CUNY The City University of New York

BUS SENSE

Senior Capstone Project Final Report

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Table of Contents:

Abstract

BusSense is an iOS application developed to address the challenges faced by Blind and Low Vision Individuals (BVI) in accessing public transportation, particularly in densely populated cities like New York. BVI individuals often encounter problems accessing public transportation due to the lack of accessibility features such as clear signage, audio announcements, and large fonts. The Americans with Disabilities Act (ADA) mandates accessibility guidelines for public transportation, but these guidelines are not always effective for BVI individuals. BusSense provides a robust framework for BVI individuals by combining existing transit information networks in a custom-built application. By organizing this information for users, BusSense streamlines what used to be a stressful process, helping BVI individuals navigate the New York City MTA bus system more easily. The application seeks to be relatively agnostic to changes in New York City's transit system, requiring no input from the MTA and adding resiliency. The goal of BusSense is to make a meaningful difference in the lives of BVI individuals by providing a more independent means of transportation. By using BusSense, BVI individuals can have greater autonomy and flexibility in accessing public transportation, helping them to lead more independent lives.

Background

Vision impairment, specifically both blindness or low vision conditions, affects a significant number of people in the world, especially in the United States. In the U.S. alone, there are more than 7 million with uncorrectable vision loss and more than 1 million with complete blindness [1]. Blind or visual-impaired (BVI) describes individuals suffering from various degrees and kinds of vision loss that cannot be cured through corrective means, such as glasses, medication, or surgery [2]. Blindness refers to the complete loss of vision through injury, disease, or genetic condition. Visually-impaired or low-vision refers to near loss of vision that cannot be fixed through corrective means, such as glasses or eye lens. There are many different conditions of low-vision from a variety of causes, but the majority of them are due to age-related eye diseases. Some of these eye conditions are age-related macular degeneration (AMD), cataract, glaucoma, and diabetic retinopathy. There are many other eye conditions that cause loss of vision and may lead to permanent blindness.

Even though visual impairments are one of the top 10 disabilities seen in adults above 18 years old, there is little accommodation provided in public infrastructure and spaces, specifically with public transportation [3]. Public transportation is a necessary aspect in leading independent lives for many individuals, especially adults over 18 years. Many residents of densely populated cities, like NYC, rely on public transportation systems for necessary aspects of their life. About 56 percent of the NYC population uses some form of the MTA (Metropolitan Transportation Authority) public transit, and around 60 percent of those who use public transit are commuting between their home and workplace [4]. Public transportation is an alternative to driving for those looking for a more affordable, less trafficked route to where they need to go. It is also a great commuting service to those who cannot drive, such as those below 18 years old or with disabilities. People with visual impairments are among the groups of people who would benefit from the MTA. Even though the MTA is widely used and provides many benefits, it is not easily accessible to those with low vision. The Americans with Disabilities Act (ADA) placed guidelines that need to be followed in order to maintain accessibility in public transportation settings, such as bus drivers announcing every stop for visually-impaired individuals [14]. However, this does not prove to be effective if the person is too far from the bus to hear the announcement, or in cases of high traffic and noise volume. Also, it is not always guaranteed that the driver will announce the stop and audio announcements do not always work for blind commuters. Furthermore, the signs in the bus with the current stop are not in large, clear font that can be seen from people with severe low vision. According to the American Foundation for the Blind, only 44 percent of BVI people are employed [6]. Many unemployed BVI individuals want to and are able to work attribute their lack of employment to difficulties in commuting to work. The World Services for the Blind performed an Employment Barriers Survey, where 100 percent of participants found transportation to be a barrier to employment [7]. The MTA can be unreliable to those with full vision as there are delays, maintenance, and unexpected situations that can occur at any time. However, it is even more difficult for BVI users to navigate without accommodation, and it is causing them to miss out on opportunities. Many public transportation stations and stops do not offer accessible features for BVI individuals. Braille is not included on all bus stop signs and is not useful in navigating to vehicle entrances. Also, public signs in these settings are not written in large font with clear contrast between the text and the background. The alternatives to the MTA for low vision people do not allow BVI individuals to lead independent lives. Transportation services, like Access-A-Ride, limit users to booking their ride days in advance and with a limited time frame. It does not allow for the flexibility and autonomy that the MTA provides for most commuters.

NYC, a large metro city, where 56 percent of the population uses some form of the MTA is home to about 60,000 residents who suffer from vision impairment. Many of these BVI individuals encounter problems accessing the public transportation of NYC on a daily basis. To help these Blind Low Vision Individuals lead more independent lives, we developed an innovative solution to aid these individuals in navigating New York's MTA bus system.

BusSense is an iOS application that provides a robust framework for Blind and Low Vision Individuals by combining existing transit information networks in a custom built application. By organizing this information for our users, we can streamline what used to be a stressful process. BusSense seeks to be relatively agnostic to changes in New York City's transit system. It requires no input whatsoever from the MTA, adding resiliency. We hope that our application will make a meaningful difference in the lives of our users.

Statement of the Problem

There is a significant disparity in how easily BVI individuals can use the MTA versus non-BVI individuals. Many shortcomings exist with the current technologies and apps available to BVI users, which discourages their use of the MTA. Some apps have not been expanded to all bus stops and train stations, and/or are not applicable specifically to public transportation systems. Other apps do not have BVI-friendly user-interface, making it difficult to use in public. Furthermore, some apps do not give proper descriptions of the user’s surroundings. They do not completely accomplish the goal of granting accessibility, reliability, flexibility, and independence to BVI individuals in the public transit bus systems.

BVI individuals should not have to resort to public transportation alternatives simply because the MTA is not accessible for them. Other methods, such as Uber and taxi services, can be expensive. Transportation services, like Access-A-Ride (AAR), are not reliable alternatives and do not accomplish the goals of providing flexibility, reliability, and independence. AAR was created by the MTA for people with disabilities who cannot use public transportation systems. However, rides must be booked a few days in advance, and there is a specific pick up time & location, and destination address [8]. It does not allow for users to freely choose when and where they would like to commute. It does not provide flexibility and autonomy. According to the MTA bi-annual Spring 2022 Customer Satisfaction Survey for NYC Transit, only 61 percent of AAR customers were satisfied, with the majority blaming the unreliable pick-up times and whether or not the ride actually arrives [9]. The inconsistency and cost of these public transportation alternatives can create problems for BVI users in other aspects of their lives, such as commuting to work, doctors appointments, and other places. Many BVI users have stated that they have been late to work due to public transportation difficulties, and their employer may think lateness is a result of bad work ethic. Some may say that BVI users can avoid this disparity in employment opportunities due to more employers implementing a remote form of working. However, not all employers are implementing a completely remote method of work, and this cannot be applied to all professions. BVI users should still be able to experience the social element of in-person interactions in their workplaces.

The MTA buses use an audio announcement at every stop, but sometimes the announcements are not working and/or are not loud enough to be heard from outside the bus. Furthermore, it does not direct users to the entrance of the bus for completely blind commuters. The signs at bus stops and on the front of buses are not accessible for low-vision readers. The bus pole signs are not created with large fonts and clear contrast between the text and sign background, making it difficult for low-vision people to read. The bus displays of the bus line number and the direction-bound on the front of the bus are written in pixelated, small fonts, making it hard for low-vision individuals as well. All of these factors make it difficult for BVI users to know if their bus has arrived and passed by them. Another concern is that if a bus passed by their bus stop, users may not be sure which bus passed by. There is a lot of unknown in their surroundings that they would like to address.

There are some existing technologies that are aimed to help make the MTA more accessible. NaviLens is an QR-activated app designed to help BVI individuals to navigate the MTA using the camera on their phone. The camera searches for and scans custom colored QR signs designed by NaviLens at bus stop poles and in train stations [10]. It then reads signs out loud and provides train arrival information in audio. However, this app was a pilot program run by the MTA and has not been expanded to all train stations and bus stops across the city. Majority stops do not have the custom colorful QR code, so it does not help current users in all settings. The MTA app itself does not provide many accessibility features to the BVI individuals; it is mainly used to notify users for bus arrival times, not navigating to the bus stops and entrances themselves. Soundscape by Microsoft Research is a navigation app that uses 3D sound to navigate users to a location [11]. However, the app is used to beacon to a predefined address set by the user, not to a bus stop or vehicle. There is a lack of existing mobile technologies that help to make public transportation easier to navigate, specifically for bus stops. Also, 'Soundscape' was discontinued in January 2023, removing a possible tool for BVI users to use. In terms of MTA-specific apps, users have mentioned the use of the 'myMTA' and 'MoveIt' apps. However, these apps pose their own challenges to BVI users. Both have UIs that are difficult for BVI users to navigate. Both display the bus updates on a map by showing the bus position along a bus route. However, visual components like map updates are not helpful information for our users to have. Also, when navigating through the app, the users have to type in their desired bus into a small search bus and look through a small, scrollable list of results. Many BVI users prefer to use apps that have large buttons near the edge of phone screens so they are easy to navigate. Large text and clear font is also useful to those with low-vision. Minimalist UIs, such as apps that have few pages to navigate between, are ideal for our users.

To address these concerns of accessibility and the lack of fitting technologies on the market, we have proposed a mobile app to help BVI individuals to navigate the MTA bus stations. Our 'Bus Sense' app would help BVI individuals navigate the MTA bus stations without the need for custom QR codes in the train stations. It would provide users the option to select when they want to hear their audio bus updates. The app would request for the user's location, and present the bus stop & route options within a 10-foot radius in an easy, swipeable interface. After the user selects their desired bus stop and route, the app would make calls to the MTA real-time APIs, and provide updates on their bus in many forms. This system for the app addresses many of the concerns that BVI individuals face and the limitations of the existing technologies. It works around the issue of not being accessible at all bus stops and train stations that NaviLens did not address. 'Bus Sense' would provide information of oncoming buses to their stop and give updates on their surroundings, which the Soundscape app did not address. Furthermore, 'Bus Sense' addresses the issue of uncertain situations where the bus does not pull up to the curb next to the bus pole by informing the user of when their bus will arrive in different metrics, as well as if other buses are ahead of their desired bus so they do not have to worry if their bus has passed by them. All these aspects of 'Bus Sense' would fulfill the goals of granting accessibility, flexibility, and independence to BVI commuters using the MTA bus system. These three goals are vital in a person's daily life when traveling to work, school, home, and more.

Rationale of Solutions

BusSense addresses the shortcomings of many existing apps available, and will be used as a supplementary app to other navigation systems that could be used by BVI users. Our app currently assumes that users will be able to navigate themselves to their desired bus stop once presented with the option of bus stops and their respective bus routes near their current location. In terms of navigating to their chosen bus stop, that could be done in supplement with other navigation apps, such as Google Maps. The main focus of BusSense is to provide more information to the user on their surroundings and of oncoming buses, which is not usually available to them through the other competitor apps mentioned above.

Many of these apps fall short when it comes to granting BVI commuters information about their surrounding buses, which reduces flexibility and independence they may feel. In order to obtain information about when their bus arrives or which buses may have passed their bus stop, users often resort to asking those around them, asking the bus driver, or waiting for the bus to announce themselves (which does not always work). The common pitfall that many of these apps have in common is the "last 30 feet of frustration" [12] where GPS inaccuracy leads to BVI individuals being close to but not exactly at the bus stops. While Be My Eyes addresses this issue [13], it requires a human expert's guidance and is not aligned with our goal of independence. NaviLens also attempts to resolve this problem by aiding BVI individuals in navigating bus and train stations with the camera on their phone, however it falls short in that it requires QR codes to be deployed by the MTA, which has yet to be expanded to all bus stops across NYC [16].

To better understand the specific concerns that BVI users face when using public transportation, we conducted some interviews with patients at the non-profit health organization called 'Lighthouse Guild', low-vision seniors at the 'The Heart Senior Day Care Center', and BVI individuals within our own networks. The 'Lighthouse Guild' organization works to provide services and resources for those facing visual impairments and blindness. One concern that was voiced in our user interviews was detecting the right bus in busier junctions where there are multiple bus lines, heavy traffic, and bike lanes. Existing applications such as NaviLens only guides users to the bus stops, but fails to take them to the buses and does not tell the users if the bus is correct or not. To address these accessibility issues that arise when navigating the MTA bus system, BusSense will notify the user when their bus is approaching and how many buses may pass by before their bus approaches their stop. BusSense stands above our competitors by preventing users from feeling frustrated or confused about buses passing by, and preventing them from identifying wrong buses in junctions with multiple bus lines. Though there are great applications for BVI users already, we believe that our app will stand out when it comes to navigating the MTA bus system.

In terms of the design of the app, the aim was to provide a simple UI for BVI users to navigate, which many apps did not provide. From the participants we interviewed, 75 percent of participants used the MTA, and of that percentage, all the participants used iPhones due to the helpful accessibility features compared to other phone models. These features include Apple's VoiceOver and SpeakContent features. In terms of these text-to-speech features, users were indifferent in how often they wanted to be presented with audio updates. Some wanted feedback every time the bus update changed. However, this can be distracting for the user. The app includes a large button for users to disable the voice if they begin to find the constant updates distracting. Furthermore, 90 percent of our users conveyed that they would prefer the swiping feature of choosing between bus stops rather than using a search bar and manually scrolling through the results and trying to tap their desired bus. Many of our users from the LightHouse Guild also stated that they would like to know when other buses have passed by, and how many buses may pass by before their desired bus arrives. This gives me more certainty on their surroundings. In terms of the metric used to provide the real-time bus update, our users provided mixed responses. While some preferred the number of stops away, others preferred the number of minutes or number of meters away. To provide wider flexibility in how users can gauge their surroundings, all of these metrics were included in the app. Throughout the few months of development, constant feedback was taken by the users in order to determine the most important features and designs of the app that would increase their ease when traveling alone on the buses.

Design and Development of Systems

BusSense takes advantage of the built in libraries such as CoreLocation to get access to the user's current location and AVSpeechSynthesizer which produces text-to-speech automatically without having to enable VoiceOver. The application also uses the MTA Bus Time API to retrieve real time bus data. The MTA API's are powered by the OneBusAway framework and SIRI (Service Interface for Real-Time Information) framework. Two API endpoints are used for the app to function properly:

- stops-for-location
  - Parameters: latitude, longitude, radius (in meters)
  - Return: List of bus stops within the radius of the coordinates. Each bus stop also lists the bus route code (monitoring reference) for each bus line that stops there.
- stop-monitoring:
  - Parameters: Monitoring reference
  - Return: More detailed information than stops-for-location. Relevant data from the returned data is the published line name (Ex: M100), destination name (Ex: Inwood 220 St via Amsterdam via Broadway), expected arrival time which is

formatted following the ISO 8601 standard, distance from stop in meters, and the number of stops away

The application works in the following steps:

1. Upon first time opening app, request the user's location
    a. If denied, user will not be able to move forward
2. Make call to stops-for-location
    a. If no stops are within range, user will not be able to move forward until they are closed to a bus stop
3. Make subsequent calls to stop-monitoring to get more detailed information for each bus stop found.
4. The data is compiled to be passed to the Bus Stop Results View for the user to select the desired bus to track at a bus stop.
5. The app moves to the Bus Tracking view which has a few functions:
    a. Read out the data such as the miles away, bus stops away, time away, and number of buses expected to pass before the user's desired bus passes by.
    b. Makes call to stop-monitoring every 30 seconds to update data and calculate the number of buses ahead. Data is calculated as follows
        i. Determine the closest desired bus by finding the bus with matching line name and destination name with the minimum expected arrival time
        ii. Use data from closest bus to extract stops away and convert distance away which is in meters to miles
        iii. Calculate time away by subtracting the time expected arrival time from the current time.

c. The user can toggle the text-to-speech

d. Finally, a back button to return to the Bus Stops Results View

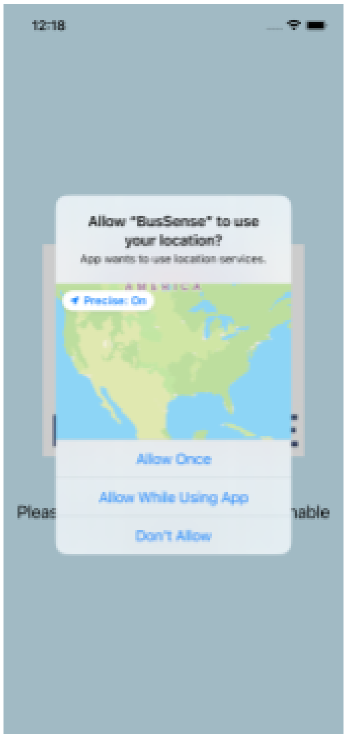

Fig. 1 Request user location for Step 1

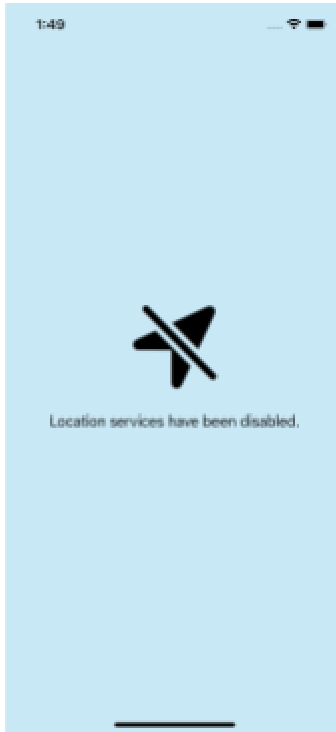

Fig. 2 Denied location permission from step 1A

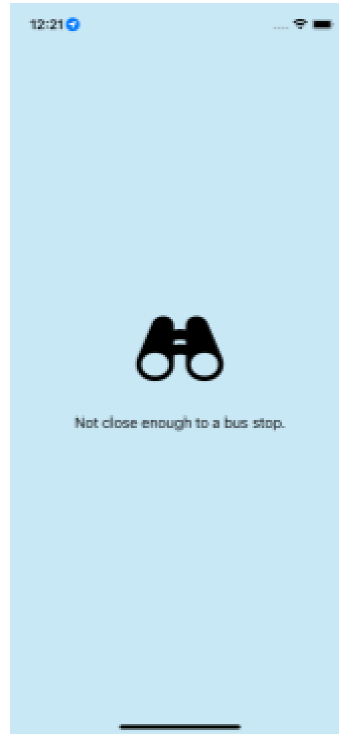

Fig. 3 No buses found within range for step 2A

Fig. 4 Bus Stop Results for step 4

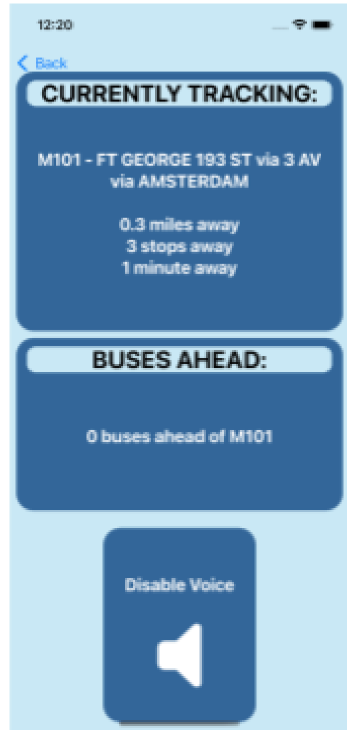

Fig. 5 Bus Tracking View for step 5

Some work was previously done to integrate machine vision into the application. The idea was to allow users to snap photos of oncoming buses to verify their number and direction. Modern cameras are very high resolution, and initial tests using the python library Tesseract were promising. Tesseract is trainable with fonts, and the MTA fonts are readily available.

The values returned by Tesseract were not always perfect, but due to the very structured nature of Bus route names, it was trivial to filter incorrect values and make educated guesses. There is no L or I bus, for example, so any L or I found by tesseract could be presumed to be a 1.

There were some issues with the idea in the real world. Firstly, it was hard and potentially dangerous for users to attempt to take photos of oncoming buses. The risk of accidentally hitting a cyclist or a vehicle was non-zero. Secondly, there may be many obstructions preventing the camera from finding a good view of the bus. It might also be unwise for users to pull out their expensive phone, as they may become the target of a theft.

Machine Vision was therefore shelved for now as a service for BusSense, although initial tests using Chat-GPT to recognise bus images has been highly successful.

Evaluation with Users & Partners

To ensure that BusSense fulfilled the needs of its prospective users, it was crucial to obtain feedback from individuals who are visually impaired or blind. Given that BusSense is exclusively designed to work with the MTA bus system, it was essential that our feedback came from individuals residing in the city. Our first step was to reach out to Dr. Seiple at The LightHouse Guild. With his help, we were able to connect with several potential testers.

Our initial interview sessions were meetings held online over Zoom, which proved to be incredibly informative. A total of eight Lighthouse Guild patients and 5 seniors from the senior centers who identified as low-vision were interviewed. Another eight participants were screened with our questions who did not identify as having severe visual impairment, but did have low-vision that made it difficult to read oncoming buses without their glasses. We were delighted to discover that many of our interviewees were enthusiastic about the concept and had numerous suggestions and pieces of advice. During the feedback sessions, we learned that the majority of visually impaired individuals preferred taking the bus over the subway, and there were several unexpected issues we had not considered.

We also found that most respondents had unpleasant experiences with Access-A-Ride, the transit system operated by the MTA. Additionally, many people faced issues with private car services such as Uber.

We encountered difficulty in recruiting participants for our feedback sessions. Our efforts to solicit potential testers online yielded limited results. As we only were able to have two low-vision users interact with the app, we had to eventually consider testing the app on people with varying degrees of visual impairments, not necessarily strictly low-vision or blind individuals.

During this time, we also held weekly sessions at the Zahn Innovation Center, which proved to be an invaluable resource for us. Our mentors and advisors at the center encouraged us to push our idea forward and identify the minimum viable product. It was during our discussions with the advisors that we realized the potential for machine vision in the application was not feasible. As a product development team, it is essential to recognize when it's time to let go of an idea, even if it had previously seemed foundational.

With the input from our testing users, we moved forward and focused on implementing the features they had requested, such as information on the number of other buses to expect, distance and time information, speech-to-text functionality, and a large, easy-to-navigate user interface.

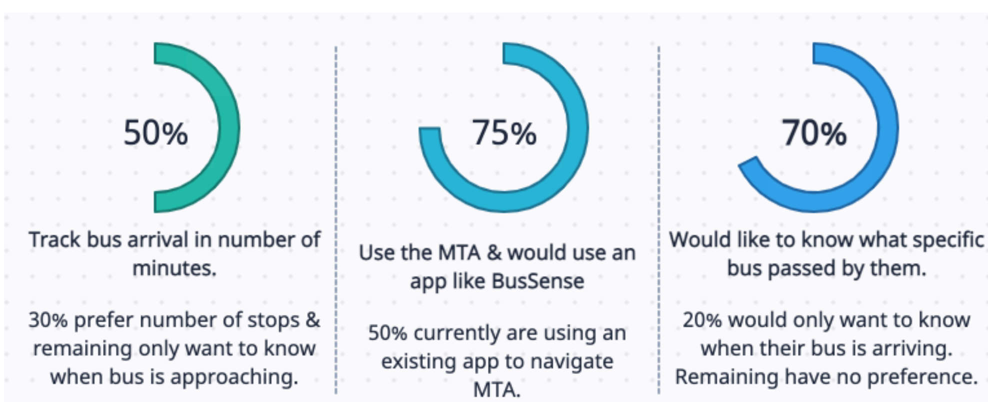

Figure 6. Feedback from 20 participants screened with questions about MTA & existing apps

An unexpected partner came about after we reached out to the Soundscape team at Microsoft. We had not expected to hear anything back, but their insight into some of the technological aspects would have been very valuable. A few weeks later we received an email from Mr. Amos Miller, a software engineer who had been a part of the now-defunct soundscape team. Me. Miller was himself searching for user feedback for his own mobility startup, Glidance. He very kindly made time to meet with us to review our idea.

Discussion of Potential Markets & Future Work

While the precise number of Blind and Low Vision individuals in the New York City area remains unknown, our rough estimates put the number at approximately 60,000 persons, or 0.7% of the total population. Of these people, we considered that many might be of advanced age or reduced mobility. We found another statistic which said that the employment rate amongst blind and low vision individuals is 44%. It seemed reasonable to us that 44% of the BVI population was a reasonable lower bound for our potential user pool - 26,400 potential daily users.

We recognize the importance of making this service accessible and affordable for everyone, especially for those who rely on it the most. For this reason, we did not want to place the cost of the service on the users themselves. Instead, we saw an opportunity to partner with the MTA and offer BusSense as an ancillary service within its information framework. By doing this, we would be able to charge the MTA annually for upkeep, improvements, and service monitoring, while ensuring that the service remains free for the users.

Expanding BusSense beyond NYC is a key part of our growth strategy. We plan to target other large northeastern urban areas with strong transit networks, such as Boston, Philadelphia, and Newark, by convincing local transit authorities to onboard BusSense and market it as an official service. This not only expands our potential user base, but also increases the revenue of the transit system.

Moving into the “Acela Corridor” of Boston, NYC, Philadelphia, Baltimore, and Washington D.C. could expand our potential user base from at least 26,400 to at least 36,000, and including the 20 largest metropolitan regions in the US could put the potential user base at about 105,000 daily users.

One of the major advantages of BusSense is its portability. As long as the user has a cellular connection and the city has some form of API for bus time, BusSense is able to perform its functions. This means that even medium and small-sized towns can benefit from this service, given some small investment in tracking technologies for the buses. Additionally, one potential revenue stream for BusSense is designing and selling small wifi or cellular connected computers with GPS that could be installed in small or medium-sized cities with relative ease. These devices would then serve as the endpoint for BusSense API calls, giving our team greater control over the data flow.

Branding

The evolution of branding for a navigational app aimed to assist blind and visually impaired individuals in navigating the MTA bus system started with its initial name, "SeekAR." However, as the app's development progressed, the decision was made to shift away from augmented reality (AR) technology and focus on providing accurate and accessible navigation assistance. Consequently, the app underwent a rebranding process and was renamed "Bus Sense." This transformation encompassed both the app's name and logo design. The rationale behind these changes was primarily driven by the need for improved accessibility for visually impaired users and the shift in technology utilized for app development. The original name, SeekAR, derived from its initial implementation of AR technology. However, it was realized that the name did not effectively cater to the needs of blind and visually impaired people. Thus, the new name, Bus Sense, was chosen to reflect the app's core purpose of guiding users through the complexities of the MTA bus system. This name conveys a sense of awareness, perception, and intuitive understanding, aligning well with the app's functionalities. During the branding process for our navigational app, we initially designed a logo that incorporated a bus and a human iris, representing the app's focus on assisting visually impaired individuals (Figure 7). However, we received feedback indicating that the logo appeared outdated and might not be clear for visually impaired users. Taking this feedback into account, we made significant changes to the logo. While retaining the bus concept, we opted for a more robust and simplistic design using geometric shapes. We chose a bright blue color with white to create better contrast and enhance visibility (Figure 8).

Figure 7. Initial Logo Design

Figure 8. Final Logo Design

Individual Contributions

The BusSense app went through many stages, from the ideation all the way to the execution and testing of the app. The four team members worked collaboratively to capture all aspects of the B.E.A.T model for the project. The roles were divided as following:

1. Min Zheng:
    a. Designed parts of the frontend UI of the app
    b. Updated the new logo design using user feedback
    c. Helped integrate the data from MTA StopMonitoring API into the app.
    d. Worked on enabling camera access to apps when the previous computer vision idea was being implemented
    e. Conducted user interviews and participated in app research.
    f. Participated in Zahn bootcamp meeting
2. Suhaima Islam: +3
    a. Organized team work schedule and meetings in accordance to course syllabus.

b. Served as point of contact in scheduling interviews and meetings with users, industry advisors, and mentors.
c. Conducted interviews and collected testing feedback from users. Performed preliminary and follow-up research on best practices for BVI-specific apps.
d. Coordinated tasks for class B.E.A.T. presentations and Zahn bootcamp assignments on branding & entrepreneurial components.
e. Created original logo design and branding component of app.
f. Contributed to development of frontend UI design and constant changes according to the user.
g. Worked on integrating the MTA API data and displaying bus real-time updates in different metrics.

3. Daniel Aguilar-Rodriguez:
    a. Participate user interviews
    b. Implement location permission request to use location
    c. Implement functions to fetch MTA bus API
    d. Reorganize code and file structure to follow MVC (Model View Controller) structure for improved readability
    e. Enable text-to-speech
    f. Implement button to toggle text-to-speech
    g. Implement realtime refresh of data
4. Joshua Burdon:
    a. Worked on integrating OCR character recognition and image processing.

b. Outlined potential market bases and developed the business plan and conducted user interviews.

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We would also like to thank Dr. William Seiple, Director of the LightHouse Guild, for providing us with resources and users that gave us great feedback during app's development.

Thank you to the Zahn Innovation Center for the opportunity to be a part of their bootcamp, and mentoring us through the branding, business, and entrepreneurship portion of our app's ideation process.

Our thanks also to Mr. Tuan Huynh from the MTA for meeting us and providing us with some insight, and to all our testers and interviewees.

The work in this project is our own. Any outside sources have been properly cited. The project is supported by the CCNY CEN Course Innovation Grant

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