Gravity: Automatic Location Tracking System between a Car and a Pedestrian

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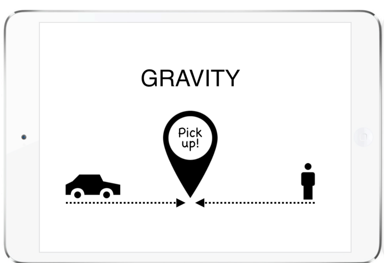

Figure 1. The concept view of "Gravity" we developed. As the name suggests, the main function of the system is to link between a car and a pedestrian in a "picking up" situation.

MobileHCI '14, Sep 23-26 2014, Toronto, ON, Canada
ACM 978-1-4503-3004-6/14/09.
http://dx.doi.org/10.1145/2628363.2634226

Abstract
The use of car navigation system is very common nowadays. Most of the car navigation services are based on turn-by-turn instructions and distance calculations. Academic research in this field has focused on evaluating basic usability. However, such products and studies have not covered users' various needs that arise in specific driving situations. For example, in a complex city space, drivers often face burdensome problems, especially when picking up pedestrians. We conducted a semistructured online survey asking specific problems, work-arounds, and their suggestions in picking-up situations. We grouped responses into several issue points based on their similarities and induced design implications for a car navigation system supporting picking-up situations. Through this user-centered design approach, we developed "Gravity—Automatic Location Tracking System between a Car and a Pedestrian" as a prototype and evaluated its usability, and we received favorable feedback.

Author Keywords
Car navigation system, user-centered design, usability

ACM Classification Keywords
H.5.2. User interfaces.

Introduction

It is very common for drivers to use car navigation systems in a car. Various types of navigation systems such as in-dash navigation systems, personal navigation devices (PNDs), and navigation apps for mobile phones have been introduced so far. In-car navigation systems allow people to move forward the way they did not know before without hesitation. Drivers can get local information about the places that they have never visited before. Like the concept "extension of man" that Marshall McLuhan suggested [9], a navigation system could be seen as a device that enables humans to overcome the limitation of their own space, expanding their mobility.

Despite their benefits, however, navigation systems on the market have rather uniform functions based on turn-by-turn instructions along with distance calculations such as "turn left a hundred meters ahead." They are insufficient to specifically provide situation-dependent information that users want in various way-finding situations. A recent study showed that there are various types of normal and natural troubles when driving with GPS [5]. To solve these different troubles that users face in real driving situations, not only basic instructions but also situation-specific solutions should be considered, which can satisfy drivers' whole user experience with the navigation systems.

To address the issues, this paper intended to develop a car navigation service that can solve specific problems in real driving situations. In particular, we aimed to deal with not a general way-finding situation where the point of interest is fixed but a "picking-up" situation where drivers and pedestrians meet on the road. Picking somebody up is a very common phenomenon, particularly in a complex city space. However, if picking someone up on the road is failed and repeated, it can lead to "phantom jams," in which small disturbances in traffic can become amplified [2]. In this regard, this situation is worth being dealt with in particular.

We have conducted a user survey with open-ended questions to find out users' distinctive behavior features in picking-up situations. Then, we induced four design implications: (1) not affecting safe driving, (2) sharing their points of interest in real time, (3) automatically tracking each other's locations, and (4) recommending spots appropriate for pulling over. We developed the prototype navigation system "Gravity," evaluated its usability, and received favorable feedback from users.

The main contribution of this paper is that we introduced a new concept of "navigation system for a specific situation where bi-directional users encounter" and developed it in practice with a user-centered design approach. We hope that other various problems that users face in real driving situations could be solved with user-centered approaches and could give both the driver and the pedestrian a better user experience.

Related Works

The research in the navigation system area has focused on basic usability. Schreiber studied that the function of a map and its aesthetic perception heavily depend on the user's situational cognitive load [11]. Another research about navigation usability revealed that when using PNDs, wrong messages can potentially reduce the credibility of those devices [6]. Jensen suggested that different output configurations—audio, visual, and audiovisual—of a GPS system affect driving behavior and performance [7]. These previous studies have significance because they have focused on the basic

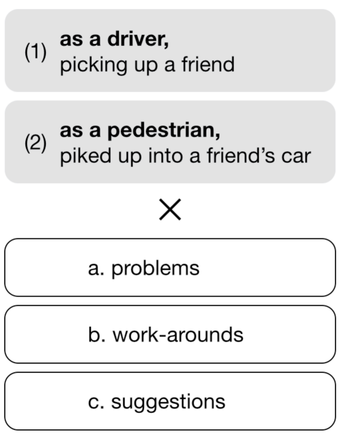

Figure 2. The structure of the user survey. We supposed two specific situations, (1) as a driver picking up a friend and (2) as a pedestrian picked up into a friend's car, and asked specific problems, work-arounds, and their suggestions in each situation.

components of navigation systems in detail. However, research about solving problems in specific situations that users face was rather insufficient.

Meanwhile, Lee developed the maps optimized for vehicular environments (MOVE) in-car navigation display, which provides situationally appropriate navigation information to the drivers [8]. Brown observed interactions among drivers, passengers, and GPS systems by recording real driving situations with a video recorder [5]. He suggested five troubles that users encounter: destinations, routes, maps and sensors, timing, and relevance and legality in detail. From Lee's research, we accept the concept of providing a situation-proper solution, and from Brown's research, we accept his approach of observing users specifically and finding out problems in detail. In this study, we use user-centered design approaches, with which we aim to apprehend the problems of picking-up situations in a complex city space. With the design guidelines obtained from a user survey, we developed a research prototype, Gravity. We also performed a user study to assess its usability.

User Survey

Using Google forms, we made a survey sheet asking about a picking-up situation where a driver and a pedestrian meet together downtown. A total of 102 participants responded to the survey (60 men [59%] and 42 women [41%]). Most of the respondents lived in the Seoul metropolitan area (80%). In order to get realistic responses from users, we supposed two specific situations: (1) as a driver picking up a friend and (2) as a pedestrian picked up into a friend's car. We asked the respondents to describe how they would behave if they were in each situation. We also asked them to provide potential problems, work-arounds, and suggestions when arranging the meeting. We collected responses and grouped them into several issues based on their similarities.

For the case of being a driver (case 1), there were three main patterns identified: (1) difference of viewpoints between the driver and the pedestrian, (2) difficulty in concentrating on safe driving, and (3) worrying about missing each other. In the case of (1), the respondents said, "When driving, I can't understand what a pedestrian says on the phone" and "There seems to be differences between driver and pedestrian, especially who has never driven a car." In the case of (2), there were opinions such as "Calling or messaging with the pedestrian continuously is very hard for my driving" and "Because I have to concentrate my driving, I can't spend my time in communicating with the friend." And in (3), the respondents said, "I'm worrying if my friend is standing where pulling over is hard or following cars are blowing horns" and "I turned left but my friend is standing in another place. I have to do a U-turn."

As work-arounds, drivers noted that they sometimes deliberately tried to be late because they thought it would be better to make a pedestrian wait than to wander, waiting for the pedestrian, while driving. Other respondents said they constantly contacted the pedestrian while driving. When asked to describe specific services that they need, some respondents said, "When contacting a pedestrian, I want to automatically track his location and guiding" and "I wish I could share my location with my friend using a smartphone in real time." Drivers need a navigation system automatically linking the car and the

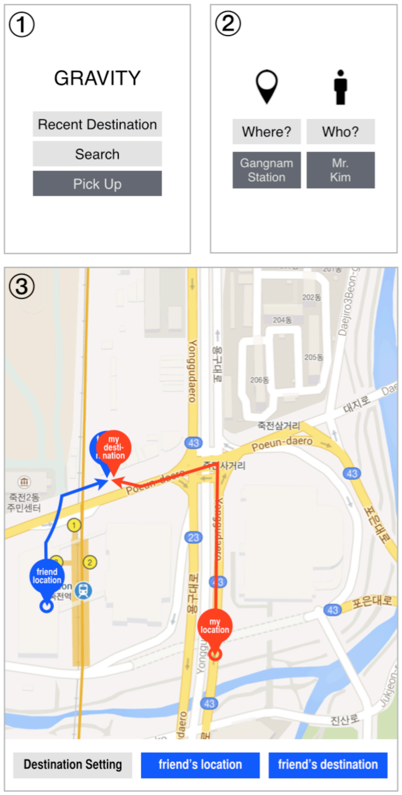

Figure 3. Key views of Gravity. ① We added a "pick up" menu separately at the first view of the system. ② After selecting the "pick up" menu, the user should set two features: (1) "where" and (2) "who." ③ On the map, the route is presented with a red line, and four main location marks are presented: (1) my location, (2) my destination, (3) friend's location, and (4) friend's destination.

pedestrian. They also suggested a "navigation system that recommends spots appropriate for pulling over."

In the case of being a pedestrian (case 2), there were two main patterns: (1) difficulty of communication with the driver and (2) uncertain waiting while not knowing the exact direction of the car. In the case of (1), the respondents said, "It is hard to understand what the driver is saying, and it makes me so confused" and "I tried but I couldn't tell the driver an appropriate spot for pulling over. I had no idea." In the case of (2), the respondents said, "I often looked around for the car because I couldn't get the exact direction of the car" and "Similar cars are passing by and it is confusing . . . I'm worried about missing my friend's car." To solve these problems, as work-arounds, respondents replied that they would communicate with the drivers constantly, waiting in front of a conspicuous place such as a gas station or convenience store. They suggested several ideas like a "navigation service that links a car and a pedestrian automatically," a "picking-up-only space," and a "push alert when the car comes close."

Design Implications

After gathering the user survey data, we conducted a repetitive ideation process. Three researchers reviewed the data and had a series of face-to-face meetings. Through these phases of analysis, we induced three main design implications for a navigation system supporting picking-up situations in a complex city space: (1) automated system without interrupting the driver's primary task (driving), (2) tracking the locations of both the car and the pedestrian in real time, and (3) sharing and setting each other's location and point of interest.

Prototype: GRAVITY

Following the design implications, we developed a prototype navigation system: Gravity—Automatic Location Tracking System between a Car and a Pedestrian. The system was developed as an iOS application, operating on an iPad (for the driver) and an iPhone (for the pedestrian). The basic components of a navigation system, such as a map and a guidance way, were implemented by using T-map API [1]. The server communication system was constructed using Parse.com service, which enabled both devices to share their locations with each other.

The main function of Gravity is "picking up." We added a "pick up" menu separately at the first view of the system (Figure 3). After selecting the "pick up" menu, the user should set two features: "where" and "who." By searching a specific location on the search bar, the user can select his or her destination. At the next view, a list of friends who were registered earlier is presented, and the user is allowed to select one of them. Then, the setting is completed (e.g., "Picking up 'Mr. Kim' nearby 'Gangnam Station'"), and the next view simply visualizes distances and estimates the time for the car driver to reach the pedestrian's destination.

After that, the main guidance is started. On the map, the route is presented with a red line, and four main location marks are presented: *my location*, *my destination*, *friend's location*, and *friend's destination*. Basically, *my location* is located in the center of the display, and the user can check the other marks by moving and zooming out the map. After the user starts driving and gets closer to the destination, both *my location* and *friend's location* are presented on the screen. The driver can select one option between the two—(*a*) set the "friend's destination" as "my

(a) driver's view

(b) pedestrian's view

(c) completion of picking up

Figure 4. User Test

destination" and (*b*) set "friend's location" as "my destination." If the driver chooses option *a*, he or she can receive a guide to the pedestrian's final destination. Of course, the pedestrian can change his or her destination freely only by touching the screen, and as it changes, the driver's destination is also altered in real time. By selecting option *b*, the driver can set up the pedestrian's real-time location as his or her destination. If the driver and the pedestrian miss each other on the way, by simply using option *b*, they can finally meet each other in a certain point. With these options, the users can come together at one spot and complete their pick-up.

User Test

We conducted a usability test of Gravity in real-driving settings. We recruited 16 participants (8 drivers and 8 pedestrians). All the tests were conducted in pairs of a driver and a pedestrian, accompanied by researchers. We provided a testing car equipped with an iPad for drivers and gave pedestrians a ride near the destination, which was set up beforehand (a nearby intersection). We asked each pair of participants to complete their picking up only using Gravity. By setting up the "pick up" menu, the test was started. Drivers drove following the directions of the system, and so did pedestrians. Once each other's location was presented on the screen, they coordinated their final location using option *a* or *b* and finally met each other at a certain spot. Except for two retrial cases due to unstable communication, all the tasks were successful. All the driving was recorded with an in-car recording system. After driving, to measure its usability, we provided the participants with a questionnaire composed of the System Usability Scale (SUS), a reliable evaluation tool developed by Brooke [4].

Result

The average SUS score of all participants is 78.91. According to the standard that Sauro (2012) suggested, the score is in the range of B+, which means that the overall satisfaction level of the system is within the highest 20% range [10]. According to another standard that Bnagor (2008) suggested, the score is in "good" range in the aspect of "adjective range" standard and "acceptable" in the "acceptability range" [3]. These results show that the participants felt that the core function of Gravity—supporting picking-up situations—is "useful," and they were satisfied to a certain degree. Calculated separately between drivers and pedestrians, the former score is 77.5, which is B+, and the latter is A−, which means that the system is slightly more useful to pedestrians than drivers in this bidirectional communication.

In the post hoc interview, the participants showed positive responses in general, such as "The concept of linking a car and a person is very good" (D3), "The core function would be very useful" (P7). In detail, there was a positive opinion about safety driving due to the navigation system ("It would be very safe because while using it, I don't need to call or message the driver" [P2]), and some participants said it could also solve uncertainty of picking-up situations ("I can check the location of my friend [driver] frequently, and I can prepare to be picked up well" [P5]). On the other hand, some participants pointed out its completion quality problem, saying, "The quality of the system is poor" (D3), and "It needs a simple UI design (P5)"; and some of them additionally suggested a specific UI component, saying, "It would be great if it shows a simple summary of the distance between me and my friend in real time, at the upper side of the view" (P5). In common with the results of the user survey, some participants expressed their need for a recommendation system showing places where it is easy to pick up based on social data ("I need some service recommending places for picking up, like avoiding bus stops" [D7]).

Conclusion and Future Work

Way finding, while driving, using GPS navigation systems, has been common in a complex city space. However, most of the systems provide a rather uniform function. In order to enhance their user experience, this research, introducing a user-centered design approach, conducted a user survey and induced design implications. Then we made a prototype, "Gravity," and evaluated its usability, and it received favorable feedback from the interview. The research could be applied and extended to other situations such as a group meeting associated with multiple users from various locations.

There are two limitations in this study: (1) the implemented system has a low degree of completion and (2) its usability was evaluated only by users' subjective satisfaction. Based on the user test results and interviews, we plan to develop the system more precisely by improving the UI structure and the design and solving unstable server problems so that it can be used in real driving situations. And as users repeatedly said, with the accumulated data, we will introduce a spot-recommending system appropriate for picking up. In the next step, we will evaluate its usability and user experience quantitatively as well as qualitatively, revealing its improvement significantly.

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