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A prototype of real-time seat usage analysis using smart sensors

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***Abstract*—The authors consider analyzing real time seats usage of library browsing rooms using smart sensor and cloud computing infrastructure as a library marketing activity. The smart sensor box checks human existence periodically, and sends the sensed data to the sensor cloud through the Internet. We apply information retrieval technology to the accumulated data. This paper shows the research plan of real time seats usage ratio using smart sensor, and roughly shows cloud system architecture and application images.**

Keywords - library marketing; seat usage data analysis; smart sensor; data mining; sensor cloud; cloud computing

I. INTRODUCTION

The role of university is discovery and transmission of knowledge. Research activities discover knowledge, and knowledge is handed down in education. University library has been accumulating scholarly materials, and provides the to students and researchers with reference for research and education in university. Almost all scholarly information had been offered as printed books and magazines until 1980s. Since late 1990s, digital scholarly information such as e-journals and e-books increased with the spread of the Internet. It has been a big issue for university libraries to handle digital scholarly materials.

The university library has also offered the place of study and research. Students and researchers have studied in a library since ancient era. Library provides the calm space with desk and chair for library patrons, and then library is the optimal place for self-study. Recently, some university libraries offer learning commons. Learning commons is the place of collaborative study and research.

Minami et al. proposed library marketing [1]. Marketing has been used in business activities. They proposed to apply marketing concept and methods to library activities to realize a better library. They also tried to grasp of a user's behavior in a library.

We consider analyzing real time seats usage of library browsing rooms using smart sensor and cloud computing infrastructure as a library marketing activity. We will set a smart sensor box to a desk in library reading rooms. The smart sensor box checks human existence periodically, and sends the sensed data to the sensor cloud through the Internet. We apply information retrieval technology to the accumulated data.

The composition of this paper is as follows. In Section 2, we briefly describe what is library marketing. Section 3 describes the research plan of real time seats usage ratio using smart sensor. Section 4 describes the sensor box and the sensor cloud. Section 4 also shows rough images of application. Finally, we conclude this paper in section 5.

II. LIBRARY MARKETING

American Marketing Association (AMA) [2] defined the concept of marketing. "Marketing is an organizational function and a set of processes for creating, communicating, and delivering value to customers and for managing customer relationships in ways that benefit the organization and its stakeholders." This definition is more profit-oriented than the current definition: "Marketing is the activity, set of institutions, and processes for creating, communicating, delivering, and exchanging offerings that have value for customers, clients, partners, and society at large."

According to the definition of Marketing by AMA, Minami et al. [1] defined the aim of marketing activities by libraries (library marketing). "Library marketing is to give better services to their users, or patrons, so that they are able to get better reputations, to be recognized as more reliable organizations, and to get more customer satisfaction (CS)/patron satisfaction (PS) eventually. Additionally, it is preferable to perform their jobs more efficiently, and with less cost; which can be another important aim of library marketing."

The research and development division of Kyushu University Library (KUL, for short) has some research teams. The library marketing team, which we belong, researches the data analysis, or data mining, methodology. One idea of library marketing is data mining from patron's book loan history, like POS (Point of Sales) data analysis. POS is a well-known data mining target, and it used in some convenience store groups. The purchase item with customer profile is gathered to the central server immediately. The specialists analyze the data and extract some useful information.

Another data mining approach is access log analysis. We studied scholarly papers recommendation methods using co-occurrence of contents access [3]. KUL manages the institutional repository named QIR (Kyu(Q)shu University Institutional Repository). QIR archives more than 160 thousand papers. There are many accesses to QIR papers

through the Internet. Two papers are download from a person in a day, and the co-occurrence access frequently happen, the two papers may have relation.

III. REAL TIME SEATS USAGE ANALYSIS USING SMART SENSOR

A. Research purpose and rough schedule

We focus on real-time seat usage investigation to the browsing rooms of the library by a smart sensor box. We belong to the library marketing research team in KUL, and this research is one of library marketing research.

To investigate human existence, we attach the passive infrared sensor unit to the sensor box. The sensor box will be set on a desk. Human body is warmer than other environment objects such as desk and chair. If a person sits down in front of a sensor box, infrared ray radiated from the human body according to heat of human body. The passive infrared sensor unit detects the infrared ray, and the value of passive infrared sensor change. It is possible to detect existence of somebody from the sensed data, if the data indicates high infrared ray (heat of body). It is also possible to check long-term trend of library patrons' behavior in KUL by collecting the sensor box data.

In this sensor project, we want to clarify followings:

- Is the smart sensor useful for improvement of library service using marketing analysis?
- Does the sensor cloud have enough performance for the large-scale sensor data processing? We construct the sensor cloud system on the private cloud system in Kyushu University [4,5].
- Can we construct a practical application for library patrons?

We set two periods in this sensor project. This is the first period is three months from November 2013 to January 2014. In this period, we may use small number of sensor boxes for troubleshooting. This is first time to collaborate with the sensor box and the sensor cloud. Some faults certainly may happen in this period. We will investigate the reason of fault, and fix the sensor cloud system. The next period will start in March 2014. In this second period, we will set more than 100 sensor boxes to cover all desks in the KUL.

B. Evaluation of sensor data

For quantitative evaluation of real-time sensing, we have to define numerical metrics. To consider quantitative metrics, we should study what is university library. S.R. Ranganathan proposed the five laws of library science in 1931 [6]. These laws are:

(1) Books are for use,
(2) Every reader his book,
(3) Every book his reader,
(4) Save the time of the reader, and
(5) The library is a growing organism.

According to the above laws, the following metrics may measure serviceability of a library.

- The probability of requested book existence in a library. If a user knows the title of a book, which the user wants to read.
- The mean time to obtain a book, since a user finds the book.

It is possible to define the same metrics for the seats in a library.

- The probability of seat request success to obtain a seat in a library.
- The mean time to obtain a seat, until a user finds a vacant seat in the library.

Library manager may want to know seats utilization efficiency. Seat in a library is classified in reserved seats or non-reserved seats.

In case of reserved seats, library manager wants to know the difference of reservation period and the time which the subscribed user actually sitting down the seat. If the subscriber doesn't use the reserved seat, the seat becomes useless for the time. The utility time per reservation time becomes a measure for reducing futility. Our smart sensor project can check a person actually sitting the seat or not.

In case of non-reserved seats, seat utility ratio will become a measure for seats offering. If there is a seat, which nobody sits down, then the library manager can decide removing the seat or moving it to other place. If most of non-reserved seats are used, then the library manager decides to increase seats in the library. Our sensor cloud can analyze total seat utility ratio.

IV. THE SENSOR BOX AND THE DATA ANALYSIS SYSTEM.

Figure 1 shows the sensor system, which we are constructing in this research. The system consists of three parts, sensor part, sensor cloud part, and application part. The sensor part consists of real smart sensors in real world. The sensor cloud part collects archives sensing data, and it analyzes sensing data for a user application. The application part provide user interface. User can check the sensed state and extracted knowledge through an application.

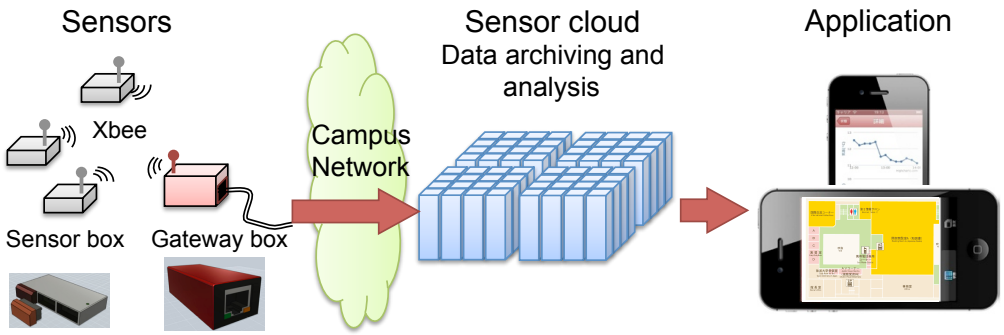

Figure 1 Three part of smart sensors

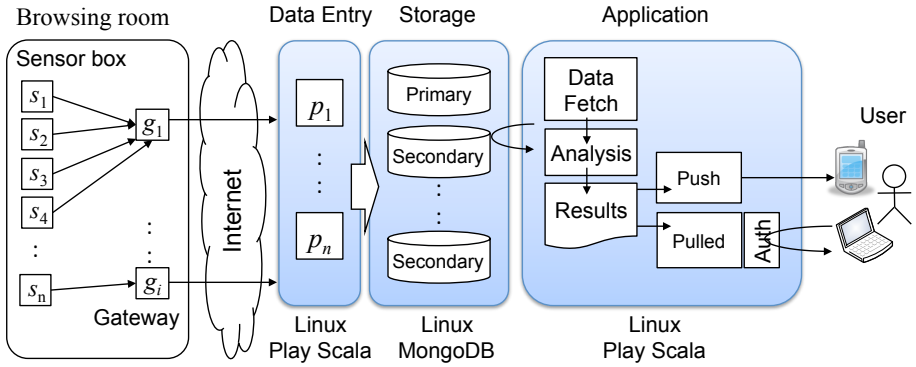

Figure 2 Outline of the sensor cloud system

A. *Smart sensor box*

We will use smart sensor box, which is developed by a venture company in Japan. The sensor box can connect various sensor units such as passive infrared sensor, illuminance, pyroelectric sensor, 3D accelerometer, temperature, humidity, atmospheric pressure, and so on. This box can change sensor units. So, user can select sensor units what the user wants to measure. Sensor box periodically reports sensing value to the gateway box. Communication between sensor boxes and the gateway box is realized using Xbee radio communication. The gateway receives sensing data from sensor boxes, and translates the received raw data to JSON format. Then, the gateway box aggregates some data for power saving, and sends the aggregated data to the sensor cloud by HTTP.

B. *Sensor cloud*

Figure 2 shows the sensor cloud system. The sensor cloud system consists of three parts: data entry part, storage part, and application part.

1) *Data entry part*

The data entry part must receive massive reports from sensor box (actually, the gateway box relays the data) in real time. We implement the data entry system on Linux machine, using Play Scala framework [7]. Play Framework makes it easy to build web applications with Java and Scala. Additionally, it is familiar with the MongoDB [8].

The number of sensor reports is in proportion to the number of sensor box. In this KUL sensor project, the number of sensor box is not many. However, we have a plan to construct a social monitoring service with smart sensors. It need massive sensor box to monitor various social events. So, we request that the data entry part must receive 10 thousand reports per second. It is impossible to receive 10 thousand reports with one machine, and then we introduce a parallel process mechanism using DNS round robin.

2) *Storage part*

We implement the storage part with MongoDB [8]. MongoDB is a cross-platform document-oriented database system. MongoDB has good features for real-time massive data storing, such as, replication by master-slave structure, high scalability and load balancing using sharding.

We set one primary node, and multiple secondary (slave) nodes. These MongoDB nodes are installed as VMs on the private cloud system in Kyushu University. Each MongoDB nodes are connected with virtual router.

3) Application part

The application part provides user interface. This part periodically fetches archived sensor data, and analyzes it. Analysis results are transformed to accessible format such as HTML. User can pull the result through user authentication.

It is possible to set warning function, like TRAP method of IEEE 1888 [9]. If a result over threshold, then warning message will push to specific user's access point, such as e-mail address.

C. *An image of sensor application for library marketing*

Figure 3 shows a temporary screen shot of application. The number, like "17/30" in Figure 3 shows the number of vacant seats and for all seats in the browsing room.

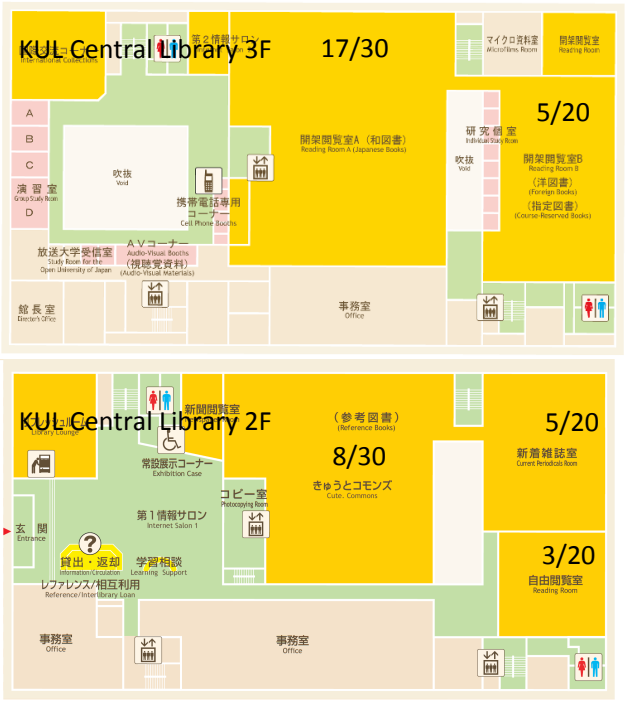

Figure 3 Temporary screen shot of application.

D. *Implemention cost*

We would like to discuss implementation costs of real-time seats usage analysis application. The cost of sensor cloud is fixed regardless of the number of smart sensors. The sensor cloud is able to receive massive data, and is able to analyze massive data. Application is implemented as a web service, and then the cost of application is also fixed. So, the implementation cost depends on the number of smart sensor boxes. If we use a lot of sensor boxes, then we have to spend a large amount of money.

V. CONCLUSIION

In this paper, we consider real time seats usage analysis using smart sensor and cloud computing infrastructure as a library marketing activity. In the future, we will set smart sensor boxes to browsing rooms in KUL. We also apply information retrieval technology to the accumulated sensor data, and evaluate effectiveness of real-time smart sensing and data analysis using some quantitative metrics. Finally, we want to improve university library service.

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