4-2014

Where Am I? : Studying Users' Indoor Navigation Location Needs

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Singapore Management University
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Technical Paper Series

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April 2014

SMU-SIS-14-100

Where Am I?: Studying Users' Indoor Navigation Location Needs

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ABSTRACT

Location has emerged as the single-most important context whilst building pervasive mobile applications. Several mobile applications have appeared that use location to provide a host of services such as location-specific advertising as well as navigation. As a result, the key challenge of positioning techniques has been to provide the most precise location of the user (device) and much effort has been put in computing this fine grained location in indoor environments. This is under the assumption that highly accurate location is crucial for all indoor services. To understand the location accuracy, that should prove sufficient, for users to navigate to a specific store in a mall, we conducted a user study that mimicked the mall-like setting in two university buildings. Our results suggest that for navigating indoors in mall-like settings, users do not require highly accurate location awareness.

Keywords

Indoor Location, Indoor Navigation, Location Accuracy.

Categories and Subject Descriptors

H.5.2 [**Information interfaces and presentation (e.g., HCI)**]: Miscellaneous.

General Terms

Experimentation, Human Factors.

1. INTRODUCTION

Indoor location has received a lot of attention in recent years with many academic and commercial systems attempted. An important usage scenario for indoor location is navigation inside buildings such as shopping malls. Such a service would allow users to identify their position in a mall and aid them in locating other stores. The usefulness of such a service is evident from Google's attempt at supporting indoor navigation in several shopping malls across different cities. However, realizing this service requires either specialised hardware [4, 12], which hinders deployability, or needs fingerprinting of the environment [1, 3, 5] that adds a significant manual overhead, both to support new buildings as well as to maintain existing buildings where the environment has changed. These overheads are under the assumption that all indoor location services require fine granular positioning.

On the other hand, outdoor navigation techniques using GPS have been around for several years and is normally accurate to 10 meters or so. However, this accuracy has been known to fall off rapidly as one enters an urban environment where buildings block, and reflect, signals. Despite these inaccuracies GPS solutions have proven useful in several consumer product applications. A key intuition is that people are generally resourceful and can deal with such variances. Analogously, in this work, we therefore ask the following question: *What level of location tracking inaccuracy can users work with for indoor navigation-based applications?* We consider this question in the context of shopping malls. Shopping malls tend to be large buildings with many points of interest for the user. Many location-based applications are of practical interest here, from simple location and navigation within the mall, to more complex applications including mobile payments and targeted advertising.

This work is part of a larger research challenge of building an effective indoor location system with existing infrastructure and user hardware that does not require any a-priori fingerprinting or strong knowledge about the environment. We hope by first understanding user-sufficient location accuracy we can build a more practical localization technique with minimal overhead. The key contribution of this paper is:

Identify the location accuracy sufficient for users to navigate indoors: We conduct a user study in two campus buildings to determine the level of location tracking accuracy, that typical users need, to navigate from their current location to a specific room in the building. For this task, which can be considered analogous to the problem of navigating to a store in a mall, we find that users need their present location on a map to be continually tracked with an accuracy of ± 1 store[1].

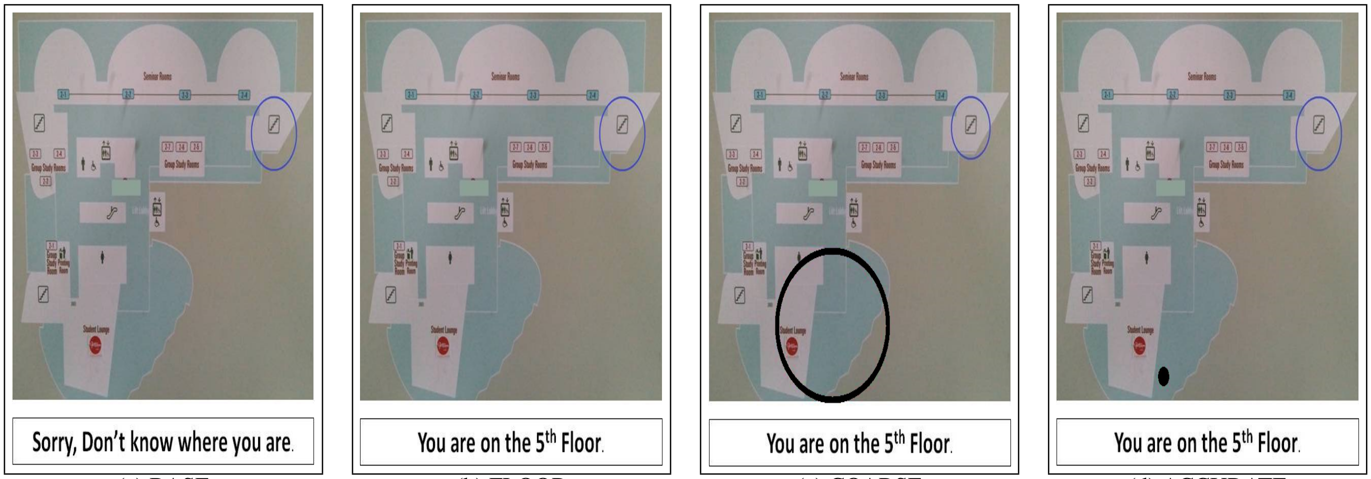
2. THE EXPERIMENTAL APPROACH

In assisting a user navigate towards a destination, we consider the assistance to be useful when 1) the user reaches the intended destination and 2) does so with ease. As the user's current location is crucial for such assistance, in our empirical study, we therefore try to understand the positioning accuracy sufficient for a *successful* and *hassle free* navigation in an indoor environment. We do so by varying the user positioning accuracy shown on an indoor navigation tool and measuring the time taken by the user to perform a simple navigation task. We argue that the quicker a user takes to reach the destination, the more useful is the navigation tool and subsequently the sufficiency of the location granularity provided. In the following sections we give an overview of the location accuracy variants used in our study as well as our experimental procedure.

2.1 Accuracy Variants

To effectively validate the location accuracy needed by end users for navigation, we use four different accuracy variants in our study.

[1] As of Dec. 2011. we observed Avg. storefront width (excluding giant stores such as Macy's etc.) across several malls was 11.6m (std. dev. of 2.8m).

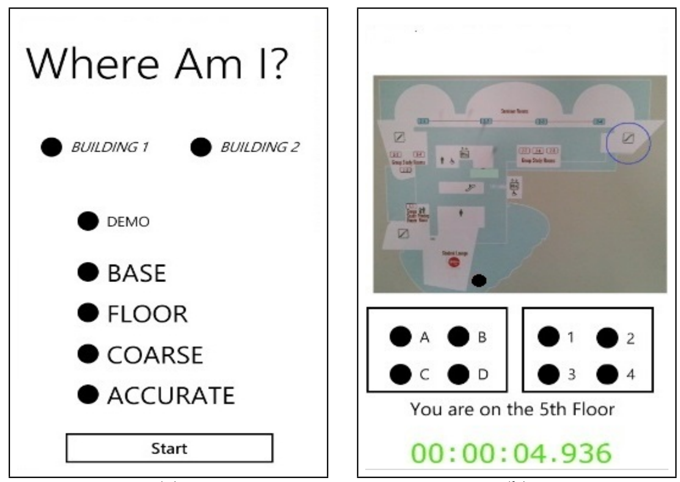


(a) BASE (b) FLOOR (c) COARSE (d) ACCURATE

Figure 3: Accuracy variants of the indoor navigation mobile application

Total Number	24
Gender	Male (14), Female (10)
Age	18-25 (8), 25-35 (10), 35+(6)
How often do you visit a mall?	Everyday (7), Once/Twice a week (15), Once/Twice a month (2)
How much time do you normally spend in a mall?	30min or less (2), 1-2 hours (12), 2-3 hours (7), >3 hours (3)
How often do you need to look at a map to find a store?	Very Often (3), Sometimes (15), Rarely (4), Not at all (2)
How often do you lose track of where you are in a mall?	Very Often (6), Sometimes (6), Rarely (12)
Would a mobile application that showed where you are in a mall be useful?	Very Useful (12), Somewhat Useful (8), Neutral (4)
When searching for a store in a mall you are more likely to:	Look for directions to stores on the same floor (17), Look for directions to stores on a different floor (7)
What level of indoor location accuracy would you be comfortable with?	I always want my exact location (18), My location within 2-3 stores either side is alright (5), I'm fine with knowing which floor I am on (1)
Do you feel more maps should be placed in malls?	Yes(24)

Table 1: User Study Demographic Statistics



(a) (b)

Figure 1: 'Where Am I?' Usage Sequence

We describe the variants in terms of their correspondence to a real mall, although in actual, these variants were adapted to an analogous framework for university campus buildings. Further, in our study each user had to perform two navigation tasks with a different variant assigned for each task. Therefore each user used *only two* (of the possible four) accuracy variants during the study.

The first variant, *BASE* (Figure 3a), displays the map of each floor of the mall without informing the user which floor they are on. This baseline is representative of the options available with current state of art applications such as Fast Mall [2] and Mall Maps [8] which provide end users with shopping mall floor plans and store directories on their mobile device. The second variant, *FLOOR* (Figure 3b), shows users which floor they are on. This variant represents a natural transitional progression between the baseline and the latter systems. The third and fourth variants, *COARSE* (Figure 3c) and *ACCURATE* (Figure 3d), show location of users with accuracies of ± 1 store and exact store respectively.

2.2 The Experimental Procedure

We recruited a total of 24 people for our user study. Our participants were a mix of students and professionals and their demographics are shown in Table 1. Most of the participants visit a mall at least once a week and spend at least 1 hour in the mall per visit. Despite the frequency of visits, they occasionally refer to a map to find the locations of stores.

For the two navigation tasks we used the second and third floors of two academic buildings (with similar sizes and slightly different layouts) to simulate the mall. The actual floor levels of the building corresponded to virtual floor levels in the mall with the rooms in each building acting as store fronts. This was done to distort any floor-level orientation the users had of their current location. The navigation task involved having each user start at the same place on the second floor of one of the buildings and find a room on the third floor of the same building (the users were not told where the room was or on which floor). We minimised any learning effects by a)

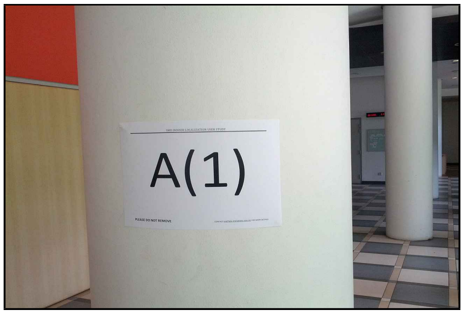


Figure 2: Location Marker. The participants enter the code mentioned on the marker to identify their current location on the map.

performing the second task in the other building, and b) counterbalancing the order of the tasks (i.e., the building order and accuracy variants tested were randomised among all the participants). In addition, we also ensured that all of our participants had never been in either of the buildings before and thus had no prior knowledge of the building layouts.

The experimental procedure for each task was as follows; First, the user was given a scenario similar to a common task in shopping malls that they had to follow ("you are in a mall and trying to locate a store on the 6th Floor"). They were then provided with a Windows Phone 7 phone containing all four system variants described earlier (Figure 1a). Each participant was then given the instructions for our study and provided with basic training in how to use the phone and the Phone 7 OS. In our study, we used a "Wizard-of-Oz" approach where our UI was real, but the location information displayed was predetermined for each task scenario. That is, no location tracking was done in real time; however, signposted landmarks (Figure 2) were provided to help the UI display the participant's current location at the appropriate granularity. So, whenever a participant encountered a landmark and wanted to know their location, they would input the *letter-number* code mentioned on the location marker (Figure 1b). The UI would then display their location with a granularity corresponding to the variant (Figure 3) being used.

Each user was then assigned one of the four systems (no additional information (*BASE*), floor level (*FLOOR*), ±1 store (*COARSE*), or exact store (*ACCURATE*) location information) and instructed to find the required destination (the destination was circled on the map in *yellow*). Their goal was to physically reach the room specified in the task from the starting point with the system provided being their only assist — Users were not allowed to ask for any additional help in the navigation process. To make the task less trivial, participants were allowed to transition between floors *only* by using the stairwells marked in *blue* on the map. As a result the navigation task involved not only finding the destination room but also locating the appropriate stairwell. Tapping the application screen allowed transitioning between floor maps displayed on the tool. Participants unaware of their current floor level had to therefore first identify whether the floor map displayed on their screen actually corresponded to the floor they were currently on. Further, it was also possible to pan the map in any direction by applying pressure to the screen and dragging the map in the desired location. We followed the users and noted the time taken by each to physically reach the destination. We further collected their thoughts on the usability and usefulness of each system.

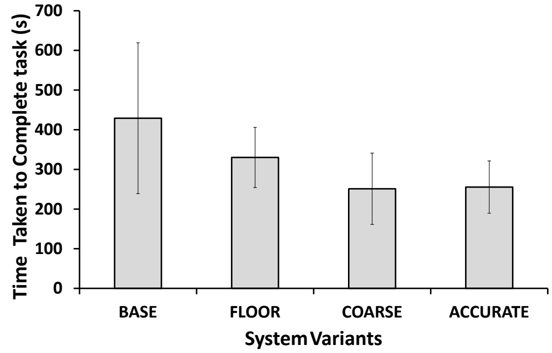


Figure 4: Results of the User Study. The only non-significant difference (using student's t-test with $p = 0.05$) is between the *COARSE* and *ACCURATE* results. All other differences are significant at $p = 0.05$.

3. STUDY RESULTS

Figure 4 shows the results of the user study. We summarise the results for both buildings together as there were no statistical differences between the two sets of results. Since each participant performed only two navigation tasks (using a different accuracy variant each time), each bar shows the average time taken by the twelve participants who used that variant (error bars show the standard deviation).

Our results showed that users can really benefit from more accurate location systems; but only up to a point. In particular, the time taken with no extra information (*BASE*) went from an average of 430s to 330s with floor level information (*FLOOR*) to just 250s with both ±1 store and exact sore accuracies (*COARSE* and *ACCURATE* respectively). In addition, the standard deviations also decreased as we moved to more accurate systems. To verify whether these differences in time were significant, we performed a one-way ANOVA test, with the time taken to find the room as the dependent variable and the accuracy variants as the independent variable. The test yielded a very low p-value ($p = 0.0014$) indicating that the navigation time is dependent on the level of location granularity provided. Further, as we noticed very little difference between the mean time taken using the *COARSE* and *ACCURATE* system variants we performed a student's t-test between the two variants. In particular, there was no statistical difference between the time taken for both systems and the participants also reported no significant usability differences between them. Hence, we conclude that ± 1 store accuracy is sufficient for finding stores in malls. This corresponds to an accuracy of ≈±12m given an average store front width of 12m, which we observed across 11 malls in 3 cities.

Figure 5 shows the user estimates on perceived usefulness of the mobile application variants for navigation assistance. The self-reported scores validate the measured scores - with users finding the *COARSE* and *ACCURATE* variants more useful in aiding the navigation task as compared to the other two variants. However, between the *COARSE* and *ACCURATE* variants, participants found the latter to be more useful. This matched the response participants gave prior to the study as to the level of indoor location accuracy they would be comfortable with; with most participants (75%) wanting a system that gave their exact location as opposed to within 2-3 stores either side (Table 1). Thus we see, that while participants generally preferred a more precise location, they managed quite well with much less.

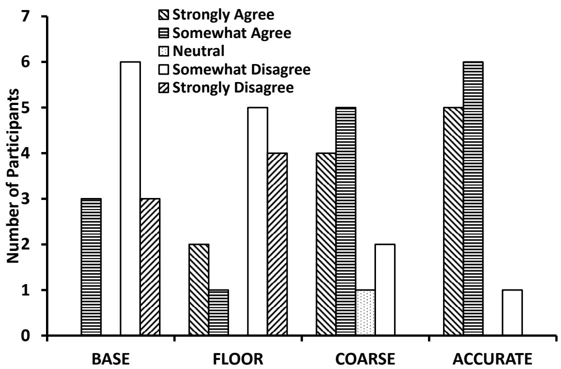


Figure 5: Was the mobile application useful in helping me navigate to my destination?

4. DISCUSSION

In this work, we observed that a location tracking accuracy of $\pm$ 1 room (equivalent to an accuracy of $\pm$ 1 store in a mall) was sufficient for users to locate a specific room (or 'store' in the mall). Intuitively, we know that human navigation abilities can be exploited when continuous localization is not viable. This is clearly evident from the fact that all participants, irrespective of the location accuracy provided, reached the destination. However, as we observed, providing more accurate location information can significantly improve the ease of navigation. Fine location granularity however, will still be needed to achieve a higher degree of pervasiveness. This will assist the envision of providing services such as aisle-level advertising as well as give rise to a new range of applications. We argue that

There are some obvious limitations of the study. The user study used 24 participants in a controlled lab environment. This leads to a clear bias as a) the sample size is small from a social science perspective, and b) the participants in this study were more tech-savvy than the general older population. However, we feel that the results will still be fairly indicative of a large slice of the shopping public.

5. RELATED WORK

To understand what location accuracy users need for indoor navigation in shopping malls, we consider the general and common task of walking to a store in the mall. Prior work [7, 10, 11, 13] has shown coarse location information is sufficient for indoor navigation, but no specific location accuracy requirements were compared. Dearman [6] explored the effect of revealing the error in location prediction to the end user for a poster-finding mission. However, the study was performed outdoors using GPS and hence not reflective of an indoor setting. Much empirical work [9, 14] exists, that has focussed on the design and information requirements for pedestrian navigation. We see our work as parallel to this effort, however, with a focus on indoor environments.

6. CONCLUSION

While research initiatives in improving indoor location accuracy are important for a full-scale realization of pervasive computing, what seems to be missing is concrete work on deploying pervasive services in urban-areas today. An appropriate and cost-effective way forward is to integrate already available technologies to achieve limited pervasiveness in infrastructure and deriving some immediate business benefits.

From this study we observed that users are quite resourceful and can deal with coarse location accuracy when considering a common task of locating a store in a mall. We observed that higher levels of indoor location accuracy provided diminishing returns and solutions that provide practical levels of accuracy are sufficient for most users' indoor navigation needs.

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