A Shopping Mall Indoor Navigation Application using Wi-Fi Positioning System

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ABSTRACT

Nowadays, shopping malls become very important in our society. Shopping mall is a type of complex public building. There is a total of 41.7 percent of people visited shopping malls at least once a week based on the previous survey. People always encountered problems when they are trying to find a certain store in the shopping mall due to the complexity of the building. structure They are forced to find their way around the malls with the old-fashioned method: asking directions, looking for way finding directory, trial, and error. Therefore, a shopping mall indoor navigation application should be developed to provide a complete direction guide to the shoppers. The indoor navigation application should allow users to easily find their way to the desired stores, display detailed information, and the latest promotions offered by each store. The indoor navigation application must be able to provide more robust, reliable and accurate indoor navigation to the users. This application only relying on the Wi-Fi positioning system (WiPS/WFPS) technique, which is a Wi-Fi-based location system. This technique enables the application to plot the shopper's current location on the mall's map and further provide the indoor navigation from and to any location in a mall. Based on the usability testing, most of the respondents are satisfied with the application from the aspects like usefulness, efficiency, ease of use, and also enhance in terms of aesthetics. Shoppers no longer get lost in the shopping mall as the maps and navigation function of the mall are resides in the palm of the shopper's hand. This paper presents a shopping mall indoor navigation application using a Wi-Fi positioning system which allows the shopper to navigate their ways in shopping and receive the information on each of the stores.

Key words : Framework, Indoor Navigation, Usability Testing, WiPS.
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1. INTRODUCTION

Have you ever been lost inside a shopping mall? The navigation process in an enclosed mall can be challenging due to similar hallways and structure design and color. Although technology today can users with comfortable outdoor navigation solutions using Global Positioning System (GPS). GPS is one of the famous positioning systems that commonly used to locate the location and position of an outdoor object [1]. However, locating an indoor object using GPS is not reliable due to the GPS signals transmitted through waves at a frequency that does not move easily through a solid object like walls [2]. A wide variety of physical barriers make GPS signal difficult to pinpoint shopper's location accurately in a shopping mall. Thus, shoppers cannot enjoy the benefits of outdoor navigation applications inside an enclosed building such as a shopping mall. This is because GPS data is not reliable or not available inside buildings [3]. Fortunately, this paradigm is changing due to the ubiquity of low-cost mobile devices. Therefore, developing a specific mobile application for the shopping mall will solve the indoor navigation issues. Thus, an indoor positioning system (IPS) that tracks and locate indoor object had been introduced to overcome the issues [4]. An IPS is a positioning system used to locate objects inside a building using different technologies, including radiofrequency using distance measurement to nearby anchor nodes (nodes with known positions, for instance, WiFi access points), magnetic positioning, audible sound positioning, etc. [5].

Wi-Fi is a technology that is adopted on most of the mobile devices such as Android, iPhone, and iPad. WiFi-positioning system (WiPS) uses wireless LAN technology to measure the location of each mobile terminal. WiPS do not need any additional devices for location sensing due to mobile terminals are equipped with wireless LAN (WLAN). WLAN coverage is usually available in public places such as a shopping mall university and office. Therefore, it is not necessary to use additional hardware and infrastructure for internal tracking purposes [6]. In this work, a shopping mall (Lowyat) indoor navigation application using WiPS is proposed. WLAN coverage is available in Lowyat Plaza. The application should offer basic navigation to help shoppers in all their activities take place inside the shopping mall.

This paper is organized as follows: Section 2 briefly reviews the existing indoor navigation mobile application especially the application used in shopping malls. The research

methodology is presented in Section 3. It discusses the proposed framework, use case and the output of the application for this work. Section 4 presents the evaluation procedure and the usability testing results of the proposed application. Section 5 will conclude this work.

2. OVERVIEW OF EXISTING INDOOR NAVIGATION APPLICATIONS

It was pretty easy for users to find their way to the desired destination using outdoor GPS with a smartphone [7]. However, people always have a high possibility to get lost indoor. Hence, indoor navigation mobile application should be introduced to locate people or objects inside a building. Indoor positioning or navigation is defined as any system that provides a precise position and navigation inside a closed structure, such as a hospital, airport, shopping mall and other closed buildings [8]. There are many existing indoor positioning and navigation mobile applications in the market, for instance, The Dubai Mall [9], InMapz[10], AnyPlace Indoor Service [11] and Sunway Pyramid application [12].

The Dubai Mall is the second-largest mall in the world, it has a total internal floor area of 5.9 million square feet. There are high chances for the visitor or even locals to get lost in the Dubai Mall. It has more than 1,200 stores and also 200 food and beverage outlets. The management had introduced an indoor navigation application with its very own GPS-like system to solve the problem. This application is available for free on both Android and iOS devices. Shoppers can search the store they are looking for and the application will instantly navigate them to the desired stores. This application also provides other information like events, promotions and parking systems in the shopping mall.

InMapz is an indoor navigation application for airports, malls, resorts, hotels, universities, amusement parks and hospitals. InMapz provides users detailed maps and way finding directions. InMapz able to provide walking direction to the users inside a building. Users can find facilities like restrooms, food and beverage and walking directions to those facilities. The application can handle complex routes even the stores are located on different levels. Store's details information for example open hours, address, phone number can be found from the application. InMapz maps are interactive showing the user's location and all the points of interest are searchable from the application. InMapz can also be found in certain shopping malls and airports in Las Vegas, Bangkok, Hong Kong, Indonesia, Philippines and Vietnam.

AnyPlace is an indoor navigation application developed by the University of Cyprus. AnyPlace seamlessly integrate GPS (for outdoor) and WiFi and sensory technology (for indoor) to realize an extremely accurate navigation application (accuracy less than 1.96 meters). AnyPlace deploys big-data management, crowdsourcing, mobile data management, multi-device optimization and energy-aware processing to realize the efficiency of indoor navigation technology.

Sunway Pyramid shopping mall has launched its mobile navigation application by using Google Maps engine and WiFi signal to determine the user's location in the mall. This application enables the shoppers to navigate around the 1.8 million square feet of space spanning four floors with over 1,000 stores. Sunway Pyramid application also provides users with exclusive rewards and promotion from certain stores

Based on the reviews, most of the existing indoor navigation applications are using WiPS technology to provide a navigation function. WiFi technology is the most commonly employed technique for indoor navigation because it is already worldwide deployed [13]. Furthermore, the major feature of WiPS is when the density of mobile users increases, the accuracy of location information will increase. Hence, WiPS technology is a technology that is suitable to use in developing a shopping mall indoor navigation.

3. SHOPINDOOR FRAMEWORKS

The methodology section discusses the development of indoor navigation namely ShopIndoor using WiPS technology. An indoor positioning system (Indoor Google Map API) is used to achieve the indoor navigation function. Researchers can develop an indoor navigation mobile application based on the framework suggested.

There are four main entities for ShopIndoor framework; user, application, database and Indoor Positioning System (IPS). Users can make several requests such as location maps, shop searching, information, latest promotions and navigation request through the application user interface. The application will then react by retrieving the required data or information from the database. For instance, the application can retrieve the location map, shop list, information and latest promotions that are stored inside the database. Once the information is retrieved successfully, the application will display it through the user interface. As for the navigation request, the application will access the services from IPS through APIs. The application will then allow the navigation service to be provided to the user. Once the real-time location of the user is tracked, then a complete navigation function will be display. The detailed direction guide and the route to reach the destination from the current user's location will be shown together with an indicator on the map that will move along with the user's movement.

The indoor navigation function implemented in this application is based on WiPS. This function can be divided into two important parts; direction guide and actual navigation. As for the direction guide, it can detect the user's current location using WiPS or the user can manually specify a starting location, followed by selecting the final destination. The APIs used in this application for direction guide functions are the Directions API and Maps SDK API [14,15]. Google

WiPS uses GPS to determine Wi-Fi networks which can then be used to find someone's location based solely on Wi-Fi. Google Maps is allowed to display in the application by using the Maps SDK API. The Directions API will generate the most efficient routes when calculating the directions. Travel time is the primary factor being optimized, but the Directions API will also consider other factors for instance the number of turns and distance when deciding which route is the most efficient before it displays to the shoppers. All the ID and location (latitude and longitude) of the stores will be stored in the database. WiPS will then track the real-time location of the shopper. An indicator will be displayed on the map to show the current location of the shopper and if there is a movement from the shopper, it will then update in the map real-time. Figure 1 shows the context diagram for the ShopIndoor application. The context diagram defines the boundary between the application, its environment and shows the entity that comes interact with it. It aims to explain the overall function required by the entity.

Devices used by users that have both Wi-Fi and GPS can be used to send information about a location back to application so that the application can determine where the location is. This works is done by sending the access points along with the location determined by the GPS function of the devices. When GPS is used to determine the location of the device and also scans the nearby networks for publicly accessible information. The information on location and nearby network will be recorded. When someone approaches to one of those networks, the location of the networks can determine the approximate location even though the users having a weak GPS signal device. The application constantly refreshes this information to ensure all of this information can provide more accurate location services.
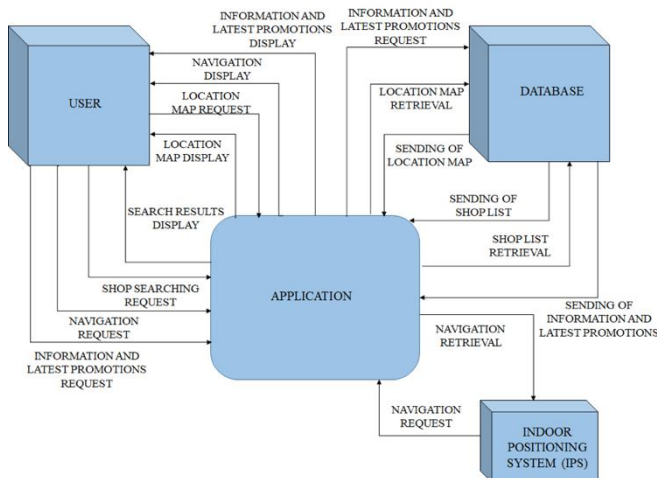

Figure 1: ShopIndoor Context Diagram

4. USE CASE

Use case diagram is to identify, clarify and organize ShopIndoor application's requirement. Figure 2 shows the use case diagram for ShopIndoor application. The use case

diagram will summarize the relationships between use cases, actors and application.

Figure 2: ShopIndoorUse Case Diagram

Users able to register an account, login account, view shop list, search shop, and see the location map. From the function of the shop list and search shop, users able to view information and latest promotions from each shop and use the direction guide which will navigate them to the desired store.

Table 1 to Table 4 show the use case specification for ShopIndoor application. Use case specification is needed to capture the specific details of the ShopIndoor use case. Use case specifications provide a way to capture the functional requirements of ShopIndoor application.

Table 1: User Case Specification for Account Login

ID	1.0	
	Name	Login Account
Use Case Definition	Short Description	User has to login account before using the functions in this application.
	Actor(s)	User
	Pre-condition	User has an account
	Post-condition	User will be able to access the application
	Main Scenario	1. User enters username and password. 2. User clicks on "Login". 3. System will check the login credentials. 4. If the login credentials are valid, system will display the main menu.

Table 2: User Case Specification for Account Registration

ID	2.0	
	Name	Register Account
Use Case Definition	Short Description	User has to register an account before using the functions in this application.
	Actor(s)	User
	Pre-condition	User does not have an account
	Post-condition	User will be able to login to the system with the new account
	Main Scenario	1. User clicks on "Register" at the login page. 2. System will display a page for registration. 3. User has to enter all the required information. 4. User has to click on "Submit" after complete the information 5. System will check whether all the required information has been entered by the user. If yes, a new account will be created.

**Table 3:** User Case Specification for Location Map Viewing

ID	3.0	
	Name	View Location Map
Use Case Definition	Short Description	User can view the location maps provided by this application.
	Actor(s)	User
	Pre-condition	User has successfully login
	Post-condition	User can choose to view location map for respective floor.
	Main Scenario	1. User clicks on "Start"on Main Menu. 2. User has to choose one shopping mall. 3. User then clicks on "Location Map". 4. User chooses a floor. 5. System will display the location map for the selected floor.

The prototype developed in this study is focus at only one shopping mall in Malaysia; Lowyat Plaza. Lowyat Plaza is the oldest shopping mall specializing in IT and electronics products in Kuala Lumpur, Malaysia. Figure 3 to Figure 7shows the output of the Lowyat Plaza indoor navigation application using WiPS. Users are only allowed to access the functions in the application once they had successfully

registered and logged in to ShopIndoor. There are three functions available at the main menu; Shop List, Location Map and Search Shop. Choosing any function of these will direct the user to the interface with the respective function. A list of shopping mall stores will show in the Shop List interface. User can access the store information and promotions by selecting a specific store in the list. The map of the shopping mall will show in the Location Map interface. Users able to select the location of each level; LG, G, UG and L1 and the respective level will then display in maps. Users also can search specific shop by entering the category or keywords of the shop in Search Shop function. The search results will then display in the same interface. Users can view the store's information and promotions or start the navigation guide to assist user navigation to the specific store.

Table 4: User Case Specification for Shop Searching

ID	4.0	
	Name	Search Shop
Use Case Definition	Short Description	User can make search specific shop based on the category and keywords entered.
	Actor(s)	User
	Pre-condition	User has successfully login
	Post-condition	User can start the direction guide or view the information and latest promotions of the selected shop.
	Main Scenario	1. User clicks on "Start" on Main Menu. 2. User has to choose a shopping mall. 3. User then clicks on "Search Shop". 4. System will display the Search Shop interface. 5. User has to enter the category and keywords about the shops. 6. System will display the search results on the current interface. 7. User clicks on a shop in the search results.Application will display the information and latest promotions of the store or user can start the direction navigation to assist him/her to navigate to the store.
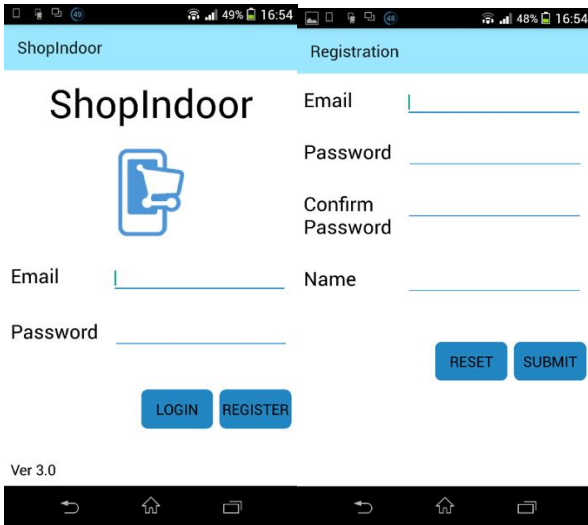
(a) (b)
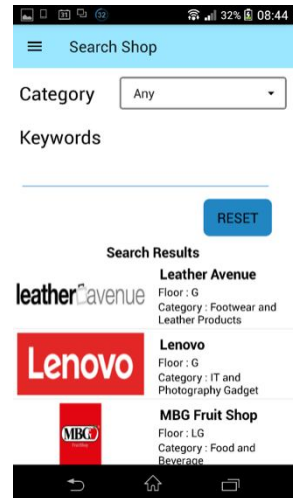**Figure 3:** (a) Loginand (b) Registration's User Interface
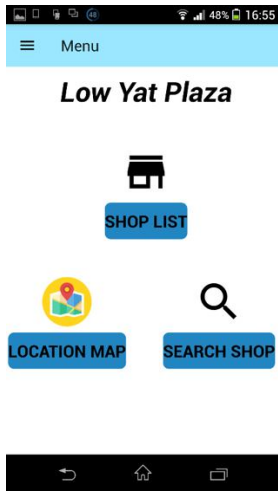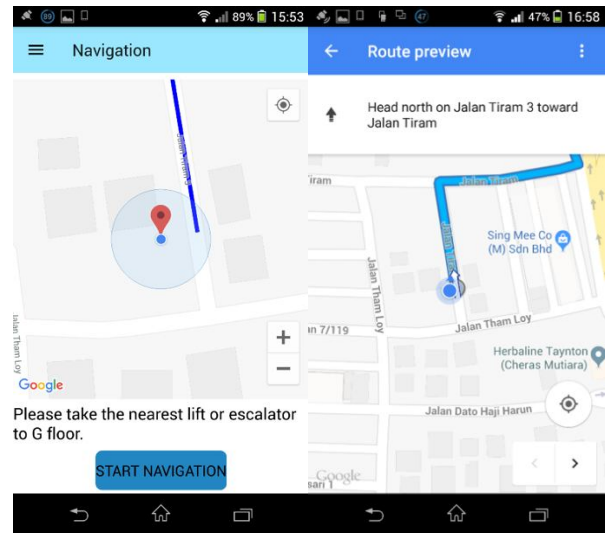

Figure 4: Main Menu's User Interface

(a) (b)
Figure 5: (a) Shop List and (b) Location Map's User Interface

Figure 6: Shop Searching's User Interface
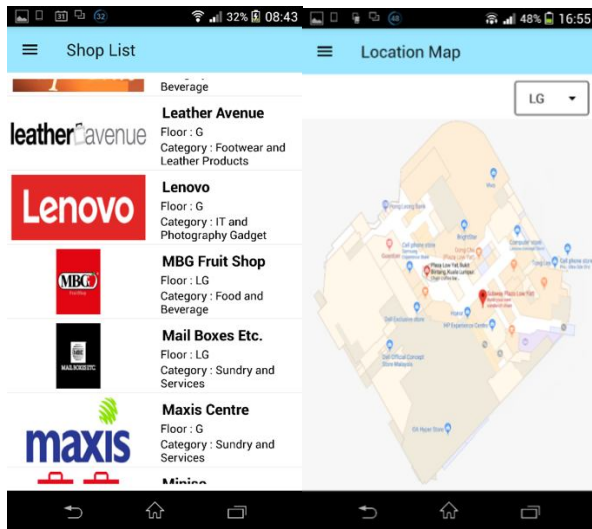

(a) (b)
Figure 7: (a) Navigation and (b) Route Preview's User Interface

5. EVALUATION PROCEDURE AND RESULT

Evaluation procedure is defined as a process of evaluation that evaluates either the specific application or the system meets its originally specific requirement or not [16,17]. Usability evaluation had been carried out to ensure the satisfaction of users toward this application. The evaluation of ShopIndoor had been conducted based on four factors; usefulness, ease of use, efficiency and aesthetic. The questions for each factor are adopted from the previous researches [18–21]. Usefulness measures whether this application is needed and useful to users, efficiency provide subjective data on how the application will help the user to reach a destination with a short time, ease of use will find out whether the functions in the application are easy to use and the contents are easy to read, and aesthetics is to measures the general view of users towards the application.

The evaluation involved twenty (20) female and twenty (20) male participants randomly interviewed within the

LowyatPlaza. They were aged between 18-45 years. The application has been demonstrated to let the user understand the function of the application before the evaluation process. The evaluation process took twenty minutes not including a demonstration of ShopIndoor. Respondents need to run and play around the application before answering the questionnaire. The questionnaire is based on a 5-point Likert scale that rates from Strongly Agree (5.00) to Strongly Disagree (1.00) [22,23]. Table 5 shows the usability evaluation results and Table 6 shows the Likert-scale point and corresponding level.

Table 5: Usability Evaluation Result

Factor	Mean ± SD
Usefulness	**4.73 ± 0.49**
The information, function and data visualization in ShopIndoor application is useful to me.	4.60 ± 0.57
The application meets my needs.	4.75 ± 0.45
Using the application is a good idea.	4.70 ± 0.45
ShopIndoor application has all the functionalities and capabilities I expect.	4.85 ± 0.49
Ease of use	**4.80 ± 0.47**
Content on the application is clear and easy to read.	4.65 ± 0.45
It requires the fewest steps possible to accomplish what I want to do with it.	4.70 ± 0.55
It is easy to interpret or understand the displayed information and output on ShopIndoor application.	4.75 ± 0.61
I thought the application was easy to use.	4.85 ± 0.44
The input and text entry methods for this application are easy.	4.90 ± 0.41
I can use it without written instructions.	4.95 ± 0.35
Efficiency	**4.57 ± 0.66**
The application saves my time when I use it.	4.70 ± 0.77
Tasks on ShopIndoor application has successfully completed within a reasonable time.	4.90 ± 0.41
The visualization of data on this application speeds up my process of interpreting information	4.10 ± 0.79
Aesthetic	**4.31 ± 0.70**
I feel happy with the design of ShopIndoor application.	3.95 ± 0.89
I found the user interface of ShopIndoor application is attractive.	3.75 ± 0.65
I think the using of this application would be pleasant.	4.60 ± 0.50
The design of the graphic symbols, icons and labels on the icons sufficiently relevant.	4.75 ± 0.81
Generally, I am satisfied with the user interface of ShopIndoor mobile application.	4.50 ± 0.61

Table 6: Likert-scale and Corresponding Level

Likert-scale point	Performance Level
0-1.67	Poor
1.68-3.34	Average
3.35-5	Good

Table 6 shows that the mean for all factors are more than 4.23 which indicate a good level of performance by referring the Likert-scale Point as shown in Table 5. Ease of use obtain the highest mean value (4.77) compare to other factors. It implied that the users can use the application easily without any specific skills to operate the application. Respondents agreed on the usefulness and the need of the application as this factor successfully obtain a mean value of 4.45. A mean value of 4.33 is achieved for efficiency factors shows that the respondents can achieve their goal within a reasonable time. The design of the user interface is acceptable by the users as it obtains a mean value of 4.23 for aesthetic factors. The above result supported by the feedbacks or the comments that respondents given in the open-ended questions at the end of the questionnaire.

Furthermore, there are total eleven comments were obtained from the open-ended question There are five comments related to the usefulness of the application for example: "The idea of this application is great and very useful to the users", "A good application that can help people to have better understand of the building", "Very useful to the customers", "Very useful and convenient" etc. While there are four respondents' comments are related to easy to use such as: "Easy to use and simple enough for the users especially the foreigners", "Simple enough for anyone to use", "High user-friendliness and ease of use" etc. The rest of the respondents provide suggestions for future improvement with additional features. Respondents suggest to include more detail about every store such as the items sold, operation hours and support multi-language. Some of the negative comments which are related to aesthetic factor. Based on Table 6, the means for question "user interface of ShopIndoor application is attractive" is lower than 4. Hence, there are some suggestions from the respondents to further improve the user interface for example using the right color theme, rearrange the icons and buttons and provide sound feedback.

6. CONCLUSION

In this work, a new real-time indoor navigation for shopping mall is proposed based on the WiFi-Positioning System. This work clearly describes the framework and function used in the ShopIndoor application based on WiPS. In general, the real-time indoor navigation system designed and developed in this work is useful, easy to use and it is efficient due to its high positioning accuracy and it provides the right information at the right time. The future developments will include more shopping malls, enhance the user interface and adding the sound feedback in order to further improve the usability of ShopIndoor.

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