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THE APPLICATION OF AXIOMATIC DESIGN THEORY ON A CELL PHONE INTERFACE FOR LOCATION-BASED BUS APPLICATION

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ABSTRACT

This paper presents our design for a user interface for mobile phone applications that enable location-based real-time transportation information such as bus routes and schedules. We solve three important user interface issues--inefficient structure, limited information, unsatisfactory visualization. Our program provides shortcuts to help switch to other parts easily. We change the display method from table view to graphical view. In addition, our program provides detailed information such as the number of transfers and location of bus stops.

Keywords: User Interface, Bus routing, Location based, Axiomatic Design

1 INTRODUCTION

Every morning, the bus station is crowded with many people waiting for a bus that arrives at the station on an irregular schedule. They may end up being late for work because of a late bus. They want to know when the bus arrives so that they can manage their time efficiently. There are several mobile phone applications to help the users by searching for real-time bus information. These applications help relieve some discomfort by providing information. However, these existing applications are still inconvenient in their user interface (UI). For example, information is presented in text format which is not an efficient or effective way to organize information because the user cannot easily compare information. Furthermore, visual information such as the bus's current location is not accessible when information is provided as text. Also, the current solutions have a complex underlying structure which results in a UI that does not allow easy switching among different viewing modes. To tackle these problems, we used the axiomatic design theory to formalize the user needs and functional requirements and designed an improved user interface with design parameters that satisfy the requirements.

Our clients are government agencies that promote public work for improving the public transportation programs and transportation infrastructures (for example, Kyung-ki province and Seoul). Our final users are citizens who use both mobile phones and public transportation.

In Section 2, we will start by looking at some existing applications and their merits and shortcomings. Then, we will present the results of our customer research. Section 3 presents the process of taking customer needs and coming up with alternative design concepts, defining functional requirements based on customer needs and design parameters to satisfy the FRs. We then describe our design testing which led to our final design. We conclude with a remark on our design significance and directions for future work.

2 BACKGROUND RESEARCH

2.1 PRIOR ART

Figure 1 Oz phone bus route information service[1]

Figure 2 Kyung-ki province bus route information service[2]

We have studied two existing bus route information services for mobile phones in Korea. One is by a mobile phone content delivery service called "Oz", and the other is by a regional government service in the Kyung-ki province.

In both systems, users can search information by using three criteria (route number, bus stop number, and bus stop name). Users can input a bus number, bus stop number or name of bus stop to get the buses' current location or number. Also, in case of Kyung-ki province's system, users can search for a specific location, and the application shows buses that go through that location. It displays information by using text. The Oz phone uses different fonts to emphasize the current bus location.

The Oz phone consists of two parts, a main menu and a bus route view. This program has just these two parts so it is

quite easy to move to the other part by the "back" button. On the other hand, in the Kyung-ki province's system the user needs to perform several clicks to approach the information, but it provides only the "back" button, so it is difficult to move from the first screen to the last one. The final information the user gets are bus location, bus stop and bus route. The Oz phone provides time interval between several buses, and the Kyung-ki province's system gives information about subway stations near the bus stop.

2.2 Results of Customer Surveys

To find out how the users feel about a location-based mobile bus information application, we conducted a user study with two questions. The first question aims to find the important factors in such an application. The question was "If you search bus route or arriving time with mobile Internet service, which factor do you think is most important?" 53 percent of respondents answered that quickness of search is the most important factor, followed by easy to compare (47%), and graphical view (11%). The second question aims to find shortcomings in the existing systems. Since most people are not familiar with either of the two systems, we want to find why they rarely use such a system. Many people (over 50%) answered that they do not know the existence of it. From this question, we cannot find a meaningful answer, but we confirm that the current bus information systems are still in infancy, so at the least, they need more publicity. We inferred several factors behind these results. We concluded that the expensive price of mobile internet service, ineffective visualization, and errors in information are major factors of lack of use. Detailed procedure and result of survey are in Appendix A.

2.3 Final Customer Needs

From the customer survey and discussion to find out hidden needs, we identified five customer needs – quick search, graphical view, accuracy, simplicity to switch view to compare information of more than one bus, more detailed information. We take first CN as quick search because most people (53%) answered that speed is most important factor when we search information. Most users of existing applications struggle with text-based information that is not presented well, so it is hard to see. Many people (33%) answered that they want to see a graphical view that is more convenient to get information at one glance. Although an unexpected situation may occur such as traffic jam and construction, the user needs to know precise prediction as much as possible. So, accuracy was selected as a third CN. Users of existing program reported that the system provides information of only one bus so it is difficult to compare with other buses. Therefore, users need a system that enables easy comparison of information about several buses. Lastly, users want to know more detailed information such as number of times to transfer and locations of bus stops.

3 Applying Axiomatic Design and Development of Optimum Cell Phone Interface for Bus Routing

3.1 Alternative Design Concepts

Our concepts are mainly classified by the visualization of the information, and the differences in visualization lead to differences in processing rate and usability. The strategy of the first concept is fast and simple. This concept consists of only two levels – a main menu and a results view. In the main menu, it provides only one searching bar for inputting the arriving point. It sets the starting point as the current location of the user automatically. The result view shows the information as a table. The strategy of the second concept is improving the graphical view and the way to provide information efficiently. In the main menu of this concept, a text box for inputting the starting point is added to give the user a choice to start the search from a location different from the current user location. In the results view, we visualize information in two ways – a graphical view and a table view. The strategy of the last concept is to show specific information as much as possible. This is concept designed to meet the customer needs of accuracy and more detailed information. The third concept provides information as a map to give more detailed information. Other parts are same as the other concepts.

3.2 Evaluate Concepts

We evaluate concepts by three main measures – usability, visualization, and easy to implement. Usability means that program should be comfortable to the user. This category is separated by five factors to achieve usable program - Fast search, Easy to convert, Easy to compare among buses, loading rate. In fast search category, we evaluate how fast user can get wanted result. Easy to compare category is related with showing method such as table, graphical views and map. Loading rate is related with application's processing rate. Processing rate is relevant with amount of information. More complicate showing method like maps needs more information, however, less complicate method like text needs less. Last category, Wide range of option means if users use graphical views or maps, their options are added.

In the visualization category, we measure how emphasize on visualization in the program. Last category is easy to implement.

We evaluate our concepts by weighted decision matrix with above selection criteria. According to this method, concept 2 got the highest score so we chose concept 2 for our final concept. After this process, we develop only concept2 and do not use any method suggested in other concepts because our project is about program. Program does not need alternative solutions but it needs only optimized flow.

Table 1 Weighted decision matrix

		Concept 1		Concept2		concept3	
Selection Criteria	Weight	Rating	Weighted score	Rating	Weighted score	Rating	Weighted score
Easy to convert	10%	4	0.4	4	0.4	4	0.4
Fast search	20%	4	0.8	3	0.6	3	0.6
Easy to compare among buses	25%	3	0.75	5	1.25	3	0.75
Loading rate	20%	5	1	4	0.8	2	0.4
Visualization	15%	2	0.3	4	0.6	5	0.75
Easy to manufacturing	5%	5	0.25	4	0.2	3	0.15
Wide range of option	5%	3	0.15	4	0.2	4	0.2
Total	100%		3.65		**4.05**		3.25

Weight is decided based on customer survey and our discussion about important factor of our program. We give

more points on the factor which is necessarily improved to solve problem of UI of existing program.

We thought that most important factor to be improved is comparison between buses. This is not convenient in existing program. And the factor which has most biggest weight except 'Easy to compare among buses' is Loading rate and Fast search. These are the most important factor which user thinks when they use searching program. These factors have parallel meaning, so we give same weight on it. Next highest one is visualization. Since this factor lacks in the existing program, provided information is inevitably limited. So, this factor is necessary to provide more information such as location of bus stop. And the last one is easy to implement and wide range of option. These factors have no difference among three concepts and not the important factor. Some of reader would pointed out that implementation easily is most important but our program is vey technically achievable as I mentioned in our design significance section. So, we do not need to care too much on this factor.

3.3 DESIGN DEVELOPMENT

3.3.1 FUNCTIONAL REQUIREMENTS AND DESIGN PARAMETERS

FR 1 and its sub-FRs satisfy fast search customer needs, simplification of screen expression and readily conversion in application promotes fast searching. The method to read and load information meets the requirements for fast searching and being informed accurate and detailed bus information. These requirements fit for FR2. Besides, FR3 is requirements for efficiently displaying information. We decide categories in FR3 to satisfy customer needs, graphical views and easily comparison with information. In these categories, there are standard screen showing and details. There exists several showing methods for priority order of buses, simple graphical views, sort of bus, way to convert bus route and fare. Structure for DPs is the same with that for FRs. Following table is full decomposed functional requirements and corresponding design parameters

Table 2 Functional Requirements and Design Parameters

FR1 Fast Search.	DP1 Method to increase searching speed.
FR11 limit amount of information.	DP11 Select important information.
FR111 Narrow range of domain(area including the bus route).	DP111 Set range of domain on setting menu.
FR112 Simple expression of screen.	DP112 Express as dot, line.
FR113 Show only fastest three ways.	DP113 Compare among possible route and choose only fastest three way.
FR114 Show only meaningful bus.	DP114 Remove information of bus which passes bus-stop, and displace it with fourth one.
FR12 easily convert and connect to other contents.	DP12 shortcut.
FR121 easily change setting.	DP121 shortcut for setting menu.
FR122 easily convert to searching bus information.	DP122 shortcut for converting.
FR123 easily refresh.	DP123 shortcut for refresh.
FR2 Reading/Loading Information.	DP2 Reading/Loading information system.
FR21 Setting starting point.	DP21 Using GPS system.
FR211 Recognize user location.	DP211 Using GPS system.
FR212 Setting starting point as input value.	DP212 Using GPS system.
FR22 Range of domain for loading.	DP22 Set range of domain on setting menu.
FR221 Mode setting for distance.	DP221 Set range of domain on setting menu.
FR2211 Established modes(Default).	DP2211 Set the 1km^2 as a default value of range to show.
FR2212 User setting(modify in setting menu).	DP2212 Choose among these options - 0.5km^2/ 1km^2/ 2km^2.
FR3 Display information.	DP3. Method to display information.
FR31 Main screen.	DP31 Put main screen as highest level of our program.
FR311 Recent searching result.	→ DP311 Showing recent searching result on the right side of main menu.
FR312 Search bar.	→ DP312 Provide text field to search.
FR32 Result of searching bus stop.	DP32 Showing result as graphical view.
FR321 Location of bus stop.	→ DP321 Display location of bus stop as on the graphical view directly.
FR322 Way to get bus stop.	DP322 Showing way to get bus stop as graphical view.
FR323 Sum of waiting time and predicted time to get out destination.	DP323 Showing sum of waiting time and predicted time to get our destination above the signature of bus-stop on graphical view.
FR33 Information about bus.	DP33 Convert to graphical view to table to show information about bus when user get into the range of bus-stop.
FR331 Bus number.	DP331 Show bus number on the first column of table.
FR332 Hide column which is unnecessary to user.	DP332 Narrow column's width in similar way 'function of hiding cell' provided by EXCEL.
FR333 Show priority order in each case (standard).	DP333 Set colors according to each standard(waiting time, going time, sum of two values) Put colored circle on the left side of table to show priority order.
FR334 Predicted time to get our destination.	DP334 using GPS system, receive bus velocity at that time and remain distance from bus stop. Using these parameter, calculate predicted time.
FR335 Predicted time to wait.	DP335 using GPS system, receive information about traffic situation. And using average velocity at that day and remaining distance from here to our destination. Calculate predicted time.
FR336 Number of times to transfer.	DP336 Search among the all bus information
FR337 Classify buses.	DP337 Set font color differently to indicate sort of bus (local line bus – green, main line – red, urban bus- blue, yellow).

3.3.2 DESIGN MATRIX

Most FR/DP pairs have no relationship. However, there are some FRs which has relationship with corresponding DPs, such as relationship with FR1/DP1 or FR31/DP31 or R2212/DP2212. (i.e. Our matrix is decoupled) In addition, there exist couplings with not corresponding FR/DP pairs. We revised FR/ DPs to reduce couplings with not corresponding FR/DP pairs. Figure 2 shows our final fully composed FR/DPs matrix. There still exist several couplings. FR321 and FR322 have couplings with DP21, DP211 and DP212 because it needs GPS system for searching locations of bus stop or ways to get bus stop. FR111 has couplings with DP22 DP221, DP2211 and DP2212 because these DP need to set and narrow range of domain that program reads.

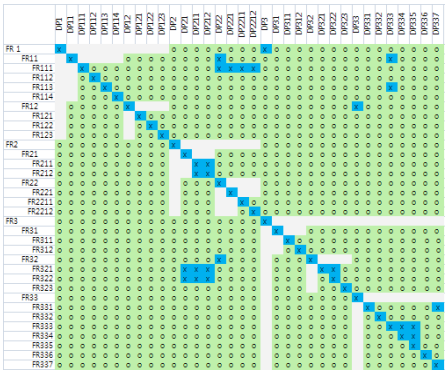

Figure 3 Design matrix

3.3.3 DESIGN TESTING

After determining the concept for the final design, we tested the design twice. The first test was to find out defects in our program and discover functions which potential users want to add. The second test aims to confirm whether our final design is useful to users. Our chosen concept is revised based on the first design testing. Below paragraph, there are detailed explanations about design testing

3.3.3.1 FIRST TESTING

First testing is done by eight chosen potential users. We explained our concept in detail with prototype. We asked them some question. Prepared questions are not specific but just narrow the field. We write down what they said and analysis answers to revise chosen concept. Prepared questions are followed.

1) Detail function
2) Efficiency (structure, usability)
3) Will you use this program frequently?
4) What function do you want to add?
5) If you do not satisfy with our chosen concept, please tell me why you do not like this.

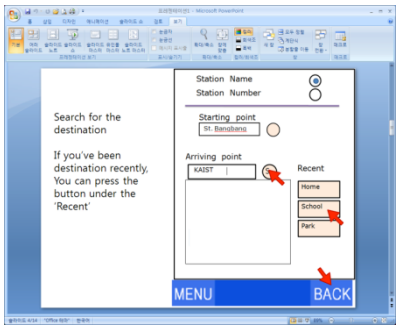

Figure 4 Prototype used in first testing

According to above procedure, we get result of first testing. People do not mention about detail function. All of them answered that they are satisfied with our detailed function.

In the second category, efficiency, we can summarize answers in two points. First opinion is that the program has simple and effective structures, it can be used at first and it will be comfortable. The other one is that some users think about fast proceeding program, they think that it is waste to express previously passed buses on graphical view or map.

Four groups can summarize answers of the third. The third question was "Will you use this program frequently?" 1st group answered that seldom take buses (1 time per month); 2nd group answered that they take bus but take subway more (1 time per week); 3rd group said that moderate (2~3 times per week); 4th group said that they take bus frequently (4~5 times per week).

The fourth question was "What function do you want to add?" The answers of interviewees can be summarized in five points. They suggested that we need to improve the function of considering specific bus stop and exact destination so that let users know what bus stop nearby their destination. They also said that users want to know the moment when bus arrive user's destination by function of alarm. Third suggestion was our concept need to be improved in refresh function. Specifically, we'd better add the function which indicates fastest bus as a first choice to user. The next suggestion was setting range of domain by setting menu is annoying work. Thus, they recommend that the mechanism to change the range of domain has to be changed. Last opinion was related to discomfort caused by small size of screen. They pointed out that our information is too many to show in one screen. Some of them urge to simplify information and show information through more organized display method.

The last question was "If you do not satisfy with our chosen concept, please tell me why you do not like this." Interviewees give us meaningful recommendation. They said that the concept using map is interesting at first, but they won't use map contents to get information. The reason is that switching among two display methods is annoying to users. They also said that table is more useful method than map. Except one thing as I stated above, interviewees are satisfied with our chosen concept. They comment on chosen concept that overall structure is simple and not complicate to use and showing location of both bus and user is efficient function.

3.3.3.2 SECOND TESTING

The second test aims to confirm whether potential user likes it or not. We show revised simulation made by powerpoint to people (20 people), and ask their thought about our solution.

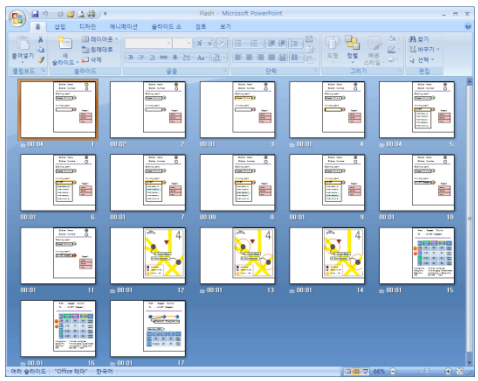

Figure 5 Prototype used in second test

We asked them three questions. The first question was "Will you use our program?" This question aims to find

out the amount of potential user. Ninety percent of them answered that they'll use our program. Second question was "If you check no, why?" This question aims to confirm what the discomfort of our concept is. Seventy nine percent of them pointed out the expensive internet fee. Remaining person answered that they rarely take bus and they satisfied with existing program (8% and 13% respectively) Last question was "How do you think about our program." More than half answered quiet good or good (60% and 27% respectively)

We can get meaningful answers not only one from above questions but also one from their own opinion. Following paragraph is our analysis of interviewees' opinion.

Most people are satisfied with our program and they want to use this program soon, but they said that they will not use this program when they should pay for it. Because, there already exists bus searching program which is free. Although existing program has several uncomfortable UI, they'll chose existing one when we ask them to pay for using our program. Also, they answered high Internet service fee is burdensome. In conclusion, whether using our program or not is depend on fare to use our program.

3.4 DETAILED EXPLANATION OF FINAL DESIGN

Main Screen

Our program aims to find the appropriate bus to get to a destination from a specific point. Therefore, it needs two points – starting point, arriving point. We can input station number or can search for station name. It provides search bars to get information of the starting point and arriving point. If user does not input starting point, program automatically sets the starting point by reading user's location using GPS(Global positioning system). Our program provides a function of automatically complete system that remaining words to reduce number of typing. In addition, our program provides a list of recent place we've searched before so that users just need to click the button.

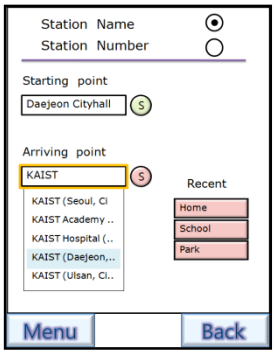

Figure 6 Main Screen

Graphical view – showing location of bus stop

This screen shows up right after click the destination. In this screen, user can see simplified map, location of user (or starting point) and several bus stops near the starting point. The number in the box pointing bus station means total time needed to go to destination. So user can determine profitable station. If we press menu button, we can choose station for collecting information. If we need information of both stations, we can click both.

Red circle around the bus stop icon shows range of bus stop. If user doesn't click for the bus station and goes into the region of the bus stop, the screen switch to next one which shows detailed information about bus at that station.

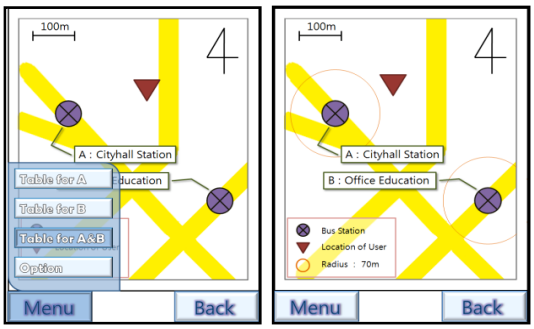

Figure 7 Graphical view to show location of bus stop

Screen for comparison.

After the station(s) is(are) decided, this screen appears. If user select specific bus stop in this screen, user can get information about buses which pass through the bus stop which user selected. If user select bus station A and B, then information about buses of both stations appear in one screen.

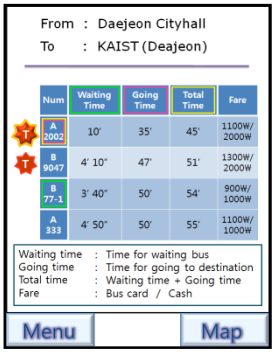

Figure 8 Screen for comparison among information buses' which pass through each bus station

Screen to show information about bus

Our program provides information as table to make user compare the information easily among several buses'. It shows bus number, needed time for waiting, needed time to arrive at destination, total needed time (sum of needed time for waiting and time to arrive at destination), information about transfer and fare. The fastest bus is expressed by colored boundary (waiting time – green, going time – red, total time - yellow). Icons on the left to the bus number mean that user needs to transfer.

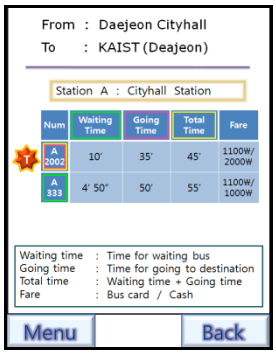

Figure 9 Screen to show detailed information about bus

Transfer Information

If user presses the transfer icon, other screen appears to show more detailed information about transfer. It shows the place you transfer and detail wasting time. You can also get the information about the way you go from transfer place to destination as a graphical view.

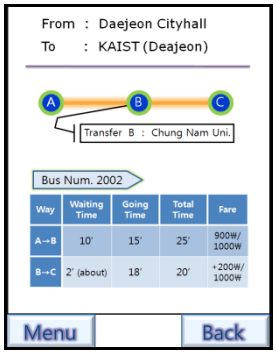

Figure 10 Screen to show transfer information

Shortcuts

Below the screen, there are two buttons – back, and menu. By pressing menu button, user can reach to other information easily. If user clicks the button 'refresh', he or she can get more precise information. In case of button 'convert to other graphical view', you can search for other station. You can also search for other root by click the button 'main page'. These two buttons helps to reduce number of times to click.

4 DESIGN SIGNIFICANCE

Our final solution is distinguished from existing solutions in three points. Firstly, our program fully utilizes the GPS system to provide a location-based personalized service, whereas, in the existing systems, GPS was used merely to confirm location of each bus. In our design, the system utilizes GPS information not only to confirm location of buses, but to get the current location of the user. Hence, our program achieves a UI that is more convenient and familiar to the user. For instance, our program has the ability to automatically set the starting point of the trip by recognizing the current location of the user and to show appropriate bus stops nearby. Secondly, our program shows information more conveniently to the user. Since our program provides information in a table view, the user can easily see a comparison of information about several buses in one screen, a feature that is non-existent in the current systems. Therefore, our program reduces the time required to search and compare information. Lastly, our solution has a simple structure and shortcuts such that the user can switch to other parts and views of the system easily. Existing systems have complicated structures but sonly provide the 'back button' to move to other parts. Hence, the user of has to perform several clicks to navigate through the system. In contrast, the user can use our system and switch to any part of the application in two clicks – press menu button and select where you want to go.

The essential technologies underlying our system are already being used in mobile phones. GPS system is already used in existing solution. Remaining technologies such as showing information in a table and providing shortcuts is only a matter of design, which was our original problem. Therefore, our solution is very technically achievable. Also, we have just few economic difficulties when we are in the developing stage. GPS system which is necessary to our program is already settled and our client, government agency can afford to support any work what we do. However, high Internet service fee is burdensome so that some of users may avoid using our program. Furthermore, it costs much money to revise and give out again to upgrade.

5 FUTURE WORK

Our ultimate purpose is comparing bus routes and choosing the best appropriate way to user. At the beginning, we had plan comparing transportation not only bus, but taxi and subway, so on. Then user could compare more information which user needs and choose the best way. However the large amount of data causes we had to cut down our prior purpose.

If we can get one more opportunity and much more time, we would try combine more transportations to search the best way to go destination.

6 CONCLUSION

Our design product is improved in functional and graphical ways compared with existing applications. We also add several functions such as recent, shortcuts, automatically complete to meet with customer needs. We expect that our program contribute to revitalize public transportation. One of the reasons why many people do not use public transportation is due to long waiting time and uncertainty for bus coming. Since our program has better UI than existing solution, the number of user will be increase so that the public transportation will be widely and commonly used.

7 REFERENCES

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