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Library & Bookstore Navigation using RFID grid

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Abstract

Nowadays in a lot of common library and bookstores, due to a large quantity of books and bookcases, normally there is a simple searching system to help people finding the book they want. However there are some problems maybe occur when users searching the book because the guide information, which is usually only a code of a book or an estimated location of a target, is not detail enough while the library and bookstores normally build in a large area. People could go to the target bookcase in the wrong way which is not shortest one, get lost inside a ton of books and bookcases or take a lot of time to find where the wanted book is in the target bookcase.

Therefore, the main purposes of this research is to help the users taking more initiative in searching process, which they do not have before, by changing library and bookstores normal environment to ubiquitous space that could interact effectively with user's performance for solving problems described above. For the target of simple using and high usability, this navigation is designed to runs on the hand-held devices, so makes interaction between navigation and user easier. Furthermore, it uses Radio frequency identification (RFID) grid for obtaining location while RFID 's advantages are low-cost, very common device and easy to attach to other things.

This navigation has been implemented and evaluated in a real life environment – Keio University Shonan Fujisawa Campus Media Center. Experimental results show that this navigation, by suggesting the route to reach the target and the location of wanted book, could saves 41.7% of time for finding target bookcase process and 48.2% of time in whole searching process when comparing with normal search.

Keyword: Library, Navigation, RFID, Positioning, Routing

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論文要旨

近年, 多くの図書館や書店には, 書籍や本棚が大量に置かれているため, ユーザをサポートする検索システムが設置されている. しかしこのガイド情報は現実世界に結びつけられて提供されないため, ユーザが本を探して歩くときにいくつかの問題は発生する. 例えば, ユーザは目的地までの最短経路が分からなかったり, 大量の本籍や本棚によって迷ってしまうことがありうる. そのため目的の本にたどり着くまでに多くの時間がかかってしまう.

そこで, 本研究の目的は, この書籍の検索プロセスにユーザが上記のような問題に遭遇せずに, 更にイニシアチブや主導権を取ることである. 上記の問題を解決するため, 図書館や書店の通常環境をユーザの行動にあわせて書籍までの道案内を行う, ユビキタス書籍検索空間を提案する. シンプル使用や高いユーザビリティを達成できることを目標として, 本ナビゲーションはハンドヘルドデバイス上で実行するように設計される. また, 低いコストで, 簡単に接続する Radio Frequency IDentification グリッドを利用し, 位置情報取得を行う.

本ナビゲーションは, 慶應義塾大学湘南藤沢キャンパスのメディアセンターで実験や評価を行った. 評価の結果, 本ナビゲーションを利用することにより, ターゲット本棚を検索プロセスに時間のおよそ 41.7 パーセントを節約することや全体検索プロセスに時間のおよそ 48.2 パーセントを節約することを達した.

キーワード: 図書館, ナビゲーション, RFID, 位置情報, ルーティング

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Chapter 1

Introduction

The first part of this chapter describes the background of this research and the next part is the explanation of research's purpose and some requirements for achieving it. The last part is the structure of this thesis.

1.1 Research Background

In recent years, by the huge development of technology and computer science, education and studying is more and more improved with the supports from a lot of modern equipment. In example, besides some traditional tools such as pen or paper, many students have a tendency to use computer for noting the lesson, writing the reports or surfing webs to get useful information for homework. It seems that most of tasks done by computer are more simply and faster.

However some study's traditional ways are still popular and useful, one of them is reading books - the easiest way to get information. The first action to get the favourite book is going to the library or bookstores and finding it. In the common library and bookstores, there are a large quantity of books which are normally sorted by their specialty and possibility of the existence of a simply searching system to help people finding the books.

Figure 1.1: Lirary with a large quantity of books

Despite of those supports, there are some problems maybe occur when users searching the book. Example in Keio University SFC Media Center, a result from the searching system(2) is only a code of a book (table 1.1), then users have to go through a lot of bookcases and match code of book with id of bookcase for finding correct one. Or in another bookstores, searching result is only an estimated location of a target bookcase by book's genre, such as "Literature space" or "Science space" or "Language space"... in a floor map (figure 1.3).

Code	Book name
509.6@HE2@1	RFID metrics : decision making tools for today's supply chains
549.7@KI4@1	RFID security : techniques, protocols and system-on-chip design
694.6@MA5@1	iPhone Web Style
007.3@TH3@1	Ubiquitous computing : design, implementation, and usability
007.609@ST2@1	Security for ubiquitous computing

Table 1.1: Some book code in Keio University SFC Media Center

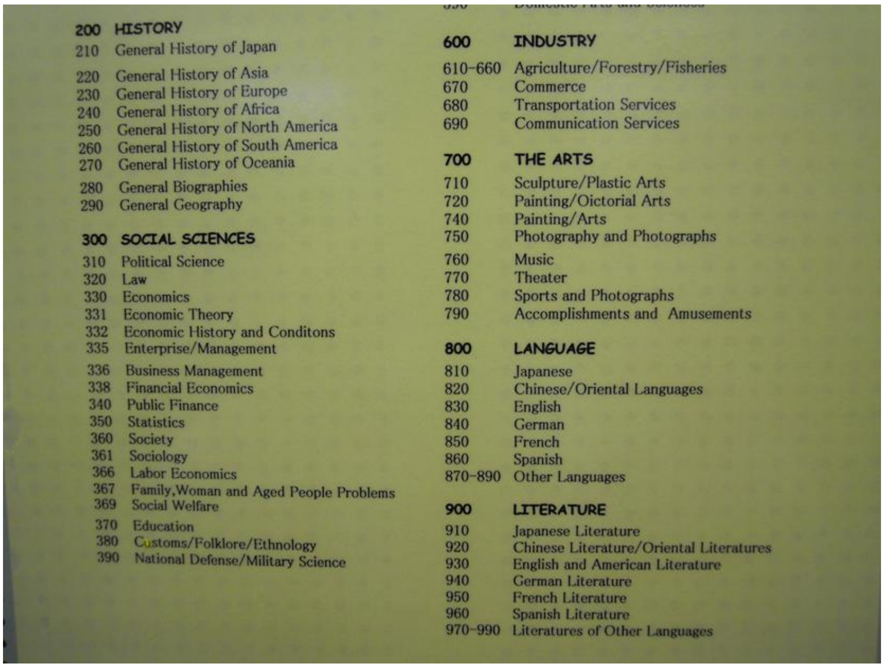

Figure 1.2: SFC Media Center Classification

The guide information is not detail enough while the library or bookstores normally build in a large area, so it's still not quick to get the wanted book because people could go to the target bookcase in the wrong way which is not shortest one, get lost inside a ton of books and bookcases or take a lot of time to find where the wanted book is in the target bookcase.

Figure 1.3: One bookstore 's floor map

1.2 Research 's Overview

Then, the main idea behind my research is to provide users with the book-searching navigation that has a more visual look of books and bookcases location inside a large area of library and bookstores. Same as some navigation run on car, by suggestion of user 's location and the route to reach the target, it would enable users to find the book more quickly.

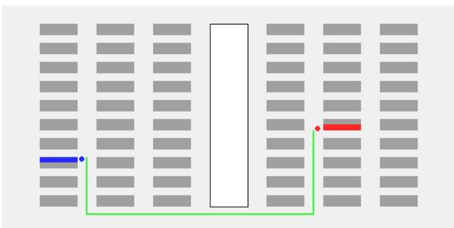

Figure 1.4: View of route

Figure 1.5: View of books

The main purposes of this research is to help the users taking more initiative in searching process, which they do not have before, by changing library and bookstores normal environment to ubiquitous space that could interact effectively with users action and performance for solving problems described above. For the target of simple using and high usability, this navigation is designed to runs on the hand-held devices, so makes interaction between navigation and user easier. Furthermore, it uses Radio frequency identification (RFID) grid for obtaining location while RFID 's advantages are low-cost, very common device and easy to attach to other things.

1.3 Thesis 's structure

The first chapter is the explanation of background and purpose of this research. The second chapter is the introduction of Local Positioning System and some technologies using in this area. The third one is the explanation of related researches. The two next chapter is the concrete explanation of application 's design and implementation. The sixth chapter is the description of evaluation 's result. The last chapter is summary, conclusion of this research.

Chapter 2

Local Positioning System

In this chapter, the first part is an overview of Local Positioning System (LPS). The next part is a description of classification criteria and some technologies using in LPS. Last part introduces concretely about the method of using Radio-Frequency IDentification (RFID) which is used in this research.

2.1 Overview

Nowadays, while Outdoor positioning methods have been well explored based on Global Positioning System (GPS) which is active on a lot of equipment, Indoor positioning or Local positioning is still a recent research area that generates a large number of new designs and algorithms.

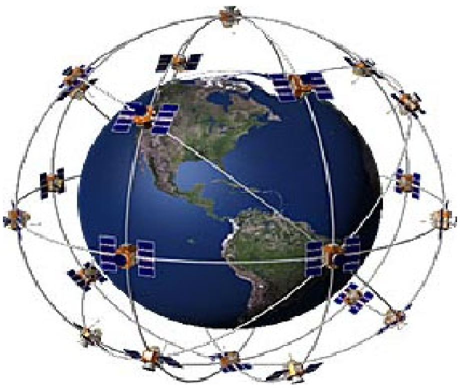

Figure 2.1: Outdoor Positioning

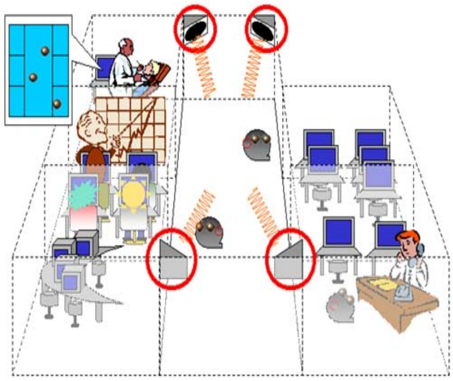

Figure 2.2: Indoor Positioning

GPS receiver does not work inside building due to the absence of sight to the satellites. Because of this reason, many technologies are being introduced in order to address indoor position. Some popular techniques are using radio waves, WiFi, Ultra Wide Band, assisted GPS, or signals from Micro Electro Mechanical Sensors (MEMS), or geographical databases.

2.2 Classification criteria

There are a lot of ways to classify indoor positioning solutions due to the broad diversity of them. Some simply criteria is the type of using sensors: passive or active, the location of the position calculation: handset or network... But one of the main and important criteria is the signal metrics, which contains the Receiver Signal Strength (RSS), the Angle Of Arrival (AOA), the Time Of Arrival (TOA) or the Time Difference Of Arrival (TDOA)(3). This criterion is chosen for the following presentation of some existing positioning systems.

2.3 Technologies

Based on criterion of signal metrics, Technologies using in Local Positioning System could be divided into two groups below.

2.3.1 Network based positioning system

The first type is "Network based positioning system" represents the Local Positioning System using sensor networks, which are mainly attached to the building and real space, to locate user position. Typical Network based LPS are Bluetooth, RFID, Wifi or Ultra Wide Band.

- Bluetooth

  The Bluetooth(4), also known as the IEEE 802.15 standard, is a an open wireless technology standard for exchanging data over short distances using short wavelength radio transmissions. Similar to cellular telephone systems, Bluetooth devices constitute mini-cells. When the number of Bluetooth cells is sufficient, the location of the device is considered to be the same as the individual cell that it is communicating with.

  The advantage of Bluetooth positioning technology is that the position information could be provided by some limited communication data. However, because the calculating accuracy depends strongly on the number of cells and their size, the disadvantage of this technology is that architecture requires a lot of relatively expensive receivers.

- WiFi

  The WiFi, also known as the IEEE 802.11b standard, is a higher bandwidth communications protocol than Bluetooth. More sophisticated than Bluetooth, the WiFi location solution approximates the location of a person based on some radio propagation characteristics (AOA, TOA, TDOA, RSS, etc.).

  Similarly to the Bluetooth solution, WiFi has the advantage of being able to provide a data channel as well as a location methodology. WiFi technology also requires relatively expensive access points in any area where a person or device needs to be tracked.

- Ultra Wide Band (UWB)

  UWB(5) was developed in 1960 for radar application using wireless communication. It is a radio technology that can be used at very low energy levels for short-range high-bandwidth communications by using a large portion of the radio spectrum. The energy emitted by the system is very weak compared with the extremely large amounts of data transmitted.

  UWB transmit data by generating pulses at specific instants occupying a large bandwidth which enables a pulse-position or time modulation. The pulse duration is very short, varying between some picoseconds and nanoseconds. Decimetre position accuracy can be achieved under good conditions with these UWB radio specifications.

2.3.2 Independent positioning system

The second type called "Independent positioning system" includes the technologies that provide autonomous user positions, like dead reckoning methods, and to a certain extent like assisted GPS.

- MEMS

  Micro-Electro-Mechanical Systems (MEMS) is the technology of very small mechanical devices driven by electricity, consist of a central unit that processes data, the microprocessor and several components that interact with the outside such as micro sensors.

  Sensors based on this technology are accelerometers, magnetometers, gyroscopes or barometers. They are used in a dead reckoning mode for an independent navigation system, works either outdoors or indoors, that the current location is estimated from a previously determined position. The performances of MEMS based navigation are affected by large errors (bias and noise) typical of these sensors.

- Assisted GPS (AGPS)

  AGPS is a system which can, under certain conditions, improve the startup performance, or TTFF (Time To First Fix) of a GPS satellite-based positioning system. It enlarges the working area of GPS to urban canyons or even indoors. The technique involves a mobile phone, able to process GPS signals, a cellular network and an assistance data server. The server is connected to a reference receiver that has a clear line of sight to the satellites, timing data from the reference receiver, computes the specific assistance data and sends them to the rover receiver. The main goal of the assistance data is, first to improve the sensitivity of a receiver, second to overcome interruptions of satellites signals, thus decreasing the time to fix first.

2.4 RFID method

Radio-Frequency IDentification (RFID) is an automatic identification process relying on passive or active tags that present the advantage of low cost equipment. Technically, it can be compared to barcode systems, but the barcode is replaced by silicon electronic chips with an antenna and the identification request is made by radio waves instead of optics. The data stored on the RFID tag can be read at limited distances. There are three types of RFID tags(6):

- Passive RFID tags: have no power source and require an external electromagnetic field to initiate a signal transmission.
- Active RFID tags: contain a battery and can transmit signals once an external source ('Interrogator') has been successfully identified.
- Battery assisted passive (BAP) RFID tags: require an external source to wake up but have significant higher forward link capability providing greater range.

Contrary to the passive tags, active tags include batteries that increase the transmitting distance. But this range remains limited and passes only from several centimetres up to several metres. An indoor positioning system based on

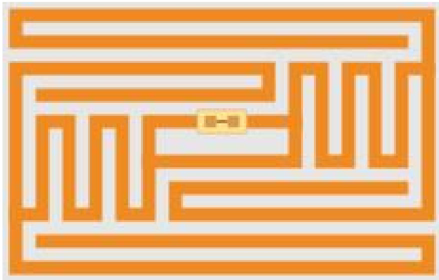

Figure 2.3: Sample of RFID tag

RFID provides the persons location when passing close to the tag. It offers only singular information on waypoints and no real tracking capability.

When comparing with other technologies, RFID method have some strong advantages like simplicity in using, compatibility with handset, the accuracy related to the number of installed cells and their size... (figure 2.4)

Technology	Processing	Accuracy	Advantages	Limitation
RFID	**Cell identity**	**Relative to cell size**	**Simple & compatible with handset**	**Number and size of cells**
WIFI	Angle of arrival	Up to 50m	2 AP provide position	Multipath AP antenna quality
	Time difference of arrival	1-30m	Good accuracy	Multipath, Network synchronisation
	Receiver signal strength	1-5m	High accuracy	Creation of RSS database
Ultra Wide Band	Angle of arrival	Few decimetres	2 AP provide position High accuracy	AP antenna quality
	Time difference of arrival	Few decimetres	High accuracy	High AP density
Micro Electro Mechanical System	Dead reckoning sensors	5% of travelled distance	Autonomous Position always possible	Large error Accuracy affected by sensors

Figure 2.4: Comparison of indoor positioning systems

2.5 Summary

Local positioning systems are used as complementary (and in some cases alternative) positioning technology to GPS, especially in areas where GPS does not reach or is weak, for example, inside buildings, or urban canyons. There are a lot of technologies have being used in this research area, and using RFID method is simply and effective way.

Chapter 3

Related Researches

The main contents of this chapter is the explanation about related researches.

3.1 Positioning applications using RFID

As a mention in last chapter, Radio frequency identification (RFID) is a rapidly developing technology for automatic identification of objects. The localization of RFID tagged objects in their environment is becoming an important feature for the ubiquitous computing applications.

In this section, two systems using RFID technology to support Indoor Positioning are explained below.

3.1.1 RFID Information Grid for Blind Navigation and Wayfinding

The navigation and location determination system for the blind using RFID tag grid, created by Scooter Willis and Sumi Helal(7). Placed in background that blind students are at a tremendous disadvantage when they arrive on a college campus, where they must face the challenges of being an incoming freshman who can not find their classrooms, meet with academic advisor, or find the line to stand in during the professor's office hours to ask a question about homework... ; this system solved the problems of user location detection and wayfinding for blind students. So the user would be informed of their location in the room within the context of the room, or outdoors within familiar contexts such as intersections, bus stations, and buildings. The system is also able to report the location, distance and direction of items in the room such as office equipment, furniture, doors and even other users.

In this system, the information grid based on passive, low-cost, High Frequency RFID tags, which are installed along outdoor pathways, in building hallways and in rooms. A single passive RFID tag represents a single grid point in the system. Once the grid or path of passive RFID tags is installed, a space survey is done to determine the precise coordinate of one reference RFID tag in the space. And by storing all information in the RFID tags about the surrounding space, the base RFID information grid can provide the foundation of precise indoor location for the blind user. The central computational system for the blind user is based on commodity electronics such as advanced cell phones or a PDA that support Bluetooth and Java programming for application development, and the RFID reader is integrated into a walking cane and a shoe.

3.1.2 Using Active and Passive RFID Technology to Support Indoor Location-Aware Systems

With the basic idea of location and context-awareness is to provide services that fit the user's current situation, R. Tesoriero, J. Gallud, M. Lozano, V. Penichet have proposed the system environment based on both active and passive RFID technology which supports the automatic positioning of mobile devices and provides location-aware information in closed spaces(8). This positioning system has been developed in a real scenario - an art museum.

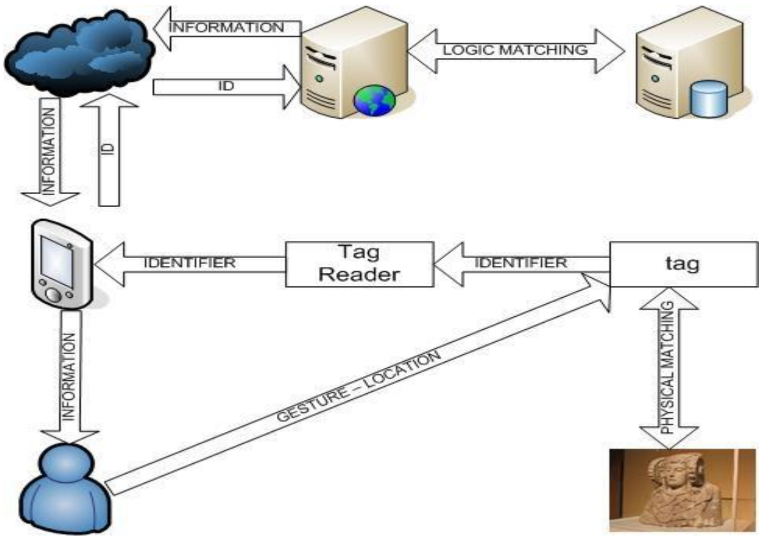

Figure 3.1: System schema

Active RFID tags were installed to identify a showcase or space in museum, and Passive RFID tags were installed to identify a art object into the showcase. In scenario, the visitors of the museum use a mobile device to interact with the environment. For the lower level, when the mobile device is close to an interesting showcase which attached active tag, the user is notified about it and the related information is retrieved and displayed on mobile. For the higher level, if the user want to get some information about a specific art object on a showcase, they can put the mobile device near the object's passive tag and retrieve extra information about it.

3.2 Document management using RFID

Not only in Indoor Positioning area, RFID technology was applied in a lot of fields of application due to its advantages.

3.2.1 NEC RFID Document Tracking System

In 2006, for solving problem of keeping track of the important documents, expensive office equipments and valuable assets, NEC Hong Kong Limited provided "RFID solutions on Document Tracking"(9) for government departments, small to medium enterprises and large corporations.

Figure 3.2: Scanning books

In this system, all items come with RFID tags will be automatically scanned and logged by the RFID reader tray which is connected to a PC or notebook. The RFID solution facilitate searching, tracking and updating items. Example for one part of this system is in figure3.2, a portable hand held reader enables librarian on the spot inventory checking and easily to identify and managing items.

3.3 Summary

Three system presented above have the same point that to utilize completely RFID advantages for reach the purpose. Returning to background and problem described in chapter 1, it's also my motivating to use RFID devices as a good method of solving location problem, one part of my system, open a door to reach the farther target of developing whole book-searching navigation in this research. When comparing with these researches, due to the differences of background, purpose or devices, my system was designed into little different way. Concrete explanation about system design is in next chapter.

Chapter 4

System Design

This chapter explains about the process of system design, from Application for Administrator, DataBase to Application for User.

4.1 System Overview

In scenario, an user who uses this navigation for searching a book in a library or bookstores would have to pass three step. In first step, user inputs the name of the book he wants, makes a request and gets from system a view of destination - the target bookcase. Next step, the user uses RFID reader installed on his handheld device to take current location and gets a view of route to target. Last step, when reaching the target bookcase, the user gets a view of estimated location of the favourite book.

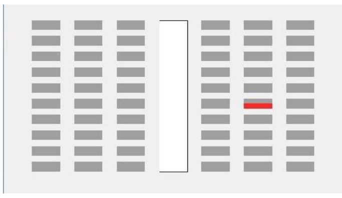

Figure 4.1: Step 1

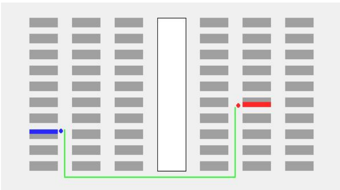

Figure 4.2: Step 2

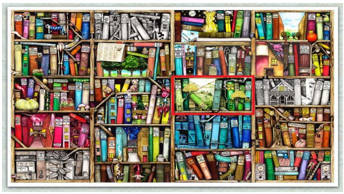

Figure 4.3: Step 3

This scenario above describes the process of recommending users the best way to get the book they want among a ton of books around them. All necessary things for the users are only one handheld device which installed this navigation and one RFID reader to interact with library's RFID tags grid. However there is one more thing that is indispensable in this process: database of library's information used in navigation. It is necessary that this database was created completely before the navigation is performed.

Then, not only application for users but also application for administrator are designed in this system. Between two applications is database, contains structure information of the library or bookstores such as floor map and order rule of books. User Application, which is the navigation run on user's handheld device, interacts most with RFID tags grid and system database. Administrator Application interacts only with system database, creates data used in navigation.

4.2 Administrator Application Design

Main tasks of Administrator application are connecting and editing data of structure database. A Software configuration of Administrator Application and function of each module inside are described in this section.

4.2.1 Software configuration

There are three main module in this application:

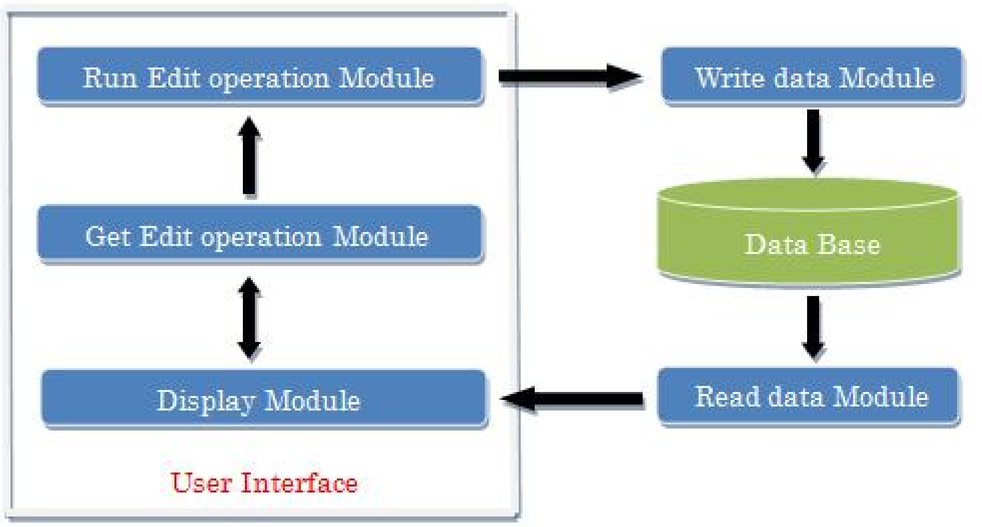

Figure 4.4: Administrator application software configuration

- **Display Module** gathers bookcases, books and RFID tags grid information from Database through **Read data Module**, displays all information above into floor map format.
- **Get Edit operation Module** records user's edit operation on floor map such as to add, to modify or to remove some nodes; exchange information with Display Module for confirming changes, send instruction to upper module.
- **Run Edit operation Module** receives instruction, performs edit operations, through **Write data Module** changes data of database.

4.3 User Application Design

User Application, the book-searching navigation, has a main task of finding the fastest and shortest way to destination. A Software configuration of User Application and function of each module inside are described in this section.

4.3.1 Software configuration

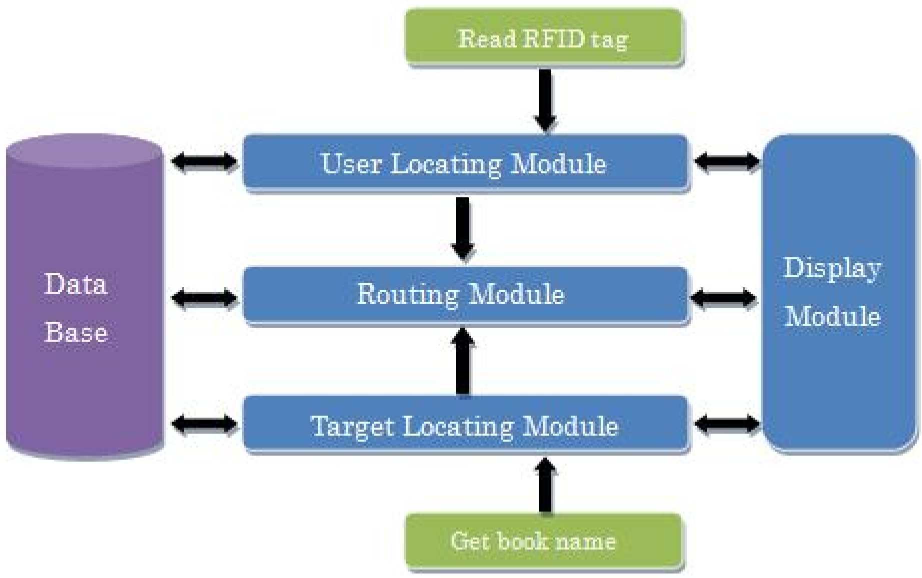

Figure 4.5: User application software configuration

- **Target Locating Module** obtains the user's wanted book ID from **Get book name Module**, accesses database and matches information, gather target bookcase's id and its location and wanted book location, sends this data to both **Display Module** and **Routing Module**.
- **User Locating Module** obtains user's nearby RFID tag ID from **Read RFID tag Module**, exchanges information with structure database, gathers user location from nearby bookcase information, sends this data to both **Display Module** and **Routing Module**.

- **Routing Module** receives target location and user location information from two modules above, builds the Graph of floor map, matches two location above with vertices, uses routing algorithm to find the shortest path, sends this data to **Display Module**
- **Display Module**, which has only main duty of intermediate point between navigation and user, continuously receives data from three modules above, analyses them and display process of determining the route.

4.3.2 Hardware configuration

Hardware devices using in User Application could be separated into 2 groups. The real space of library or bookstores need install the high density RFID tags grid, at least one tag per bookcase. Each RFID tag is programmed with information describing the surroundings for identifying and locating. Necessary devices for one user are one handheld device, using for interaction with searching navigation, connected to one RFID reader for obtaining data of RFID tags

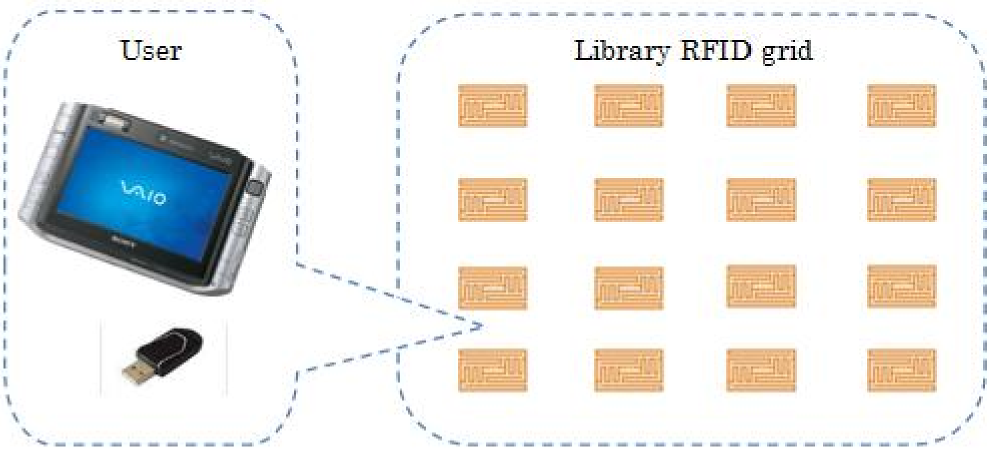

Figure 4.6: User application hardware configuration

4.4 Database Design

Database using for both Administrator Application and User Application is created from two tables of data - Bookcases table and RFID table (figure 4.7)

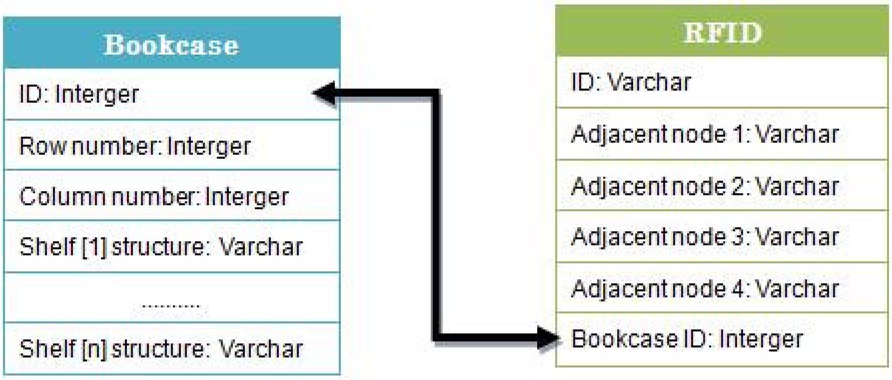

Figure 4.7: Structure Database

- **Bookcase Table**

  This table consists structure data of each bookcase. The first data field is ID used for identification, next two field describe number of shelves in this bookcase, in general almost bookcases have the same number of row and column. Remaining fields are books information in each shelf, represented the "smallest" book id and the "biggest" book id in this shelf by one encoding string (supposing that all of books are sorted by order of book id - the fact that be common in a lot of library and bookstores). Data of this table is used most in step of obtaining target location and estimated location of the book.

- **RFID Table**

  This table consist surrounding information of each RFID tag. The ID field is used for identification, next four field describes adjacent nodes around RFID tag above, combines with the last field, the ID of bookcase contain RFID tag, for the purpose of building graph of floor map. Data of this table is used most in step of obtaining current location and process of calculating the route.

4.5 Operation for administrator

Software design for Administrator's Application has been featured in figure4.4. In this section, each main operations of Administrator are presented.

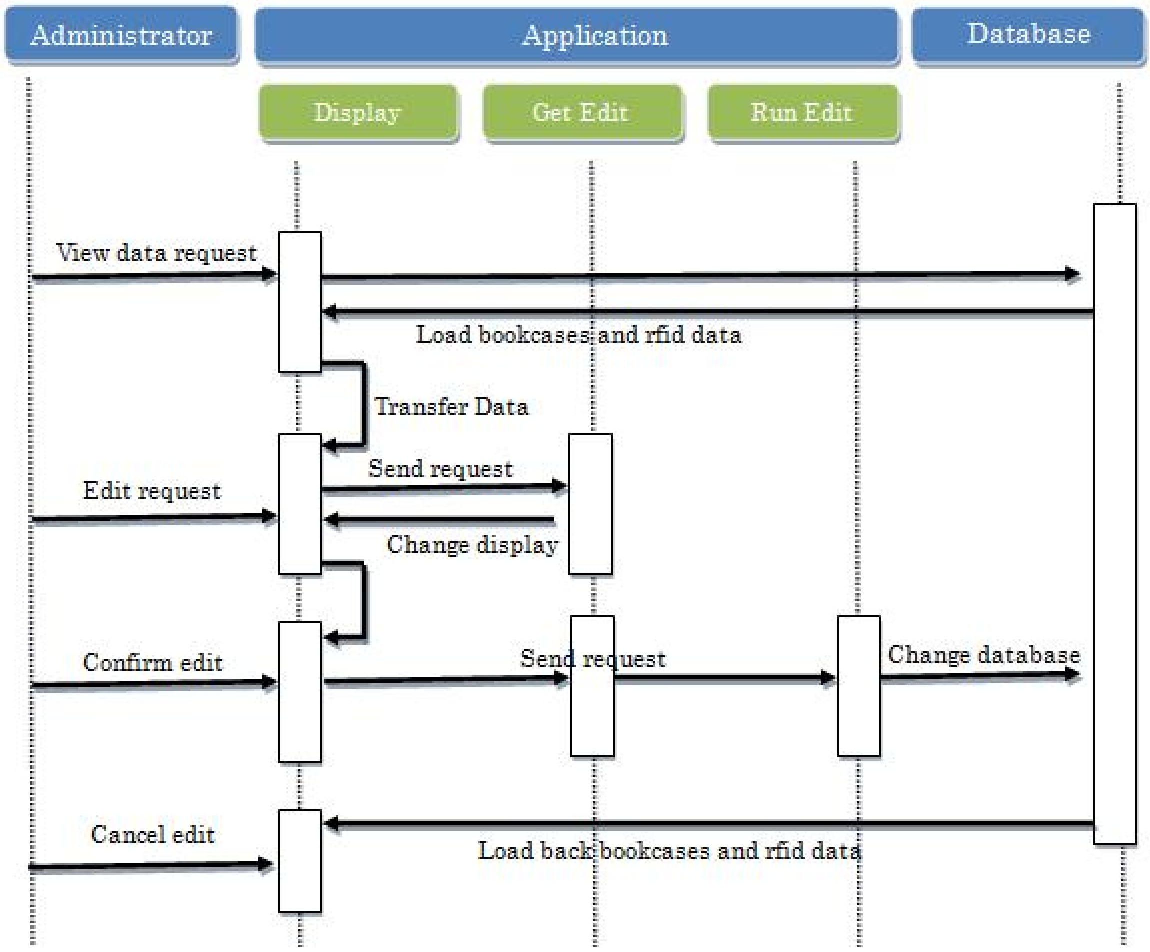

Figure 4.8: Overview of Operation for administrator

Because the main tasks of Administrator application are connecting and editing data of structure database, the main duty of Administrator is to modify structure data in Database to fit real space situation.

- **Load and Display Database**

  After receiving request from Administrator, **Display Module** accesses to **Database**, gathers all information of bookcases and RFID grid, transforms data to floor map displayed on the screen, waits for another request from Administrator.

- **Edit process**

  After building a simulation of floor map, **Display Module** allows to start process of modifying. Administrator adds, removes or edits data of bookcases or RFID tags grid; **Get Edit Operation Module** makes all changes displayed on **Display Module**

- **Confirm/Cancel edit request** Last step of edit processing, once Administrator confirms the modifying, all changes before are transferred to **Run Edit operation Module**. Based on request, **Run Edit operation Module** perform a task of writing new data into **Database**

4.6 Operation for user

Software configuration of User Application has been featured in figure4.5. In this section, three main operations of Navigation process are presented.

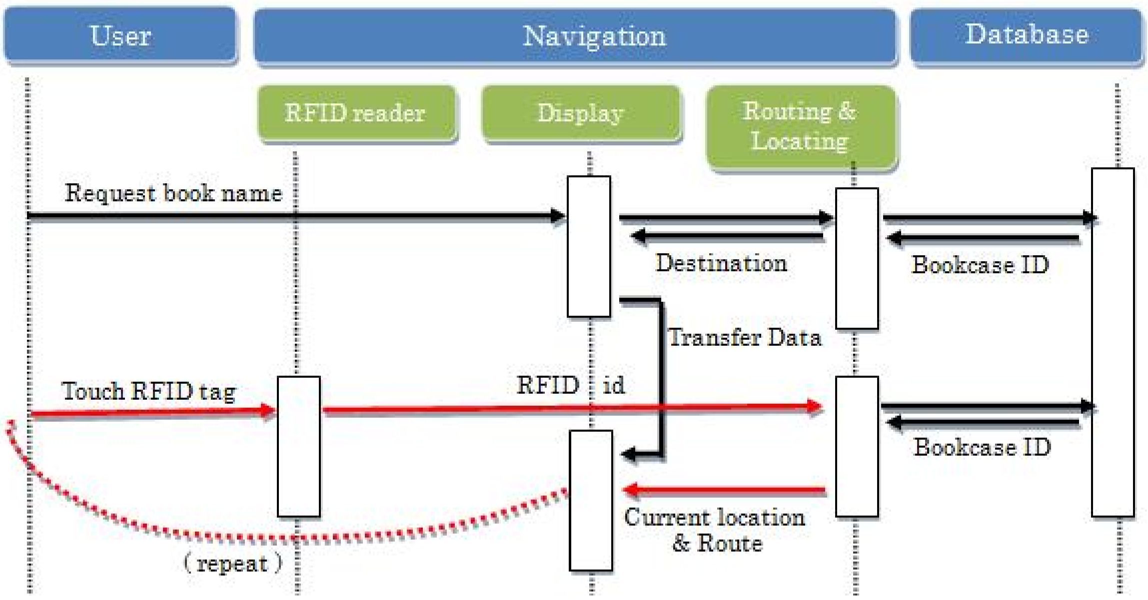

Figure 4.9: Overview of Operation for user

- **Obtaining target bookcase**

  Start with the name of the book requested by user, **Target Locating Module** accesses **Database** and obtains bookcase id, transfers it to **Routing Module**. In **Routing Module**, destination of the route is determined, data is transferred to **Display Module** for informing user.

- **Obtaining current location and route**

  User current location is gathered by matching user's nearby RFID tag ID with floor map information in **Database**. After determining both current location and destination, **Routing** uses Graph theory and Routing algorithm to find a shortest path, which is displayed in Navigation. This process of this operation could be repeated, user could go to another bookcase and obtain a new route, until user reaches the target location.

  Two operations above are describe on Figure4.9

- **Obtaining book location** Last operation of User Application: after verifying that user have reached the target bookcase, **Display Module** recommends user book estimated location in this bookcase by matching book id with bookcase structure data

4.7 Summary

Hardware configuration, Software configuration and main Operation of both Administrator Application and User Application were explained in this chapter. All of system designs above is the preparation for next chapter - System Implementation.

Chapter 5

System Implementation

The main contents of this chapter is the concrete explanation of applications implementation

5.1 User Application Implementation

This section describes the environment and each software's module implementation of User Application.

5.1.1 Implementation environment

About hardware environment, User Application of this system is implemented on Vaio Type-U (10) with the support from ASI4000USB RFID reader(11). Vaio Type-U is the small and portable PC with touch screen, that is used easily as hand-held device. The second hardware device, ASI4000USB, is a small size RFID reader/writer connecting to computer through COM Port.

Configuration	
CPU	Intel®Core™2 Solo(1.20GHz)
Memory	1024 MB
HDD	64 GB
OS	Windows Vista 32bit

Table 5.1: Vaio-U using in User Application

Configuration	
Size	21 mm 51 mm 9.9 mm
Weight	10 gram
Connector	USB port
Tags	ISO15693, Felica

Table 5.2: ASI4000 RFID reader/writer

About software implementation environment, User Application is divided into 2 parts (Fig.5.1)

- **Visual Basic program :** the small part of User Application, with the main task of communicating with **ASI4000 RFID reader/writer**, obtaining information of RFID tags and sending data to socket using network programming. This program is edited and run by Visual Studio 2010 tool.

- **Java program :** the main part of User Application, receiving data from above program through socket, creating navigation for searching process. This program is edited and run by Netbeans IDE tool.

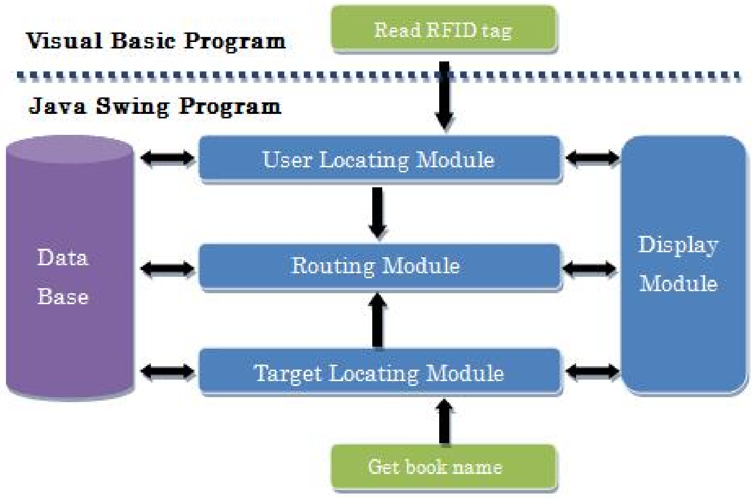

Figure 5.1: User application software configuration

An Implementation of some important parts of User Application is presented in next parts.

5.1.2 Obtaining user 's location

First part of this function is **Read RFID tag** module, which is Visual Basic program. As described above, this module has a task of obtaining information of RFID tags and sending this data to reserved socket.

- Open connection with RFID reader : accesses to RegistryKey "HARDWARE \DEVICEMAP \SERIALCOMM" of system, obtains value of COM Port of RFID reader device, uses **ArtTechnology** library of Visual Basic program for initializing and opening connection with device.

- Create Socket program Server : creates new TCPListenner of Socket in localhost on reserved port, waits for request from Socket program Client.

- Get ID and data of RFID tags : whenever RFID tags is putted near RFID readers, program receives tag ID and it's data as 64-bits signed integer, converts it to more simply readable String
- Send data to Socket : encodes string above and sends to initialized Socket

Two top steps are called one times when starting program. Next two step are called whenever having new data from ASI4000 RFID device, kept running continuously for updating location.

Open connection with RFID reader
Private Sub EnumSerialPortNames)   Private Sub btnPortUpdate_ Click()   Private Sub btnComOpen_ Click()
Create Socket program Server
Private Sub Form_ Load   Private InitSocket()
Get ID and data of RFID tags   **Send data to Socket**
Private Sub Inventory()

Table 5.3: Obtaining user's location VB class

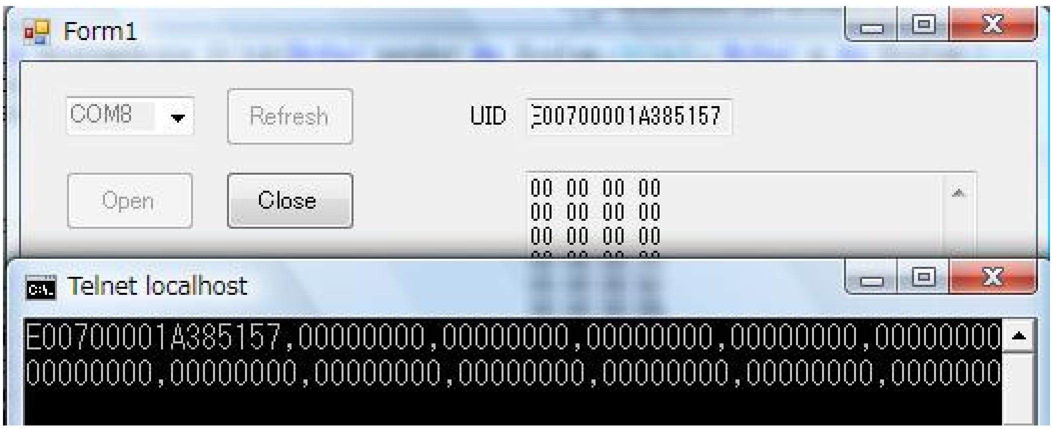

Figure 5.2: Testing VB Socket Server

Other part of **Obtaining user 's location** function is **User Locating** module represented by one class of User Application 's Java program.

- Client Open Socket : opens connection with the Socket created by Visual Basic program above, set Timeout 250 milliseconds per each read request, creates new BufferedReader of InputStream for obtaining data from Socket.
- Get RFID tag data : gets data from BufferedReader of InputStream from Socket, transfers String data to main class. Main class, Graphics class which is described later, matches id with database, obtains user location, displays in floor map.

Client Open Socket
public void initSocket()
private Socket openSocket()
public void closeSocket()
Get RFID tag data
public String rfid()

Table 5.4: Obtaining user's location Java class

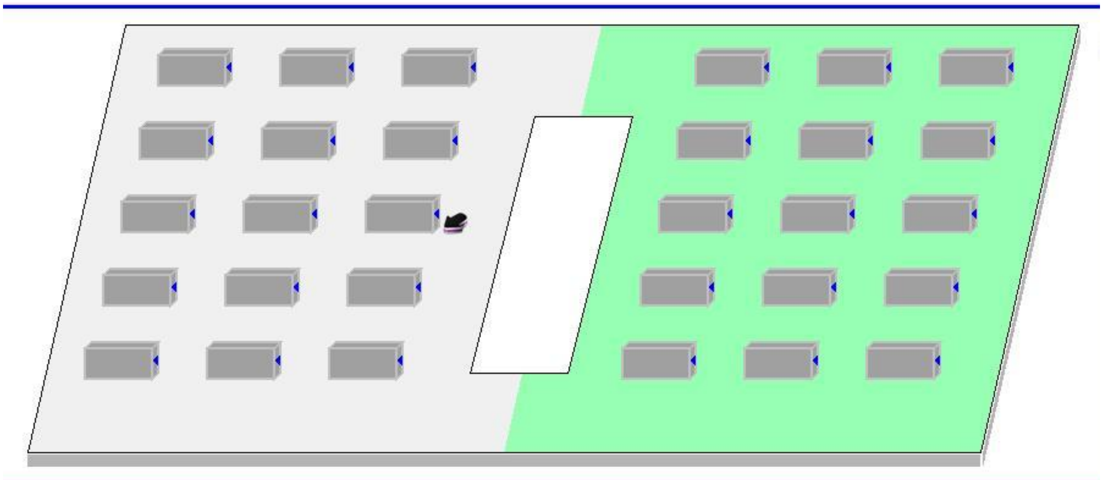

Figure 5.3: Testing Current Location Obtaining

5.1.3 Obtaining route to target

Once received user location and target location, system calls the function of routing. An 2D-array, which describes the graph of floor map structure, was built before this action. The code below (table 5.5) represents the Dijkstra routing algorithm (12) to find shortest distance and path between source node and each other one.

About this algorithm, after determining the source node, it's define distance of node **i** by the distance between it to source node. By performance inside **While loop**, distance of node **i** is improved step by step. Start from source node, it founds unmarked node with smallest distance, marks it visited meaning it's distance is final and minimal. Then, from current node (node **u** in code above) calculates distance of all unmarked node, if distance from node **i** to source node greater than distance from node **u** to **i** plus distance from node **u** to source, replaces distance from node **i** to source node by the new value. If all nodes have been visited, process is finish. Array **pre** is used to track the path from source to other nodes.

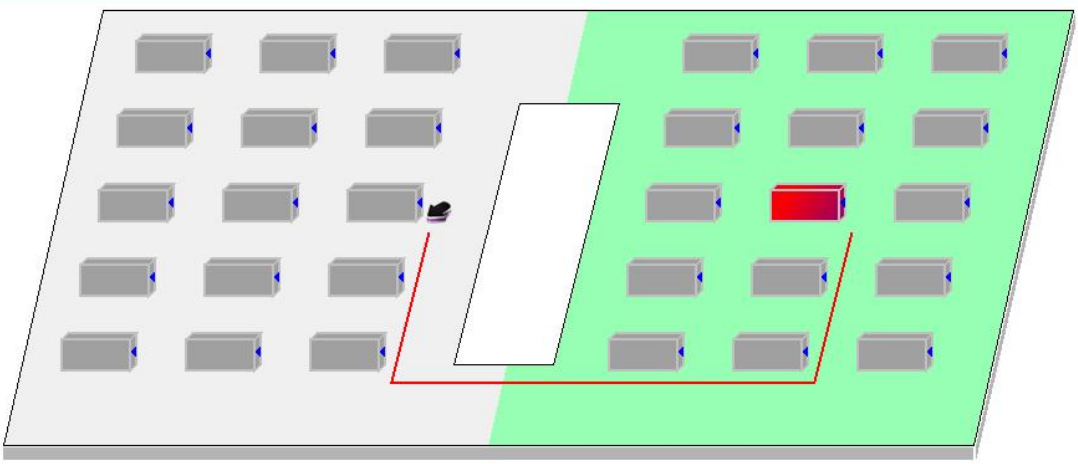

Figure 5.4: Testing Route Obtaining

```
// Initializations
// Unknown distance from source to i and Previous node in path
for (i=1;i<=n;i++)
    { mark[i]=0; distance[i]=999; pre[i]=0; }
// Distance from source to source
distance[source]=0;
// The main loop
while (count<n)
{
    int min=1000;
    // Find unmarked node with smallest distance
    for (i=1;i<=n;i++)
       {
       if ((mark[i]==0)&&(distance[i]<=min))
          { min=distance[i]; u=i; }
       }
    // Mark this node
    mark[u]=1; count++;
    Improve distance of all unmarked node
    for (i=1;i<=n;i++)
       {
       if ((mark[i]==0)&&(graph[u][i]!=1000)
       &&(distance[i]>distance[u]+graph[u][i]))
          {
          distance[i]=distance[u]+graph[u][i];
          pre[i]=u;
          }
       }
}
```

Table 5.5: Routing function

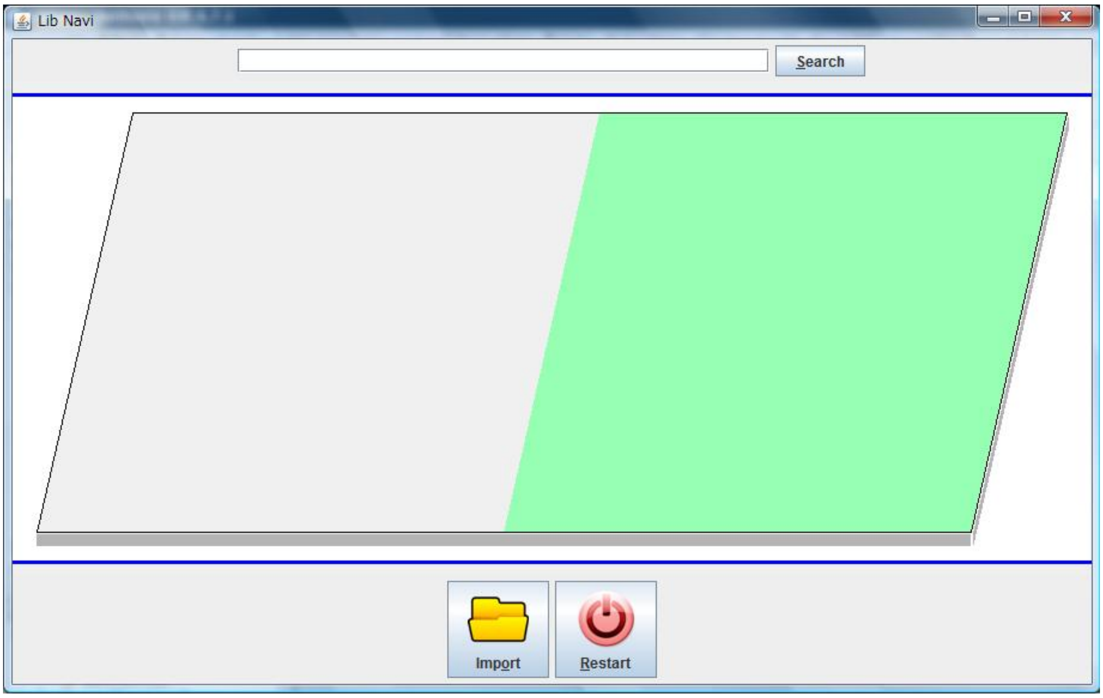

Figure 5.5: Start screen of Application

5.1.4 Designing Graphics & Interface

First step of this function is to design and define function of buttons. There are 3 buttons:

- btnSearch : gets books name from JTextField in left side, searching location of target bookcase
- btnOpen : opens a JFileChooser dialog box, allows user choose database file for importing in Application. If this file is valid, database would be displayed on the center of screen.
- btnReset: resets program, input database and all variable, brings back to Start screenfigure 5.5

Next step of this function is to set layout of Java Swing program. TextField **txtBook** and Button **btnSearch** are on the top JPanel. Button **btnOpen** and **btnReset** are on the bottom JPanel. Middle of Java Swing program is floor map defined by Floor class using only for draw.

```
window = new JFrame("Lib Navi");
window.setDefaultCloseOperation(JFrame.EXIT_ON_CLOSE);
window.setSize(917,575);
top = new JPanel();
top.setLayout(new FlowLayout());
top.add(txtBook);
top.add(btnSearch);
bot = new JPanel();
bot.setLayout(new FlowLayout());
bot.add(btnOpen);
bot.add(btnReset);
floorMap = new Floor();
window.getContentPane().add(top, BorderLayout.PAGE_START);
window.getContentPane().add(floorMap);
window.getContentPane().add(bot, BorderLayout.PAGE_END);
window.setVisible(true);
```

Table 5.6: GUI Layout

Final is Floor class, using for draw floor map of library structure, position and route to target. Code and draw commands for this class are listed below.

```
class Floor extends JPanel {
Floor(){
    setSize(900,400);
}
public void paint(Graphics g) {
    Graphics2D g2d = (Graphics2D) g;
    Drawing code
}
}
```

Table 5.7: Floor class structure

Drawing command
Color.RGBtoHSB
Color.getHSBColor
g2d.setColor
g2d.fillRect
g2d.fillPolygon
g2d.setStroke
g2d.drawLine
g2d.drawRect
g2d.drawPolygon

Table 5.8: Some used Graphics2d drawing commands

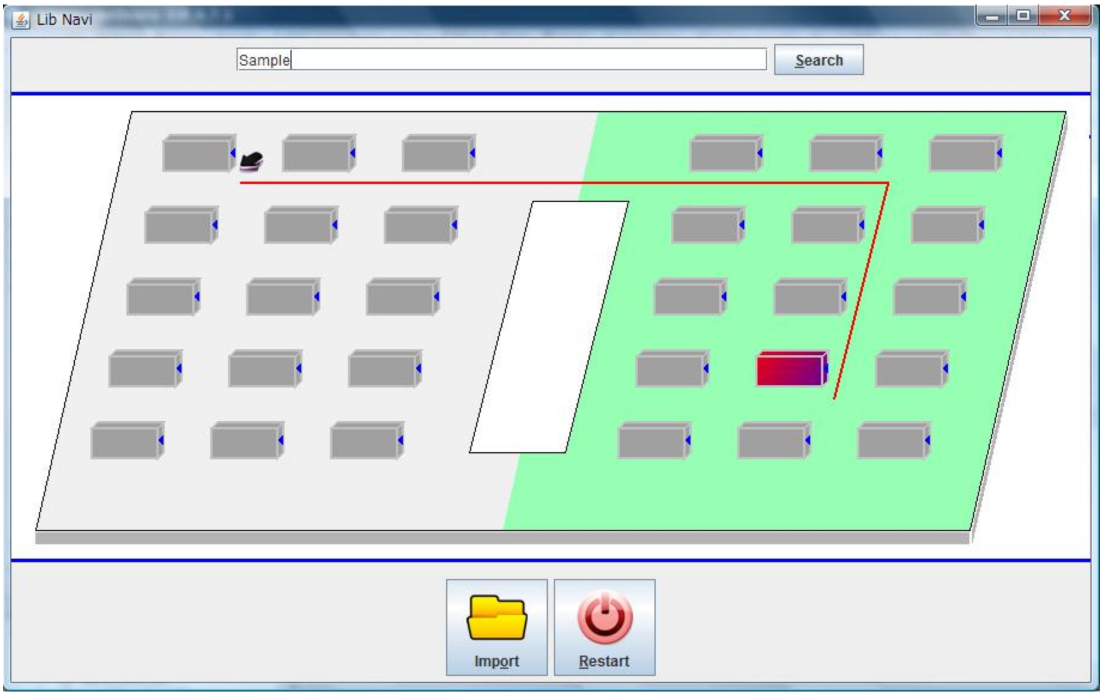

Figure 5.6: Full feature screen of Application

5.2 Administrator Application Implementation

5.2.1 Implementation environment

Administrator Application of this system is a Java program with the main task of creating database of floor map, implemented on Fujitsu FMV-BIBLO Notebook(13).

Configuration	
CPU	Intel®Core™2 Duo(2.40GHz)
Memory	2048 MB
HDD	300 GB
OS	Windows Vista 32bit

Table 5.9: FMV Biblo using in Admistrator Application

Other hardware using in this application is ASI4000USB(11) - small size RFID reader/writer connect to computer through COM Port.

5.2.2 Setting up RFID tags

ASI4000USB device is used to write proper data into RFID tags. This data refers to RFID Structure Table(figure 5.7) presented in System Design.

RFID
ID: Varchar
Adjacent node 1: Varchar
Adjacent node 2: Varchar
Adjacent node 3: Varchar
Adjacent node 4: Varchar
Bookcase ID: Interger

Figure 5.7: RFID Data Table

5.3 Summary

Hardware and environment for implementation; structure of functions, classes and commands of important parts; design of graphics and interface were explained in this chapter.

Chapter 6

Evaluation

This chapter contains the explanation of experiment method, evaluation policy, description of evaluation result and consideration.

6.1 Experiment Overview

6.1.1 Experiment Environment

Environment using for experiment and evaluation of this system is at Keio University Shonan Fujisawa Campus Media Center due to the requirement of large area for testing and evaluating the navigation. An area contains about 30 bookcases of third floor is chosen for this process.

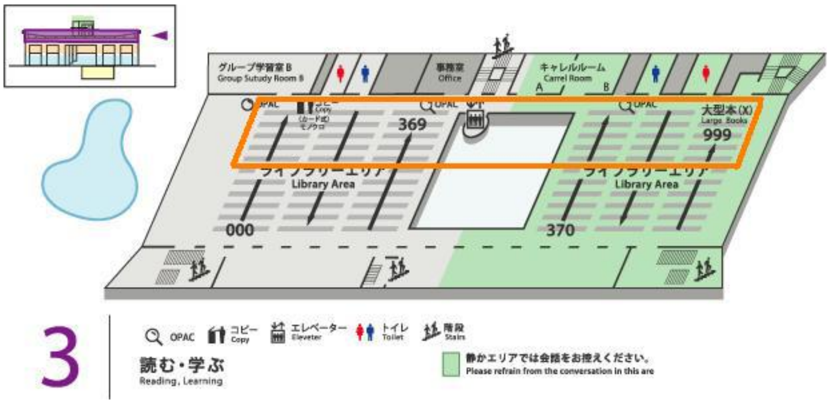

Figure 6.1: SFC Media Center(1) 3F

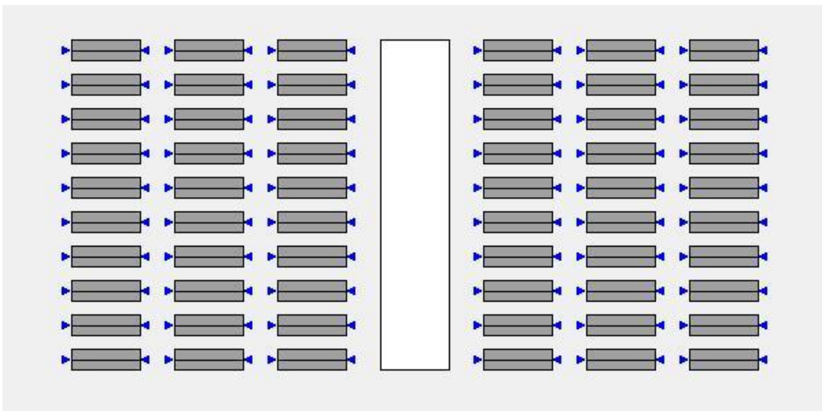

Figure 6.2: Sample of RFID grid

Next step is to install RFID tag to suitable place of each bookcase(figure 6.3 & 6.4), create the grid of RFID tags(figure 6.2) in real space of library and bookstores. This action is done by hand.

Figure 6.3: Position for installing RFID grid

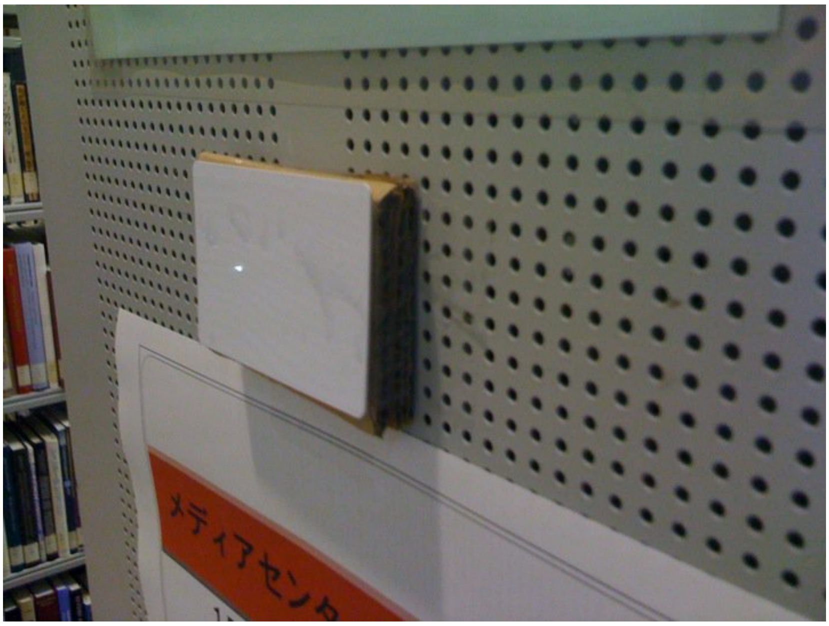

Figure 6.4: Position for installing 1 RFID tag

6.1.2 Experiment Procedure

Steps of experiment and evaluation process is in order below

- Explain about overview of software, function and ability, usage information to tester
- Run demo program, show how to use this navigation more concretely
- Let tester use normal searching system to search the book and reach the target
- Let tester use navigation for the same actions above
- Measure searching time & Take evaluation and comment from tester by using questionnaire

6.1.3 Evaluation policy

Evaluation is taken based on some important feature below

- Navigation effect: accuracy of result such as location and route, speed and time saving, improvement or advantages with other system
- Software Usability: interact with environment, system operation and user interface
- User feeling: pleasure or trouble when using

Evaluation method is to take searching time of users in experiment and analyse statistics from questionnaire.

6.1.4 Questionnaire

Questions using in qualitative evaluation are showed below. Each question has 5 level of rating.

Question list about Navigation effect:

1. How do you evaluate the accuracy of the route to target by this navigation? (Bad/Not good/Normal/Good/Very Good) - a general rating about the route from current location to destination recommend by this navigation.

2. How do you evaluate the accuracy of recommend book location? (Bad/Not good/Normal/Good/Very Good) - a general rating about the book location recommend by this navigation.

3. Do you feel of getting lost when using KOSMOS or OPAC for searching? (A lot/Usually/Sometimes/Very little/Never) - an investigation about searching process of using existing system.

4. Do you feel of getting lost when using this navigation for searching? (A lot/Usually/Sometimes/Very little/Never) - an investigation about searching process of using this navigation.

5. Do you think this navigation help user taking more initiative (easier) in searching? (Totally disagree/Disagree/Neither/Agree/Totally agree) - a general evaluation of this navigation effect.

6. Do you want to use this system than KOSMOS or OPAC system? (Totally disagree/Disagree/Neither/Agree/Totally agree) - a comparison with other existing searching system.

Question list about Software & Usability:

7. Do you think it's simple to match things in the navigation with same one in real space? (Totally disagree/Disagree/Neither/Agree/Totally agree) - a rating about how easy to understand when using this navigation.

8. Do you feel easy to find and read data from EFID tag? (Totally disagree/Disagree/Neither/Agree/Totally agree) - a rating about RFID grid.

9. Your rating about the short range interact with RFID tag? (Dislike/A little dislike/Normal/No problem/Good) - a rating about only few centimetres interact with RFID tag.

10. Do you think it's easy to use this navigation while walking? (Totally disagree/Disagree/Neither/Agree/Totally agree) - a general rating about usability.

11. Do you feel pleasure in whole searching process? (Totally disagree/Disagree/Neither/Agree/Totally agree) - an investigation about user feeling.

6.2 Evaluation & Consideration

6.2.1 Qualitative evaluation

By using questionnaire, evaluation result is showed below.

Navigation effect:

Rating	Bad	Not good	Normal	Good	Very Good	Point
Result	0	0	0	4	6	4.6

Table 6.1: Question 1: Accuracy of the route

Rating	Bad	Not good	Normal	Good	Very Good	Point
Result	0	0	0	6	4	4.4

Table 6.2: Question 2: Accuracy of book location

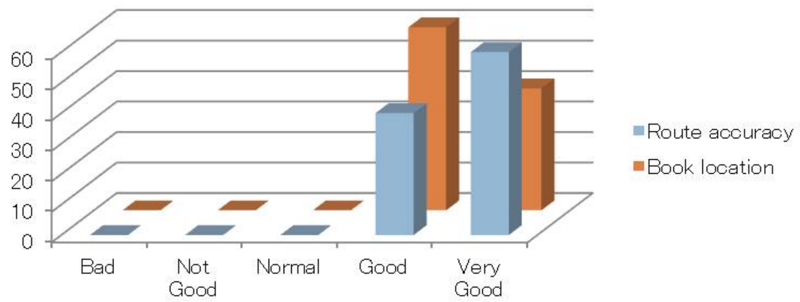

Figure 6.5: Summary result of question 1 and 2

In general, all of the tester rate Good and Very Good for the accuracy of the route to target (table 6.1) and book location (table 6.2) recommend by this navigation. It means that this navigation did well in obtaining user location, target bookcase location, wanted book location; building database based on real structure data; determining graph of floor map and the route.

Rating	A lot	Usually	Sometimes	Very little	Never	Point
Result	1	5	4	0	0	2.3

Table 6.3: Question 3: Getting lost with KOSMOS & OPAC

Rating	A lot	Usually	Sometimes	Very little	Never	Point
Result	0	0	1	4	5	4.4

Table 6.4: Question 4: Getting lost with this navigation

Rating	Totally disagree	Disagree	Neither	Agree	Totally agree	Point
Result	0	0	0	5	5	4.5

Table 6.5: Question 5: This navigation help user taking more initiative

Rating	Totally disagree	Disagree	Neither	Agree	Totally agree	Point
Result	0	0	0	6	4	4.4

Table 6.6: Question 6: User want to use this navigation

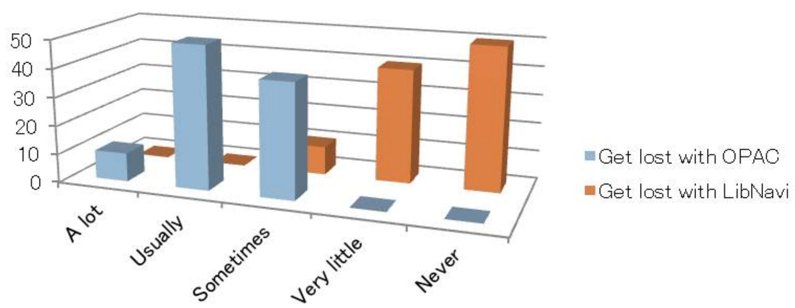

Figure 6.6: Graph of question 3 and 4

When using KOSMOS or OPAC for searching, 60% of the tester usually and 40% of the tester sometimes feel of getting lost (table 6.3); while 90% of the tester do not when using this navigation (table 6.4). It proves that existing searching system such as KOSMOS or OPAC, which provide user with only a code of the book or an estimated location of destination, do not support user enough. And this navigation with more visual look of floor map and bookcases could prevent users from getting lost.

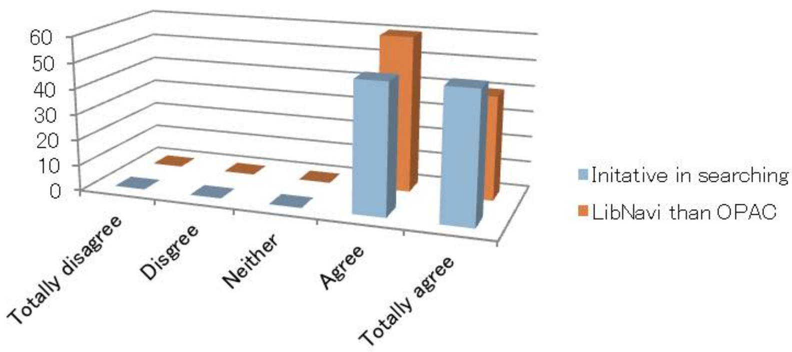

Figure 6.7: Graph of question 5 and 6

100% of the tester agree that this navigation help user taking more initiative in searching process (table 6.5) and want to use this system than existing system like OPAC and KOSMOS (table 6.6). It means that this navigation, which has new approach to users for reaching the target, brings some positive effect in searching process. Instead of going through a lot of bookcases and matching code of book with id of bookcase for finding correct one, users only have to follow the suggestion by this navigation, which enable them to find the book more easily.

Software & Usability:

Rating	Totally disagree	Disagree	Neither	Agree	Totally agree	Point
Result	0	1	1	7	1	3.8

Table 6.7: Question 7: Easy to understand

Rating	Totally disagree	Disagree	Neither	Agree	Totally agree	Point
Result	0	1	2	4	3	3.9

Table 6.8: Question 8: Easy to find and read data from RFID tag

Rating	Dislike	A little dislike	Normal	No problem	Good	Point
Result	0	1	2	4	3	3.9

Table 6.9: Question 9: Short range interact with RFID tag

80% of the tester think it is simple to match things in the navigation with same one in real space while only 10% of the tester disagree with that(table 6.7). It means that it is easy to understand location and route when using this navigation. However, one disadvantage of this navigation is the lack of equipment like compass to show direction for user. A support from compass would make it's easier to recognize direction and location. This is one future work for this navigation.

Besides, 70% of the tester agree that it's easy to find and read data from RFID tag (table 6.8) - a good rating about RFID tags grid installed in library and bookcases. In other side, only 10% of the tester dislike the short range interact with passive RFID tags while 70% feel no problem with it. In this current system, the data from RFID tag only could be read at distance of few centimetre due to the limited ability of equipments. It is not big problem due to the result of evaluation, but this is another disadvantage of this system that should be improved in the near future.

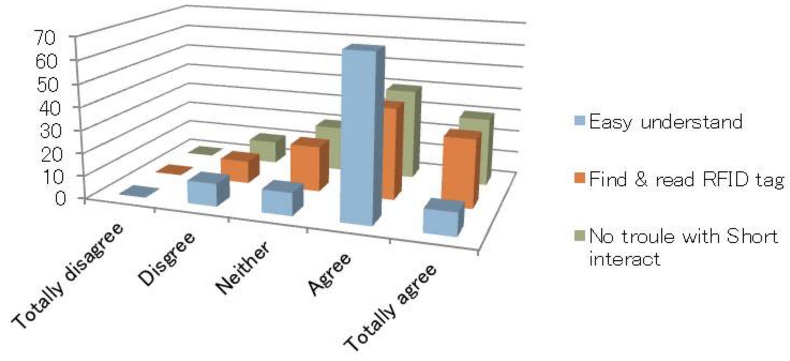

Figure 6.8: Graph of question 7, 8 and 9

Rating	Totally disagree	Disagree	Neither	Agree	Totally agree	Point
Result	0	0	0	9	1	4.1

Table 6.10: Question 10: Easy to use while walking

Rating	Totally disagree	Disagree	Neither	Agree	Totally agree	Point
Result	0	0	1	7	2	4.1

Table 6.11: Question 11: Pleasure in using

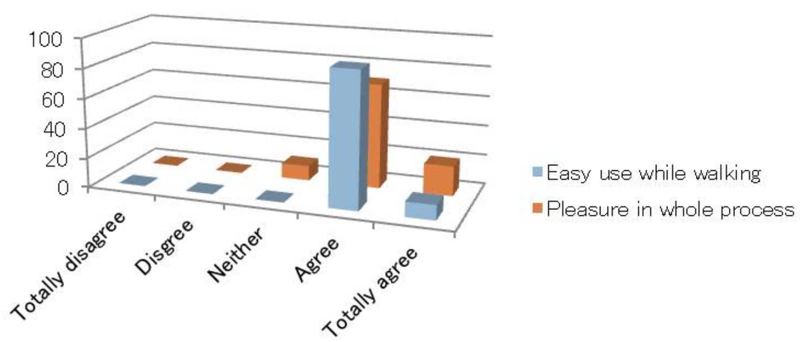

Figure 6.9: Graph of question 10 and 11

In last, 100% of the tester agree that it's easy to use this navigation while walking and 90% of them feel pleasure in whole searching process.

6.2.2 Quantitative evaluation

By taking and comparing time of searching process by using both normal searching system and this navigation, evaluation result is showed below.

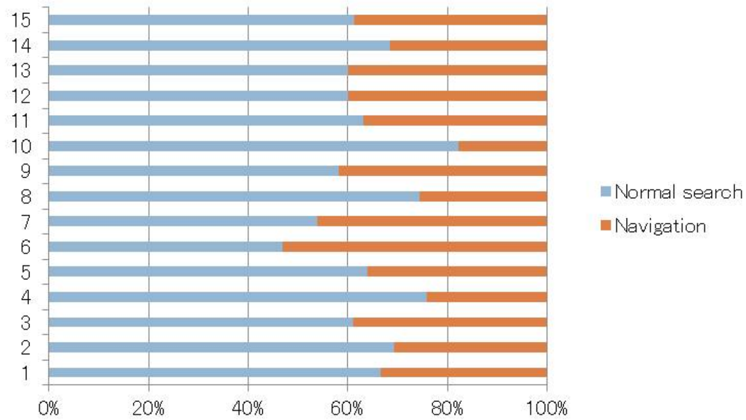

Figure 6.10: Finding target bookcase time comparing

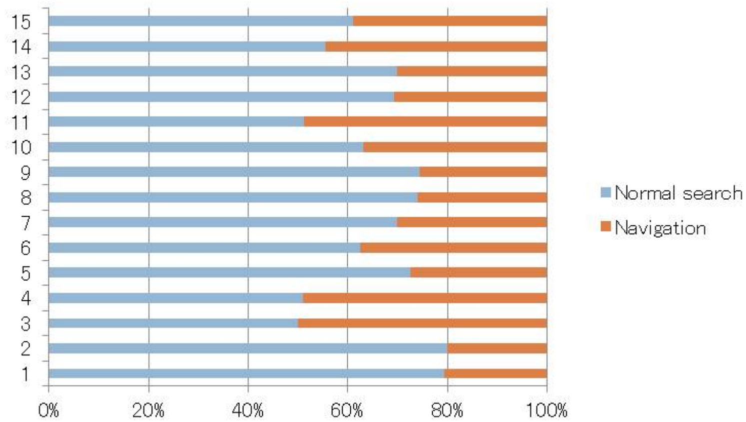

Figure 6.11: Finding book location time comparing

When comparing with normal search, for finding target bookcase process, this navigation saves 41.7% of time in average. For finding book location in the target bookcase, this navigation saves 43.9% of time in average

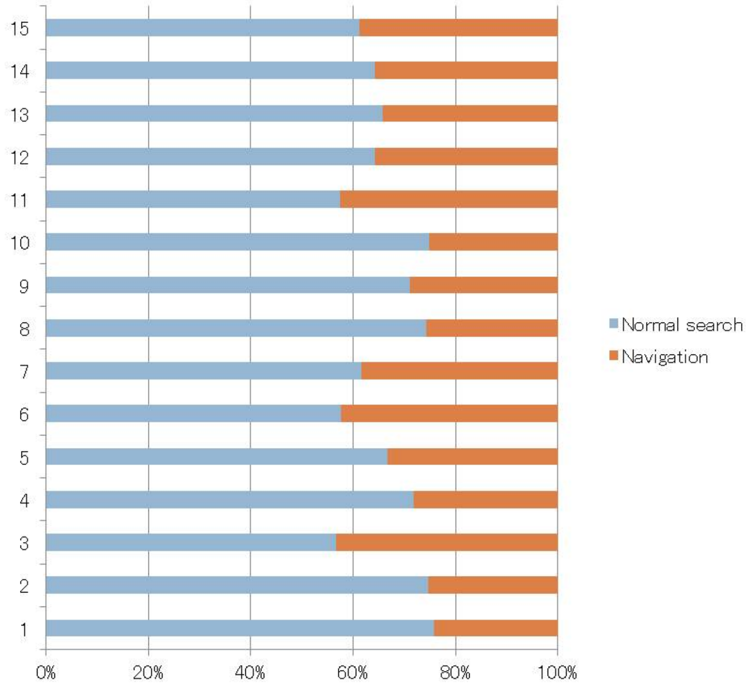

Figure 6.12: Whole searching process time comparing

And average 48.2% of time is saved in whole searching process. The truly fascinating statistics are summarized after analysing searching time from tester, although they only had three or four times to test this navigation before evaluating. The result would be improved if user had more times to use this navigation.

Chapter 7

Conclusion

This thesis proposed the book-searching navigation run on hand-held devices that supports users to find the book in the library or bookstores more quickly and easily.

Placed in background that an user who wants find only the favourite book among a ton of books, could get lost inside the matrix of bookcases and shelves while the support information is not detail enough, this navigation provided one new searching method with more visual look of books and bookcases, solved problem of wasting time in searching. By interacting with low-cost RFID grid installed along space of library and bookstores, this navigation could recommend users precisely the route from current location to the destination and estimated location of the book they want in the target bookcase.

This navigation has been implemented and evaluated in a real life environment – Keio University Shonan Fujisawa Campus Media Center. Experimental results show that this navigation could saves 41.7% of time for finding target bookcase process, 43.9% of time for finding book location process and 48.2% of time in whole searching process when comparing with normal search.

As our future work, importing equipment like the compass for get correct direction of user and improving the short interact with RFID tags are two main works to be aimed for this navigation in near future.

In the end of this thesis, not keyword but key clause is proposed for summary this navigation and research: **helping user taking more initiative, changing library environment to ubiquitous space, simple using and high usability application, common and low cost device**.

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