SaSYS: A Swipe Gesture-Based System for Exploring Urban Environments for the Visually Impaired

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Abstract. Exploring and learning an environment is a particularly challenging issue faced by visually impaired people. Existing interaction techniques for allowing users to learn an environment may not be useful while traveling because they often use dedicated hardware or require users to focus on tactile or auditory feedback. In this paper, we introduce an intuitive interaction technique for selecting areas of interests in urban environments by performing simple swipe gestures on touchscreen. Based on the swipe-based interaction, we developed SaSYS, a location-aware system that enables users to discover points of interest (POI) around them using off-the-shelf smartphones. Our approach can be easily implemented on handheld devices without requiring any dedicated hardware and having users to constantly focus on tactile or auditory feedback. SaSYS also provides a fine-grained control over Text-to-Speech (TTS). Our user study shows that 9 of 11 users preferred swipe-based interaction to existing pointing-based interaction.

Keywords: Accessibility, mobile devices, visually impaired, touchscreens, location-based services.

1 Introduction

Traveling to unfamiliar places still remains one of the major challenges faced by people with visual impairments. Although many guidance systems providing turn-by-turn directions to predetermined destinations have been developed, such systems are inadequate in that they fail to address one of the most important navigational needs: exploring and learning one's surroundings [9, 23]. Visually impaired people often get knowledge about what is around them by walking with sighted people. However, it is important to enhance their ability to explore surrounding points of interest (POI) for making their travels more independent and enjoyable. This need is also recognized by large-scale field tests in our research project, carried over a decade, using ubiquitous computing technologies for enhancing mobility experience of the visually impaired [18, 19, 20].

Map exploration systems [21, 24] are one of the effective options for visually impaired people to learn an environment. They often adopt tactile or auditory feedback to interact with information on maps, and this may require dedicated hardware.

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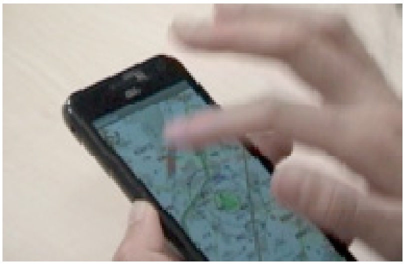

Fig. 1. Participant searching for POIs using SaSYS by performing swipe gestures

These interaction techniques may be useful for learning an environment in detail, but are hard to apply to discover POIs while walking. Automatically notifying immediate surroundings could be another option [1, 3], but may not be useful when users want to retrieve POIs at their discretion. Thus, how to allow users to interact with the surrounding geo-located information space is the key to effectively support exploratory traveling [16]. To this end, we introduce a novel and simple touch-based interaction method, *swipe-to-search* that allows visually impaired users to select areas of interests. Users intuitively specify the direction (relative to the direction they are facing) and distance of areas of interest by swipe gestures on touchscreen. For example, users can find nearby POIs in front of them by performing short swipe-up gestures, and distant POIs on their right by performing long swipe-right gestures. In this paper, it is shown that swipe-to-search is usable and acceptable to visually impaired users. Pointing a smartphone towards areas of interest has been used for retrieving POIs [23], but this method could have usability issues. For example, the user might lose his sense of direction and spatial orientation because he must make a 180° turn while searching backward.

Based on swipe-to-search, we developed SaSYS (Swipe and Scan Your Surroundings) on a smartphone, which enables users to search for POIs such as restaurants and stores (Figure 1). SaSYS provides interaction methods that can be used to control audio information by allowing the user to draw shapes on touchscreen. For example, while listening to user reviews about some restaurants, the user can skip to the next review by drawing a triangle. SaSYS also offers auditory and olfactory features of POI such as "There is a café on the right, near which coffee aroma can be experienced".

This paper presents two major contributions. First, we present the design, implementation and evaluation of a swipe-based interaction technique that offers several benefits over the existing pointing-based approaches. Second, we designed and implemented speech feedback control feature on touch-based interface. Importance of speech feedback control has been recognized in the literature [6], but none of the existing systems presents any concrete implementation. We conducted a user study with 11 visually impaired users comparing SaSYS's swipe-based interaction against pointing-based interaction. We also investigated the usefulness of TTS (Text-to-Speech) controls provided by SaSYS.

The rest of this paper is organized as follows. In Section 2, we explore interaction techniques that help visually impaired users learn an environment. In Section 3, we describe the design of our interaction methods and implementation of SaSYS in detail. Section 4 and 5 present the design of a user study to verify the usability of our interaction techniques and its results. In Section 6, we discuss our findings and future work. Finally, section 7 concludes this paper.

2 Related Work

In this section, we investigate IT-assisted interaction techniques that support exploratory traveling for people with visual impairments. We also briefly investigate eye-free interaction techniques on touch-based mobile devices for exploring the potential of our approach to be used in map-based applications.

2.1 Exploration Support Systems

We investigated two major areas of work that give an opportunity for visually impaired users to explore and learn about their surroundings: (a) map exploration systems that enable users to learn spatial and geographic information, and (b) navigation and wayfinding systems that provide POI information in situ during navigation.

The BATS [13] project uses force-feedback and spatial sound to deliver spatial information with tactile input devices. Pielot et al. [14] developed an auditory city map that leverages computer vision technology to trace a tangible object regarded as the representation of the listener on a virtual map. Some map exploration systems allow the user to grasp layout of streets. Poppinga et al. [15] examined the use of vibration and speech feedback on handheld touch screens to make the road network accessible to the user. Timbremap [21] uses the sonification to guide the user's finger to trace routes on a mobile device. While map exploration systems listed above provide spatial information in detail, SpaceSence [24] offers high-level spatial relationships between two locations. It uses custom spatial tactile feedback hardware on a mobile device, which generates vibrations to the user's palm indicating location of POI. However, these techniques require the user to concentrate on sound and/or tactile feedback, which make them difficult to use while traveling. Furthermore, many of these systems need haptic input devices or dedicated hardware (costly and bothersome to carry). Thus, approaches in map exploration systems may not be useful for exploring urban environments.

Bellotti et al.'s tour guide system [1] and Chatty Environment [3] provide information when the user passes near the objects with a RFID tag. This type of push-based approach may be appropriate for providing POI information in situations such as museum or zoo tours. However, in urban environments, it would be more appropriate to allow the user to search for areas of interest at will. Yang et al. [23] addressed this issue by providing both push- and pull-based information retrieval. Their system automatically notifies the user of nearby POIs, and at the same time allows the user to search distant locations by pointing a handheld device. In this way, the system enhances the chance to discover POIs and encourages the user to learn the surroundings in the process of wayfinding. Pointing-based mobile interaction has been recognized as an effective means of location selection [4, 17], and adopted by several exploration and navigation systems for sighted people as well [16, 22]. However, as stated earlier, 'point-to-search' technique may have problems especially for visually impaired users. Furthermore, pointing allows the user to show only desired directions without any mechanism for specifying distance. Allowing the user to adjust the scope of search space could provide a better user experience when the user wants to search further or closer areas.

2.2 Touch-Based Mobile Device Accessibility

As handheld devices such as smartphones have gained widespread popularity, many research efforts have been investigating interaction techniques in order to make touch-based mobile devices accessible to visually impaired people. For example, SlideRule [8] uses multi-touch gestures to menu and item selection for applications such as e-mail clients, music players, and phone books. Also Apple's VoiceOver[1], screen-reading technology, allows visually impaired users to use iPhone. Text-based contents are getting accessible to the user, but visual-based contents (e.g., maps) still remain inaccessible [2]. While existing interaction techniques cover several useful applications such as a mobile messenger or a mobile player [10], little attention has been given to gesture-based interaction techniques for map-based applications (e.g., Google Maps, Yelp[2], etc.). Our swipe-to-search method has potential to be used for these map-based applications for visually impaired users.

3 SaSYS System

SaSYS is a location-aware system running on touch-based handheld devices that allows visually impaired users to discover POIs and get detailed information about them. To provide useful and easy-to-use interaction methods for searching and obtaining POI information, we designed SaSYS to achieve the following:

- SaSYS enables users to search for POIs in all directions, and allows them to adjust the scope of search areas at will.
- SaSYS enables users to obtain information effectively from auditory information, as needed, by allowing them to choose what to listen to.

Furthermore, we explored what kind of POI information could be useful for visually impaired people [5, 7]. SaSYS can provide olfactory and auditory features of POI (currently manually collected in a specific area).

The current system was developed through an iterative design process in consultation with a blind teacher of University of Tsukuba's Special Needs Education School for the Visually Impaired. Since he works with visually impaired students, his comments and suggestions were really helpful to incrementally improve our system. The system development process included three iterations of design, implementation,

[1] http://www.apple.com/accessibility/iphone/vision.html
[2] http://www.yelp.com/yelpmobile

testing and refinement. First, we conducted initial prototype test with the blind teacher to assess the feasibility of our swipe-to-search approach, and discover potential usability problems. He provided the following feedback for ensuring better user experience:

- *Only intentional touches should be recognized; the prototype should provide some kind of a 'touch trigger' to avoid accidental activation.* Therefore, we chose the volume keys on the side to act as a 'touch trigger', effectively ignoring touch inputs when one of the volume keys is not pressed.
- *Let users know what appears onscreen, and provide instructions in order not to get lost while navigating the application.* Thus, we give instructions for non-triggered touches as well. For example, if the POIs list shows up on screen, the following voice instruction is given: "POIs list. Swipe up and down to navigate POIs and double-tap to select one."
- *Minimize the number of drawings for TTS controls to remember them easily.* Therefore, we made the basic shapes to mean different interactions depending on whether or not they are drawn while the volume key is pressed. For example, while listening to audio information, drawing a greater-than sign with the volume-up key pressed would cause *speech rate up*, whereas doing the same with the volume-down key pressed would skip to the next sentence (Figure 4).

After refining the prototype as described above, we again consulted the blind teacher to ensure usability improvements before conducting a user study. Moreover, we demonstrated the refined prototype to 3 blind individuals at the 2013 TRON Enableware Symposium[3] to examine our swipe-based system's usability. One of them was iPhone user and the others had never experienced using smartphones. All of them could understand, and perform swipe-to-search with interest, indicating the potential of our interaction technique.

SaSYS interactions consist of two modes: scanning mode to retrieve POIs by swipe gestures, and content listening mode to listen details of selected POI information. The following sections present two modes illustrating how we achieve the design goals and describe implementation of SaSYS in detail, highlighting its novel interactive features.

3.1 Scanning Mode

Scanning mode allows the user to retrieve POIs and select one from the list of POIs. SaSYS's swipe-to-search interaction is derived from very simple and intuitive ideas. Suppose that you were asked to present a desired direction on the paper. Drawing an arrow might be one of the easiest ways to show the direction. Additionally what if you were asked to indicate the relative distances you want to know? You can intuitively express the sense of distance by drawing different lengths of arrows. We have implemented these ideas on a touch screen smartphone. The user first touches any point on touch screen, which is regarded as the current location, then draw a line towards a desired direction. This simple gesture gives the user a POIs list within the area of interest.

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[3] http://www.tron-enableware.org/en/

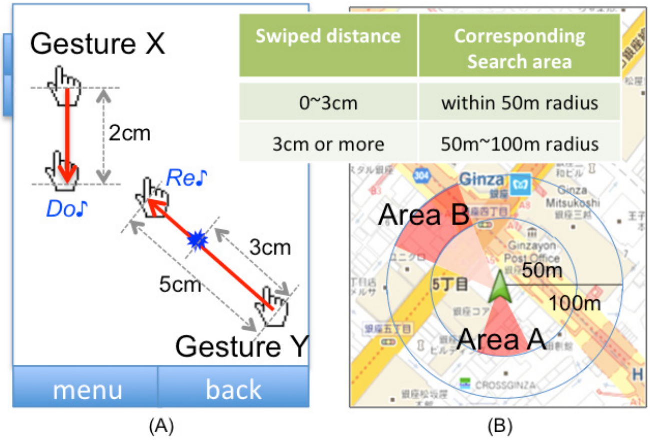


Fig. 2. Examples of swipe-to-search. (A) Gesture X retrieves POIs within Area A, and (B) Gesture Y retrieves POIs within Area B.

An example of swipe-to-search is illustrated in Figure 2. In the example, swiped distances between 0 to 3cm retrieve POIs within 50m radius, and 3cm or more retrieve POIs within from 50 to 100m radius in the 8 cardinal directions. The user can customize the swiped distances and their corresponding search radii. When the user performs a short swipe-down gesture ("Gesture X" in Figure 2A), SaSYS offers a POIs list within 50m behind the user (Area A in Figure 2B). Also, the user can retrieve POIs between 50m and 100m front-left by performing a long swipe gesture diagonally ("Gesture Y" in Figure 2A and Area B in Figure 2B). In this manner, the user can intuitively explore nearby places by short swipes and distant places by long swipes in all directions.

POI retrieval process includes three steps: (a) measure a direction and distance of a swipe gesture, (b) convert swiped distance to predetermined search ranges and calculate the latitude and longitude of the center of a target area, and (c) get POIs information within the area and read the search results via TTS.

In addition to explicit speech feedback about swipe gestures performed by the user, SaSYS provides vibrotactile and auditory feedback for assisting the user to perform swipe-to-search. For example, while performing Gesture Y as depicted in Figure 2A, the user will receive vibrotactile feedback as he advances from Area A to Area B, crossing the 50m radius of Area A (3cm gesture equivalent). The duration of the vibration will be in effect corresponding to (3±α)cm, where α (currently 20mm) is a configurable parameter. It helps the user perform swipe gestures as he intended by allowing him to know how long he slid his finger. Auditory feedback, one of 7 notes in the major scale, is given according to the radius of search areas (e.g., Figure 2B has two areas, A and B) when the user's finger lifts off the screen after finishing the swipe gesture. Swipe gestures specifying further areas get higher notes; for example, if search space is divided into 3 areas, then swipe gestures searching for the third area play "Mi".

The user can perform swipe-up and swipe-down gesture to navigate the list of retrieved POIs. SaSYS reads brief description of the POI that includes the name and distance from user's current location. The user can select POI for detailed information by double-tap. We use hardware back button (standard for most Android phones) to go back to the swipe-to-search mode from navigating the POI list.

(A) (B)

Fig. 3. Participants performing TTS controls: (A) skip by drawing a triangle and (B) forward by drawing a greater-than sign

3.2 Contents Listening Mode

After the user selects POI on the list, SaSYS provides more detailed information with several controls that make TTS repeat, forward, skip, etc. When sighted people search for POI using mobile applications (e.g., nearby restaurants for lunch), they might look over or into detailed information to filter information they want to get (e.g., the latest review). However, it is difficult for visually impaired users to get desired information efficiently through unilateral auditory information. The user may have to listen again from the beginning for missed information that sighted people may not need even a second to read again. Although the need for TTS controls has been reported [6], few systems provide this feature. Therefore, it is necessary to provide TTS controls feature for visually impaired users to obtain desired information effectively from TTS by allowing them to choose what to listen to.

We use gesture-based interactions that allow the users to control TTS by letting them draw shapes on touchscreen (Figure 3). TTS controls include play, pause,

Functionality	User Interface
Play and pause	Double tap with pressing the volume down key
Forward	Drawing  with pressing the volume down key
Backward	Drawing  with pressing the volume down key
Next content	Drawing  with pressing the volume down key
Previous content	Drawing  with pressing the volume down key
Change the information category	Drawing  with pressing the volume up key
Repeat	Drawing  with pressing the volume down key
Speech rate up	Drawing  with pressing the volume up key
Speech rate down	Drawing  with pressing the volume up key

Fig. 4. The gesture set used for TTS controls

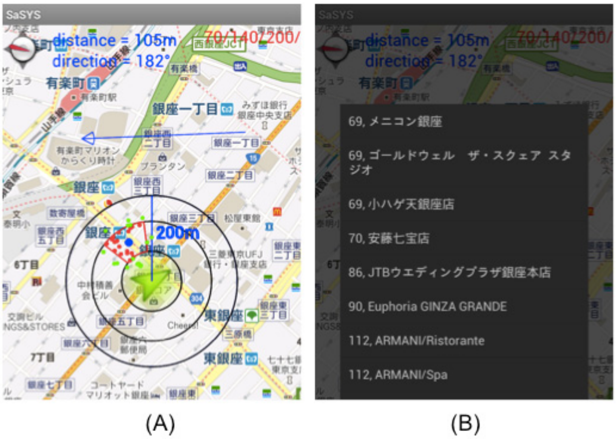


Fig. 5. A screenshot after performing 'swipe-to-search'. (A) The blue arrow shows the gesture performed by the user; the green and red dots present retrieved POIs but only red dots will be introduced to the user. (B) The list of retrieved POIs.

repeat, go forward and backward by the sentence, skip to the next and previous by the item (e.g., each customer review), and speech rate up and down. By providing various control features, SaSYS helps the user 'look over' or 'look into' detailed information. We initially assigned gestures to each TTS control in accordance with design guidelines for accessible touchscreens [10, 11]. For denoting gestures, Figure 4 shows a set of shapes provided by SaSYS. However, in the future, it would be desirable to enable the user to customize the gesture-shape mapping.

3.3 Implementation

SaSYS is implemented on Android platform, and currently running on Samsung Galaxy S2 and Galaxy Nexus. SaSYS makes use of smartphone's GPS-based positioning and a built-in compass to identify the user's current position and orientation. We used commercially available SOVOX Classic TTS engine with Japanese language pack to provide POI information and interact with the user. We also utilized Gesture Builder which is an application included in Android 1.6 and higher SDK platforms to create custom gestures used for TTS control interactions. Gesture Builder allows developers to create a library of pre-defined gestures that can be used in their applications.

When the user performs a swipe gesture, SaSYS retrieves POIs on the map (Figure 5A), and then immediately transit to the screen that shows the list of search results (Figure 5B). After the user selects POI, SaSYS moves to the screen that shows detailed information (Figure 3).

SaSYS offers rich information about points of interest. The current implementation of SaSYS supports a use case of practical importance of going around in Ginza, a famous shopping and entertainment district in Tokyo. We used Kokosil[4] API that provides local businesses information in Ginza. To help the user find desired information easily,

[4] `http://home.ginza.kokosil.net/en/`

Selected POI	Description provided by SaSYS
Bank	There is a bakery on the right, near which the smell of bread can be experienced
Bakery	It smells of bread
Post office	There is a bakery on the left, near which the smell of bread can be experienced

Fig. 6. Examples of contextual cues as auditory and olfactory features of POI

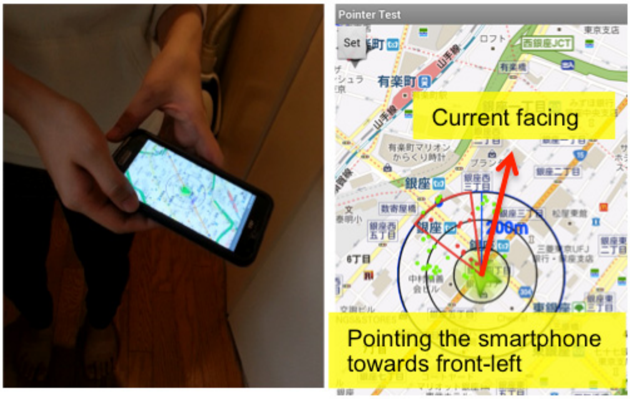
we categorized POI information into four types: general information, user reviews, advertisements (e.g., discount coupons, events, etc.) and contextual cues. The user can move between not only items but also categories so as to save time by listening to only information of interest. General information includes a short description about POI, business hours, address, regular holidays and additional features such as history of POI. User reviews and advertisements are retrieved from Kokosil and Twitter. Advertisements often contain URL for further information, but it can be tiresome for the user listen to the meaningless characters via TTS. Thus, SaSYS examines posts and removes URLs if any. Contextual cues are information about auditory and olfactory features of POI. For example, aroma of coffee near a café or sound of outdoor air conditioner units. This contextual information can be useful to visually impaired people when they get near to a desired POI. To the best of our knowledge, there is no content provider that offers auditory or olfactory features of POI. Therefore, we manually collected contextual information of POIs in Ginza. This information is created as a CSV file. When the user selects POI, SaSYS searches this file whether the POI has any contextual features. Figure 6 presents contextual cues provided by SaSYS.

4 User Study Design

To verify the usability of interaction techniques provided by SaSYS, we conducted experimental evaluation with 11 visually impaired participants in the laboratory. Our user study consists of three parts: A) verifying the ease-of-use and usefulness of swipe-to-search approach by comparing to point-to-search approach, B) verifying the effectiveness of TTS controls feature, and C) obtaining user feedback on the overall system. The whole process of the experiment was conducted in Japanese, and was video taped for later analysis.

4.1 Participants

Eleven visually impaired participants (4 male and 7 female; P1-P11) were recruited for the study. Their degree of visual impairments varied: 9 of them were blind and 2



(A) (B)

Fig. 7. An example of performing Pointer Test: (A) searching POIs on front-left by pointing the smartphone to that direction, and (B) a screenshot after performing (A)

had low vision. The average age of the participants was 23.09 (SD=8.1). 2 participants were iPhone users. The others are not smartphone users but 3 of them had experience with touchscreen mobile devices. All participants use white canes as mobility aids and 6 participants had experience with GPS navigation systems. The entire study took on average 2 hours.

4.2 Part A: Swipe-Based Interaction

For comparison with pointing-based interaction, we developed an Android application called ‘Pointer Test’ that provides the same functionalities as SaSYS, but using point-to-search. Pointer Test retrieves POIs by pointing the smartphone in a desired direction and double tapping on the screen (Figure 7).

To allow the users to develop a clear impression of both approaches, we asked them to perform the following task using both applications:

“Imagine that you stand at an exit of Ginza subway station. Before traveling, you want to know what is around you. Explore your surroundings with the given application. Please try to find four specific stores in Ginza and remember their locations. After 10 minutes, represent each location on a LEGO board with blocks, and tell us the names of each store”

Both SaSYS and Pointer Test used the same POIs set which consists of 66 POIs in Ginza within a 200m radius centered on the participant’s simulated location. We divided SaSYS’s search space into 3 areas by swiped distances: searches from 0 to 70m radius (corresponds to from 0 to 2cm swipes), from 70 to 140m radius (corresponds to from 2 to 4cm swipes), and from 140 to 200m radius (corresponds to over 4cm swipes). We limited the number of POIs for the experimental purpose because navigating too many search results was cumbersome to the participants. The participants were asked to

Fig. 8. (A) Participant putting blocks on a LEGO board to present spatial relationships among the location of stores. (B) Spatial relationship of POIs as perceived by a participant.

remember the direction and distance of the given POIs when they discover them and present their location on the LEGO board (the center of the board was regarded as the current position of the user) (Figure 8). We used LEGO to enable the participants to simply express the relative spatial relationships among stores. To avoid making the task into a test of how well the participants were able to remember the given locations, we allowed the users to ask the name of given stores while performing the task.

To minimize the influence of area familiarity from the former session, we set different current locations for each session (exit A3 at first and then exit B4 of Ginza subway station, regardless of which application would be used first). We randomly chose 6 participants to use swipe-to-search first and the others to use point-to-search first. At the beginning of each task, we conducted a training session for all participants until they became familiar with the application. After finishing the task for both applications, we asked the participants to answer the questionnaire about ease-of-use and usefulness of each approach.

4.3 Part B: TTS Controls

We asked the participants to answer three questions while listening to POI information about a restaurant. To avoid making the task too simple, we added more user reviews and advertisements manually, collected from social network services. The questions include *(Q1) What time does the restaurant close?, (Q2) how much the cheapest menu of the restaurant in the user reviews? and (Q3) what services does the coupon offer during lunch?*

We gave enough time to the participants to interact with TTS controls and give the answers. At the beginning of the task, we provided a training session for drawing shapes on the touchscreen until the participants could remember all controls and perform them. When the participants had difficulty in performing the task, the experimenter assisted them to draw the shapes.

After the participants finished the task, we asked them to answer the questionnaire about the effectiveness of TTS controls provided by SaSYS.

4.4 Part C: User Feedback on the Overall System Design

After the participants had completed the tasks we conducted an interview about the overall experience with SaSYS. We asked the participants to provide any comments on SaSYS including additional functionalities that they would like to have, potential use cases, gesture-based interactions on the touchscreen, etc.

We also investigated whether the auditory and olfactory features of POI provided by SaSYS could be useful for visually impaired people. Furthermore, we asked the participants to mention other helpful contextual information that they would like to acquire through SaSYS.

5 Results

5.1 Part A: Swipe-Based Interaction Results

The participants generally were able to complete the task using both applications. All participants could discover the given stores, but some participants had difficulties in remembering the location and name of the stores when they were asked to put the blocks on the LEGO board. 11 participants presented the location of 4 given stores using the 2 interaction methods, 88 items in total. They were able to properly put the blocks with the store names 71 times, only the locations without the names 4 times, and completely failed to put the blocks 13 times (8 times with SaSYS and 5 times with Pointer Test). After finishing both sessions, the participants rated each interaction method in terms of usefulness and ease-of-use using a 5-point Likert scale (1=Disagree strongly, 5=Agree strongly). The results are shown in Table1.

Table 1. The ratings on Ease-of-Use and Usefulness for each interaction method (Mean, SD)

Interaction method	Ease-of-Use	Usefulness
Swipe-to-search	3.91 (1.04)	4.36 (0.81)
Point-to-search	3.18 (1.33)	3.72 (1.19)

Although a Wilcoxon test did not find a significant difference regarding both ease-of-use (z=1.26, p=.24) and usefulness (z=1.51, p=.14), 9 of 11 participants preferred swiped-based interaction to pointing-based interaction (P9 chose swipe-to-search on the condition that search space is not divided by swiped distances) when they were asked to indicate their favorite of the two interaction methods.

We also asked the participants to comment on the reasons why they thought the method they chose was better than the other. The participants who liked *swipe-to-search* commented as follows:

- Easy to search backward while walking (P1, P6, P7, P8, P9 and P11).
- Pointing a device is not realistic in a crowded place, whereas swiping on the screen allows him to intuitively imagine his surroundings (P2).

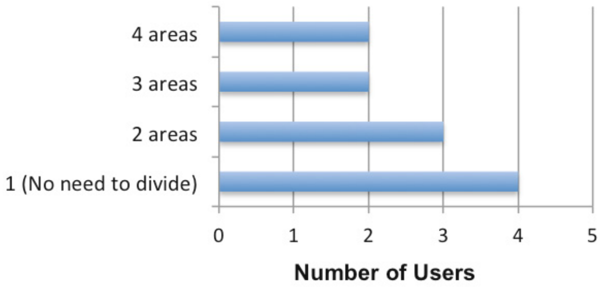


Fig. 9. Participants' preference of the number of areas they would like the search space to be divided into

- Pointing a device on the street would be embarrassing (P4).
- Adjusting search areas by swiped distances would be useful in different use cases (P10).

On the other hand, the participants who liked *point-to-search* commented as follows:

- Retrieving POIs by double tapping was easy to use and simple (P3 and P5)

Participants explicitly mentioned the concerns about losing their sense of direction and the awareness of their body position in relation to the surroundings when they turn around for searching backward with Pointer Test. P8 said, *"Compared to performing swipes, it is quite demanding to turn around with holding the device [for searching]. I found [Pointer Test] tiresome for having to change my body position."* P7 also pointed out, *"Turning the direction [of the device] or changing one's own body position would end up losing the sense of direction."*

Although most participants preferred SaSYS's swipe-based interaction method, some participants were either neutral or positive about Pointer Test's pointing-based interaction method. P2 noted, *"I think it would be useful to go to the [discovered] place by moving the device [with Pointer Test] after understanding the surroundings by moving the finger [with SaSYS]…So it is hard to say which one is better"* and added *"but surely, the one with moving the finger [swipe-based interaction method] is necessary as a means of imaging the surroundings."* Similarly, P6 commented, *"While I generally prefer swipe [based interaction] mode, it would be good to know [information about] a building right in front of me by pointing the device and double-tapping"* Integrating SaSYS with wayfinding systems such as TP3 [23] could respond to the needs.

Some participants found it difficult to control the distance by sliding their fingers on the touchscreen. P11 thought that dividing search space by swiped distances was not a desirable feature for him because he has a slight finger-motion impairment. However, P10 liked swipe-to-search because she could control search areas by swiped distances. We asked the participants about the desirable number of areas for this feature. The preference was varied (Figure 9). The result indicates that interaction de signs for visually impaired users should take individual characteristics into account. Thus, the number of areas should be customized according to each user's preference.

5.2 Part B: TTS Controls Results

Overall, participants could easily remember the given drawings for each control and perform the task. 8 of 11 participants answered correctly to all the questions, but 3 participants gave a wrong answer only to one question each (both P1 and P6 answered incorrectly to Q(3), and P9 answered incorrectly to Q(2)). SaSYS takes 248 seconds to read the prepared POI information with normal speech rate. Participants used TTS controls on average for 504 seconds (SD=119) to find answers for the given questions. 10 of 11 participants found that they needed TTS controls when they were asked to indicate whether the TTS control feature is necessary.

We also asked the participants to rate the usefulness of each TTS control provided by SaSYS using a 5-point Likert scale (1=Disagree strongly, 5=Agree strongly). Overall, the participants found the given functionalities were useful. In particular, the 'speech rate' control was thought of as the most useful functionality whereas 'repeat' was thought of as the least useful among the given functionalities (Table 2).

Table 2. Results of questionnaire on usefulness of each TTS control functionality

Functionality	Average rating (SD)
Repeat	3.72 (1.19)
Forward	4.18 (0.75)
Backward	4.27 (0.79)
Speech rate	4.28 (0.4)
Skip to other items	4.27 (0.64)
Skip to other categories	4.36 (0.67)

Most participants liked the drawings we assigned and the recognition rates of the drawings were acceptable, but some participants had difficulty drawing swirls to repeat. P3 mentioned, *"It would be better to assign symbols less similar [to triangles to the repeat control] because swirls are recognized as triangles."* As noted earlier, it is important to allow the user to customize interactions as much as possible.

Overall, the participants liked gesture-based interaction to control auditory information. When we asked the participants about their preference between button-based interface and gesture-based interface, if the drawing recognition was not a problem, surprisingly 8 of 10 participants (who thought the TTS control feature was necessary) chose the gesture-based interface. This shows that symbol-based gestures have a potential to be used as an effective interface with touchscreen for the visually impaired.

5.3 Part C: User Feedback on the Overall System Design Results

Participants explicitly commented that SaSYS would encourage them to explore their surroundings and to participate in shopping and leisure activities. P6 said, *"I would like to use [systems like SaSYS] all the time. I would like to search stores right now."*

P11 who is currently using an iPhone compared SaSYS with existing navigation systems providing turn-by-turn instructions. P11 pointed out, *"Navigation systems require* *predetermined destinations…I think they are useless in situations like going around Asakusa (one of the famous districts in Tokyo).”* He also commented, *“I think I can use [SaSYS] like equipment for leisure time amusement. For example, when I want to go shopping or look for some restaurants in Ginza.”*

We investigated additional features for improving the user experiences with SaSYS. Several participants thought that it would be better to share their findings (e.g., a bakery near the station) with other users. Some participants suggested that it is important to know the current direction they are facing.

We found that all participants thought contextual information (olfactory and auditory feature of POI) would be helpful when they get near to a desired POI (or destination). We also asked the participants to whether SaSYS requires any additional features. Several participants noted that information about the following would be helpful: shapes and types of entrances (e.g., whether it is a manual door or an automatic door), the position of the entrance (whether in the middle or the end of a building), whether there are steps or slopes near the entrances and the texture of the floor of the entrance hall (e.g., carpets, concrete, wood, etc.). Furthermore, some participants mentioned that the characteristics such as the colors of signboards or the shapes of buildings could be used as clues when they ask the way to sighted individuals. P6 and P11 suggested that the order of buildings in a city block with street names would be helpful. For example, “Your are on Harumi Avenue. You can find building A, B and C in order.” Although the current prototype of SaSYS does not provide turn-by-turn navigation to POI, we believe that POI description should contain useful information for visually impaired people that sighted people may take for granted.

A number of participants enjoyed the experiences with SaSYS and our user study. P10 said, *“Overall, I enjoyed [the user study]. It would be very useful once I get used to smartphones.”*

6 Discussion

Regarding part A of the user study, it was encouraging that participants intuitively understood the concept of swipe-to-search and were able to find POIs. Most participants preferred the swipe-to-search method, but two participants thought the point-to-search method was better for them because of its simplicity. We observed that they seemed to avoid touch input as much as possible, which made them feel the pointing-based interaction was simpler than swipe-based interaction. Several users also were positive to the point-to-search method. Further extension of SaSYS could add the pointing-based interaction method to allow users to select a proper mode according to their preferences or use cases.

Although several participants thought dividing search space by swiped distances could be useful, some participants found that it was difficult or tiresome to adjust swiping distances in order to select desired search areas. We found two possible explanations for why this feature was not well accepted: first, individual ability and attributes (e.g., spatial ability, tactile sensibility, age, etc.) could affect the performance [12]; and to perform the task, users had to interact much more with SaSYS. To scan all areas, SaSYS required users to search 24 times (8 directions with 3 search areas), which made the system seem more tiresome compared to Pointer Test (which only takes 8 times to scan non-divided search space). Note that we extremely limited the number of POIs (66 stores) for the task. We believe that adjusting search areas is necessary when dealing with dozens of POIs within a specific area in real-world scenarios. This issue will be improved by allowing users to customize the number of search areas.

During part B of the user study, we observed that several participants spent much more time on finding the answer to *Q(3)* (find a coupon available at lunch time) compared to *Q(1)* and *Q(2)*. They seemed to have difficulty figuring out the starting point of each item (a coupon), whereas they easily distinguished items (user reviews) from each other because each review starts with the date of posting. We believe that numbering items or giving users feedback (e.g., vibration or auditory icons) at the end of each item could provide a better user experience in case of auditory information.

It was interesting that most participants used and rated the speech rate control the highest. Overall, users preferred speech rate up and down functionalities to quickly “look though” the contents rather than fast-forwarding or skipping functionalities. Participants seemed to be concerned about the possibility of missing out on important information. One participant used only speech rate controls to perform the task. This suggests that providing just the speech rate controls could allow users to obtain information effectively. On the other hand, the repeat control was thought relatively less useful because the recognition rates of swirl shapes were poor, and the backward control could substitute for the repeat functionality. We believe that assigning and registering custom drawings by the user could improve this issue.

Our study also confirmed that providing contextual information could benefit visually impaired users. Our current implementation of SaSYS provides only manually collected olfactory and auditory features of POIs in Ginza, but these features can be affected by certain situations (e.g., rains can affect olfactory senses). Furthermore, it would be desirable to provide richer contextual information anywhere and at any time suggested by participants. Future work should investigate into how to collect and manage contextual information for visually impaired users.

7 Conclusion

We presented a novel and intuitive interaction technique, *swipe-to-search*, to allow visually impaired people to search the surrounding geo-located information space. Based on swipe-to-search, we developed SaSYS, using off-the-shelf smartphone. SaSYS also provides text-to-speech control feature, which gives the users liberty to what to listen to. Our user study showed that swipe-based interaction method was accepted well by users as a means of location selecting. Users also preferred swipe-to-search method to existing point-to-search method. Moreover, we showed that TTS controls are highly useful to visually impaired users. Users thought the speech rate control was the most useful functionality. We also showed that olfactory and auditory features of POI would be helpful to visually impaired people. In short, participants found that SaSYS would be useful for exploring unfamiliar places and discovering surrounding POIs.

The user study revealed valuable insights into the design requirements of an effective location-based service like SaSYS. Based on these insights and the understanding of user interaction gained through our laboratory study, we are planning to conduct a field test in future in order to increase independence and enjoyment of traveling experience for the visually impaired.

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