" is to ask the learner to choose an image that describes the word given by the system. The system immediately checks whether his answer is correct or not. These quizzes

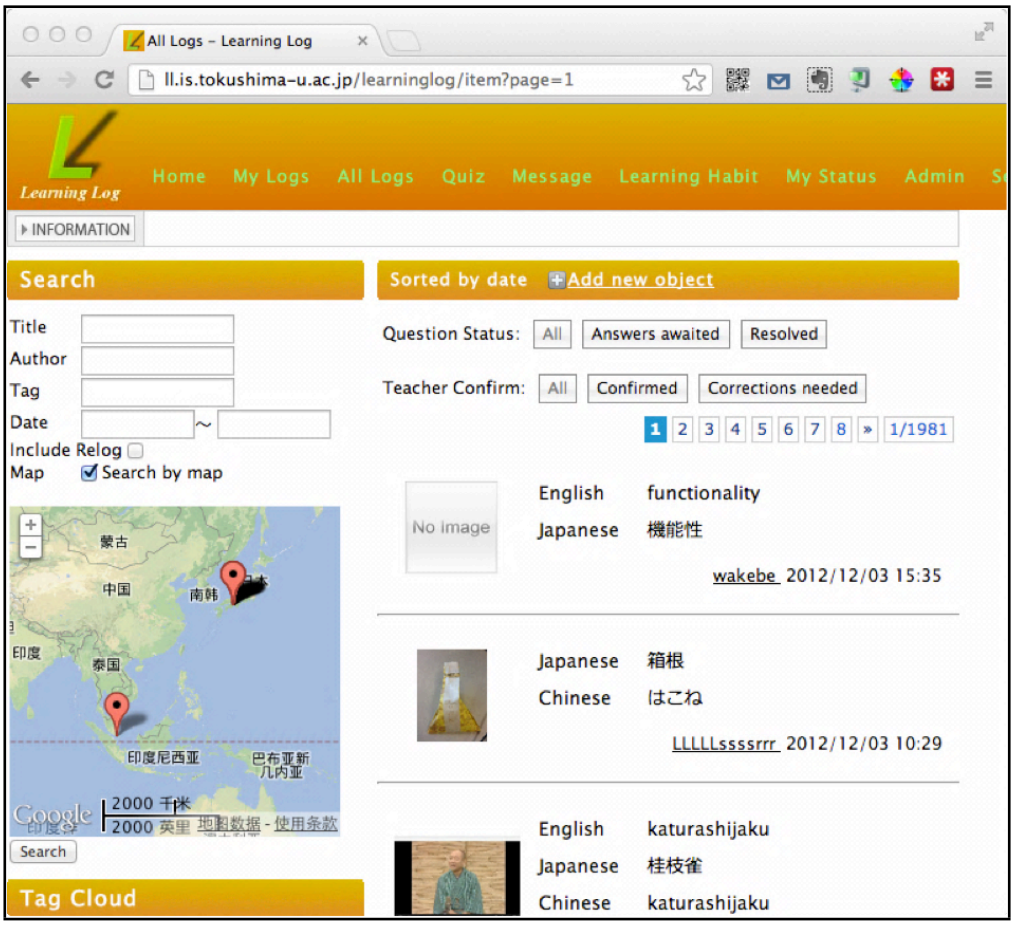

Figure 3.3: SCROLL interface of Web (ULLO List)

are generated according to his profile, location, time and the results of past quizzes and help the learners to recall what they have learned. The quiz function is designed not only to help the learners to reinforce what they have learned, but also to recommend what other learners have learned and to remind them of what they learned in the past according to their current location and their preferred time. In order to achieve these targets, they can practice with the quizzes whenever they want. In addition, they can send their location information to the server all the time. Therefore, the sever side can automatically assign quizzes for them based on their location and time information. It notifies them to check the quiz by showing an alert message and vibrating the mobile phone. Whenever they move around an area where they have encountered some objects,

the system will send them quizzes regarding those objects. Furthermore, they can set a time schedule to receive the reminder quizzes.

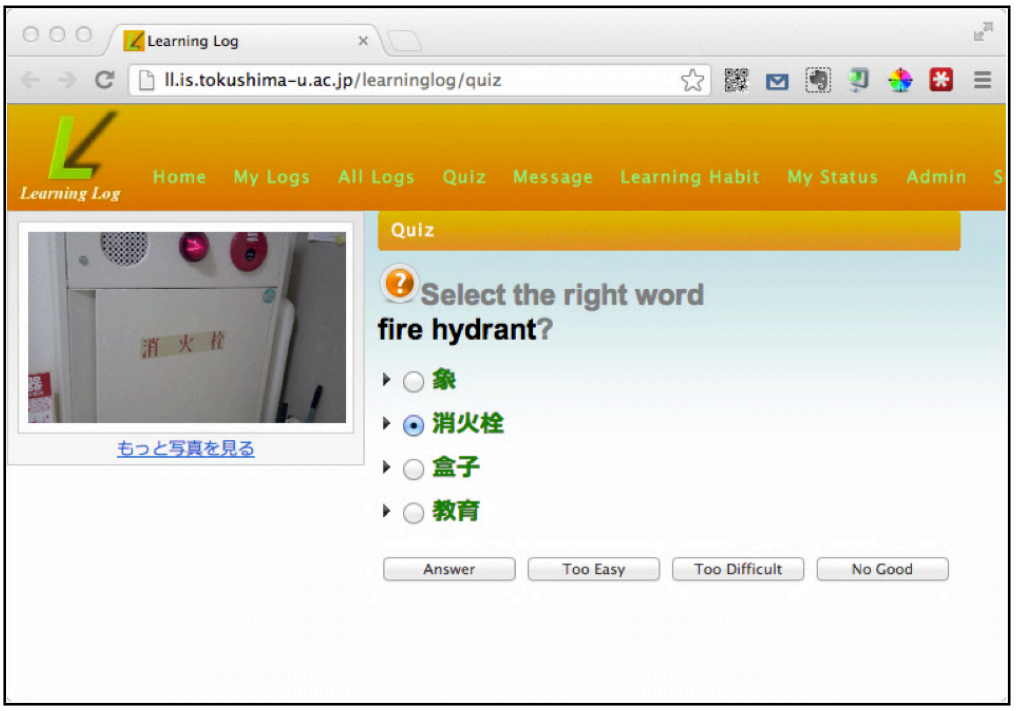

Figure 3.4: SCROLL interface of Web (Quiz)

3.3.4 ULL Navigator

LL navigator provides mobile augmented reality that allows the learner to navigate through the ULLOs. Like Wikitude (*Wikitude*, n.d.) and Sekai-Camera (*Sekai Camera Web*, n.d.), it provides the learner with a live direct view of the physical real-world environment augmented by a real time contextual awareness of the surrounding objects. Firstly, in this paper we focus ULL recorder. Current ULL recorder requires learners capturing learning content (e.g. photos) manually. This is not so convenient and it would disturb learning activity. So we tried to find a better way to log learner's learning content automatically unconsciously. Then we found SenseCam can do that. After that,

among the very large amount of captured photos by SenseCam, what are learning contents? That is the second problem. After using SenseCam, we found that there is lots of context data such as temperature, brightness that can be used to help learner recall the captured object. Besides, these data can also be used to help us improve our ULL reminder. This is an extra benefit from passive capture.

Chapter 4

PACALL System

4.1 Life-log Camera

4.1.1 Introduction

In this research, we use a life-log camera named SenseCam that is a prototype device under the development of Microsoft Research (Hodges et al., 2006).

Figure 4.1: SenseCam

In 2009, SenseCam was licensed to Vicon and is available as a product called Vicon Revue. The price of SenseCam is £299. It is a small digital camera that is combined with a number of sensors to help to capture a series of images of the wearer's whole daily life at the proper time and it can be worn around the neck (Figure 4.1). Originally this device is designed for memory aid.

4.1.2 Sensor Data

There are two functionality of SenseCam:

1. Recording sensor data and the status of SenseCam.
2. Taking photos whenever the internal sensor is triggered by a change of environment.

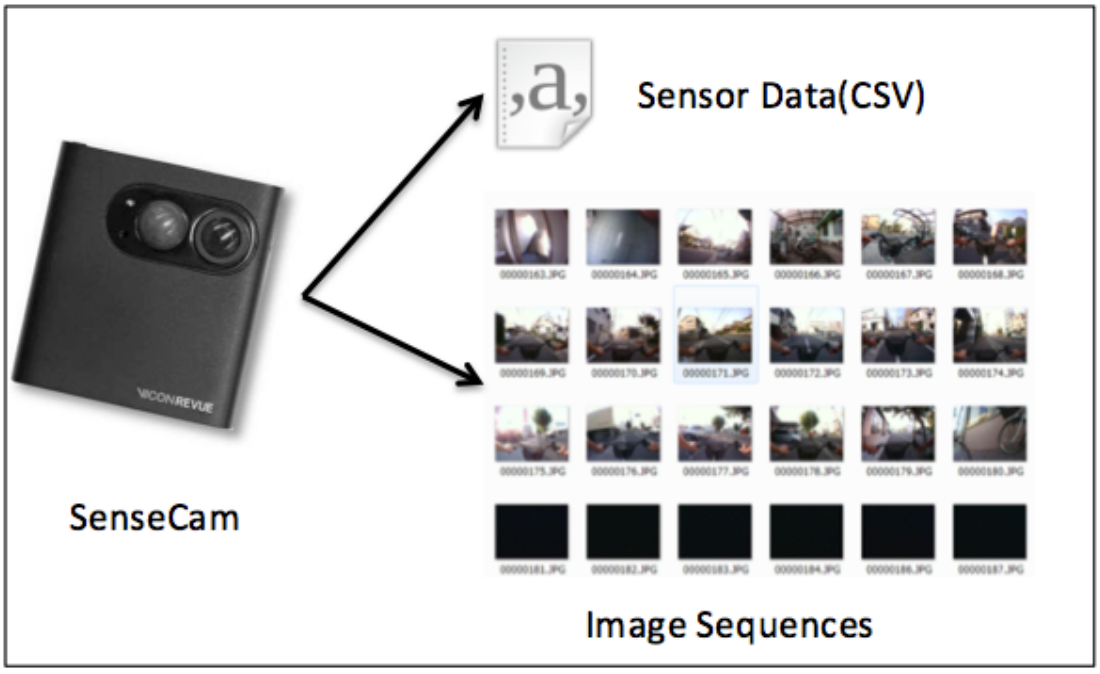

Figure 4.2: SenseCam and data format

The SenseCam uses sensors as triggers to capture images along with a time trigger. As it is shown in Figure 4.2, when using the SenseCam all actions are saved into a single file named SENSOR.CSV including sensor data and the names of photos. Once the SenseCam is connected to computer, all the photos and the SENSOR.CSV file will be imported automatically.

Figure 4.3 is an example of SENSOR.CSV. Each line starts with a flag (e.g. CAM, ACC) and a timestamp. Meanings of some flags that we are using in this research are shown in Table 4.1.

```
CAM,2011/07/01 16:55:41,00021945.JPG,P
ACC,2011/07/01 16:55:53,-0.079,00.866,00.029
TMP,2011/07/01 16:55:53,0034.0
CLR,2011/07/01 16:55:53,02000
PIR,2011/07/01 16:55:53,1
BAT,2011/07/01 16:55:53,41772
MAG,2011/07/01 16:55:53,769,531,-1693
CAM,2011/07/01 16:55:55,00021946.JPG,P
ACC,2011/07/01 16:56:02,00.115,01.003,-0.003
TMP,2011/07/01 16:56:02,0034.0
```

Figure 4.3: Example of SENSOR.CSV

Table 4.1: Flags in SENSOR.CSV

Flag	Sensor/Meaning	Data Interpretation
CAM	Image capture	Image filename, capture reason (P: PIR, T: Timer, M: Manual, L: Light level change)
PIR	Passive infrared detector	1: the PIR is triggered, 0: not triggered
CLR	Color light sensor	Value for 'white' light
TMP	Temperature sensor	Temperature
ACC	Accelerometer	Acceleration values in x, y and z axis
MAG	Magnetic sensor	Magnetic values in x, y and z axis

The SenseCam itself has an algorithm for capturing images by a time trigger and other triggers that use sensor data. However, because SenseCam is designed for memory aid, it takes photos continuously even if it is dark or the situation is not been changed. The result is that there are so many photos that are duplicated or blurred or dark.

In the first step of this research, we attempted to analyze photos by sensor data. For example, CLR indicates whether the photo is taken in a brignt environment or not, i.e. bright photo or dark photo. ACC indicates when the photo was taken whether the camera was shaking or not. However, after comparing to the image processing, we think analyzing photos by image processing make more sense because image processing are more accurate than that by sensor data. Nonetheless, data in the line of CAM with the capture reason of M means this photo was taken by learner manually and this is recommendable to learner.

4.1.3 SenseCam Photos

In this research, we use the product named Vicon Revue that is based on the prototype of SenseCam developed by Microsoft. This device is designed for memory aid. Therefore, it records photos all the time using its algorithm.

The default algorithm is using several triggers including time trigger and sensor triggers. The default interval of taking photos is 30 seconds. When the sensors detect changes, photos are also taken instantly. For example, when walking into a warm room from cold outside, the temperature sensor detects changes of temperature and triggers camera to take a photo.

There are 5 triggers in SenseCam:

1. Time trigger: It triggers camera to take photos continuously at stated intervals. The default interval is 30 seconds.

2. Accelerometer trigger: When camera moved, a photo will be taken by this trigger.

3. Temperature trigger: Detect changes of temperature, if temperature changed, a photo will be taken.

4. Light trigger: When the light changed, a photo will be taken.

5. Passive infrared trigger: SenseCam also detects if there are something move in front of SenseCam by this trigger, and takes a photo.

Also, user can use manual button to take a photo manually.

When the photo is taken by time trigger, it does not depends on movement or other changes of context. That is to say, there may be many duplicated photos. Besides, small changes such as brightness and angular, also cause camera to take a photo. The result is that there are many duplicated photos and similar photos among life-log photos. Accelerometer trigger takes photos during movements, and it usually takes many blurry photos. Temperature trigger usually takes photos when the location changed from outdoor to indoor or indoor to outdoor. It also happens during movement, so is light trigger. Passive infrared trigger records moving objects in front of camera. When user writes something and the hand moves in front of camera, hand is usually recorded by SenseCam.

4.2 Comparison between passive mode and active mode

Since this research is based on our previous works that use active mode to register ULLOs, we have to find out differences between active mode and passive mode in this

research. We have compared both on features as Table 4.2 shows.

Table 4.2: Comparison between active mode and passive mode

Flag	Passive	Active
Number of photos within the same time	Many (<3000/day)	Few (<20/day)
Photo quality	Poor (SenseCam)	Good (Camera /Smartphone/Tablet PC)
Recording time distribution	Continuous	Intermittent
Content completeness	High (user's whole daily life)	Low (only specific scenes)
Content type	Poor (only image)	Good (image, audio, video, etc.)
Consciousness	Unconscious	Conscious
Reflection	Yes	No
Workload	Low (capture automatically)	High (review&upload in a large amount of photos) Little high (capture manually & upload manually)

In the first three rows of Table 4.2, the two modes are compared in terms of photos. When we use SenseCam to have a passive way of learning, SenseCam takes photos continuously, while in the active mode, smartphone photos can only be taken at the time we want to. As a result, the passive mode brings more photos than the active mode. However, because of the storage problem and some other technology limitation, photos token by SenseCam have lower quantity, but it is acceptable to be used as ULLO.

In the next two rows of Table 4.2, the comparison is made in terms of learning contents. When we use camera or smartphone, many learning contents are logged in the spare time, for example at lunchtime. However when we use SenseCam, because the recording is processed continuously, we can get photos whenever in the classroom or on the street. So content is relatively complete. The content type in the active mode is richer than that

in the passive mode because in this research the learning content type that we can get from SenseCam is only photo.

In the last two rows, the comparison is about learners. In the passive mode photos are taken unconsciously, while in the active mode learner must take photos consciously. When learners use SenseCam, they must review the whole learning process, and have a reflection on what they have seen and what they have learned and what they missed to learn. This process will help learners to remember learned contents.

By this comparison, we understand that passive mode has so many advantages over active mode for the language learning by photos. Only the quality of photos is low, but it is acceptable. However the biggest disadvantage is workload. SenseCam takes photos continuously. Consequently a huge amount of photos come out. More photos, the heavier the workload. If this workload is reduced, learners can learn language in the passive mode more easily. This is the key issue to use passive mode in language learning. In this research, we are focusing on reducing workload when reviewing the photos and propose a system that can filter the photos to help learners review and upload ULLOs easily.

4.3 Learning Process

Our system is a sub-item of Ubiquitous Learning Log, and we named it as PACALL. It is short for passive capture for learning log. The whole process of passive capture happens unconsciously. However it is no doubt that the simple photo capture is not the whole process of learning. It is necessary for learners to look through the captured

photos and find the learning contents with the help from our system. After entering the information of the image such as title and description, this learning content will be saved into SCROLL system as a ULLO. Figure 4.4 shows the relationship between PACALL and SCROLL.

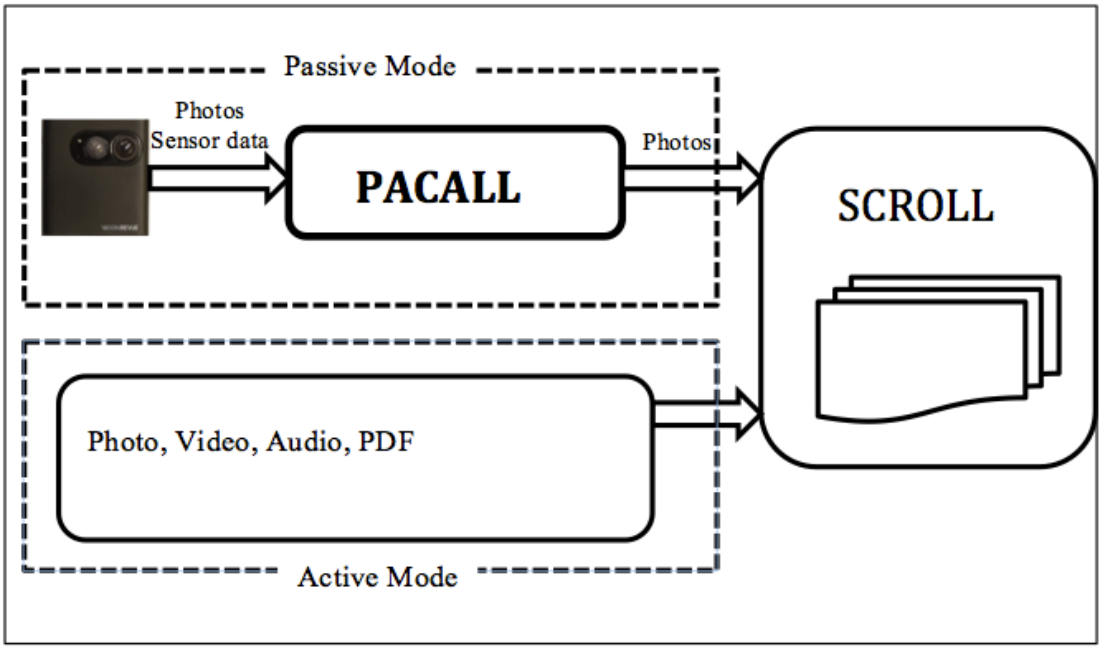

Figure 4.4: The Relationship between PACALL and SCROLL

A process of passive capture includes capture, reflect and store. Such process is called a PACALL frame.

Capture

Capture a series of photos for life-logs in daily life. The log includes all what learner has seen. Besides, massive redundant contents are also included in this log. We use SenseCam in the process of capture.

Reflect

After capturing life-log, a learner needs to have a reflection of what s/he has learned. In this process, since there are so many photos, we provide a system

to filter the redundant photos by analyzing sensor data or image processing technology.

Store

When a learner finds an important learned content, the content must be stored into main learning log system - SCROLL. During this process, s/he also needs to enter the information of learned content such as title, description or tags.

4.4 Photo Classification

Our system is a sub-system of Ubiquitous Learning Log, and we named it as PACALL. It stands for PAssive CApture for Learning Log. We want to have the whole of the capturing process happened in the passive mode unconsciously. After that, PACALL analyzing all the captured photos and finding several important ones to help learners determine which are valuable to record.

Figure 4.5 is the flow of PACALL in analyzing captured photos. There are 5 steps:

1. Loading raw data.
2. Filtering bad photos.
3. Finding good photos.
4. Photo recommendation.
5. Learning Analytics.

We will introduce these 5 steps in detail.

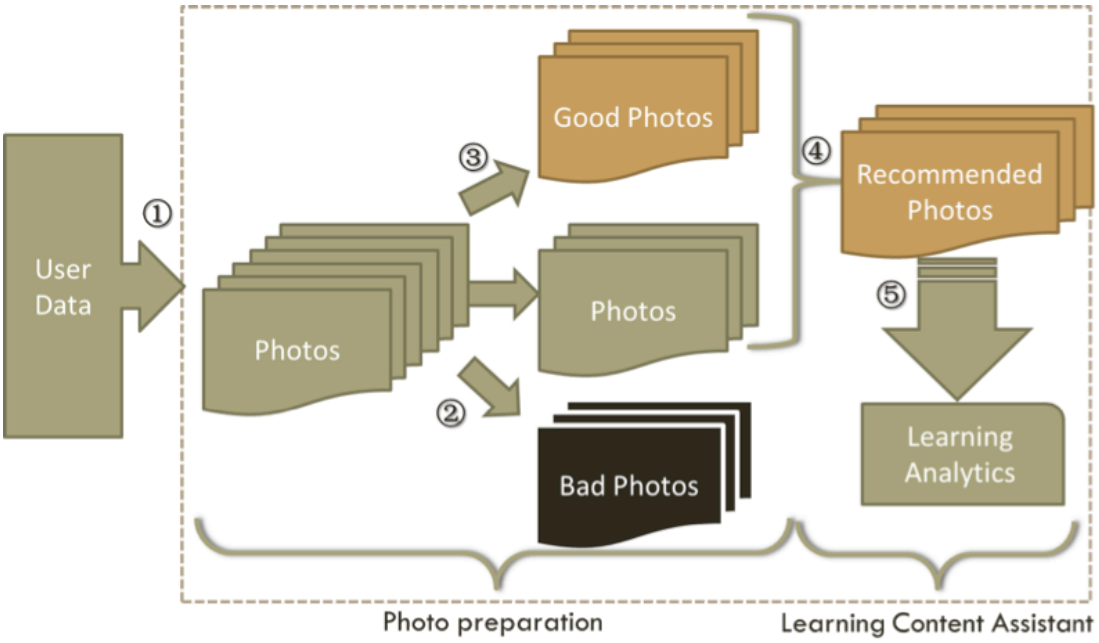

Figure 4.5: The flow of analyzing captured photos

4.4.1 Loading raw data

There are 3 types of raw data in PACALL:

- Life-log photos
- Sensor data
- GPS data

Life-log photos are captured by SenseCam at the present. In the future, we plan to apply this system to common photos. That will be interesting and useful. Imaging that you have tour and took many photos, and then you can use this system to find out learning content.

Sensor data is record by SenseCam and GPS data is created by portable GPS unit.

4.4.2 Filtering bad photos

Before filtering bad photos, we must define the bad photo and good photo. In this research, we define that bad photo is a photo that is hardly to recognize its content or that is duplicated with other photos, while good photo is a photo that contains clear objects. We define three types of bad photos:

- Dark: Dark means a photo taken with insufficient light and the photo is dark.
- Duplicate: Duplicate means the photos are duplicated.
- Defocused: Defocused means the photos are blurry and cannot be recognized well.

4.4.3 Finding good photos

As it is defined in bad photos, the good photo is clear photo and contains clear objects. Therefore, we are using OpenCV to find out good photos mainly by feature detection. After finding out good photos, left photos are common ones. Those photos are not so clear but maybe contain learning contents. However the priority of those photos is lower than good photos when shown to learner to choose.

4.4.4 Photo recommendation

Until now, bad photos are filtered out and system selected several good photos for learner. Photo preparation is finished, and it steps into the stage of learning content

assistant. We attempt to abstract useful information from photos by machine, and recommend photos that contain information. Therefore we define 4 types of recommended photos:

Text photo

Character photo means a photo that contains characters. These characters are probable used as learning content. Text detection can be used to find these photos.

Feature photo

Feature photo means a photo that contains some features. This photo is clear not blurry.

Face photo

It is certain that face photo means a photo that contains faces. Actually, these photos are usually not appropriate for learning content because of privacy issues. Anyway, faces are also information from photos.

ULLO-like photo

If there is a similar photo that was already registered to the SCROLL as a ULLO, maybe this photo is also can be used as a ULLO.

4.5 System Design

In this research, the SenseCam that we are using is produced by Vicon Revue (*Vicon Revue | Memories for life*, n.d.). There is an additional software for Vicon Revue named Vicon Revue Desktop (Figure 4.6), which is developed by Adobe AIR (*Adobe AIR |*

Adobe AIR 3 | Deploy applications, n.d.). Actually, this is a life-log photo browser and help user reflect his/her activities. In this research, we just use the import function of this software. When the SenseCam is connected to the computer, all photos will be imported into computer. The location of SenseCam repository is in the user's document folder and the name is Vicon Revue Data.

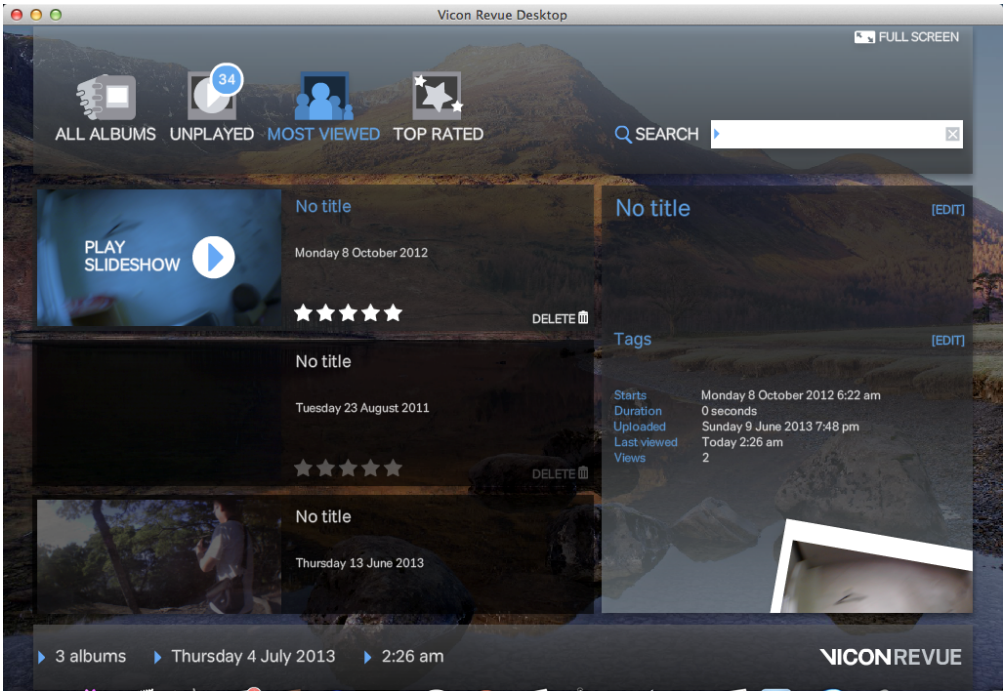

Figure 4.6: Vicon Revue Desktop

We design PACALL system as a B/S(Browser/Server) system. Figure 4.7 shows the system architecture.

All the photos captured by SenseCam and sensor data are imported into local repository on learner's computer.

And then, learner must upload all the data to PACALL system. Since SenseCam usually takes hundreds or thousands of photos, it is not easy to upload all the photos to the server. Here we use HTML5 folder upload function to implement it. After uploaded, all the photos will be converted into different sizes. This process is done by static file server. When

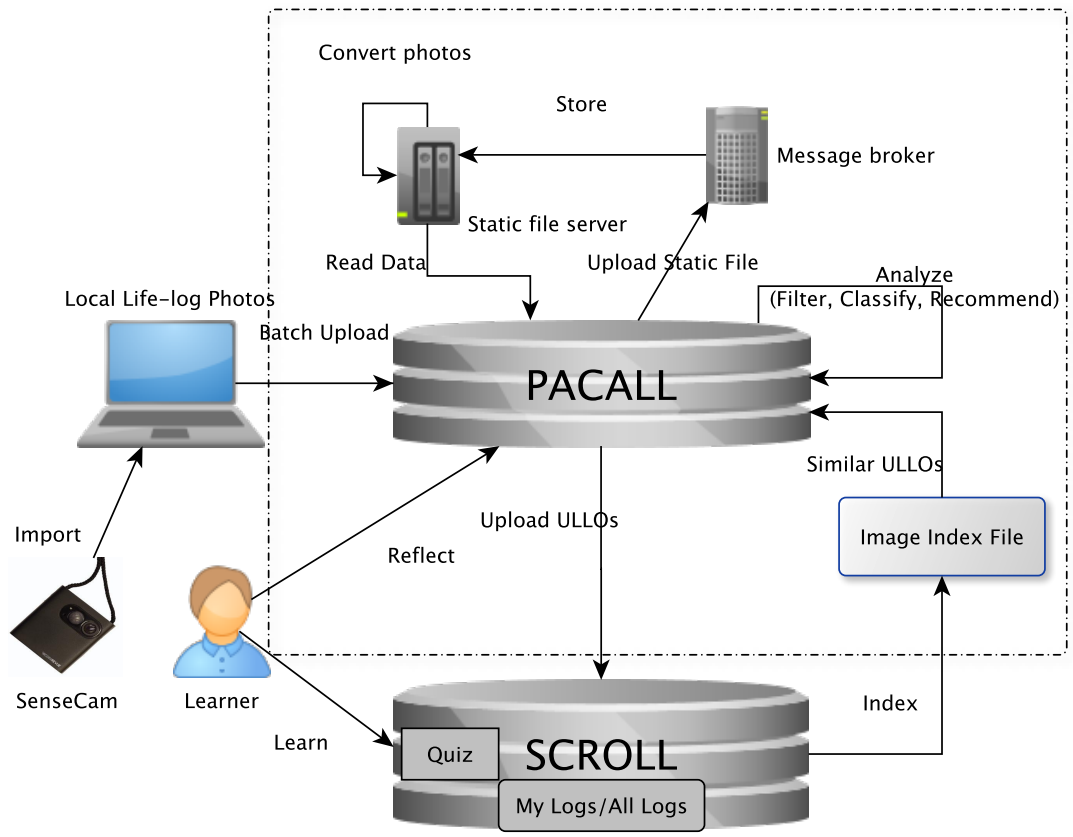

Figure 4.7: System Structure

a photo is uploaded to static file server, it will be converted automatically. Because the process converting costs more time than uploading, we place a message broker between PACALL main system and static file server to make two processes asynchronous.

Once all the files are uploaded to PACALL system, learner should start the analyze process. Then PACALL system will analyze all the data including filtering bad photos, recommending good photos. Besides, PACALL system also finds similar ULLOs by image index that contains all the ULLO photos index. This process takes very long time, and the system will show the status of process.

After data analyzing, system will show the result to learner. Learner selects learning contents and uploads them to SCROLL as ULLOs. Each photo uploaed to SCROLL

will be indexed into image index. We use LIRE (Lux & Chatzichristofis, 2008) that is a lucene plugin to index and retrieval photos. When finished this process, learner may leave PACALL system and return SCROLL to use the functionalities such as ULLO finder, ULLO reminder, ULLO navigator to enjoy learning with ULLOs.

4.6 User Interface and Functionalities

In the Section 4.5, we introduced our research design especially design of the flow of analyzing photos. We developed functionalities in detail.

4.6.1 PACALL Uploader

PACALL Uploader helps learner upload all the photos after capturing. We want to make it easy to upload all the captured photos to the server. Because of the limitation of web technology, this process is not so easy in the past. However with HTML5, it becomes possible. When a learner wants to upload the whole folder, learner can select a photo folder and upload all the photos to the server. Also, the file of sensor data and GPS data will also be uploaded. In addition, this functionality is Google Chrome only at present, because of the compatibility of folder upload and html5 form upload.

4.6.2 PACALL Browser

After uploading the raw data (photos, sensor data and GPS data), system will analyze all the data and show the result for learner.

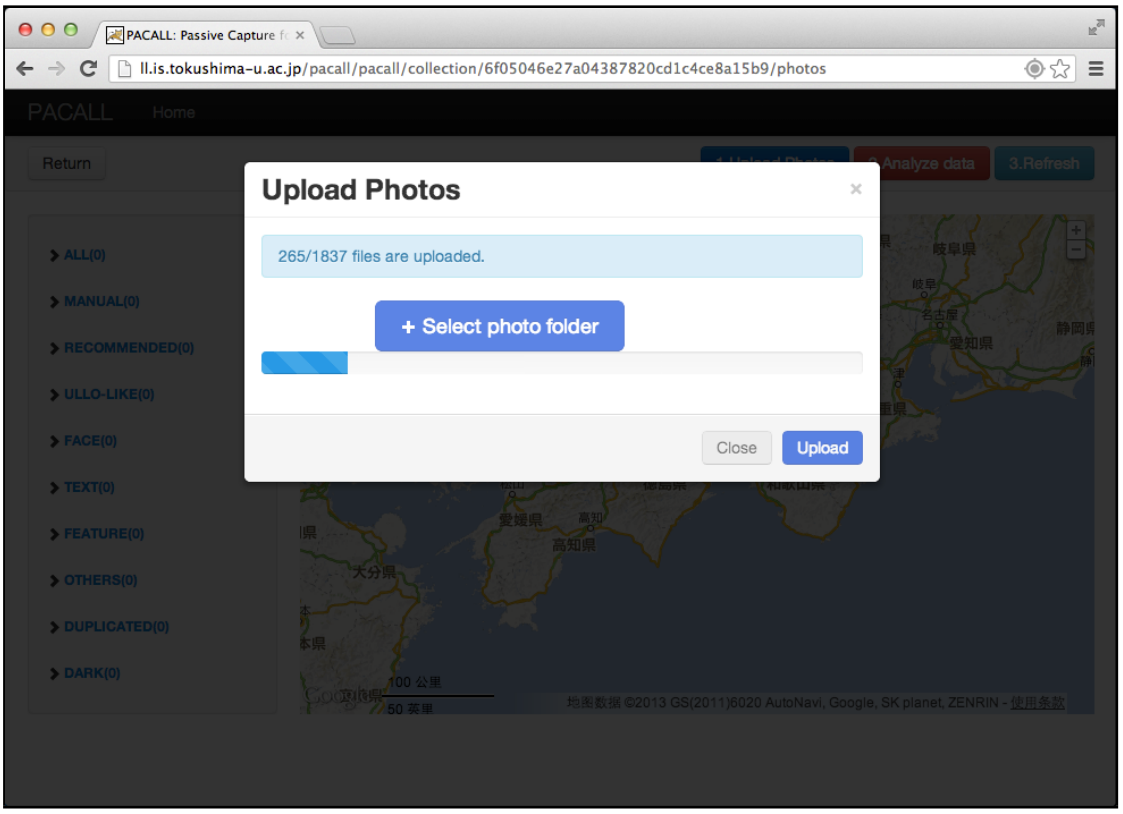

Figure 4.8: Interface of PACALL Uploader

When all the photos are uploaded to the server, the learner can have a reflection of all the photos with the help of PACALL. PACALL Browser is an interface of browsing all the photos, and it tags photos and provides some information of photos to help learner find important photos (Figure 4.9). Currently, we provide three main functionalities in PACALL Browser – PACALL Filter, PACALL Searcher and PACALL Recognizer.

PACALL Filter classifies all the photos into categories such as Manual, Normal, Duplicate, Dark, Face and Recommendation. Here manual means that photo is captured by pressing manual button of SenseCam. It usually happened when learner finds something valuable to record. Duplicate and Dark contains bad photo. Face means the photos contains faces and Recommendation includes Manual, Faces and other good photos that

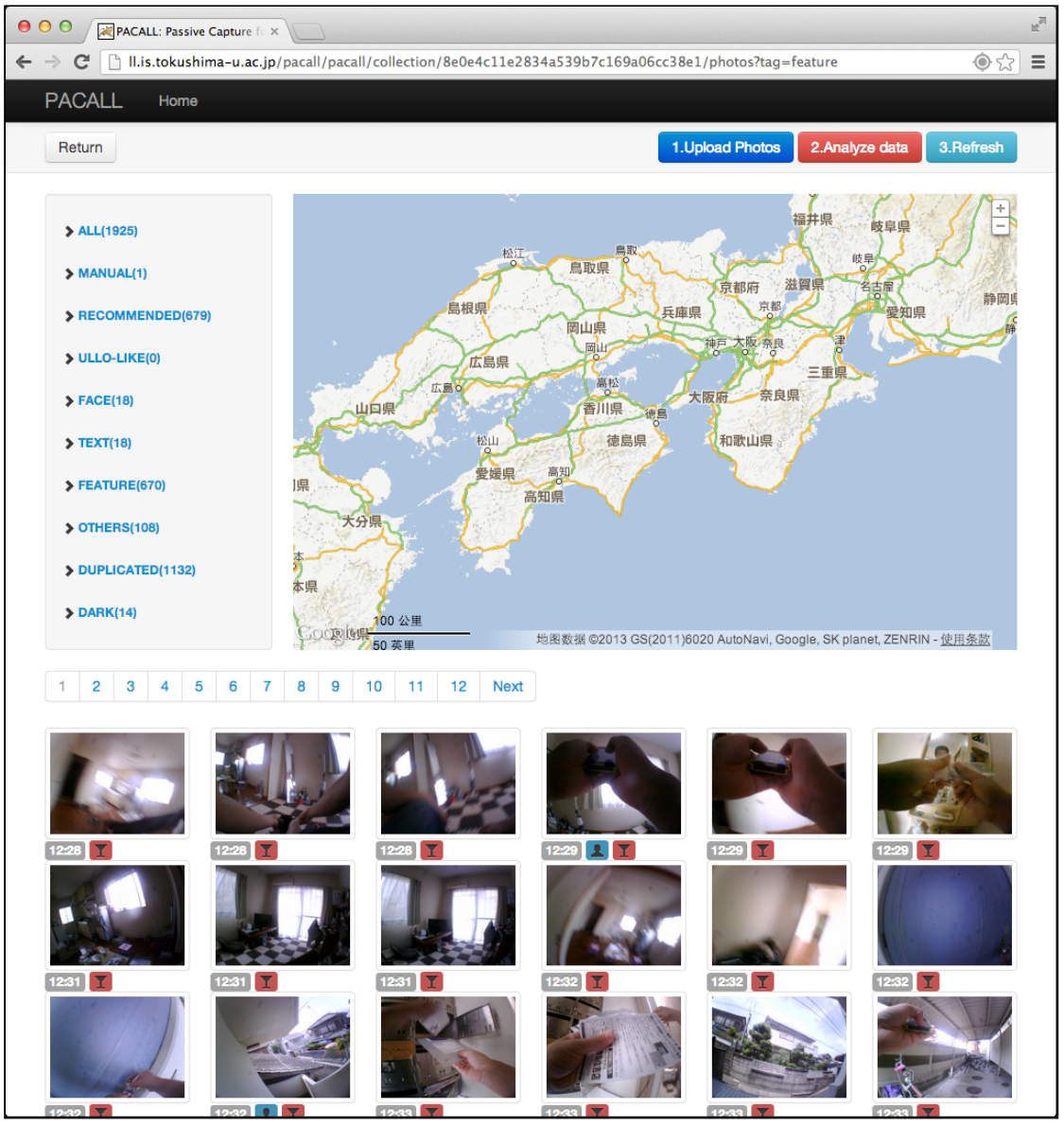

Figure 4.9: Interface of PACALL Browser

contain information or have similar photos that have been uploaded to SCROLL before. Such photos have tag under the photo like 3d or 4d means there are similar photos uploaded to system 3 or 4 days ago.

4.6.3 PACALL Recaller

When a learner clicks one photo in PACALL browser, the PACALL recaller will be opened. The photo and the similar photos and sensor data will be shown on this page to help user recall the captured content.

There is also a "Upload" button on this page. If the learner decide to upload this photo to SCROLL as a ULLO, s/he can clicks this button, the photo will be uploaded to the SCROLL system directly and the page will jump to the learning log registration page (Figure 4.10).

Figure 4.10 is the interface of ULLO registration in SCROLL system. On this page, a learner can see the location of the selected photo and other similar photos that captured by SenseCam. If there are some similar photos that are already existed in SCROLL, the similar photos will be also shown on this page. Once "Upload Now" is clicked, the system will ask student to answer a survey that let system know whether learner know it and noticed this object when it was captured. The data can be used to evaluate our system and help learners analyze the learning situations. When an object is uploaded to the system, SCROLL system will use "organize", "recall" and "evaluate" model to help learner remember uploaded objects and vocabularies. For example, if a learner uploaded a photo and set the title as 消火栓 in Japanese, but s/he does not know how to speak it in English, then s/he can send a question along with the uploaded ULLO. SCROLL will send this question to all Chinese users. After receiving the answer from Chinese users, this learner learned a new Chinese word. In the quiz module of SCROLL, learner can

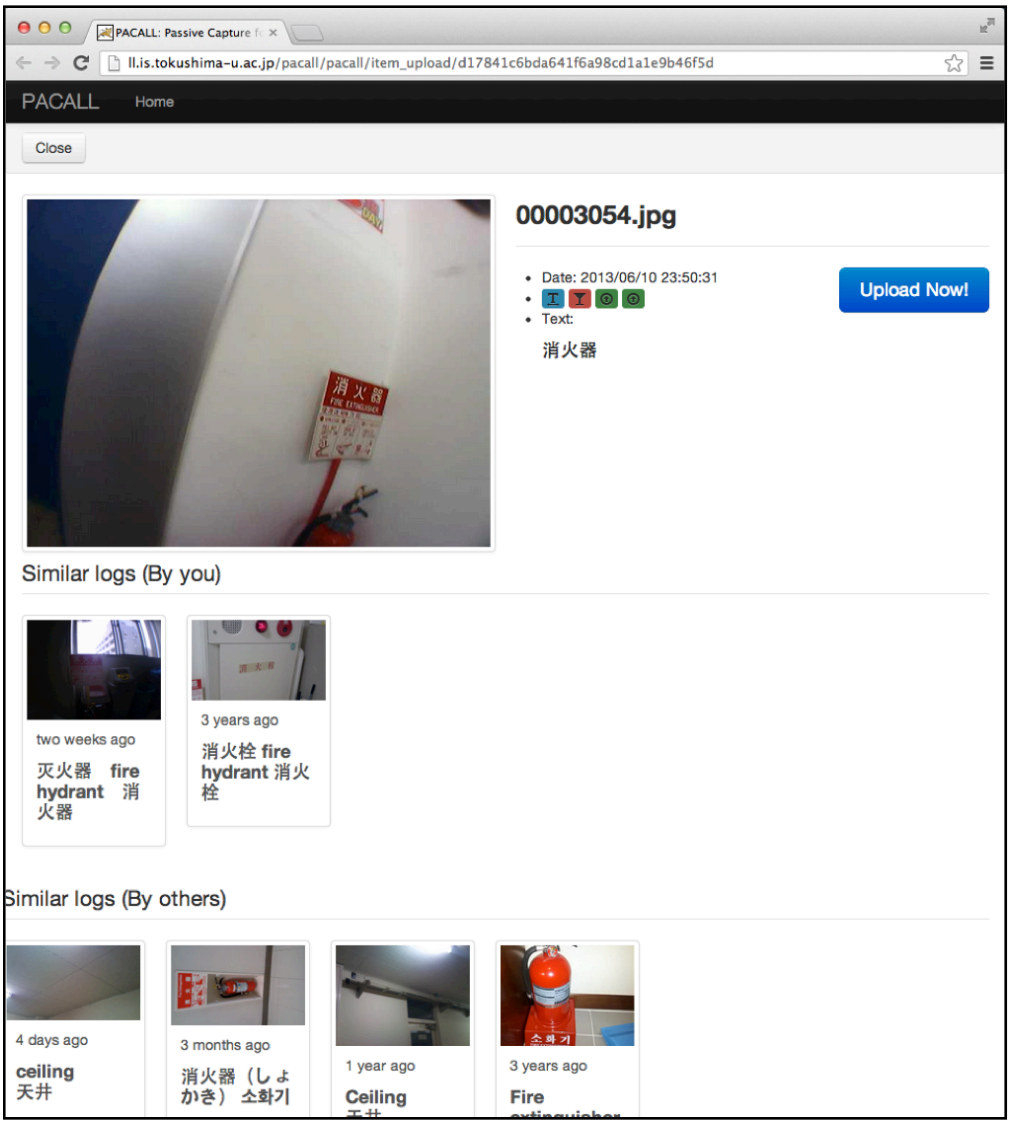

Figure 4.10: PACALL Recaller

answer the quizzes that are generated by uploaded ULLOs. By answering these quizzes, learner's knowledge will be enhanced.

Chapter 5

Evaluations

5.1 Evaluation I

5.1.1 Objectives

We conducted this evaluation while basic functionalities of PACALL were finished. We considered to conduct an initial evaluation experiment to compare passive mode to active mode. Therefore, objectives of this evaluation experiment are listed as follows:

1. Compare the learning with SenseCam to the learning with Tablet PC.
2. Find out whether the learning contents taken unconsciously in passive mode are useful to learners
3. Investigate the user experiences on using SenseCam and PACALL

5.1.2 Method

The Evaluation I is an initial evaluation experiment. Since this is an initial evaluation experiment, the study group consisted of 4 Japanese university students. In this experiment, they are asked to upload photos of learned objects along with titles both in Japanese and English. The method of recording photos is in different ways. The whole evaluation experiment lasted for 3 weeks (from July 18, 2011 to August 7, 2011) consisted of 3 stages:

Stage 1: SenseCam

On this stage, students were asked to wear SenseCam every day for one week. Every evening, they need to review all the life-log pictures and choose proper pictures to upload to the SCROLL. They are requested to record the time spent.

Stage 2: Tablet PC

In our previous works, we have compared the learning effectiveness between Tablet PC and a traditional learning method like taking notes. SCROLL with Tablet PC is more effective than traditional learning method. In this experiment, we compare SenseCam with Tablet PC in terms of log methods, for logging with Tablet PC is considered as an active mode while a log with SenseCam is considered as passive mode.

On this stage, all the students were asked to record and upload the learning log objects every day with Tablet PC for one week. We used Samsung Galaxy Tab in this experiment. The operating system of this Tablet PC is android, and we have developed an android client that can upload the picture to the system conveniently.

Stage 3: SenseCam+PACALL

On this stage, PACALL system was introduced into this experiment. It is almost the same as stage 1. All the students should wear SenseCam every day for one week. Every evening, they used PACALL system to classify the life-log pictures and upload the proper pictures. They were requested to record their time spent. Besides, they were asked to count the number of classification after all the pictures uploaded.

5.1.3 Results and Discussion

5.1.3.1 Learning chances - Differences on how many ULLOs uploaded per day?

We examined the differences of the number of uploaded ULLOs among these three learning methods. Figure 5.1 shows the average number of uploaded ULLOs for each subject.

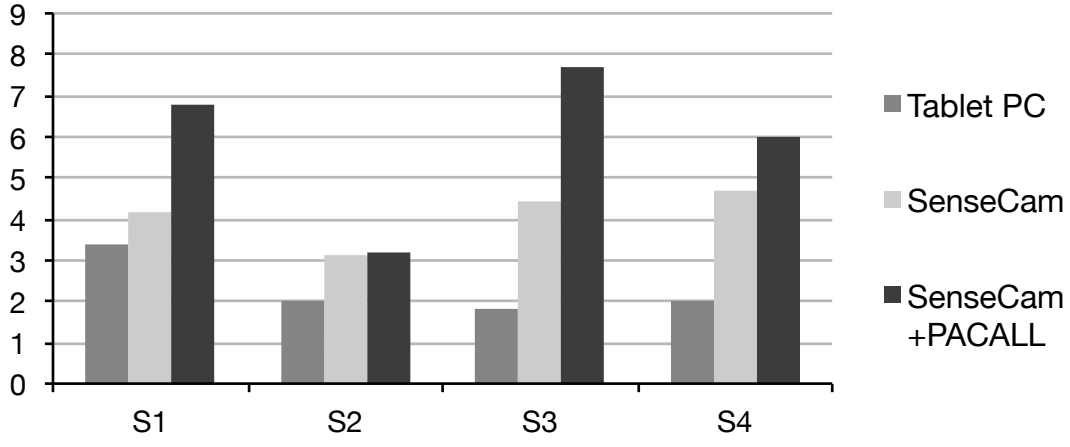

Figure 5.1: The average number of uploaded ULLOs

On this chart, the horizontal axis shows four subjects, and the vertical shows the average number of ULLOs that uploaded by subjects. We can see that SenseCam and SenseCam

+ PACALL have got a higher value than Tablet PC. It is sure that the number of pictures captured by SenseCam is larger than that by Tablet PC.

As the result, the passive mode with SenseCam offered them more learning chances than the active mode. Moreover, it is found out that PACALL increased the number of uploaded pictures in most cases (except S2). After this evaluation experiment, we want to find out why uploaded pictures did not increase in S2, and then we interviewed S2. We learned that at that time he was not so serious in this experiment and just wanted to upload 3 pictures one day to complete the "daily task".

However from the result of Figure 5.3, it shows that he just spend nearly half of the time to review and upload pictures in SenseCam + PACALL by comparing the time cost in SenseCam , so if he spent more time, the number of uploaded ULLOs would be increased.

In normal circumstances of their daily lives pictures captured by SenseCam would be almost the same whether it comes with PACALL or without and the number of uploaded objects would not be so different. However, from the feedback, we understand that the PACALL could reduce the workload of reviewing life-log pictures. Learners can choose pictures and upload them quickly. So the number of uploaded pictures by SenseCam + PACALL is larger than that by SenseCam only.

5.1.3.2 Learning quality - Can learners remember uploaded ULLOs that are taken unconsciously in passive mode?

What is the difference on learning effect between the active mode and the passive mode? This is the second question that we wanted to find the answer. Therefore, we gave all the

students a test after each stage to see whether they have remembered the uploaded objects or not. We made a test that contained the uploaded pictures and asked the students to write down the title of pictures and judge the memory level (from 0 to 5). If s/he remembered clearly, the memory level is 5 and if s/he absolutely cannot remember it then the memory level is 0. Figure 5.2 shows this result.

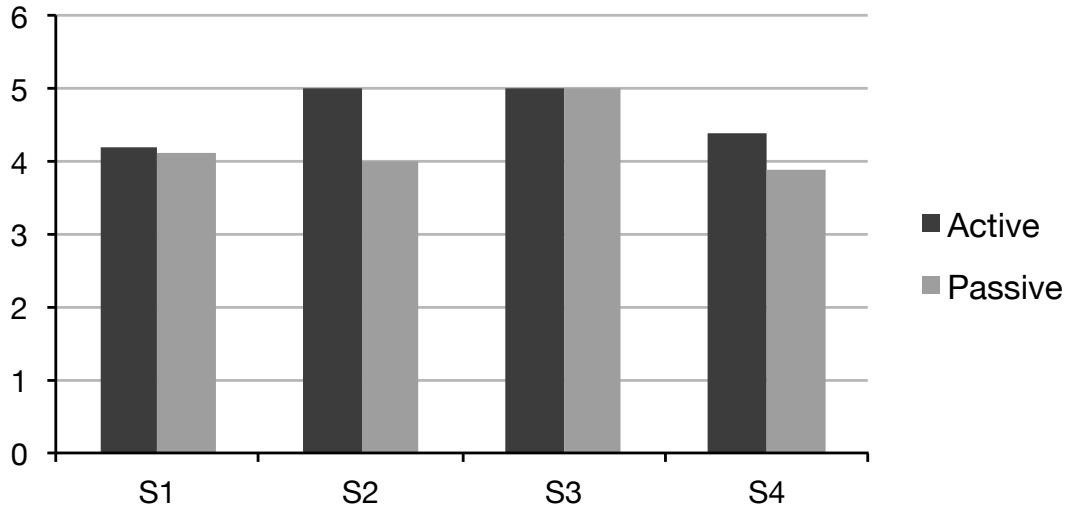

Figure 5.2: Memory level between active and passive

On the Figure 5.2, we can see the memory level of active is a little higher than that of passive. Under the active mode, the learner takes picture consciously, so the impression of photos is deeper than those taken under the passive mode. And the feedback endorsed it. Besides, the number of the photos under the passive mode is larger than that of the active mode. It may be one of the factors which make the impact weak. However, 5.1.3.1 shows that they registered more photos under the passive mode, and it means learner can remember more logs in passive mode than that in active mode, so this result is acceptable.

5.1.3.3 Workload problem - How much value does the PACALL add to passive learning mode?

We examined how PACALL has contributed to reducing the time spent on the whole procedure. We asked students to report the spent time, and Figure 5.3 shows this result.

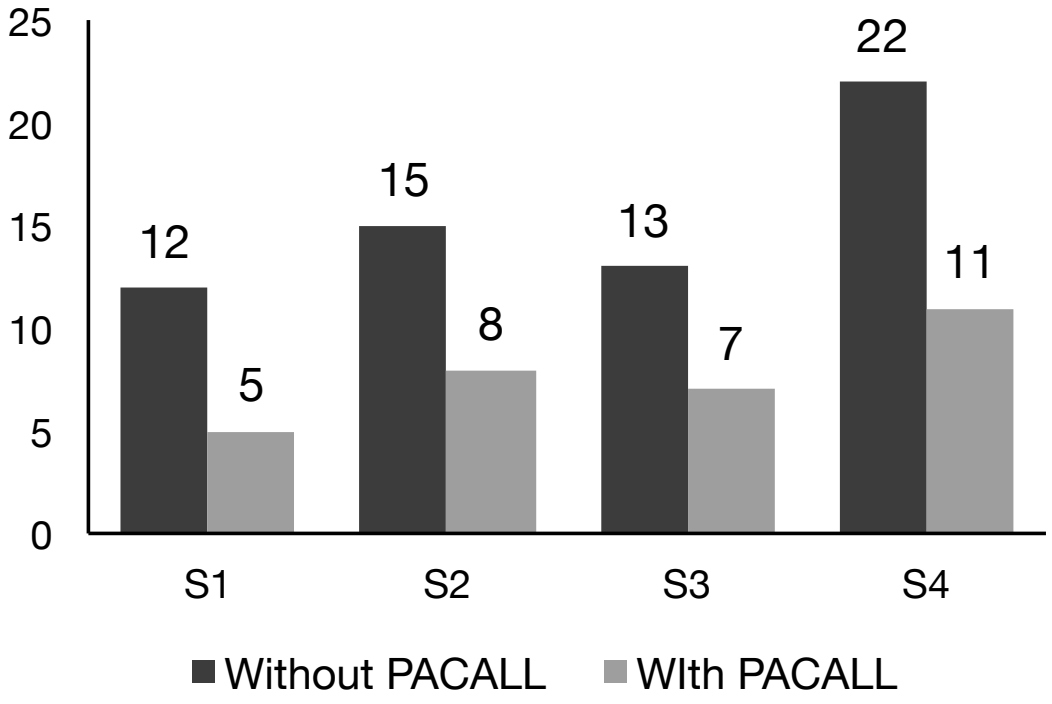

Figure 5.3: Average time cost between No PACALL and PACALL

This chart clearly shows that the developed system can reduce the time cost of reviewing life-log pictures nearly in half. Of course, the workload in passive mode is higher than that in active mode, but the learning contents are scarcely missed. In the future, we will focus on how to reduce the workload and help learner to have a reflection and find learning content more easily.

5.1.3.4 Questionnaire

Table 5.4 is the questionnaire in this evaluation experiment. We use this questionnaire to have a survey on differences between active mode and passive mode.

Table 5.1: Questionnaire of Evaluation I

No.	Question	Mean	SD
Q1	Do you think SenseCam is easy to use?	4.50	0.58
Q2	Did the SenseCam take clear and beautiful photos?	2.25	1.25
Q3	Was it easy to upload learning log with life-log photos?	3.75	1.25
Q4	During this evaluation experiments, which period did you usually use life-log camera in a day?	-	-
Q5	Do you think the tablet PC/digital camera easy to use?	4.25	0.50
Q6	Did the tablet PC/digital camera take clear and beautiful photos?	5.00	0.00
Q7	Was it easy to upload learning log with photos that taken by tablet PC/digital camera?	3.50	1.00
Q8	During this evaluation experiments, which period did you usually use tablet PC/digital camera in a day?	-	-
Q9	Do you feel ashamed when you use life-log camera?	4.50	0.58
Q10	Do you feel ashamed when you use tablet PC/digital camera to take learning log photos?	3.00	1.54
Q11	Is the life-log camera easy to carry?	4.50	0.58
Q12	Is the tablet PC/digital camera easy to carry?	2.50	1.00

Q13	Are you satisfied with uploading learning logs by using categorization?	3.67	0.94
Q14	Did you noticed the learning content that taken by life-log camera?	3.75	1.89
Q15	Is the interface of PACALL easy to use?	4.25	0.50
Q16	Do you think PACALL is useful to record Learning Log?	4.50	0.58
Q17	Which do you think is easier to use, tablet PC/digital camera or life-log camera?	3.00	1.63

Answers for Q4, Q8 are listed as follows.

- Q4: During this evaluation experiments, which period did you usually use life-log camera in a day?
    1. lunchbreak, afternoon, night
    2. lunchbreak, afternoon, night
    3. lunchbreak, afternoon, night
    4. lunchbreak, afternoon, night
- Q8: During this evaluation experiments, which period did you usually use tablet PC/digital camera in a day?
    1. afternoon
    2. afternoon, night
    3. afternoon, night

4. afternoon, night

Q1 - Q8 are questions on comparing usabilities. Q1 and Q5 suggests that both SenseCam and tablet PC/digital camera are easy to use. However, Q2 and Q6 shows that the quality of photos taken by SenseCam are lower than that by tabletPC/digital camera. From Q3 and Q7, we learned that both are not so easy to upload as ULLOs.

Q5 and Q8 shows difference between SenseCam and tablet PC/digital camera. In this experiment, all the learners like to start work from noon. However, learners can use SenseCam during the busy time (for lunch). Of course, tablet PC/digital camera can be also used during this period, but from Q12, we learned that the reason is tablet PC/digital camera is difficult to carry.

Q9 shows when using SenseCam, user usually feels ashamed while he/she is not so ashamed when using tablet PC/digital camera (Q10). This problem will be discussed in the next section.

Q11 and Q12 compare portability between SenseCam and tablet PC/digital camera. We can see that SenseCam is easier to carry than tablet PC/digital camera. Then it is easy to be used for long period.

Q13 suggests there are problems with photo classification. We must improve our algorithm in the future.

Q14 shows whether learner noticed the captured learning content or not. We want to use the passive mode to reduce the missed chances of learning. For this question, lower is better. However, 1.89 in SD suggests that it depends on learner himself/herself.

We are happy to see the result from Q15 and Q16. It means our system is easy to use and this system is useful.

Finally, most participants think both of life-log camera and tablet PC/digital camera are easy to use. It means passive mode is not so difficult to use in daily life, and it can be used as same as active mode.

5.1.3.5 Feedback

We received some suggestions and feedbacks from students. They help us to understand the usage of PACALL. Besides, their suggestion and feedbacks are helpful for us to improve our system. We pick out some typical feedbacks, and list them as follows.

The followings are some feedbacks on whether the PACALL is easy to use or not.

- I think PACALL is easy to use. When I use the SenseCam without PACALL, I must find the photos in the folder from browser. However when using PACALL, I just select the photo and click "upload". The photo and time are shown in PACALL, which are helpful for selecting photos. Besides, inappropriate photos that are not clear such as dark, defocused or duplicated are already excluded by this system.
- It is better to use the Android Tablet PC in conjunction with PACALL system.
- In the passive mode, the learning contents are recorded even when I do not want to learn anything. On the other hand, in the active mode, photos can only be taken when I want to learn something.

- I feel very embarrassed when using SenseCam.
- The accuracy is not good enough in analyzing blurred photos.

The above comments show that this system is easily to use and the users seem satisfied with this system. In the passive mode the learning contents could be recorded even if learners do not want to learn. It means that the life-log pictures bring more chances to learn the vocabulary. However, the learners may feel embarrassed when wearing the SenseCam in public area such as in the supermarket or on the street. We think this problem is caused by two reason - one is the design of SenseCam, and another is learners were worried about the privacy problem. This is yet to be solved at present. But in the future, we believe that the SenseCam will get smaller and looks more likeable, then hopefully, learners will not get so embarrassed.

Since the first evaluation experiment was focused on comparison between active learning and passive learning, and almost all the data including photos and sensor data files are stored in learners' computer, we were not able to evaluate accuracy of photo classification. Furthermore, the method of analyzing photos are based on sensor data. From participants' comments, we found that this method is not good for analyzing photos because of time difference between capturing photos and recording sensor values. We think image process is more intuitionistic than analyzing sensor data in photo classification because it is exactly analyze photo on photo itself. Moreover, image processing is not only applied for life-log photos, but also can be used for common photos.

5.2 Evaluation II

5.2.1 Objectives

After evaluation I, we changed the method of photo classification from analyzing sensor data to image processing. Also, the storage of photos and sensor data was changed to the server side in order to analyze the result.

We conducted evaluation II in the year 2013. Objectives of this evaluation experiment are focused on image processing.

5.2.2 Method

This evaluation experiment lasted for 5 days (from February 4,2013 to February 8, 2013). It consisted of 3 Japanese university students. They were asked to wear life-log camera, and used PACALL system to upload learning log. After one-day recording, they must upload all the photos and sensor data files to PACALL system. Then the system analyzed photos and showed the result of classification. Participants in this evaluation are asked to ensure whether the classification was appropriate or not for each photo manually. Besides, they were also asked to write down feelings. After 5 days, a survey was conducted by questionnaire.

5.2.3 Result and Discussion

5.2.3.1 How many bad photos will be filtered?

Figure 5.4, 5.5, 5.6 are percetage of classfication for all the types of photos from each participant. Notice that, the only good type of photo in this evaluation is Normal, and it includes Feature photo, Face photo and text photo.

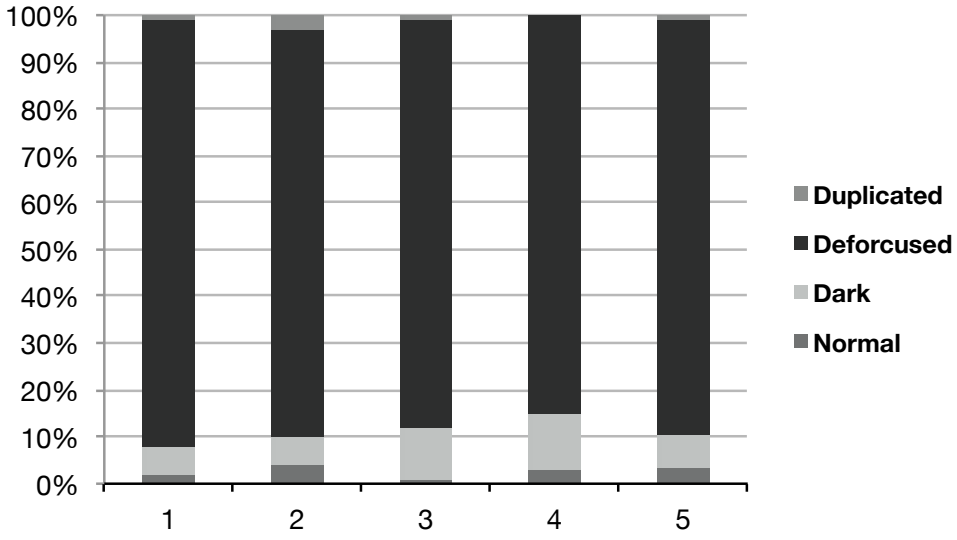

Figure 5.4: Percentage of each classification (S1)

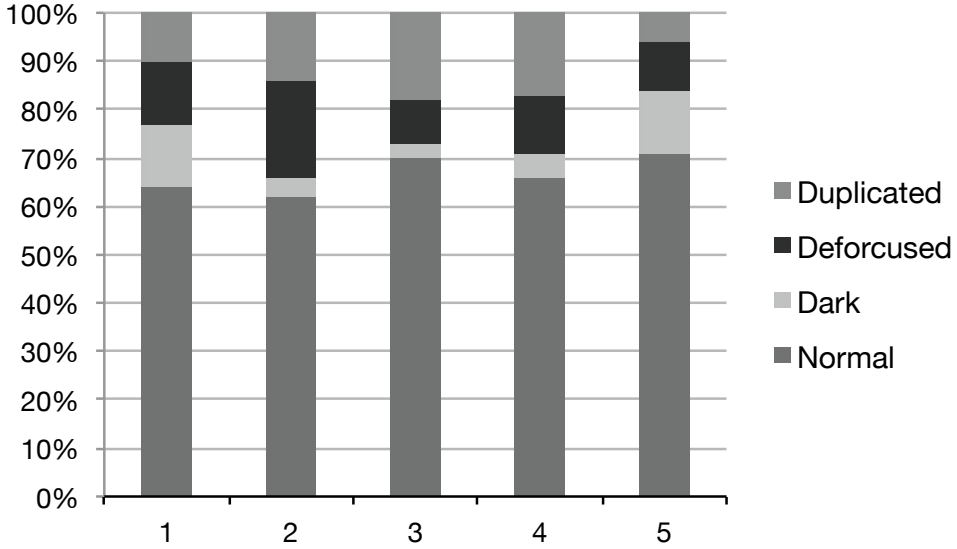

Figure 5.5: Percentage of each classification (S2)

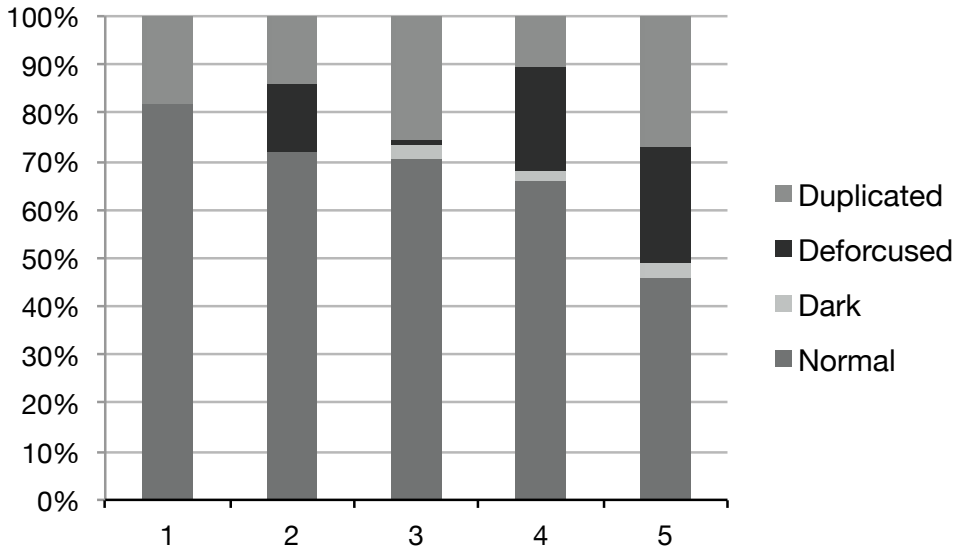

Figure 5.6: Percentage of classification (S3)

Table 5.2 shows precision and recall for all the types of photo classifications.

Table 5.2: Average Precision and Average Recall for Image Processing

	Average Precision	Average Recall
Normal	61%	88%
Dark	60%	64%
Defocused	87%	62%
Duplicated	92%	44%

5.2.3.2 How many photos will be recommended?

Feature shows numbers of recommendable photos in classifications of feature, face and text that extracted from Normal.

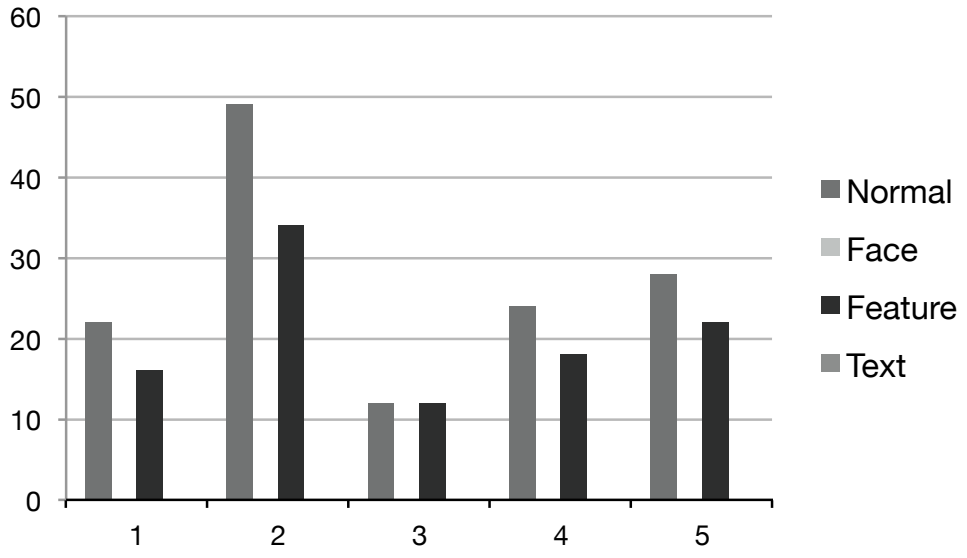

Figure 5.7: Numbers of recommendable photos (S1)

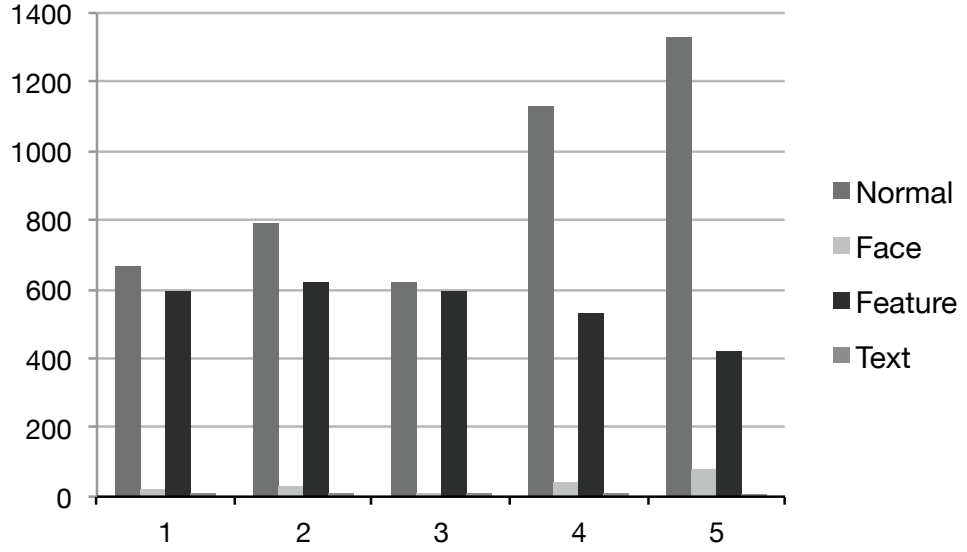

Figure 5.8: Numbers of recommendable photos (S2)

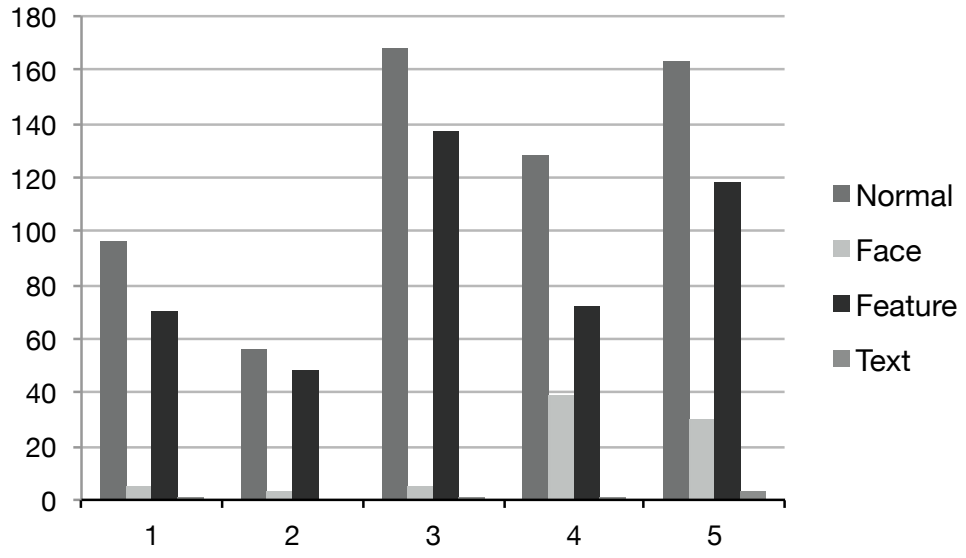

Figure 5.9: Numbers of recommendable photos (S3)

Table 5.3 shows precision and recall for face photos. Since text photos and feature photos is difficult to judge where the text is and what the object is, we did not ask participants to evaluate it.

Table 5.3: Average Precision and Average Recall for Face Photos

	Average Precision	Average Recall
Face	34%	7%

5.2.3.3 Processing time

Figure 5.10 shows the relationship between processing time and the number of photos. The vertical axis shows time and the horizontal shows the number of photos. There are two cases - one is defocused photos are more than normal photos (Case 1), another is normal photos are more than defocused photos (Case 2).

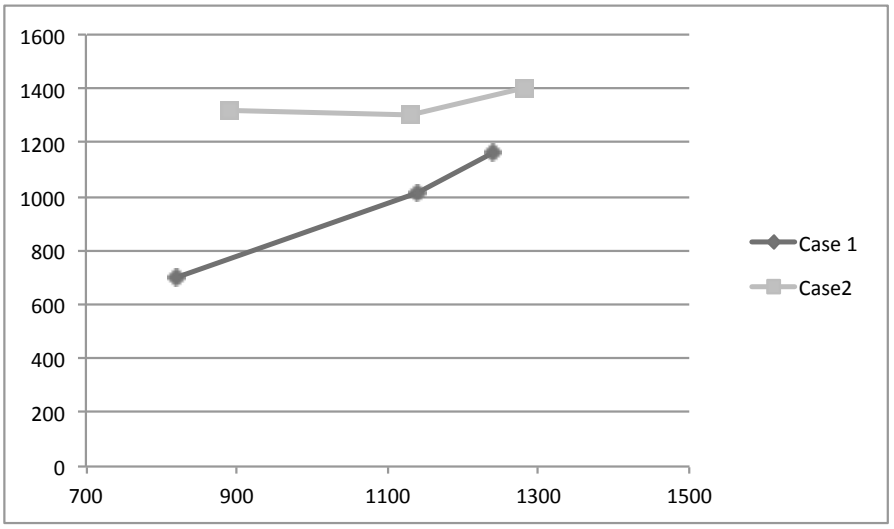

Figure 5.10: Processing time (S1)

5.2.3.4 Questionnaire

Table 5.4 is the questionnaire in this evaluation experiment. Q1 - Q7 are questions on life-log camera. Q8 - Q15 are questions on image processing. Q16 - Q19 are questionnaire on comparison between life-log camera and android device. By the way, Q16 - Q19 are answered by participants only who had used android device to upload learning log before this experiment.

Table 5.4: Questionnaire of Evaluation II

No.	Question	Mean	SD
Q1	Did you feel comfortable to wear life-log camera in the daily life?	3	0.82
Q2	Did you feel convenient to use life-log camera to take photos?	3.66	0.47

Q3	Do you think life-log the camera can take too many photos?	4.67	0.471
Q4	Do you think it can help you have a reflection of what you have learned in one day, when you uploaded photos that taken by life-log cameara?	4	0.82
Q5	When you upload learning log with life-log camera, can you remember the scene of photos when it was taken?	4.67	0.47
Q6	When you use life-log camera, is there any photo that you want to upload as learning log but it was not taken automatically by life-log camera?	3.67	0.94
Q7	Tell us your feelings when using life-log camera?	-	-
Q8	Have you searched photos that you want to uploaded as learning log in categories that created by system?	3.34	0.47
Q9	Do you think it is too long to wait for all the photos are categorized by system?	3.00	1.41
Q10	Do you think it is too long when you upload photos from categorized photos?	2.34	0.47

Q11	Do you think categorization can help learner upload more learning log?	3.00	0.816
Q12	Are you satisfied with current categorization?	3.00	1.41
Q13	Are you satisfied with uploading learning logs by using categorization?	3.67	0.94
Q14	If you want add other categories into current system, please tell us.	-	-
Q15	Tell us your feelings on system	-	-

No.	Question	Options	Percentage
Q16	Which learning method do you think can help learner uploading more learning logs, life-log camera or android device?	Life-log Camera Android Device	100%
Q17	Which do you think is more appropriate for learning log, life-log camera or android device?	Life-log Camera Android Device	33%
Q18	Which do you think is more appropriate for learning, life-log camear or android device?	Life-log Camera Android Device	66%
Q19	Which device do you want to use to capture learning content for learning log, life-log camera or android device?	Life-log Camera Android Device	0%

In this questionnaire, there are several open format questions, and answers are listed as follows.

- Q7: Tell us your feelings when using life-log camera.
    1. I would care about the attention from others, and once I walked into shops, I took off it.
    2. I feel it is not so good to upload my private photos to the server.
    3. I feel a little shy to use it outside.
- Q14: If you want add other categories into current system, please tell us.
    1. Timestamp of photo
    2. Location
- Q15: Tell us your feelings on system.
    1. The accuracy of classification is not so good.
    2. The accuracy of dark is not so good.
    3. Too many defocused photos.
- Q16: Which learning method do you think can help learner uploading more learning logs, life-log camera or android device? (The reason to choose life-log camera)
    1. Since it takes photos automatically = More uploaded learning logs.
    2. When I use android device, I must launch the application when I found the object. Sometimes it is not so convenient.
    3. It (Android device) can be used only when I noticed it.

- Q17: Which do you think is more appropriate for learning log, life-log camera or android device? (The reason to choose life-log camera)

  1. It takes photos unconsciously.

- Q17: Which do you think is more appropriate for learning log, life-log camera or android device? (The reason to choose android device)

  1. The learning log that captured consciously has higher quality than that captured unconsciously.

- Q17: Which do you think is more appropriate for learning log, life-log camera or android device? (The reason to choose neutral)

  1. Each method has it pros and cons. I think user should use tools that suit himself/herself.

- Q18: Which do you think is more appropriate for learning, life-log camear or android device? (The reason to choose life-log camera)

  1. I can use these photos to reflect what I have learned.

- Q19: Which device do you want to use to capture learning content for learning log, life-log camera or android device? (The reason to choose android device)

  1. Because I must wear life-log camera always around my neck.
  2. When I use android device, I can remember not only the object but also the motivation and my mind at that time.

5.2.3.5 Discussion

1. Image processing:

   From section 5.2.3.2, we can see that percentage of each classification depends on learner's learning habits. For example, life-log camera produces more defocused photos when learner usually goes outside while life-log camera produces more duplicated photos when learner usually stays indoor. The overall average precision of defocused photos is 87%, it suggests that there must be some problems in capturing photos. If the threshold of image processing can be set dynamically, it will be better.

   There are very few photos that can be found out as face photo or text photo. Face photo are only captured when learner meets other people in daily life. However, the module of face detection is not so accuracy in this evalutaion experiments. We learned that the basic data of face detection should be trained to make it more accuracy, and we should make further efforts on it. The result of text detection is not satisfied in this experiment, and the current algorithm should be improved.

   Text photo and feature photo are difficult to evaluate whether it is accurate or not because the system only shows the result of classification, and learners do not know which part of photo is detected as text or feature.

   It is strange the same numbers of photos costs different time. And there are 700 seconds at max value between same numbers of photos. In short, less and better photos can shorten the time of registering learning log.

2. Log ULLOs with life-log camera

   Average number of daily ULLO with life-log camera per learner was 15.3 photos. When using android, the number of it was about 5 photos. Life-log camera can record more learning contents than smartphone. However, from the feedback we learned that when using life-log camera learner usually feels not so comfortable and they worried about privacy problems . Therefore, although there are more ULLOs by life-log camera, they want to use smartphone rather than life-log camera. Besides, other categories such timestamp and location of photos are also required in future.

5.3 Evaluation III

5.3.1 Objectives

We improved our system after evaluation II both on algorithm and user interface, and conducted evaluation III in June 2013. This evaluation experiments focused on analyze learner's life-log camera habits. Therefore, objectives of this evaluation experiment are listed as follows:

1. Analyze how learner uses life-log camera in the daily life.

2. Log learners' activities when using PACALL system and analyze the usability of PACALL system.

3. Use meta-knowledge model to analyze how passive mode supports learning

5.3.2 Method

The evaluation III consisted of 7 students in the University of Tokushima. Table 5.5 shows their information in detail.

Table 5.5: Subjects in Evaluation III

Subject	Gender	Nationality	Grade
S1	Male	China	Doctoral student
S2	Male	China	Doctoral student
S3	Male	China	Master student
S4	Male	Japan	Master student
S5	Male	Japan	Master student
S6	Male	Japan	Senior student
S7	Female	Mongolia	Doctoral student

This evaluation experiment started from June 10, 2013. All the participants must use PACALL system to record their learning logs for 5 days. They had to wear life-log camera in the daily life, and uploaded all the photos that were taken in a day to the PACALL system.

After analyzing photos by system, they should select photos that contains learning contents to SCROLL. At the same time, a questionnaire (Figure 5.11) was required to answered to record whether they had noticed the learning content when photos were taken and whether they had already had this knowledge or not.

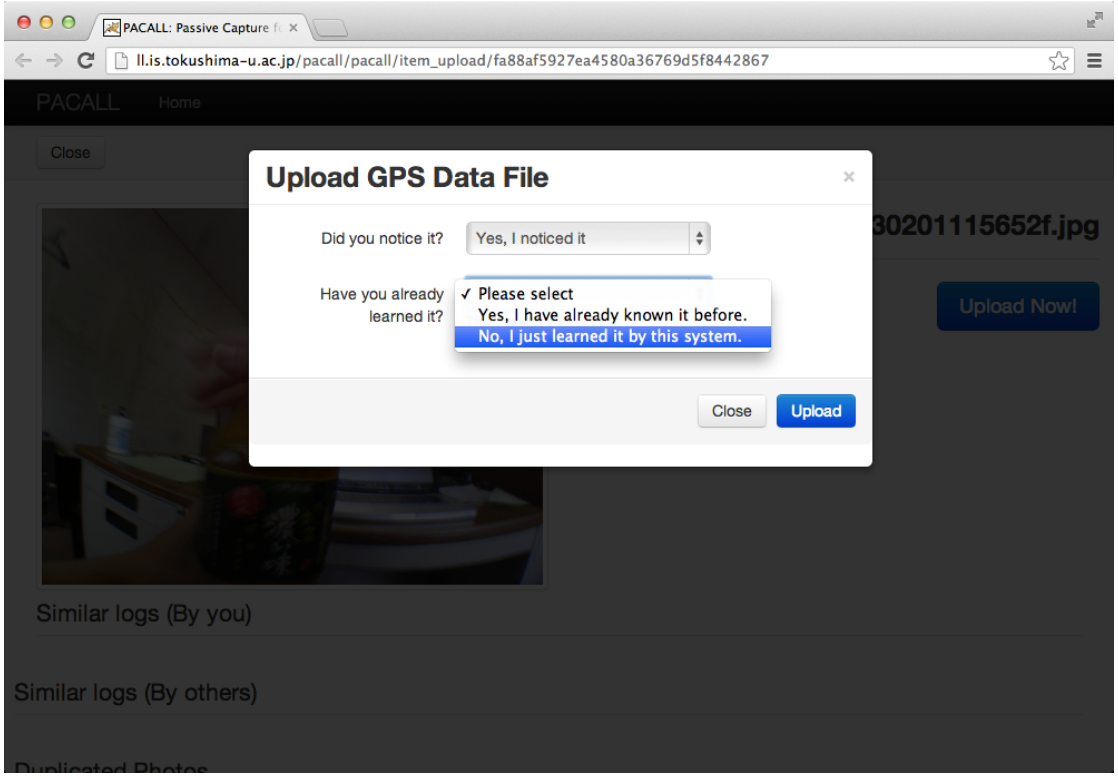

Figure 5.11: Questionnaire for Meta-Knowledge Model

After 5 days, we collect all the data from database and analyze learning activities.

5.3.3 Result and Discussion

5.3.3.1 How many life-log photos in one day?

In Evaluation II, we have counted the number of daily life-log photos. In this evaluation experiment, we make further discussion on this title.

Figure 5.12 shows the number of daily life-log photos by 7 subjects in this experiment. And Table 5.6 shows the average number of life-log photos in one day.

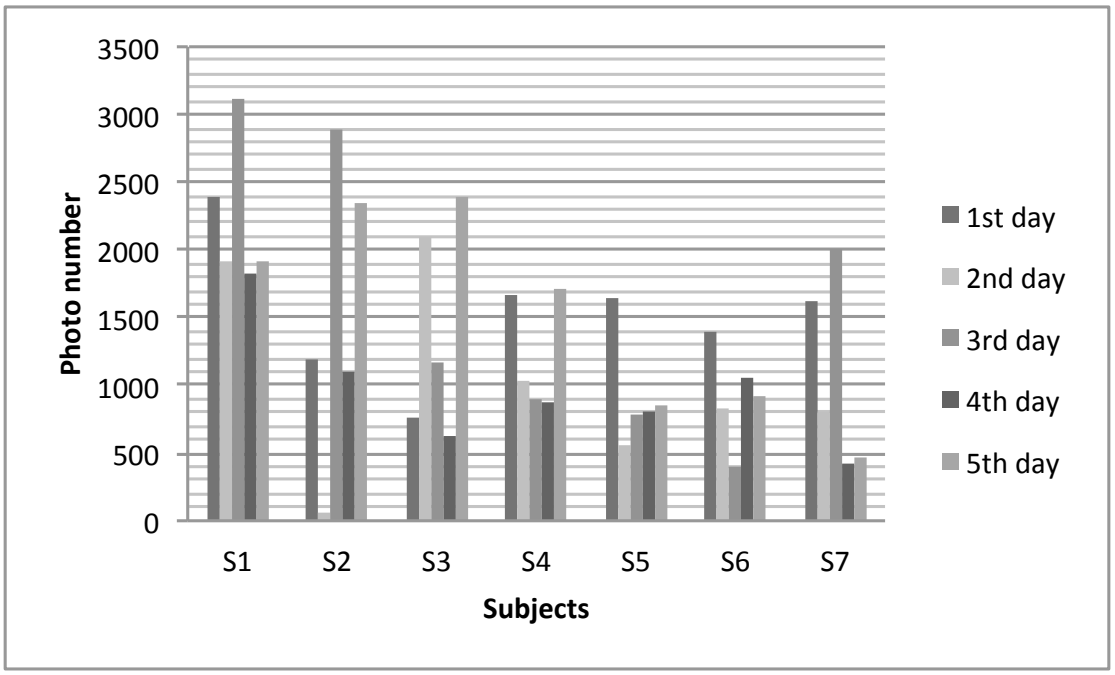

Figure 5.12: Number of Daily Life-log Photos

Table 5.6: Average Number of Life-log Photos In One Day

Subject	Average number	SD
S1	2235.6	540.75
S2	1518.8	1113.65
S3	1410.8	791.34
S4	1238.0	414.62
S5	932.0	411.14
S6	918.8	366.88
S7	1060.6	716.62

This result just shows how many life-log photos can be taken in one day. However, it makes a great difference between different people. But we can also see the value is from 900 to 1500 in general.

5.3.3.2 How long does learner use life-log camera in one day?

First of all, it is usual for learner to use camera in one day uncontinuously. Therefore, when we talk about how long, we must consider this factor. We devided one-day capturing into several periods by timestamp of photo at first. And then calculate the time in one day.

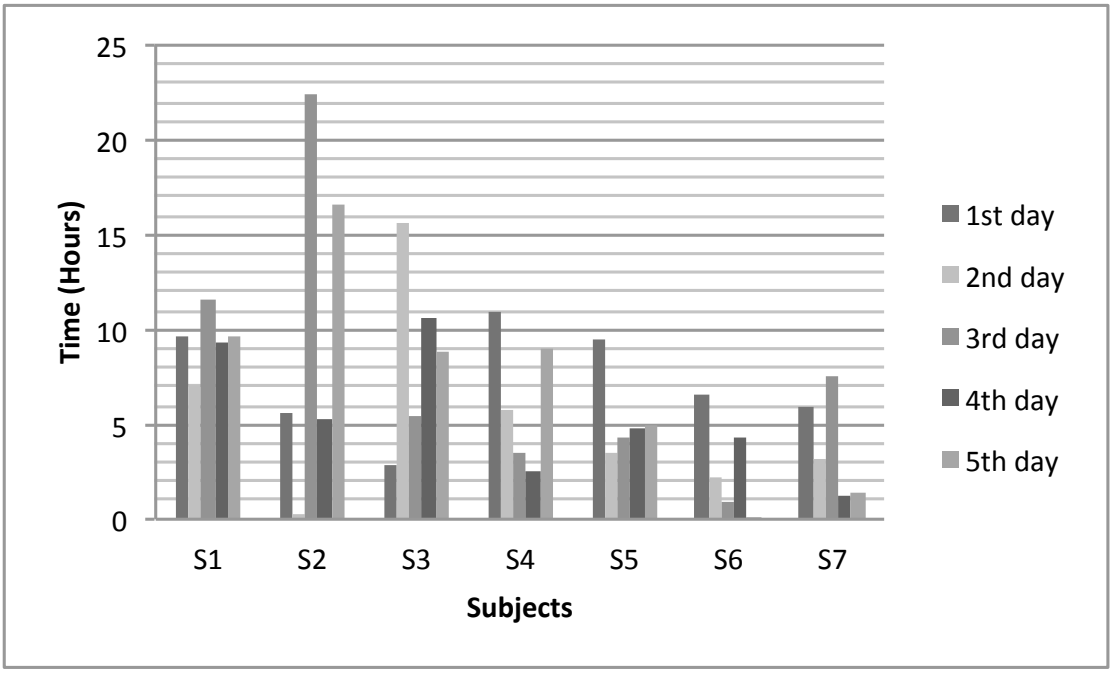

Figure 5.13: Usage Time

Figure 5.13 shows the result of how long learner used life-log camera in one day in this evaluation experiment. From this figure, we can see that in most cases life-log camera was used for about 5 hours a day. From the date of photos, we learned that most of them used life-log camera only in afternoon.

5.3.3.3 How many life-log photos in one hour?

Until now, we have learned that how many life-log photos in one day and how long learner used life-log camera in one day. But because different people have different custom to use camera, we want to learn how many photos that life-log can take within a certain time. Therefore, we calculated the number of life-log photos in one hour. Figure 5.14 shows the relationship between time and photo number.

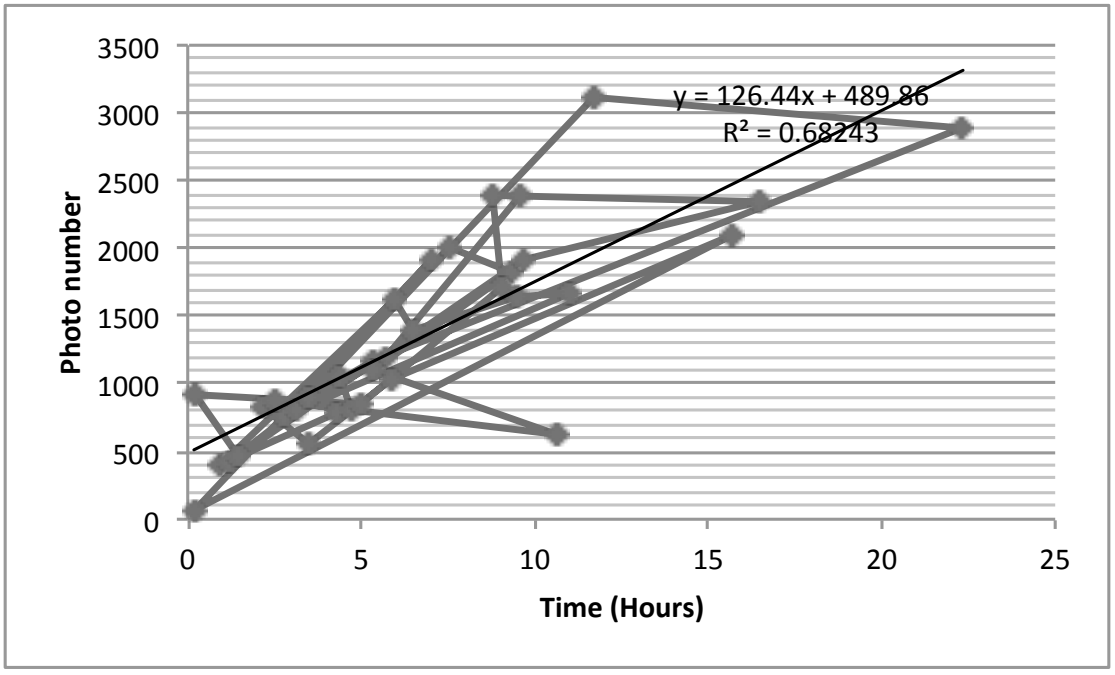

Figure 5.14: Relationship between time and photo number

However, R^2 is only 0.68243. That means the accuracy of trendline is low. This is caused by triggers in SenseCam. For example, when the SenseCam is moved, it will take more photos by the accelerometer trigger.

5.3.3.4 How long does it take to upload and analyze photos?

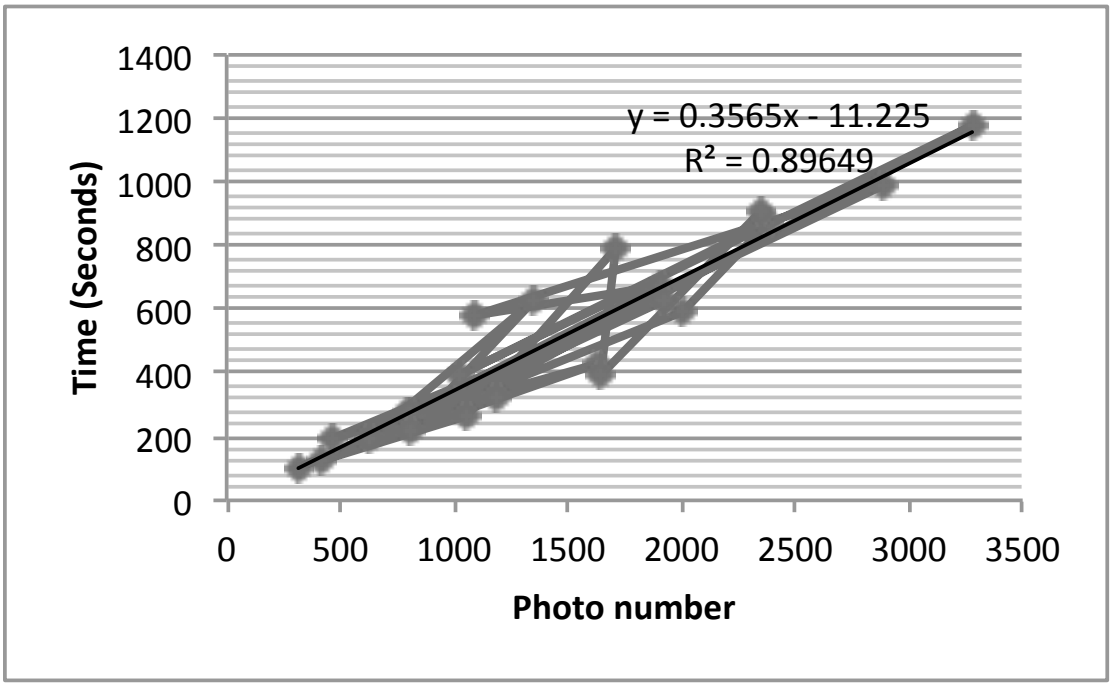

Figure 5.15: Time for Uploading Photos

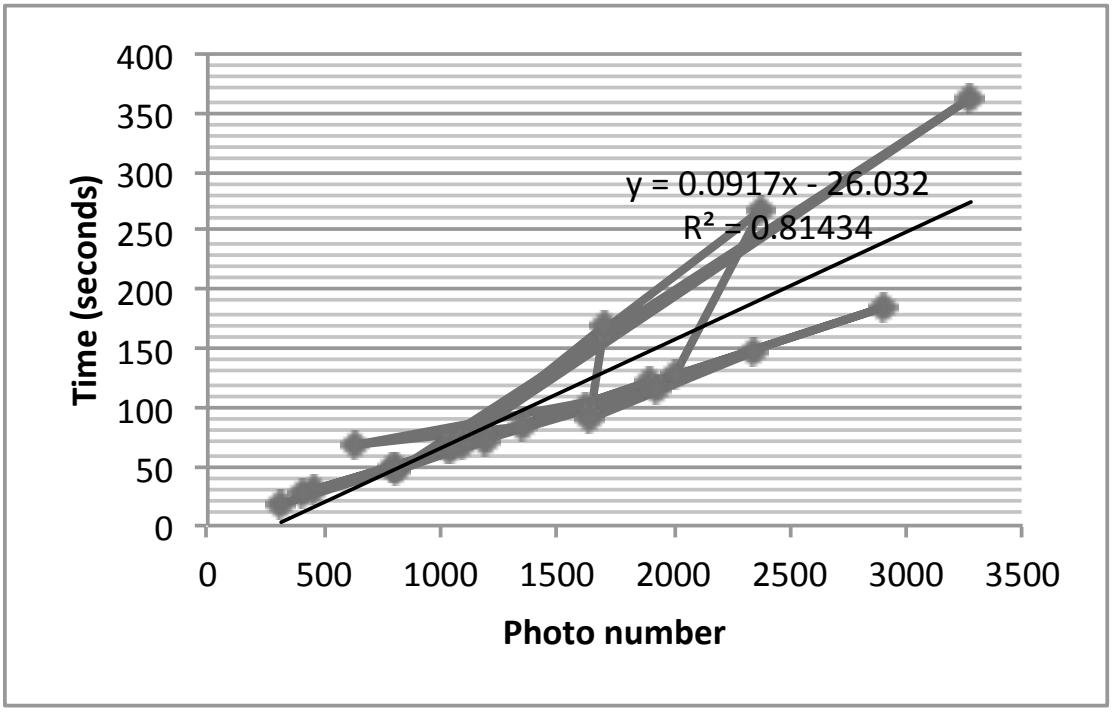

Figure 5.16: Time for Composing Sensor Data

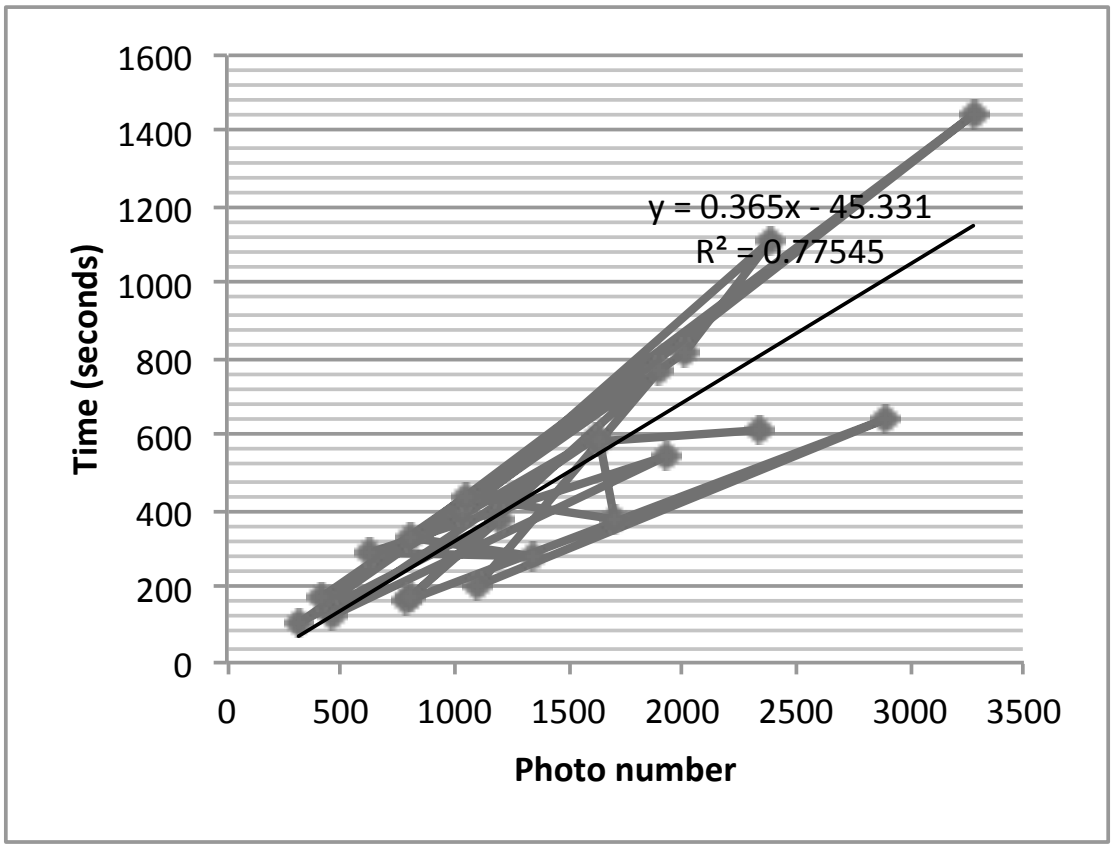

Figure 5.17: Time for Analyzing Photos

There are 3-step process before learner use PACALL to have reflection with life-log photos: uploading photos, composing photo information with sensor data, analyzing photos. Figure 5.15, 5.16, 5.17 shows the time for each process.

From these 3 figures, we can draw conclusions as follows:

1. Time for each processes grows linearly as number of photos increased. The largest number of photos in this evaluation is 3278. It cost 1183 seconds for uploading, 362 seconds for composing sensor data and 1447 seconds for analyzing. Total time was 2992 seconds (49.9 minutes). However, in section 5.12 we discussed that in most cases, there are no more than 1500 photos one day, and then the total

time is about 1137 seconds (19 minitus). In view of current technology, this result is acceptable.

2. Time for composing sensor data costs less than other two processes. Since uploading depends on network in most cases and it is difficult to optimize, we suggest that in order to reduce processing time, future work should focus on optimizing the algorithm of analyzing, i.e. image processing.

5.3.3.5 How does PACALL system help learner reduce workload?

We learned that in this experiments, when using life-log camera, it takes about 1500 photos one day. This would cause workload problem. And our system PACALL using image processing to solve this problem. We improved our algorithm after Evaluation II, and collect this data again to see how PACALL system helps learner reduce workload. Actually, since the custom is different from person to person. After accumulate a large mount of data, we analyze and calculate the average value for each classification. The result is shown in Figure 5.18.

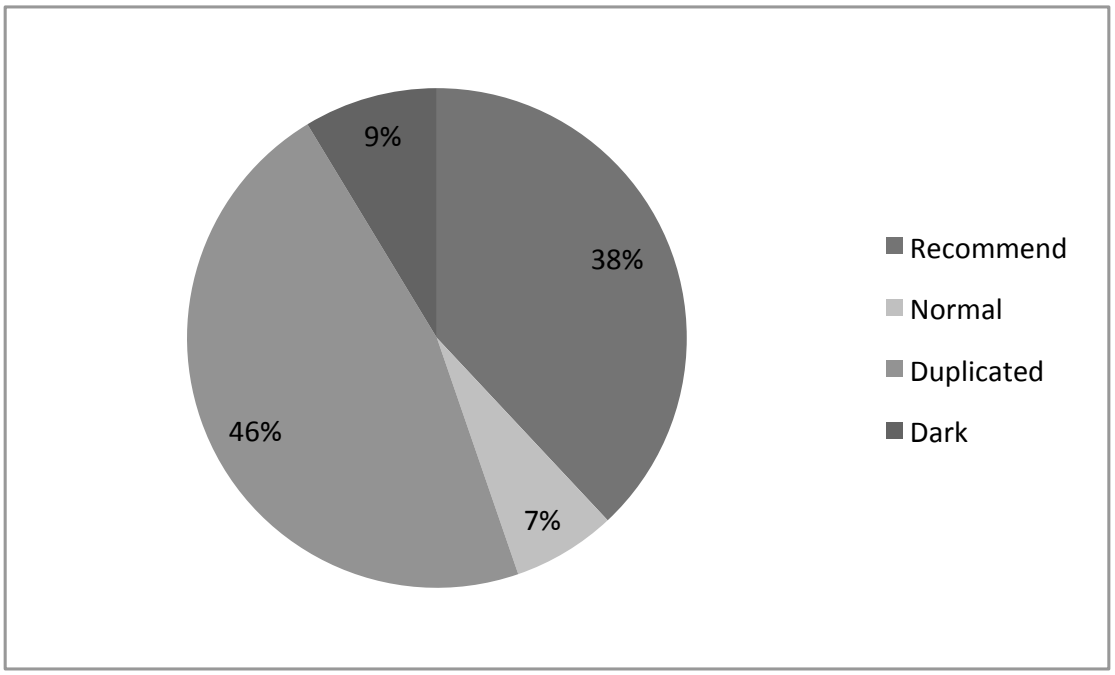

Figure 5.18: Photo classifications

The classification Recommendation includes photos that contains face, text, feature or have similar ULLOs in SCROLL system. On this figure, we can see the PACALL filters out about 54% life-log photos. This means it can reduce 54% workload in average.

5.3.3.6 How does PACALL help learner learn?

We use meta-knowledge model to analyze how PACALL help learner learn. Figure 5.19 shows result with meta-knowledge model.

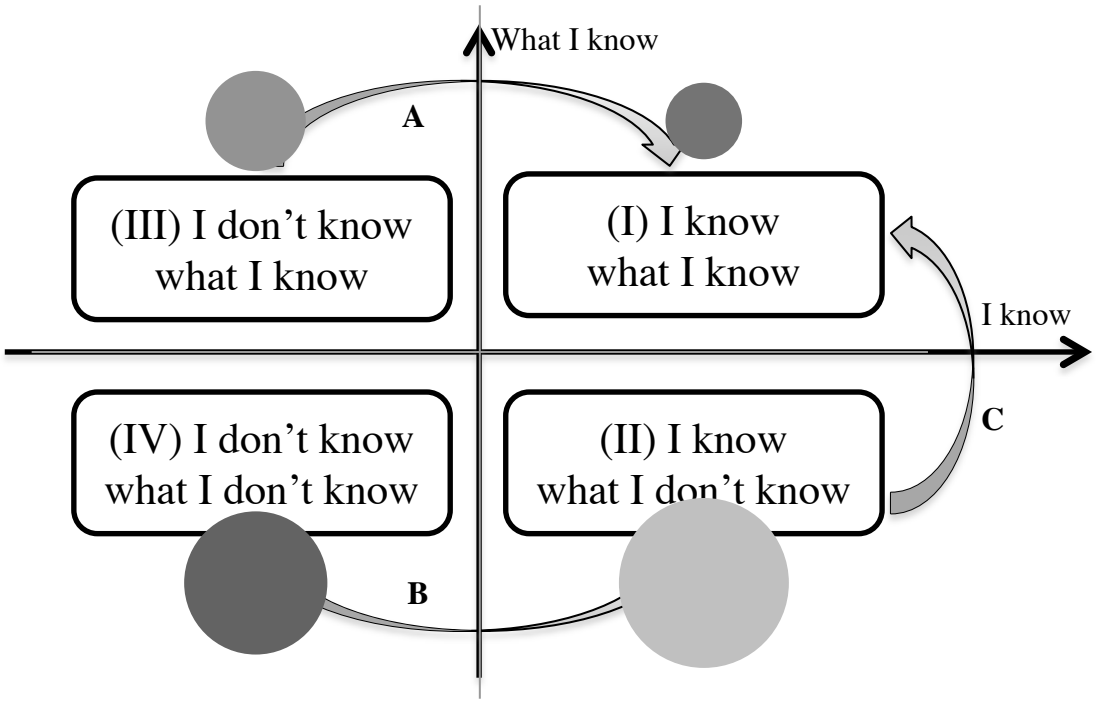

Figure 5.19: Result with Meta-Knowledge Model

As shown in Figure 5.19, the size of round in each quadrant means the number of photos that learner uploaded to SCROLL in each categories. It is easy to see that: (II) > (IV) > (III) > (I). It suggests that fewest learning contents are under "I know what I know". That is to say, most things in the daily life are not learned or not noticed, our passive learning environment is meaningful and can help learner notice something that he/she have not noticed and help he/she learn it.

Both (II) and (IV) are larger than (I) and (III). That means most learning contents are "What I don′t know". It suggests that in our daily life, knowledge that we don't know is more than that we know. In passive learning environment, whether you have noticed the learning content that you have not learned it before or not noticed, you can learn it in system.

The most interesting thing is that (I)<(III) but (II)>(IV). It means when we have learned something, we usually pay less attention on it. But when we meet something that we do not know, we usually pay more attention on it. That is to say, learner usually pays more attention on unknown than that on known. However, in passive learning environment, all the objects whether learner has learned or not and whether learner has paid attention or not, he/she can get benefit from passive learning. For something learner has learned, system can help them revise it even though he/she have not noticed. For something learner has not learned, system can also increase change of learning.

Chapter 6

Conclusions

This doctoral dissertation is a contribution to the solution of how to help learner record ubiquitous learning logs in daily life in a passive environment. In order to build this passive environment, we use a life-log camera named SenseCam to capture life-log photos passively. However, life-log camera takes photos automatically and unconsciously, it usually takes too many photos but few photos are valuable to be used as ULLOs. Therefore, we designed and developed a system named PACALL to help learners find out learning contents from life-log photos. PACALL is not only a system, but also a learning environment. This system supports learner in following way:

1. Analyze life-log photos, filter bad photos and recommend good photos for learner in order to reduce learner's workload.

2. Help learner have a reflection of what they have learned in one day.

3. Increase the chance of learning.

4. Help learner upload life-log photos as ULLOs.

In this study, we use image processing to analyze and classify photos. Duplicated photos and dark photos are usually two bad types of photos in life-log photos. Filtering out these two type of photos can help learner reduce their workload. Also, recommendation of good life-log photos are can help learner to reflect life-log photos in shorter time. Besides, in this study, CBIR is also used to suggest similar ULLOs that exist in SCROLL system to help learner make further learning.

Three kinds of evaluations were conducted in this study.

Evaluation I compares passive mode to active mode. We used the original mode in SCROLL - recording ULLOs by tablet PC/camera as active mode. The result confirms that passive mode - recording ULLOs by life-log camera helps learner register more ULLOs and increase the chances of learning. But the quality of life-log photos is lower than common photos. Besides, we used SenseCam in this study as life-log camera. Most learners felt ashamed when using SenseCam in public. We think this problem is caused by two reason - one is the design of SenseCam, and another is learners were worried about the privacy problem.

Evaluation II was conducted to help us evaluate the algorithm of image processing. The result shows how PACALL reduce learner's workload by photo classification and photo recommendation. In addition, the result in this evaluation also suggests that algorithm of image processing in passive learning environment is very important.

Evaluation III was conducted to analyze learner's learning activities in passive learning environment by using quantitative method. Especially, this evaluation shows how PACALL help learner learn in passive learning environment by meta-knowledge model.

Current PACALL system supports NMEA GPS data format. However, because of the current device, we have not conducted the evaluation experiment by using GPS data. This is one of our future works. Another future work is learning analytics. We want to analyze the accumulated data of learning logs to find leaners' learning patterns and learning habits in order to supply more appropriate learning materials at more appropriate place and more appropriate time to improve learning effects. In addition, the algorithm of image processing also needs improvements.

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