Towards Identifying Design Paradigms for Describing Indoor Floor Maps to Individuals with Visual Impairment

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ABSTRACT
Navigation, an essential facet of everyday life, is one of the big challenges faced by individuals with visual impairment. In-spite of the presence of aids like canes, seeing-eye dogs and GPS devices, they still face considerable difficulty in everyday navigation. While navigating indoors is relatively safer, it is still a stressful exercise. We propose to look into methods to understand the underlying principles to generate verbal description from floor maps specially catered to individuals with visual impairment (VI). We invited five individuals with VI to give sample 'verbal descriptions' of a building of our choice to their peers with VI. We picked a public building that houses the city's disability services the participants are familiar with, prior to the experiment. We then invited them to criticize each of the answers to obtain additional feedback. We analyzed the answers to derive the lexicology and language preferences. A prototype system was built using the derived paradigms and evaluated with a group of seventeen visually impaired people. Feedback obtained from the visually impaired participants in our experiments suggests that this case study is an effective approach for developing such a system.

Author Keywords
Human Factors, Visually Impaired, Navigation, Blind, Campus, Training, iPhone, Accessibility.

ACM Classification Keywords
H.5.2. Information interfaces and presentation (e.g., HCI): User-centered design; Training, help, and documentation; Evaluation.

INTRODUCTION
Human senses provide visual and non-visual features for understanding the environment. The visual features can be categorized into geometrical and non-geometrical features [1]. When it comes to indoor navigation, geometric features pertain to the structure of the building. The non-geometric features could be lighting conditions, texture, objects for reference, etc. [2]. The problem we on hand is: "What information is essential to aide navigation in the absence of visual cues?" Studies show that VI users use both geometric and non-geometric features to compensate for lack of visual cues. Giudice et al [3] showed that using verbal descriptions of layout geometry help users navigate the space. Holmes et al, 19906 showed that pre-journey learning is useful for blind individuals when navigating a new environment. When working with cross-modality (graphical input and audio output), rather than assuming any mapping will work, a careful examination of how users present and interpret information is required.

Firstly, we need to decide what information (entrance, exit, East facing, etc…) and how much of it (in terms of number of landmarks and geometric cues) to present. Secondly, we need to take into consideration the users experience and proficiency in understanding such information. Thirdly, the ordering and structuring of such information needs to be determined. Tried and testing methods of verbal communication need to be invoked. There isn't one single "how-to" guide or ideal way to achieve this that has been published yet. Hence we adopt a case study based learning approach to arrive at the guidelines to do the mapping from images to meta data to verbal description.

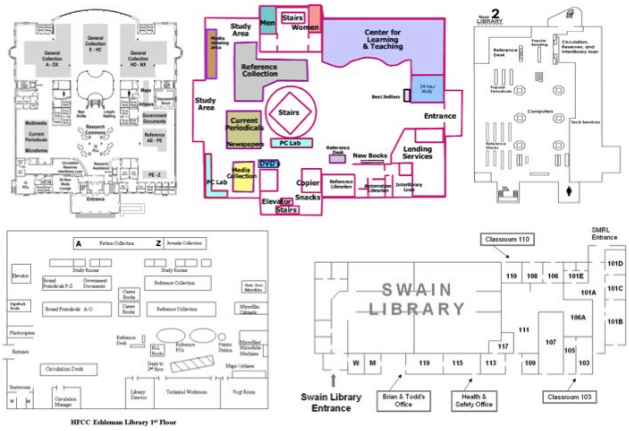


Figure 1 : Some sample floor plans showing the breath of possible layouts.

Generating useful verbal description for a given spatial layout is a rather challenging task. A verbal description specifically **tailored to individuals with visual impairment** is an unexplored territory. Generating static verbal description given a start and end location for spatial routing has had some attention in the recent years. These methods are inapplicable in our context for the following reasons. [4] uses corridor layouts generated with the help of an experimenters using software with a user interface for the user to manually mark out some of the necessary inputs. Most of the maps as seen in Figure 1 cannot be broken down in corridors since they have a more generic layout. Hence description in terms of intersections is not the most apt way to describe these maps. Another assumption made is the availability of orientation of the map, which is not available in images published on the websites. Also,

directions in terms of absolute orientation need the user to face a certain direction and keep track of orientation all along the route. [5] proposed and tested two types of description for navigation. First method is called allocentric, where the description is absolute in terms of cardinal directions. The second is called egocentric method, which uses the user as the point of reference and describes every other location as a relative position from the user. We do not use the allocentric or egocentric descriptions proposed, because the problem we are trying to solve deals with describing the entire spatial layout in one go, as opposed to taking a user input in real time and describing the layout around that location. And finally we are trying to learn the lexicology and language that is most applicable to an individual with VI.

CASE STUDY – 1

In the absence of a standardized "how-to" guide when it comes to giving spatial information verbally, we resort to analyzing human written text messages and using the domain expertise of the orientation and mobility instructors, for this task. We performed a small case study and tried to learn how blind users verbally describe a building that they are familiar with and also tried to learn how they usually receive layout information from sighted individuals.

Participant Recruitment

It is to be noted that one of the authors of this paper is blind. She was actively involved in designing of the experiments, participant recruitment and analysis. She did not participate in the experiments to eliminate any possible bias. We asked a small group of four blind students at Arizona State University (average age = 27, range = 21 to 52), to describe a building on campus that they usually need to go to use the accessible textbook materials and are very familiar with, to another blind individual who is new to the building. We chose this building for the following reasons: the building has four entrances, unto 20 landmarks that are of interest and has a rectangular structure (which is a common shape for buildings). The three students and one professional who participated work in this building, and access it regularly. Two of the participants were born blind and the other two lost their vision during their teens.

Experiment

The users were given complete freedom to describe it as per their preferences in terminology and schema. The instructions for the task were explicit. "You are not describing this building to a sighted person but a person who is completely blind. We can safely assume that the audience in question has taken the Orientation and Mobility (O&M) training as mandated in America. You may use the terminology as recommended by the O&M instructors if you choose to. You may use any method of your choice to describe the building. Please be as detailed as possible as there is no word limit on your answers." They were given two days to complete the assignment. We were in turn asked questions like: "do we need to start with a particular entrance", "should I describe every location in the building", etc. We asked them to describe it the way they find most useful to a fellow visually impaired student.

Initial Data

As we started receiving the answers from the participant, we realized how diverse the answers can be. We also realize we had no authority to figure out what is a good description and which ones are the bad ones. We needed to figure out not only the over all rating but go into the nuances by sentence and figure out if it needs to be included in our future analysis for the natural language processor. A sample description given by one of the female participants is given below:

"If you enter the DRC from the southeast entrance you will enter the reception area. This is set up like a waiting room might be. There will be a receptionist desk straight ahead of you and another desk to the right. To the left, there are several sofa chairs and tables. If you walk between the desks and head north, you will be walking down the main hall of the DRC. There are offices on either side as well as the transportation center behind you at the south side. If you walk down the main hall, you will notice an opening on the left that leads to the lab and other offices. If you keep going, you will approach the bathrooms and drinking fountain on the left. The door directly after the girl's bathroom is the multi-purpose room. If you keep going you will notice another opening on the left. This is the testing center. On the right is a lobby with tables set up for tutoring. There is a walkway between the tables leading to a door on the northeast side of the building. If you continue down the main hall you will pass the alternative format center on right and the north entrance to the building."

We have included a few participant responses in the Appendix. We summarize our observations from the responses below:

1. Navigation bias: From our acquaintance with this particular participants, we could tell that they were describing their everyday path taken, when they accesses the building facilities. In spite of being asked for an overall description of the building, the users tend towards giving descriptions geared towards navigation. Their preference in entrance, usage of specific rooms and interaction with the building staff is evident from their descriptions. There is a small element of personalization in their description.

2. Gender based observation: There is a use of relative positions as well as the cardinal directions in the description. One of the female participants only used the relative positions in terms of "left/right/straight" to describe the landmarks inside the building. The two the male participants in our study used a lot more cardinal directions instead of "to the left/to the right".

3. Visual Disability: The low vision students did use more landmarks when compared to blind students. However, we observed that there were not a lot of obvious

fundamental differences between low vision and blind student generated descriptions.

4. Common vocabulary: The commonly used words for descriptions are “to the left/right of”, “straight ahead”, “across the room to the left/right”, “down the xyx, find abc”, “going further”, “immediate left”, “down the hallway”, etc.

5. Detail: The participants wrote the description using all the landmarks they could remember. They did not leave out any landmark that they deemed unimportant or unnecessary. They used references to non-structural landmarks like tables, chairs, desk, receptionist, etc. to make it more explicit.

CASE STUDY – 2

As we admit that we are at loss when it comes to rating the verbal descriptions in question, we decided to recruit the same participants as critiques to obtain further feedback. The second stage of this study involved critiquing the descriptions and rating them by usefulness. We made a list of all the descriptions and distributed them to all the participants. For sake of reference for the participant, we included his/her version as well. To this list, we added a description obtained from a sighted person who works in the same building. This was included to learn the kind of criticism it would face, in comparison to the rest of the descriptions. The participants were asked to comment on each description and rate it on a scale of 1-5 with respect to clarity, usefulness and accuracy. They were further asked to list the pros and cons of each description in question. They were encouraged to write a conclusion based on all the responses obtained. We used this feedback to arrive at paradigms to be used for generating verbal description. The case study was inspired by [6], where they had asked the residents of Venice to provide descriptions of routes in the city and used this data analyze how humans model descriptions.

Sighted Individuals Vs Individuals with VI

We wanted to also learn if sighted peoples descriptions lack the clarity that is required and if the descriptions of the individuals with VI were indeed very different. We asked a sighted employee who works in the building to provide a verbal description of the building to the target audience given the same instructions. We include this description in the list that was sent out for critiques.

Experiment

The participants received an anonymous set of verbal descriptions and a set of specific questionnaire to answer. For each of the five descriptions, they had to rate it in terms of clarity, usability, accuracy and safety. They were also asked to give an overall rank with 1 being their favorite and 5 being the least favorite. They were then asked to do deeper analysis on each of the description submitted. Write down the pros and cons of each description. They could critique their own description given this new exercise. They were encouraged to handpick the sentences and terminology that they thought was useful.

Analysis

It came to our surprise as to how much dislike the sighted volunteers description had gotten. We expected it to get some criticism but the participants were brutal when rating it. It is safe to assume that sighted people lack the required depth when it comes to providing useful details. It also made use realize the importance of these two case studies in designing our system. Our observations can be summarized below:

1. One of the key comments from the participants was about the use of cardinal directions, where some users indicated their discomfort in being able to figure out directions inside the building unless they concentrated on every step during their journey. In spite of this comment, every participant started his or her description at one of the entrances of the building, described by its cardinal position (e.g. North entrance).

2. A detail that got good feedback from the participants is the description of the overall shape of the building. Another detail that the participants pointed out was the usage of words like “immediate”, ”few steps” and ”right after”, that convey distance information.

3. An interesting observation is that the participants critiqued their own description and pointed out possible improvements after reading the rest of the entries. Some of them admitted at the difficulty level in coming up with a good description of the building and confessed that their descriptions may be “confusing to a first time visitor”.

4. One of the most criticized details pertains to a certain description using “start at the main entrance” without describing the location of the entrance with respect to cardinal directions or the position wrt the building.

5. The description given by the sighted volunteer got the lowest rating (average- 1.5) and most criticism of all the included responses. The participants complained about lack of details, incorrect directions and described it as confusing. One of the participant blatantly mentioned that this person is confused or lacks proper direction sense.

6. The participants were surprised when they read about the existence of landmarks that they never knew prior to this experiment, in spite of being familiar with the building.

In spite of the diversity in descriptions, the ratings given to the descriptions and the participant feedback provide a conclusive indication to the direction to follow to generate the paradigms needed to describe a building. We arrived at our verbal design rules after we got the participants to critique each other’s description and based on the formulation of the descriptions as obtained from the participants.

RESULTS

After a detailed analysis the descriptions and interaction with the participants, we tried to mimic the observations and the feedback, in designing the verbal description generator. The summary of the observations is given below. In the following sub section, we describe the steps taken to generate a verbal description given these guidelines.

1. Shape: Start the description with the overall shape of building. Describe the available entrances to the building with reference to the shape and the cardinal directions (if this information is available).

2. Start point: Use the entrance of the building as the reference point to start the description of the landmarks inside the building. We detect the text for entrance or in their absence, symbols like doors/double doors that could potentially be the entrance to the building. We start at this location and base rest of the descriptions form this point. For floors that are not the base/main floor, we detect the elevators and start at an elevator.

3. Entrance: From the study, there is no one entrance that can be deemed the best reference when more than one entrance is available to access the building. The safe bet is to start with the entrance that is labeled the "main entrance" or the one leading into the center of the building.

4. Flow: Most of the users describe the locations as they enter the main door and describe what is to be found as you walk along. We start our description with all the locations found when navigating straight from the main door. They then described what is found to the left and to the right at intersections. This scheme has many outliers when dealing with non-rectangular layouts, which we explore in the subsequent sections.

5. Position: The users frequently used 'to the left' and 'to the right' to describe locations with respect to a previously mentioned/described location. We describe rooms/landmarks in terms of their relative position 'left'/'right' with respect to a location already described in a previous step.

6. Distance: From the descriptions, the only indicators to the distance was the usage of terms like "to the immediate left/right" and "further ahead", indicating proximity and large distance, respectively. We use a similar scheme to convey the proximity of locations.

7. Popular references: All the users included landmarks like lobby, reception, restrooms, stairs, elevators, lobby, etc. We created a local dictionary of building related terminology that was used to create an importance map for the landmarks.

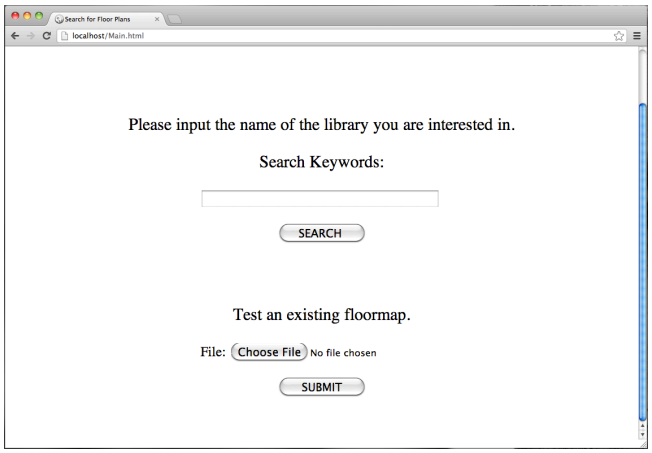
8. Segmentation of space: The building used for the case study used a rectangular building with long hallways running across the length and breadth of the building. The users based their descriptions on the landmarks encountered walking along these hallways. They branched away from the main hall way and described location encountered along the branches of the hallway, thereby, dividing the space into segments. This was not done explicitly but can be observed consistently in the descriptions. We use a similar scheme to segment the space.

8. Categorization of the essentials: A few participants included finer details like the position of presence of pillars, number of steps, position of the tables in the hallway, etc. in their descriptions. While this level of details is not available without real-time indoor imagery of the space, we chose to ignore these details. The details of positioning of locations, presence of hallways and stairs, location of restrooms and water fountains, etc. are what we deem essential. We give utmost importance to delivering this information and pay attention to the format of this information to best deliver the message.

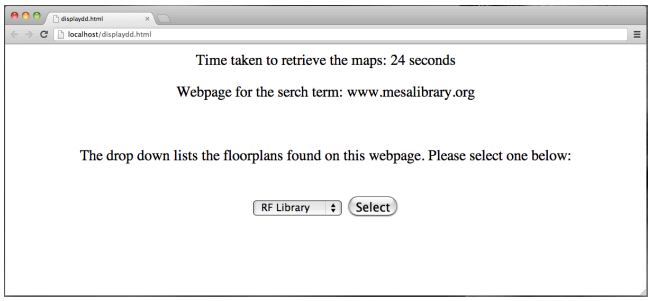
The paradigms arrived at are very course in outlook. This was necessary to generalize these rules to different layouts that could exist. We asked the participants to describe a rectangular layout, which has four entrances. Most of the users wrote that they picked the entrance that leads into the longer side of the building because it was easier to describe. Looking at the descriptions, it is evident that the participants, in spite of being familiar with the building, have not explored it fully. This also points out to the need for a verbal description system. Perhaps having them explore the map would give them more confidence to find new locations and trace their way back. The landmarks that everybody used in common are the restrooms and lobbies. We try to emphasize these landmarks in our descriptions and use them as major reference points. The proposed paradigms address the different aspects involved in describing a physical space. We arrived upon a rule for each of these aspects that work for the common layouts and can be extended to complicated layouts with reasonable accuracy in depiction.

OVERALL SYSTEM

These experiments were the backbone that went into creating a larger system. We built a prototype system that takes in a floor plan as an input. This can be via custom Internet search given the name of the location or via user provided image of floor map. Our system then analyses the given map by extracting the landmarks, shape information and layout information. These points are included in the verbal description to mimic the paradigms extracted from case study 1 and 2. This work has been demonstrated at ASSETS [7] and the details of the system published in [8].



a)



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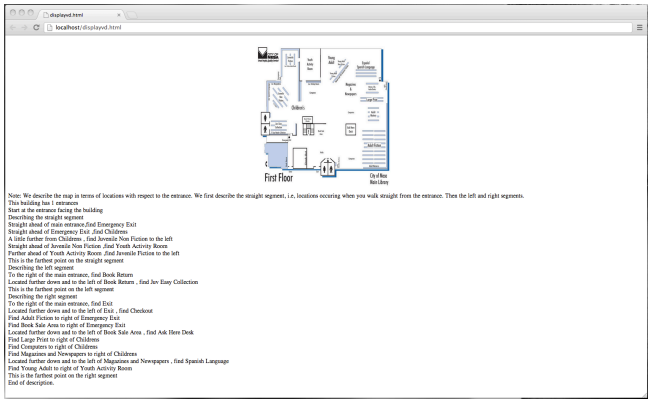

c)

Figure 2: An demo of the overall system built with the derived paradigms from the method study. The input is collected from the user in a). The existence of multiple floors or buildings is shown in b) for users choosing. A sample output is shown in c).

CONCLUSION

We recognize a void in existence of an indoor navigation system designed specifically for blind individuals. The existing systems provide voice over for images without considering the nuances that go into usability for our target audience. We designed a set of experiments that iteratively learn from our target audience. The overall system was very well received by the audience and suggests a positive direction for developing such a system.

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Appendix: Participant responses to the case study – 1 & 2

Participant 1(highest rated, average=5/5): *"The Disability Resources Center building is a rectangular building with the long sides going from north to south. When you enter from the north door, the door to your almost immediate left will be the entrance to the room where most of the braille transcribing is done. Across from this door on the hall's west side is the office of the supervisor of this department. Moving southward down the hall, one comes across an open study and get-together space on the left with a door leading to the outside with steep steps almost immediately after opening it. Across from this open area is a window with a small hall just south of it that represent the location of the testing center. Moving further south down the main north-south corridor one comes to a flight of stairs going up to the second floor on the left. A little further south on the right is the men's bathroom labeled in braille followed by the break/lunch room (at its west end there is a door leading out to an enclosed patio) followed by a drinking fountain followed by the door to the ladies' bathroom also labeled in braille. Meanwhile, the left-hand side of the main hall has doors leading to various private offices and a meeting room. Beyond the ladies bathroom on the right as you continue down the main hall is another hall that is very important. It leads back to the computer lab (on its north side) and the offices of the various disability counselors (south side). Returning to the main hall and continuing south, one enters a relatively large room where the two secrataries sit. The main desk if you have questions is directly in front of you. The other secretary sits east of the main desk and beyond her is another door leading to the outside at the southeast corner of the building. Across from the second secretary's desk on the north side of this room are doors that lead to first the office of the director's private secretary and then, beyond that, the office of the director of the department. Finally, next to the main secretary's desk on the right is a closed door that leads to the Transportation room."*

Participant 2: "*The building is a rectangle with the longer side along North-South. It has four entrances. The main entrance is the easiest to use for description, hence I want to use this. When you enter through the main entrance, you will find a waiting and tutoring hall with tables and chairs. If you walk further, you will find the receptionists desk. From here, you can go straight, left or right. If you go right, you will find a hallway and the Alternative Formatting Center to the right and the supervisors office to the left. If you keep going further, you will find the Northern entrance. If you go straight ahead from the receptionist's desk, you will find the Testing center supervisors office to your right. And further ahead, you will find the testing center. If you take a left from the receptionist, you will enter another hallway. You will find a meeting room and some offices to your left. To your right you will find the men's restroom, a common purpose room and the women's restroom. Going further, you will find that the hall way widens. Here, to the right, you will find a computer lab and offices of DACs. If you continue along the hallway, you will find another reception area, the transportation center and the South-East entrance."*

Participant 3: "*If you enter the DRC from the southeast entrance you will enter the reception area. This is set up like a waiting room might be. There will be a receptionist desk straight ahead of you and another desk to the right. To the left, there are several sofa chairs and tables. If you walk between the desks and head north, you will be walking down the main hall of the DRC. There are offices on either side as well as the transportation center behind you at the south side. If you walk down the main hall, you will notice an opening on the left that leads to the lab and other offices. If you keep going, you will approach the bathrooms and drinking fountain on the left. The door directly after the girl's bathroom is the multi-purpose room. If you keep going you will notice another opening on the left. This is the testing center. On the right is a lobby with tables set up for tutoring. There is a walkway between the tables leading to a door on the northeast side of the building. If you continue down the main hall you will pass the alternative format center on right and the north entrance to the building."*