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Crowdsourcing Annotating Storefront Accessibility Data Using

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Abstract

The storefront accessibility can substantially impact the way people who are blind or visually impaired (BVI) travel in urban environments. Entrance localization is one of the biggest challenges to the BVI people. In addition, improperly designed staircases and obstructive store decorations can create considerable mobility challenges for BVI people, making it more difficult for them to navigate their community hence reducing their desire to travel. Unfortunately, there are few approaches to acquiring this information in advance through computational tools or services. In this paper, we propose a solution to collect large-scale accessibility data of New York City (NYC) storefronts using a crowd-sourcing approach on Google Street View (GSV) panoramas. We develop a web-based crowdsourcing application, ***DoorFront***, which enables volunteers not only to remotely label storefront accessibility data on GSV images, but also to validate the labeling result to ensure high data quality. In order to study the usability and user experience of our application, an informal beta-test is conducted and a user experience survey is designed for testing volunteers. The user feedback is very positive and indicates the high potential and usability of the proposed application. DoorFront has been successfully launched and can be accessed at: https:doorfront.org.

Keywords

Crowdsourcing, Storefront Accessibility, Independent Travel, Visually Impaired, Open-Source Data

Introduction

In the United States, the number of blind or visually impaired (BVI) people continues to increase. According to the report by the CDC organization, approximately 12 million people 40 years and over in the United States have vision impairment, including 1 million who are blind, 3 million who have vision impairment after correction, and 8 million who have vision impairment due to uncorrected refractive error (CDC, 2021). Visual impairment can have a profound effect on their quality of life, affecting them physically and psychologically and interfering with their daily activities, especially traveling, which is identified as the most stressful event in their lives (Nadine Donaldson, 2017).

For BVI people, how and where to go can be a significant challenge. Localizing the entrance of a store or facility is a difficult task for BVI people. Additionally, improperly designed staircases and obstructive store decorations are still common barriers for BVI people. In New York City (NYC), for example, although the Mayor's Office for People with Disabilities (MOPD, 2021) requires businesses to provide equal access to goods and services for customers with disabilities in an integrated environment, most small businesses do not follow this principle. As a result, monitoring compliance that relies on owner self-inspection is clearly challenging as thousands of small businesses in NYC still have physical barriers (stairs) at store entrances. Neither organizations that serve people with BVI (American Council of the Blind et al.), nor software developers have identified appropriate storefront accessibility data to use as travel guides. The existing accessibility information is mainly concerned with sidewalk situations such as defective curbs and problems caused by tree roots (DOT, 2021), and there are few emphases on the accessibility of storefronts. Moreover, studies indicate that most of the sidewalk assessment is conducted through physical audits (May et al, 2014, Law et al, 2018), but inperson audits are not only costly and time-consuming but also lack timeliness (Rundle et al, 2011).

To further support the independent travel of the blind and visually impaired and reduce their stress in travel planning, we propose a solution that uses an approach integrating online crowdsourcing and online map imagery (e.g., Google Street View images) to gather a large amount of storefront information that can be used as reference guide materials. Our ultimate goal is to create a large-scale open-source database of NYC storefronts accessibility data with a close community engagement. In this paper, we focus on developing a crowdsourcing web application that enables volunteers to remotely label storefront accessibility data on Google Street View (GSV) images. Volunteers can virtually "walk through" New York city streets via the function of the GSV and select a cropped image of a specific storefront from a custom volunteer's perspective in order to label our required targets. The novelty and contributions in this work include:

(1) A web-based application *DoorFront* that provides a user-friendly interface and interactive tool combined with Google Street View for volunteers to annotate storefront information.

(2) A volunteer contribution credits system that allows students, especially high school students, to acquire community service credits or certificates by annotating storefront accessibility data using the *DoorFront*.

While this paper mainly focuses on a data collection approach using crowdsourcing, we anticipate future work will include georeferencing the collected image labels and deposits of the data into the NYC Open Data platform (NYC Open Data, 2021). With our storefront accessibility data, technical companies can develop more flexible applications to assist the visually impaired. For example, imagine a mobile app that provides BVI people a turn-by-turn navigation to enter a facility based on our accessibility data, or automatically recommends a travel site or a restaurant with an accessible entrance.

Related Work

Local and state governments often need to collect street-level accessibility data, but it is challenging to acquire a complete set of data at the city scale. We believe that the use of crowdsourcing methods will make data collection more efficient and economical due to the omnipresent Internet and convenient mobile technologies. Many studies have indicated that the use of online crowdsourcing plays a significant role in supporting urban mobility and public transportation (Krajzewicz, 2010, Marzano, Gilberto, et al, 2019). The solutions most relevant to our work are those that can combine Google Street View (GSV) images and online crowdsourcing to collect street-level accessibility data. For example, Bus Stop CSI (Crowdsourcing Streetview Inspections) allows people to remotely label bus stop landmark locations with GSV images (Kotaro Hara et al, 2013). Sidewalk accessibility data is important to people with mobility disabilities, hence some work has focused on collection of sidewalk data using crowdsourcing (Saha, Manaswi, et al, 2019) or machine learning approaches (Weld, Galen, et al, 2019). However, they emphasize the problem related to sidewalks and their contribution to the mobility disability community. Other approaches have collected massive unban image-based datasets such as LabelMe (Russell, Bryan C., et al, 2007) and Places (Zhou, Bolei, et al, 2018), using computer vision algorithms.

In this work, inspired by the previous crowdsourcing platforms (Kotaro Hara et al, 2013, Saha, Manaswi, et al, 2019), we propose a solution that combines online crowdsourcing and GSV images to collect large-scale accessibility data of NYC storefronts.

Discussion

User Study

In this project, our ultimate desire is to collect a large amount of data at the city scale that is useful to the visually impaired. Although we have predefined four important storefront accessibility objects, namely doors, doorknobs, stairs and ramps, we still want to find out the usefulness of the information we collect. In addition, we would like to know if there are other important storefront accessibility data for BVI people that we have not collected. In order to gain a more comprehensive understanding of the challenges and needs of the visually impaired during their independent travels, we conduct informal interviews with six blind adults to learn about what challenges they might encounter during their independent travels.

In the series of interviews, we learned that most of the participants were daily commuters prior to COVID-19. Based on their descriptions, we found that they encountered many challenges when traveling, such as keeping walking straight, determining current location and localizing store entrances. Most relevant to this paper is that most participants experienced difficulty in finding the exact location of the main entrance of their desired store or facility. For instance, one participant claimed that finding a store entrance would be the second biggest challenge in his daily life. He often needs to spend a considerable amount of time to find the location of the door. Sometimes, he will also ask volunteers for help, but these people usually only tell him that the store is in front of him but do not provide him with the exact location of the store entrance. Even those having guide dogs state that being informed in advance of the storefront accessibility of their destination store can significantly reduce the time it takes to find the entrance. According to the interviews, guide dogs can only distinguish doors but cannot tell if a door is the entrance to the destination store. Therefore, knowing the entry location of a store in advance enables them to better instruct the guide dog. In addition, most participants indicated that the information of doors and door knobs (both types and locations) help them to easily enter buildings. This information would help them make more effective judgments.

In summary, most participants felt that having information about store accessibility in advance, especially the type of entrance (door, ramp or stair) and entrance location, would greatly reduce their stress in getting around. In addition, stairs, ramps, the types of doors and door knobs would be very beneficial to them.

Application Design and Development

Our web-based crowdsourcing application, called DoorFront, is designed to allow volunteers to label the NYC storefronts' image data with predefined accessibility categories (doors, stairs, ramps, and doorknobs). Our goal is to provide a user-friendly platform to collect a completed city-scale image dataset of storefront accessibility information with annotations. In order to achieve our goal, we have separated our application requirements into two tasks.

- First, we develop an interface that combines GSV to allow volunteers to virtually walk through the city and choose specific scenes based on their own perspectives.
- Second, we propose a solution to manage the volunteers and increase their engagement.

Crowdsourcing and Annotation Interface

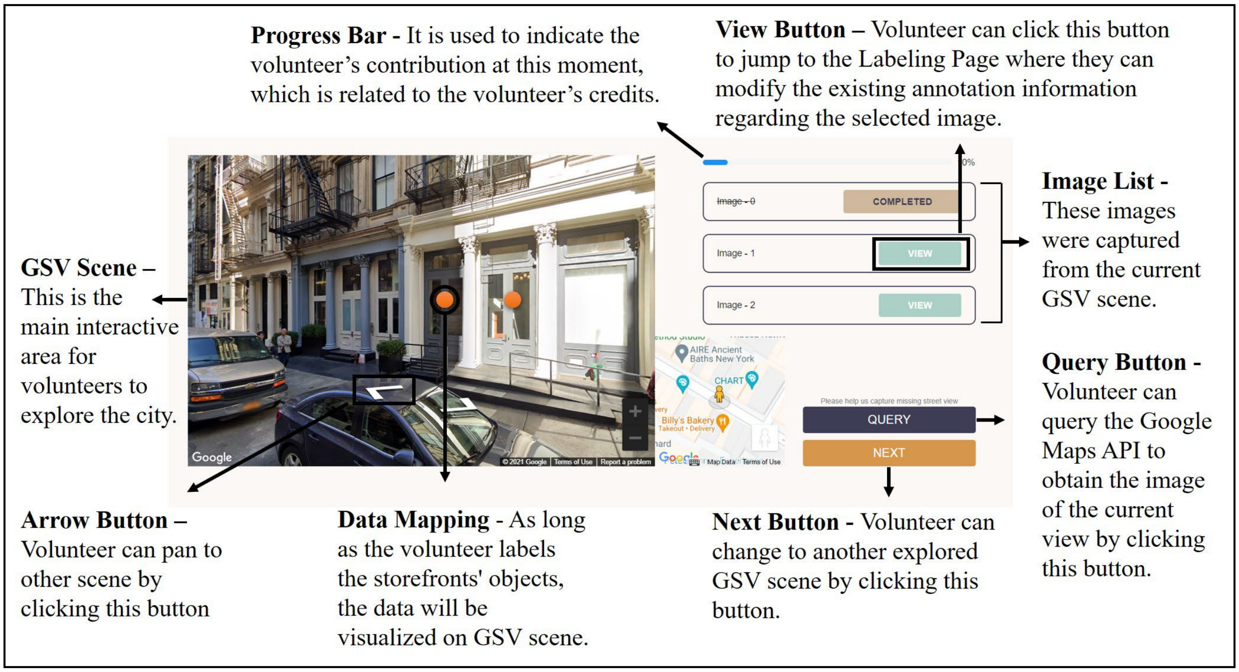

Fig. 1. The Interface of Exploration Page.

The primary goal of the project is to create a volunteer-based platform that provides an interactive labeling tool to collect street-level accessibility information of NYC storefronts. Our labeling tool can be mainly divided into two parts that were designed as two web pages, namely the Exploration Page, and the Labeling Page. On the Exploration Page (Fig. 1), a GSV scene is displayed as the main interactive area that allows volunteers to virtually turn around to view the 360-degree views of the scene and to essentially walk through the city by clicking the "Arrow" button embedded in the GSV scene. Regarding the Labeling Page (Fig. 2), it offers a tool for volunteers to label storefront accessibility objects with a user interface design inspired by *LabelBox* (LabelBox, 2021). In addition, we created a validation tool with the same interface as the Labeling Page, allowing volunteers to contribute to the validation of existing annotated images, which can improve the quality of our data.

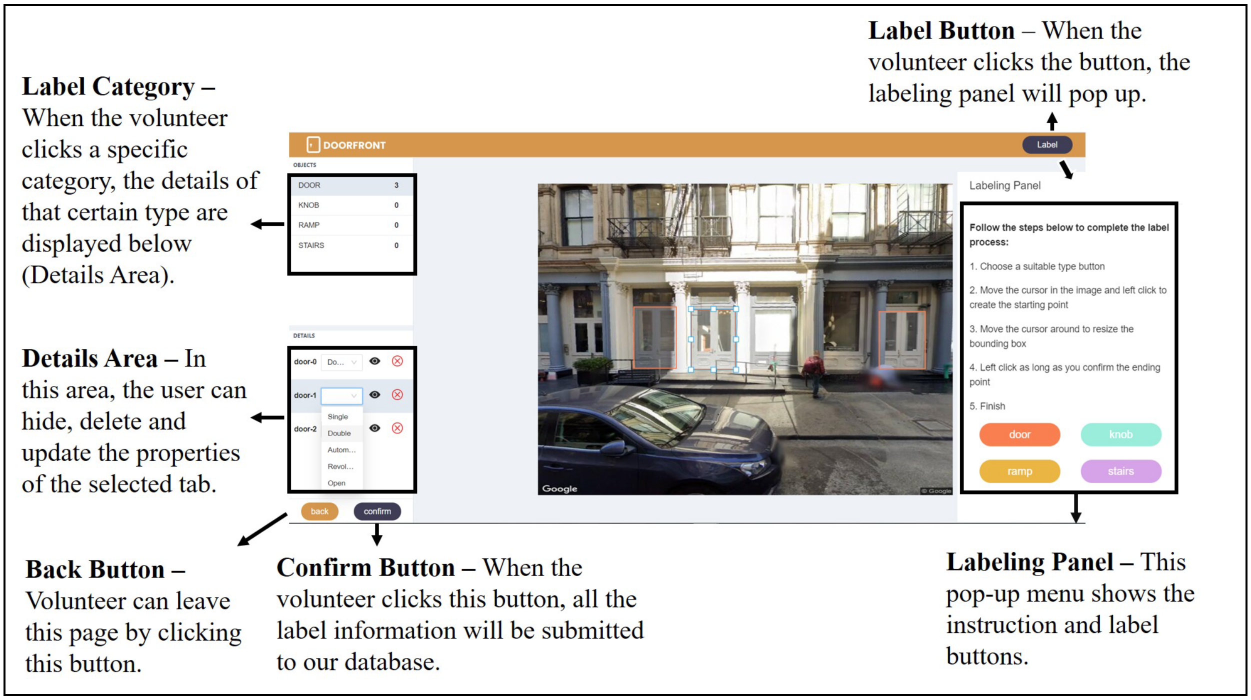

Fig. 2. The Interface of Labeling Page.

When volunteers enter the Exploration Page (Fig. 1.), they will be randomly dropped in a GSV scene that has been labeled by other volunteers. Within the Exploration Page, there are two approaches for volunteers to change the GSV scene. The primary approach is to use the built-in panning feature of GSV by clicking the embedded “Arrow” button to change the GSV scene, which allows volunteers to virtually “walk through” NYC. While the other approach is to click the "NEXT" button to reload another explored GSV. If the current GSV scene has not been labeled yet, volunteers can adjust the view direction by spanning the panorama to select the image with an appropriate view for labeling. When the volunteer presses the “QUERY” button, our application will automatically query the Google Maps API to get the corresponding image display in the current view, based on the current camera’s location and heading direction. In order to avoid storing the wrong image data and to ensure proper use of cloud storage space, a pop-up preview window appears when we get the cropped image of the current scene and asks the volunteer to confirm the selected image. Our application will only save those images that are confirmed by volunteers so that the wrong image data would not take up our cloud storage space. When the image confirmation process is complete, the page will automatically jump to the Labeling Page (Fig. 2), where volunteers can categorize the storefront accessibility objects and select the appropriate subtype if one exists, e.g., various door types and doorknob types. Once the volunteer finishes the labeling process, the data of storefront accessibility objects will be saved in our database and displayed on the original GSV scene with a color marker on the labeled object. Our tool will automatically adjust the marker's position based on the current viewport and field of view (FOV), which means the markers stick on the labeled object accurately, even though they are not part of the GSV. When the image list appears, which indicates that the current GSV scene has been labeled, the volunteer can verify whether the storefront accessibility objects of the current scene have been fully identified by looking at the markers on the GSV. Moreover, if volunteers find an incorrect annotation, they can click on the "View" button in the image to fix the incorrect annotation.

Volunteer Engagement

The participation of volunteers is a significant factor in this project. To increase volunteer engagement, we dedicate a contribution credit system for the volunteers. Our ultimate goal is to encourage volunteers, especially high school or college students, to give back to their local community. Students can gain community service credits or certificates by annotating storefront accessibility data using the proposed web application. For the credit system, we design an incentive mechanism that gives extra credit as a reward when volunteers label a certain number of images. On the Exploration Page, we created a progress bar (percentage format) to show the number of images that the current volunteer has labeled. For example, 10% means that the volunteer has labeled one image, and if volunteers continuously label ten images (reaches 100%), they will be rewarded with extra points.

Evaluation

In order to study the usability and user experience of our application, we conducted an informal beta-test and designed a user experience survey for testing volunteers. A total of 13 student volunteers participated in the test and completed the survey. In this test, with the help of the 13 participants, we collected 234 images in total, including 676 labels with four predefined categories (doors, stairs, ramps, and doorknobs). The number of labels for each specific category is shown in the following table (Table 1).

Table 1. The Number of Labels for Each Category.

Category	Amount
Door	358
Doorknob	283
Stair	33
Ramp	2

To assess the label accuracy, we manually inspected 50 out of 234 images (20%), including 112 labels. During this inspection, we found 7 incorrect labels: 3 out of them were labeled with incorrect category and 4 out of them had inaccurate bounding boxes, such as oversized and misplaced. Based on the data, the accuracy rate is approximately 93.75%. We realize that this result is not statistically significant since only a limited manual inspection was performed. Therefore, we anticipate future work will design and implement a robust cross-validation mechanism that allows volunteers to evaluate the collected labels.

Table 2. The Survey Questions and Answers.

Questions	Answers
1. How do you like the way we collect data through Google Street View? (Please rate from 1 to 5)	1: 0% 2: 0% 3: 15% 4: 31% 5: 54%
2. Do you like the interface of our application? (Please rate from 1 to 5)	1: 0% 2: 15% 3: 15% 4: 23% 5: 47%
3. What is the average amount of time you spend on each scene (panorama)? (In general, there are two sidewalks in each scene where volunteers can label the storefront accessibility data)	1 - 2 minutes: 46% 3 - 5 minutes: 23% 5 - 8 minutes: 23% 8 - 10 minutes: 8%
4. What is the average number of images you have queried (Click Query Button) in each scene (panorama)?	2: 23% 3: 8% 4: 8% 5: 15% More than 5: 46%
5. What is the average time for labeling one image?	Less than 1 minute: 54% 1 - 2 minutes: 31% 3 - 5 minutes: 15% More than 5 minutes: 0%
6. How long are you willing to spend on each volunteer time?	Less than 5 minutes: 15% 5 - 30 minutes: 54% 30 - 60 minutes: 31% More than 60 minutes: 0%
7. How many scenes are you willing to explore during each volunteer hour (panorama)?	Less than 10: 31% 10 - 20: 39% 20 - 30: 15% More than 30: 15%
8. Would you like to introduce this app to your friends to help us collect storefront accessibility data?	Yes: 92% No: 8%

Questions	Answers
9. Would you prefer to label random areas or label specific areas selected by yourself?	I prefer to label random areas: 54% I prefer to label selected areas: 46%
10. Would you prefer to label an area close to your home?	Yes: 85% No: 15%
11. Would you be interested in volunteering more time to label if a badge or credit mechanism is introduced to the platform?	Yes: 100% No: 0%

In terms of the user experience survey, those questions as listed in Table 2 were designed with three main objectives in mind. First, we aimed to evaluate the usability of our application through volunteer ratings. Second, we intended to evaluate the labeling feature and understand the user experience by analyzing the average labeling time. Third, we wanted to evaluate user engagement by analyzing the volunteering time of volunteers and labeling areas. The answers to the survey listed in Table 2, especially regarding the usability and user experience (Q1, Q2, Q5, Q7 and Q8 in Table 2), received a positive response with more than 50% of the votes, as we expected. In addition, we restricted the labeling areas to central Manhattan in this beta test, but 7 out of 13 (54%) participants claimed that they would like to be free to choose a place (Q9 in Table 2). Moreover, 11 out of 13 (85%) people preferred to label the area near their homes (Q10 in Table 2). With these feedbacks, we plan to add new functionality that will allow volunteers to enter addresses to flexibly explore the desired areas.

Through this survey, not only did we receive important feedback on user interface designs and app usability, but we also received positive and encouraging reviews about our idea and the app. One volunteer said that it was a fun volunteer experience, and she was very happy and satisfied with the clear user interface of our app where she could virtually navigate NYC and contribute to the community. Another volunteer also emphasized he understood how important the storefront accessibility data is and looked forward to seeing more and more applications using our collected data in the future. These reviews testify to the high potential and usability of our application.

Conclusion

In this paper, we have designed a crowdsourced web application, *DoorFront*, to collect large-scale storefront accessibility data in New York City. We conducted a pilot user study with 13 student volunteers and received positive and encouraging feedback. To encourage more students to contribute to this large-scale crowdsourcing project, we have developed a credit system to increase volunteer engagement. The ultimate goal of this project is to make the data available on the NYC Open Data platform (NYC Open Data, 2021). The informal survey indicated the high potential and usability of our application.

The current online crowdsourcing framework faces the following limitations. Though GSV has provided massive street-level images, some of them cannot be used for the following reasons: (1) Some storefront GSV images are incomplete due to occlusions by vehicles or constructions; (2) GSV images are often updated once every few years, hence our image data may be out of date. To address the above problem, we will develop an in-situ mobile app to allow volunteers to collect those missing data if they identify such cases.

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