GUIDECALL: AFFORDABLE AND TRUSTWORTHY VIDEO CALL-BASED REMOTE ASSISTANCE FOR PEOPLE WITH VISUAL IMPAIRMENTS

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The following faculty members have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfilment of the requirement for the degree of Master of Science, with a major in Computer Science.

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LIST OF ABBREVIATIONS

AI	Artificial Intelligence
AWS	Amazon Web Services
BLE	Bluetooth Low Energy
BVI	Blind or Visually Impaired
FCM	Firebase Cloud Messaging
GCP	Google Cloud Platform
GPS	Global Positioning System
JVM	Java Virtual Machine
LP	Light Perception
RSSI	Received Signal Strength Indication
SDK	Software development Kit
OS	Operating System
POI	Point of Interest

ABSTRACT

Blind and Visually Impaired (BVI) individuals often face many challenges while performing daily tasks or exploring new places. Assistive technologies can help a BVI individual to be independent by addressing some of these challenges, but there remain many tasks that still require some sort of human assistance. Given that human assistance from someone nearby is not always possible or preferable, there is an increasing trend of using video-calls to receive assistance from a human remotely. To better understand how well current remote video-calling applications serve the needs of BVI individuals, this work conducts an online user study with 55 participants. The responses received suggest that the current approaches to provide remote assistance through video calls are either too expensive or do not use helpers whom a BVI individual can fully trust.

This work presents a smartphone application called GuideCall that enables BVI individuals to draw assistance through a video call with a single volunteer helper selected from one of many pre-constructed situation appropriate groups of trusted individuals. GuideCall provides a unique combination of features not present in commodity video-calling applications and is specifically built to meet the needs of BVI individuals. Preliminary evaluations show GuideCall to be fairly effective in many daily tasks BVI individuals encounter, potentially proving to be an inexpensive option for receiving assistance while being more confident about the quality of assistance, privacy, and safety.

CHAPTER 1

INTRODUCTION

Visual perception plays a major role in completing many tasks of our daily routine, such as indoor and outdoor wayfinding, locating objects, of interest at a store or office, comprehending visual signs and printed text, and getting a general sense of the current state of the surroundings. These tasks can pose great challenges for blind or visually impaired (BVI) individuals leading to the need to spend significant amount of additional time and effort (compared to sighted users) to complete these tasks (if they can be completed at all), potentially taking on undue physical risks in some cases.

There has, thus, been prior research to overcome these challenges. For example, there has been a lot of work in the area of indoor and outdoor wayfinding through the use of global positioning systems (GPS), computer vision and artificial intelligence (AI), and wireless technologies to provide location and associated contextual information for BVI users (for example, [9, 16, 19]). Even with these emerging advancements, there will continue to be many instances when the limitations of these solutions (such as lack of infrastructure or conditions unsuitable for the technology to work) will result in a BVI user not fully being confident in relying on them. In such cases, it always helps to be able to rely on another human's assistance to bridge the gap and provide the necessary assistance. Unfortunately, there are many situations where a BVI person may be alone with no one present in spatial proximity to provide assistance upon request.

There has thus been a growing trend of BVI individuals resorting to remote assistance from others by transmitting real time images or videos [1, 2]. The remote sighted assistant or "helper" comprehends the received images visually and passes along any information gleaned to the BVI user, thereby "filling in" any of the latter's information gaps towards completion of

the task. These systems, unfortunately, are either expensive to use due to high labor costs of the helpers (in the case of Aira [1]), or untrustworthy due to the use of unknown and typically untrained volunteers (in the case of BeMyEyes [2]). Additionally, contacting outside help may be restricted in situations that involve the workplace. Personal video calls through applications like FaceTime are common, serving as an inexpensive, trustworthy option utilizing known helpers. Finding someone to help in a hurry may not be easy with such commodity applications intended primarily to connect with a single person at a time, and they were never designed to serve BVI user needs.

This research presents the GuideCall remote video-based assistance system that allows a BVI user to seek and get assistance from a trusted set of known individuals through a free smartphone-based application. GuideCall allows the user to populate and create trusted groups for specific life scenarios (such as work, personal) and reach out simultaneously to all members of a group when assistance is needed. The first person to accept the call takes on the assistant's role with all others notified that assistance is no longer needed. Beyond a simple video call interface that is designed to be BVI-friendly, GuideCall provides tools for a remote assistant to

(i) control the BVI user's smartphone to better assist them

(ii) see real-time location information in embedded maps as a user moves around utilizing GPS or other indoor positioning information available.

Such a unique combination of features is designed to make GuideCall to be more effective in completing the daily tasks when assistance is needed. Results of an evaluation study establish the efficacy of GuideCall in facilitating typically challenging tasks for BVI users. A systematic study is subsequently performed to better understand whether the options GuideCall provides will prove practical and useful to BVI individuals. Although applications like Aira and BeMyEyes have been around for a while, we believe this research presents the

first systematic study to understand who BVI individuals trust to provide assistance in various situations of work, home, and outside of work and home. The major contributions of this research can be enumerated as the following:

i) A literature review of the various options to receive remote assistance through smartphones to accomplish various daily tasks for BVI individuals, and identification of areas of improvement with respect to the existing options.

ii) A detailed description of the design and implementation of the proposed GuideCall app and its unique features such as customized group-calling, indoor wayfinding capabilities, and tools for helpers.

iii) An extensive evaluation of the effectiveness of GuideCall (and remote video-based assistance in general) in completing challenging tasks for BVI individuals and its current limitations.

CHAPTER 2

LITERATURE REVIEW

Numerous assistive technologies have been developed over the years to assist BVI persons with daily tasks. With the advent of GPS-based positioning, outdoor wayfinding has become easier using mapping software from Google, Apple, Microsoft, MapQuest, OpenStreetMap and others. However, indoor wayfinding had still remained a big challenge. There have been many recent efforts in the area utilizing wireless devices or computer vision to provide location information and context within indoor spaces [18, 15, 8, 16, 9, 10]. In addition to the application to wayfinding, the use of computer vision promises to serve as the "artificial eye" allowing a BVI person to capture and analyze images using a smartphone and identify text and objects around them as captured within images [19]. This has resulted in many applications emerging such as CamFind [4], TapTapSee [17], KNFB [5], BeSpecular [3] and SeeingAI [6], or something as simple as an app for magnification [7]. Other advances have been in the area of web accessibility and screen readers allowing BVI persons to participate in today's increasingly digital society.

2.1 GPS Accuracy Defects

The various assistive technologies mentioned above have limitations, however. GPS location accuracy isn't always good enough to guide BVI users on walkways. There are many outdoor locations with poor line of sight, such as around skyscrapers, where GPS accuracy is very poor to be even used for even approximate positioning. For indoor wayfinding, the use of wireless communication devices present challenges in terms of interference with other wireless signals and fading. Providing such an infrastructure of wireless devices within indoor spaces is in itself a large undertaking and it may not be economically feasible to adopt everywhere at adequate densities. Computer vision-based approaches have limitations in terms of how well

(angle, lighting, etc.) a BVI person can capture images for analysis in addition to being able to pose and receive meaningful queries and responses. Web and computer screen accessibility technologies can fail periodically due to inadequate conformity to standards by content designers or device resource limitations.

2.2 Human – Machine Interaction

In general, assistive technologies can fail due to software or hardware malfunctions or incorrect usage by the human involved. Keeping a human in the loop to correct or overcome limitations of any assistive technology being used provides greater peace of mind to a BVI user and encourages adoption and use towards overcoming daily visual challenges and/or breaking down social accessibility barriers. The evolution of self-driving or autonomous cars provides a similar case-in-point. Even with many advances in the technology, a need to keep a human in the loop for assistance has been felt. As a result, humans are likely to be involved from within these cars or from a remote location, to provide assistance for unanticipated situations. Such remote human involvement for rare corner cases allows technology offerings to be possibly provided earlier and at a lower cost to users than if full automation were desired. For BVI users, access to technology for independent living cannot come soon enough.

2.3 Privacy and Cost

Given that on-call human involvement can be important to provide BVI users the confidence to meet many daily challenges, it is natural that there have been efforts to facilitate such involvement through the use of technology. It can be challenging to find human assistance in the geographic vicinity of a BVI user when the need arises. Thus, most approaches have focused on remote assistance from someone that is expecting such a request and prepared to assist. BVI users can make individual calls and share image or live video from smartphones through apps like Skype, FaceTime, etc., but it may take a while before someone accepts to

assist given the sequential nature of finding such a person. Group calls on the other hand do not easily allow selecting one user and continuing a call with them for further assistance. These commercial collaboration services were also never designed keeping in mind the needs of a BVI user and to serve as an assistive technology with a remote person helping another for visual tasks and wayfinding.

VizWiz was introduced a way for a BVI user to pose questions about their environment to remote crowd workers who could look at shared images and answer questions [11]. Aira is a successful commercial venture that allows the BVI user to call in to a dedicated number and receive assistance from a trained orientation and mobility specialist [1]. The BVI person can use a smartphone or an extra-cost eyeglass device that provides images to the remote helper to look at and provide assistance. BeMyEyes is a similar service to Aira but is based on the use of a smartphone app and relies on unpaid volunteers to serve as assistants [2]. All three of these approaches have limitations. Both VizWiz and BeMyEyes provide assistance from people who have not established trust with the BVI user. This is a very important factor for a BVI user to feel confident about the assistance they are receiving. A trusted helper can potentially alleviate privacy concerns of the BVI user and allow images to be shared that may contain potentially sensitive financial, personal, or corporate information. Previous work has also identified safety as a factor to consider due to incidents where a BeMyEyes volunteer attempted to come to the geographic vicinity of the BVI user to provide assistance [14]. Because Aira uses trained employees, there is likely to be greater trust established with those providing assistance. But because these agents work for Aira, sensitive corporate information from a BVI employee could be transmitted outside the premises. The biggest disadvantage with Aira is the high cost of the service, which runs at about $1/minute and can easily add up to hundreds of dollars a month for a BVI user. On average, BVI people cannot afford such costly services to perform the challenges they face in day-day life.

2.4 Quality of Assistance

GuideCall as a system attempts to provide the level of quality of assistance BVI users receive from Aira but at a much lower cost or for free. It is built as a smartphone app that a BVI person uses to request assistance from a trusted group. Because assistance is sought from a chosen group simultaneously (in parallel), the delay in getting someone to help is likely to be much shorter than sequential calls for assistance (such as with Skype or FaceTime). Multiple groups can be configured for various assistance-requiring scenarios, be it at work, home, or somewhere else. At work, where sensitive corporate information may not be shared with an outside person, a group could be created comprising only of co-workers. At home, trusted friends and relatives could provide assistance in finding documents or objects. Each potential helper can be labelled with trust levels. A BVI user only needs a smartphone with access to Wi-Fi and/or data service from a cellular network. GuideCall provides real-time location updates for helpers using embedded maps allowing them to provide more knowledgeable assistance, not just in GPS-covered satellite locations, but also indoor locations that are so provisioned.

There has been other work in peripheral areas that are related to this work. The work in [13] investigated the appropriateness of social network question asking as a resource for blind users using VizWiz Social. HintMe [20] is another Q & A posing tool developed for BVI users utilizing their smartphones. Prior research has generally identified various tasks that BVI individuals require assistance with and are amenable to seeking remote assistance [12]. The main difference of this work with such prior work is that GuideCall seeks assistance through video calls. A video call has the potential to help accomplish a different set of tasks than what an app built to pose queries was designed to do. This brings forth its own system design challenges along with the need to consider multimodal interactions with a remote helper. We suggest that this mode of seeking assistance is a very important area to consider for research.

CHAPTER 3

PROPOSED SYSTEM

After laying out the motivation for building an application such as GuideCall in the previous chapter, this chapter provides some details about the system architecture of the designed GuideCall application and its various components. Designed as a single smartphone application which operates in two modes: BVI user and Helper. An overview of system architecture is shown in Figure 1.

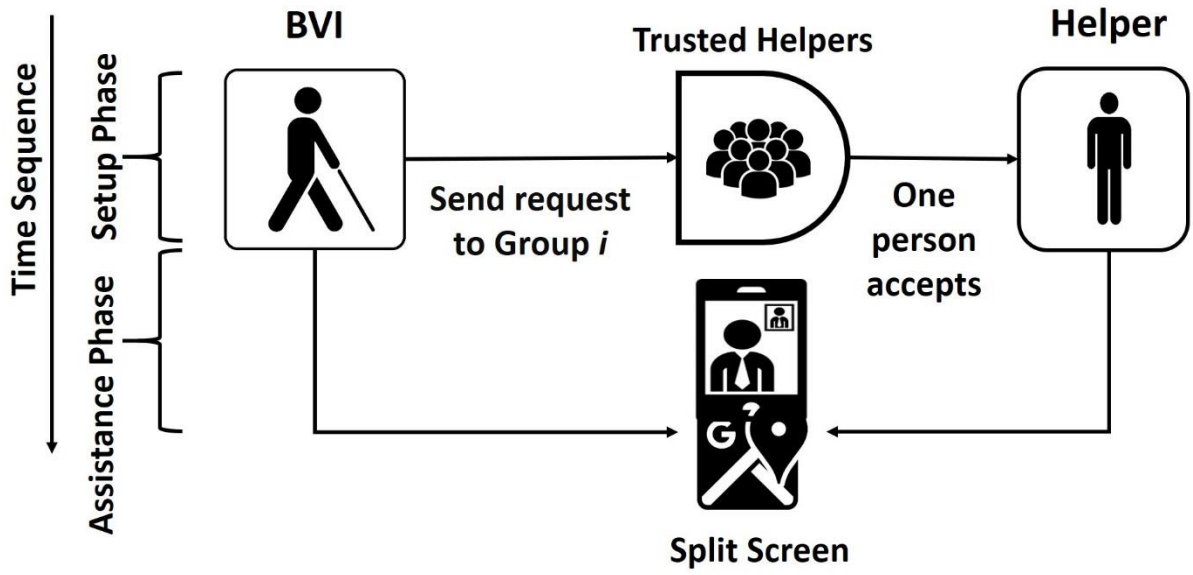


Figure 1: GuideCall System Architecture

3.1 System Workflow

Whenever the BVI user needs assistance, the following steps will be followed through the application:

Step 1: The BVI user opens the GuideCall app and if already signed in, the BVI mode screen activity will be displayed.

Step 2: Utilizing native accessibility features on the smartphone OS, (Google Talkback) the buttons and images inside the activity will be read to the user.

Step 3: To receive assistance, the BVI user selects a Help button. This triggers a notification "Help Required" to be sent to the smartphones of all potential helpers through a group chat application that contains all potential helpers within the selected group i (i = 1_ _ _n).

Step 4: One of the trusted helpers (who elects to provide assistance) will select the received message and click a Call option that becomes available. This will result in a video call to be connected between this helper and the BVI user and a notification to be sent to all other helper candidates in the chat that a helper is connected successfully with the BVI user. This will assure other potential helpers that someone has accepted to be a helper for providing assistance.

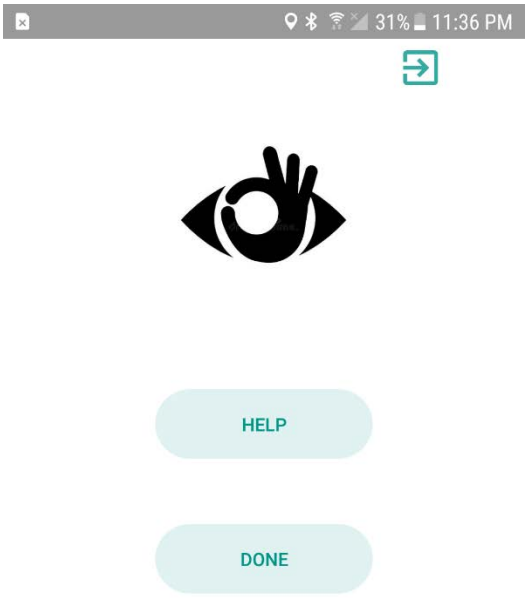
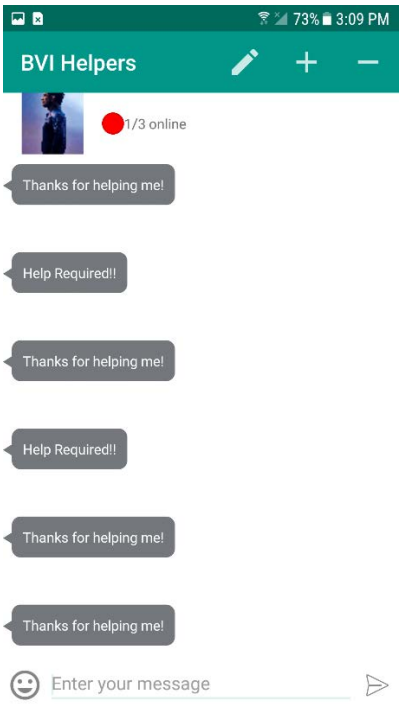


Figure 2: Initial Screen on BVI side

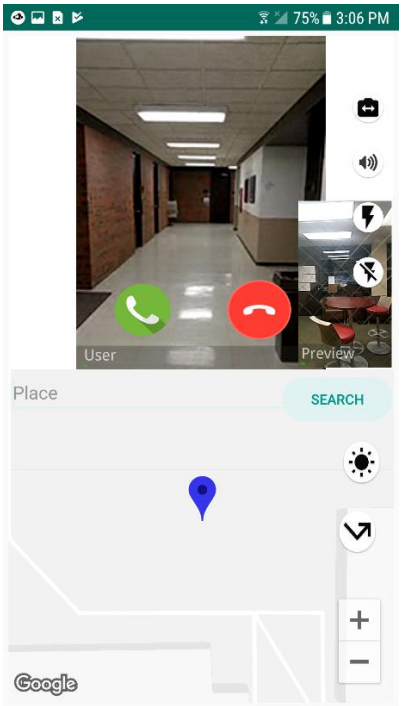
Step 5: When the call is connected, a video stream of the BVI user will be shared with the helper so that they can be the "eyes" of the BVI user in assisting with visual perception. To assist effectively, a helper user can access features of the BVI user's phone such as cameras (front and back), flash light, and microphone (to switch the speaker on if necessary). The video call can be viewed in full screen by double tapping on the frame and allows pinching by the helper to zoom in and out. Along with the video call, Google Maps is integrated into the application to assist BVI users in outdoor environments. This allows the helper to study both the default view and the satellite view and understand the BVI user's location and orientation and guide them towards the destination. Incorporation of indoor maps is a unique feature for GuideCall. In locations provisioned with an accessible indoor wayfinding system such as NavCog [9] or GuideBeacon [16], real-time location updates of the user walking can be shown on an image of the floorplan. This feature allows a helper to continuously learn about the context surrounding the BVI user and incorporate that in their instructions.

Step 6: Once a BVI user has got the assistance they need from a helper, they can end the call by clicking a Done button. This button will send a message of "Thanks for helping me" to the group chat and enables others to understand that the BVI user was successfully assisted.

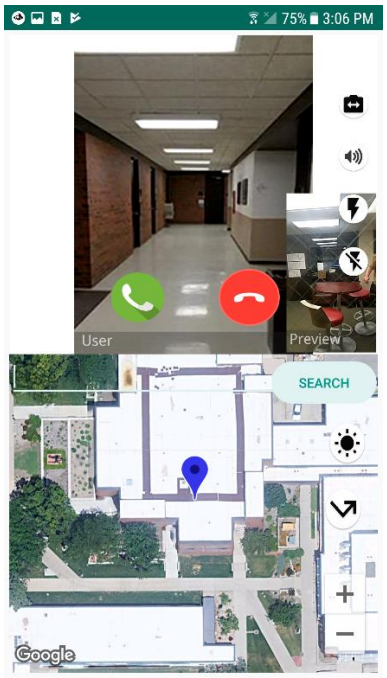
The simple start screen on the BVI user's side is shown in Figure 2. A sequence of snapshots of the app on the helper side is shown in Figure 3. The helper side app does not necessarily have to be run on a smartphone, but it can also be run on a desktop or laptop providing another convenient option for a helper. To provide ease of access to users, there are some additional features to each of the messages sent or received by any user. A user can call any user inside the application by clicking a Call button. When there is a need of assistance for a BVI user, this feature is used by a helper to make a dedicated call to the BVI user. Each group chat has a capacity of 100 participants. When the capacity of a group reaches maximum, the



a) Help requested as Chat Notification



b) Outdoor default map view



c) Outdoor satellite view

d) Indoor wayfinding view

Figure 3: Stages on helper side of GuideCall

user can create another group to add new users to and link the two groups if they choose to in order to create a virtual larger group. This linkage allows both the groups to receive the alert message whenever there is a need for assistance. GuideCall allows a BVI user to create different groups like Work group, Relatives group, Friends group, etc. Users can decide to which group the alert message should be sent in the application. Situations at work that involve sensitive documents or images can rely on the Work group, while personal situations may rely on one of the other groups.

CHAPTER 4

IMPLEMENTATION

Different services were used to implement the application and provide back-end support. In this chapter, we will be discussing the services that were used to build this application from the core to final product in detail. There were a lot of open sources being used in this application to provide better features like existing systems at no cost. The application could be scaled and integrated with more features and moved from free tier plans to paid premium subscription plans in future.

4.1 Quickblox

Quickblox is an open-source and cross platform cloud communication service that supports video calling, instant messaging and push notifications which provided back-end support to the GuideCall implemented as an Android application. The service provides infrastructure for chat, API and dashboard which is used as a core for building Group Chat in this application. The servers can be hosted on Amazon Web Services (AWS), Google Cloud Platform (GCP) or Microsoft Azure cloud providers. It provides secure access to cloud servers and supports on-premises installations with no connection to the outside networks. Chat connects and socializes the users by having peer to peer chat and group chat. Guide Call application includes a simple authentical process with Single Sign-on and integration across all popular platforms. Software Development Kit (SDK) is a set of software development tools that allows the developers to create applications, software packages, frameworks, build hardware and software platforms and operating systems. In order to access the SDK provided by Quickblox, the libraries of Android SDK in Quickblox should be added and connect it to the cloud. Apache Maven, an automation tool that is used to build Java applications are used

as repositories for this application. The service provides full back-end support to Android, iOS and Web applications.

Upon signing in as a developer, Quickblox allows to create an application to provide back-end support. Once the application is created, unique credentials such as Application ID, Authorization Key, Authorization Secret will be given to the created application. With these credentials, we can access the application from our code. When the user creates an account in GuideCall, the credentials and information will be sent to Quickblox server immediately and the user can start using all the features provided by Quickblox in GuideCall application. Each and every user will have unique User ID stored in Quickblox server to uniquely identify users. Once the group chat is created, the information about the group chat such as users in the group, user IDs of users in the group will be sent to the server and a unique Group Chat ID will be created at Quickblox. The administrator who maintains the information about users and chat can retrieve all the information about the users, messages, groups and images from Quickblox server. Quickblox allows the developers to use APIs and create applications that provide instant message at all times. On free tier plan with restricted usage of messages per day, it also sends notification to administrator once the daily limit is reached. In GuideCall application, Quickblox was used to store user account information, credentials and group chats. Whenever the user log in, the application will verify credentials entered by the user with credentials in the server to allow the user for further access in the application.

With Quickblox in GuideCall application, Android SDKs are easier to use with better communication features and data services. The common way to interact with Quickblox is represented in four stages. Firstly, the GuideCall application should initialize framework with application that was created on Quickblox server. Once initialized, a session should be created for the user to actively stay inside the application and use all the features. By using auto session management, SDK saves application session parameters locally on device in secure storage.

The secured storage uses device hardware encryption mechanism. For earlier versions of Android devices, encryption is not supported, and the storage can be set to unsecured without storing any session parameters on device locally. For an authenticated valid user, the application will perform actions with Quickblox communication services and data entities such as users, locations, files, custom objects and pushes.

4.2 Vidyo

Vidyo offers software-based collaboration technology and product-based visual communication products. It is designed for developers to easily integrate communication within their technology. This service enables video communication across all the platforms. We have integrated and enabled Vidyo APIs to support video call features in the system. All the required libraries and functions that is required to apply video calls are in built inside the application for the users to have a good communication experience. Since the video call is the most accessible way to help BVI people, we used the features of Vidyo framework to build according to the system. SDKs provided by Vidyo have been specifically tuned for mobile devices to deliver a high-quality experience for both the users. The video call feature in the system delivers real-time video assistance over wireless networks.

As the video call require scarce mobile CPU and consumes more data and memory, we have used codecs that are designed deliberately for smart phone devices according to manufacturing. The application delivers optimal performance for mobile chipsets. When the video connection is poor due to connectivity issues, the cutting-edge error concealment techniques preserves the integrity of video and protect the call from packet loss and broken video. To efficiently manage all the resources in smart phone, SDKs are adjusted to balance available CPU and resolution with ceaseless optimized video.

4.3 Sinch

GuideCall application was developed with two versions of video call feature integrated. Initially the application had video call features provided by Vidyo, but due to technical issues faced over a period of time, the video call features were integrated into a new service called Sinch. It is a cloud communication service that provides access to features such as instant messaging, voice calling, video calling and push notifications. Sinch provides high quality product and superior level of service that allows for smoother integration. The service offers a good mix of consistent quality and reliability with great scalability and portability that the GuideCall application depends on. The voice quality is preserved and prioritized by keeping the conversation between BVI and helper in streaming.

4.4 Google Firebase

Google Firebase allows the developers to quickly deliver high quality applications with mobile and web application development as base platform. Some of the key features are data analytics, databases, messaging and crash reporting. We use this service to store all the information about BVI's whereabouts. When BVI move from one place to another place, the location of BVI will be updated to Firebase Cloud database. The helper will instantly receive the location from the cloud database and update in Google Maps. Location of BVI will be updated at faster rate for the helper. Whenever the app is installed on a smart phone, Firebase will create a unique ID for that phone. This ID will be used to send or receive notifications from other users in the application. While registering for an account, the helpers will be registered to the group of users who will receive notifications from BVI users. When BVI users click Help button, a notification with the content "Help Required For BVI" will be pushed to all the BVI users in the group. When the helpers click the notification, Group Chat activity will be opened.

Firebase Cloud Messaging (FCM) allows the developers to store and sync application data in milliseconds at real time database globally. BVI user's information are stored in this database. Since the application can collaborate across devices with real-time syncing, the information is uploaded and downloaded at ease. The real-time databases that runs on cloud storage does not require servers and require only web and mobile SDKs. The back-end code in the application which responds to events triggered by real-time databases are executed using cloud functions for Firebase. The application uses local cache on the smart device to server and store changes when the users are offline. When the device comes online, the local data in cache will be automatically synchronized to the database.

CHAPTER 5

GUIDECALL FEATURES

In this chapter, the components of GuideCall application are discussed. The phrase “activity” used in this chapter refers to a page in an application that performs certain tasks within that activity. Initially, the application starts with displaying the logo and title of Guide Call to both the users. Since the greater part of highlights require Internet connectivity, the smart phone ought to be associated with the Internet either through Wi-Fi or Cellular Data. A set of few specific access of permissions in the smart phone is permitted from users. The application at first asks authorization to access system permissions to both the users. BVI users give consent for accessing Location (GPS), Bluetooth, Storage and Camera. Helper users offer access to Camera only.

The system consents can likewise be manually given by the users in the Settings application under the Apps tab. For smart phones such as One Plus, LG, Huawei, Oppo, Vivo and Xiaomi, the consents ought to be set manually at times depending on the Android version of the smart phone. For such brands, the manufacturer makes the application not to run in background for sparing battery life. The battery saver mode will confine the applications to send push notifications. Since the helper user needs to receive notifications when BVI needs assistance, this application should be removed from the optimization list in battery saving mode. Once the permissions are set, the application detects whether the smart phone is connected to the Internet or not. For the most part, BVI users will utilize features such as Google Talk back in Android and Voice over in iOS smart devices to comprehend the messages or articles and read out the images using the buttons that are present on the screen to users. This application is supported by Google Talk back so that the users can click the respective button to get assistance.

5.1 User Accounts

The application requires users to register their accounts on cloud to access the features like Video Call, Group Chat and Map Assistance. Since it is a single application for both the users, the account information is fundamental to differentiate the user as BVI or helper. This application requires very less data such as username, password and email from the users. The account information of all the users are safely secured in the cloud.

At the point when the smart phone is connected to the Internet, the application opens the Log in activity for both users. If the users do not have an account, they can create an account in the application by single tapping the Signup button. As soon as they tapped the button, the current activity will be redirected to Sign Up activity. A hint will be provided for each of the text boxes displaying what the user should enter in that specific text box. The users are required to enter the Username, Password and Email in their respective text boxes. A Switch button is provided for the users to select whether they are BVI or not. This information would know the application which type of user is using the application. All these information will be stored in the smart phone to check for next time when the users visit the application.

Once the account is registered, the user will be redirected to Log in activity. Now, the user can successfully log into the application with username and password. The user needs to sign in just once in this application except if the user chooses to log out of the application. When the application is loaded, the user credentials will be checked from the cloud storage by the system. If the credentials match the information stored in the cloud, the activity will be loaded according to the type of users. For BVI users, the BVI Screen activity will be loaded which is shown in Figure 2. For Helper users, the helper screen activity will be loaded in the application.

5.2 Group Chat

Upon logging into the system, BVI users can create a group containing only the trusted helpers from their own sighted friends or relatives. The group can be constructed by a helper user upon the request by BVI. Whenever a group is created, a unique group ID will be generated. The group ID will help BVI user to send notifications and alert message to the respective group. Users can be added or removed from the group chat. Users can upload an image to set as their display picture in their account. A display picture for the group can also be uploaded by the users. Any user can create a private chat with other user in this application. Generally, helper users cannot include BVI users in private chat. If there is any change in the information provided by the user, the new information can be updated inside the Profile activity. Users can change their password inside the Profile activity. All the new information will be updated to cloud database. A group name can be added at the creation of the group and can be changed by any user in the group. A user can delete the group by clicking the Delete Group button in the application. Only the users who are added to the group will have access to all these features.

In the chat, a status icon is displayed to know the number of users available online at that time. This status icon and data will continue changing relying upon on the user's availability. Trusted helpers can view this information to ensure that there are users available online to assist BVI people. For example, if the user gets a call for assistance and cannot help due to unavoidable circumstance, the user can make sure that other users are available online by taking a gander at the status icon.

To provide ease access to users, there are three features to each of the messages sent or received by the users. Firstly, the user can call any user in the application by clicking Call button. When there is a need of assistance from BVI, the helper can call the BVI using this

button. Furthermore, the user can update the messages sent to the group by clicking Update button. Finally, the user can delete any messages that are sent or received in the group. The messages deleted by the user will be deleted from the application in the user's phone but remains in the cloud server. Each group chat has capacity limit of having 100 participants. When the capacity of a group reaches maximum, the user can create a new group and add new users into it. Currently, both the groups will receive the alert message whenever there is a need for assistance. BVI users may have different groups like Work group, Relatives group and Friends group. BVI Users can decide to which group the alert message ought to be sent in the application.

5.3 Video Call

As referenced before, the BVI will be assisted through a video call by Helper in this application. At whatever point there is a need of assistance, the BVI will click Help button. BVI will be waiting for the helper to be connected with a video call. Once the BVI receives incoming call, the user can click Answer button to accept the call. A ringtone will be played to notify that BVI user is receiving a call. The helper’s name will also be displayed and will be read out to BVI user to know which helper is trying to assist them. After the video call connection is established, the Helper user can be the view of BVI through the camera. To assist effectively, Helper user can access the features such as camera change, flash light and microphone of BVI user's smart phone. The camera can be changed from back camera to front camera and the other way around. If any objects are not seen properly or in case of low perceivability in the video call, the Helper users can switch on the flashlight of BVI user's phone from their own phone. The video call can be viewed in full screen by double tapping on the frame. Since, there is no time limit for the video call, BVI people can get full assistance as long as they want.

5.4 Map Assistance

When BVI receives the call from the aide, the location of BVI will be shared with the helper in order to assist effectively. A split screen that shares the video call and map is shown to the helper. If BVI user wants to navigate to an outdoor or indoor place, the map will be helpful for Helper user to assist BVI. Since the helper can see the exact location of BVI with map, the system will aid effectively to BVI. Each movement of BVI can be tracked by the helper and updated quickly in real time. We have integrated both indoor and outdoor maps for the helper to assist BVI.

5.4.1 Outdoor Maps

Google Maps, a web mapping service that offers satellite imagery, street maps, panoramic view of streets, real-time traffic conditions and route planning. We have used Google Maps API to display the location of BVI to the helper. The location coordinates of BVI will be uploaded to the cloud database in real time. This information will be received by the split screen shown on the Helper side. With the data obtained, the coordinates will be placed on the Google Maps frame in the split screen. Places API and Directions API from Google Maps are used to show the surrounding places near BVI and route map to any place through Google Maps in the application. All the features such as navigation, routing, place description of Google Maps can be accessed from inside the application.

5.4.2 Indoor Maps

Upon entering an indoor space and starting the application on their smartphones, the app scans for Received Signal Strength Indication (RSSI) of beacons around. BLE (Bluetooth Low Energy) beacons are deliberately set in the indoor space. As soon as the user gets into the proximity of a beacon within a building, beacon instance and namespace ID (Eddy stone format) or proximity UUID, major and minor (iBeacon parameters) are captured by the

smartphone that is carried by the user. Having this information, the wayfinding app can extract the name of the place, and then download the micro-location that the beacon is associated with. BLE beacons include both POIs (Point of Interests) and other points that may be useful to improve the wayfinding experience. Beacons locations in the physical environment are correlated to a pair of pixel coordinates (x, y) that were obtained either automatically through indoor representation tools such as IBeaconMap or manually using off the shelf graphics editor software. In case the manual option has opted, the admin is responsible to choose POIs where beacons must be placed, then find their coordinates on the floorplan and insert them into the database. As the user wanders around the building, the smartphone detects proximity to the beacons to determine the user location and then download POIs (x, y) and display it on the helper screen.

5.5 BVI Screen

When the BVI user loads the application, BVI Screen will be displayed to the user as shown in Figure 2. This screen will have three buttons such as Help, Done and Logout. Help button will make the user to proceed to next activity by broadcasting a message to the Group Chat. The Done button will acknowledge the helper in the Group Chat who provided assistance to BVI. This application is developed in such a way that it reduces the user interaction between the application and user. Logout option will make the user to log out of the application. From next time onward, when the user log in, the user should provide credentials. When the user re-log in to the application, the user can see the chat options which is generally shown at Helper's screen. BVI user can change their profile, adjust the settings, and add or remove a member in a group. Once BVI user is logged in, BVI Screen activity will only be displayed until they prefer to log out of the application. In order to access the settings in the application, BVI user should re-log in to the application.

5.6 Helper Screen

As said earlier, Helper Screen will have features to create a private chat or group chat, addition or removal of users and change of profile settings. Helper Screen will display all the Chat dialogs that the user is being part of in the application. The broadcast message will have Call option for Helper to assist. The split screen containing video call and map assistance is shown on the helper screen. To assist efficiently, Helper can change the camera view in BVI's smart phone by clicking Camera Change button. To have a good visibility near BVI user's surroundings, the helper can turn on flashlight of BVI user's smart phone. BVI users can search for a place in the search box provided in the application. The requested search results will be displayed on Google Maps for the helper. Users can click on the search results and click the Maps button to draw a route from BVI's location to the search results.

CHAPTER 6

EXPERIMENTAL EVALUATION

The primary objective in evaluating GuideCall was to measure its efficacy for tasks that prove challenging for BVI persons to accomplish independently. The general BVI specifications and helper specifications were shown in Table 1 and Table 2 respectively.

TABLE 1

BVI REQUIREMENTS

Components	Specifications
Operating System	Android OS, Fire OS
Minimum SDK	4.4 (KitKat)
Maximum SDK	9.0 (Pie)
Data	Wi-fi or Cellular Data
Location	Yes
Bluetooth	Yes

For evaluation, we selected two smart phones such as One Plus 5 and Samsung Galaxy S7. We programmed all the modules in Java in Android Studio 3.1.3. We deployed the applications on the smart phones with the latest Android Oreo 8.1 (API level 27) version. The application supports from Android KitKat 4.4 (API level 19) version. We installed all the APIs and libraries in Android Studio and compiled using JRE 1.8.0 with Java Virtual Machine (JVM) OpenJDK 64-bit server by JetBrains. We created two virtual mobile devices of different

Nexus specifications. We implemented the modules on Lenovo Idea pad Intel core i7 with 8GB CPU.

TABLE 2

HELPER REQUIREMENTS

Components	Specifications
Operating System	Android OS, Fire OS, Bluestacks
Minimum SDK	4.4 (KitKat)
Maximum SDK	9.0 (Pie)
Data	Wi-fi or Cellular Data
Location	No
Bluetooth	No

Four different tasks, that were identified through discussions with BVI individuals as challenging to accomplish independently, were chosen. Some of the challenges were familiar to BVI users as they perform in their day-day routine life and some of the challenges might happen to BVI users occasionally or they might not face a situation in real. The evaluation wants to explore all the areas where BVI finds difficult to perform challenges and activities. All the tasks given to them were challenging and efficacy of tasks were measured.

6.1 Outdoor Wayfinding

To locate and navigate to any unfamiliar outdoor location, BVI users typically employ a GPS-based application. Unfortunately, the instructions from such mapping applications may not be fine-grained enough for BVI pedestrian navigation. Additionally, real-time information such as safety in crossing streets (especially those without any crosswalks and traffic lights) is

lacking. For this task, we ask a BVI participant to walk to the entrance of a nearby (about 400 ft away using shortest path) building unfamiliar to them. Any path taken require crossing a street without crosswalks or signals. The starting point of this path is Envision Research Institute and the stopping point is Sedgwick County Emergency Communications. Both the locations were unfamiliar for some BVI participants.

6.2 Indoor Wayfinding

Upon entry into any unfamiliar space, finding a specific destination within that space is always challenging. Without anyone to ask around, feeling around the entire space with hands is the only option currently if no other indoor wayfinding system for BVI users is present (as is typical). For this task, a participant is asked to locate Usability laboratory (about 100 ft away on the shortest path) from the entrance lobby of a floor.

6.3 Computer Screen Task

BVI individuals heavily depend on a screen reader to interpret textual information on a computer screen. In instances where a screen reader does not work (frozen computer screen, image on screen instead of text), help is necessary. In this task, a computer screen with an image mimicking a frozen screen with error message is displayed and BVI users are asked to comprehend the situation. If the BVI participants were able to know the error, then they might think about solving it. But if it's an unknown error, it will be hard for them to solve the error.

6.4 Locating Objects

A common challenge is that of locating an item. Such situations arise in locating documents or objects within offices or homes especially if misplaced. In this task, BVI individuals are asked to find a misplaced handout document on an office desk kept second to last with seven other documents in the pile.

6.5 Methodology

Seven BVI subjects (A-G) with varying level of visual impairments (see Table 3) were recruited. Given that this was a system evaluation and took considerable time from each participant (60 to 90 minutes), we believe the number of subjects chosen is adequate and in line with other assistive technology system evaluations. Each participant was paid $50 to complete the four challenge tasks. As a counter-balancing step, some participants were asked to only use GuideCall to understand if doing tasks without GuideCall first were positively impacting results for those that who utilize GuideCall later. Some of the participants were more used to relying on spatially available human helpers or not doing the task at all, while some were very used to utilizing various smartphone apps to accomplish similar tasks as best as they could. Given that the ability to track user location indoors is a significant feature of GuideCall, that task was the most extensively tested (in terms of number of participants) without and then with GuideCall.

TABLE 3

PARTICIPANTS IMPAIRMENTS

User Label	Participant Characteristics
A	Blind, Cane User
B	Light Perception (LP) only, cane user
C	20/500 one eye, LP other, cane user
D	20/150 both eyes, <20-degree visual field, cane user
E	Blind one eye, 20/800 other, dog user
F	Blind, cane user, speech impairment
G	LP only, mobility impairment, used walker

For all tasks, participants were allowed to use assistive technologies they would generally use (if they do) to complete tasks. These include the use of smartphone-based mapping applications for outdoor wayfinding such as Google and Apple Maps, apps like SeeingAI [6] or magnifiers like SuperVision [7]. We believe this makes for a fair comparison between a remote video-calling app versus using other means. Qualitative evaluations with each participant was used to compare against other video-calling applications (such as FaceTime, BeMyEyes, Aira), if they had used such other applications before.

CHAPTER 7

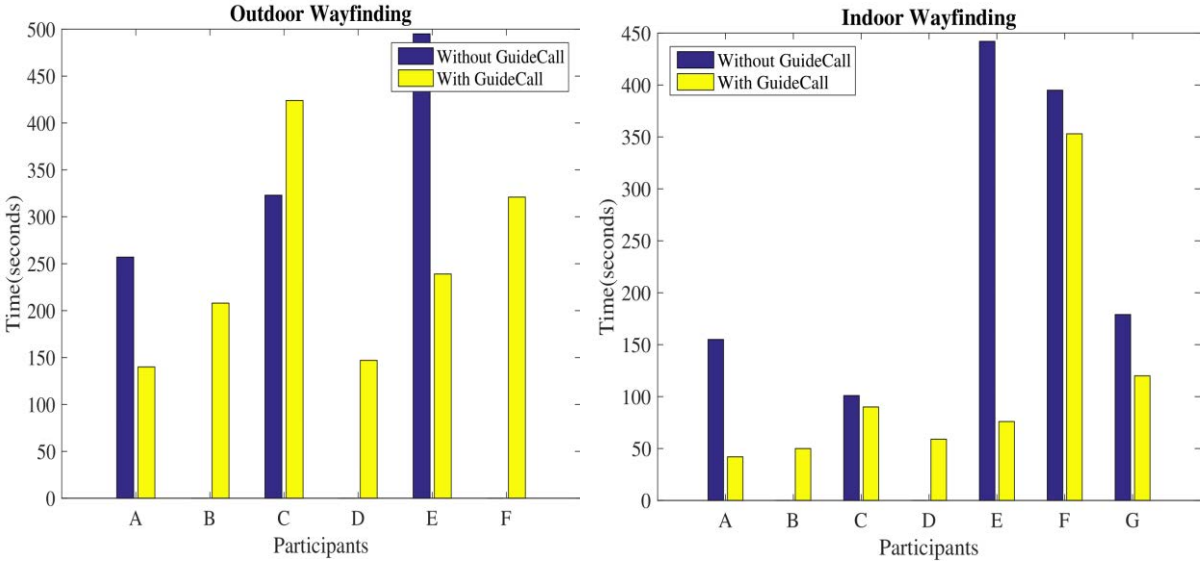
RESULTS

For all tasks, effectiveness of GuideCall is measured using the metric of task completion time. For wayfinding-related tasks, the metric of steps walked was also used to better drill down on why task completion took a certain amount of time (was it because of greater distances walked or just delays in receiving assistance). In addition, extensive qualitative feedback was gathered to evaluate the following: (i) the perceived effectiveness and issues in using GuideCall to a BVI user in completing tasks, (ii) the perceived strengths and weakness of using GuideCall compared to other options such as Aira and BeMyEyes to a BVI user, and (iii) the impact of a helper's familiarity to GuideCall and/or to the geographic area where assistance is sought. The usability of the Android-based GuideCall app's user interface was not tested in detail primarily due to the fact that most of our subjects were iOS users. We have made functionality of the app the primary focus of the evaluations. Some feedback regarding usability from the perspectives of the BVI user and the helper have been captured through a user opinion survey after each user completed their allocated tasks.

7.1 Quantitative Results

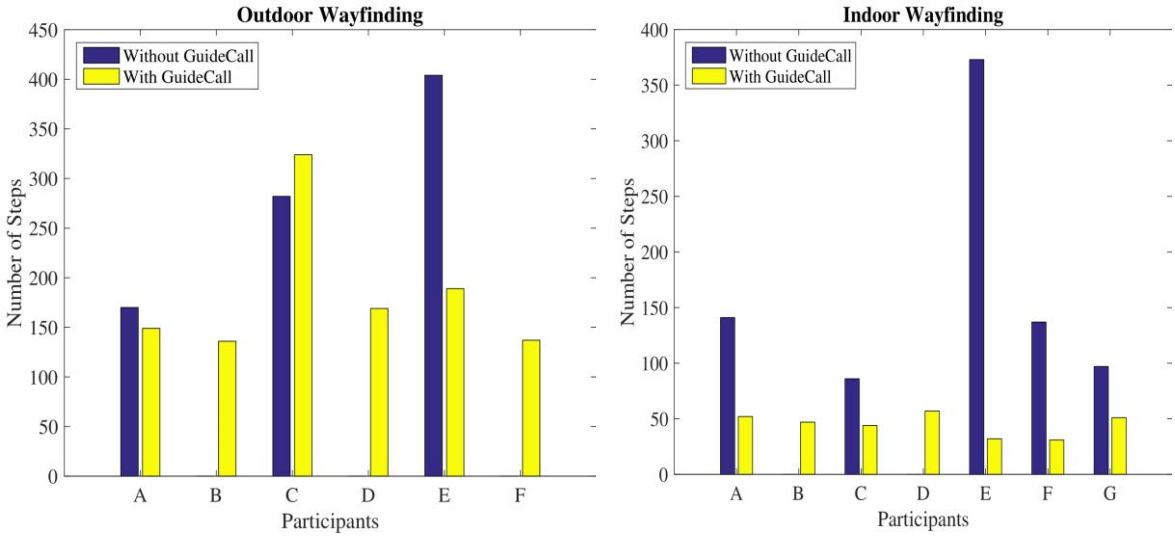
Task completion times and steps taken for the wayfinding related tasks are shown without and then with GuideCall in Figures 4. For the outdoor wayfinding task, navigation time (Figure 4a) for participants A and E show notable benefits of using a helper for guidance over Google Maps. The result for participant C showed the participant taking a lot more time with GuideCall than without; this was due to the use of a helper that was new to GuideCall and its features and had trouble determining from the outdoor satellite view where the main entrance to the target destination building was. Participants B, D, and F had better outcomes with GuideCall than all participants that did not use GuideCall. The corresponding step count results

in 4b show that reduction in time taken with GuideCall is primarily due to the luxury of being directed through shorter paths to the destination and minimizing the need to exploring alternate paths. Some of the participants were not able to perform certain tasks because of not exposed to such situations or need a physical human assistance. Such participants were excluded for the results and shown with the participants who could complete tasks in both the ways.



a) Time for outdoor wayfinding

b) Time for indoor wayfinding

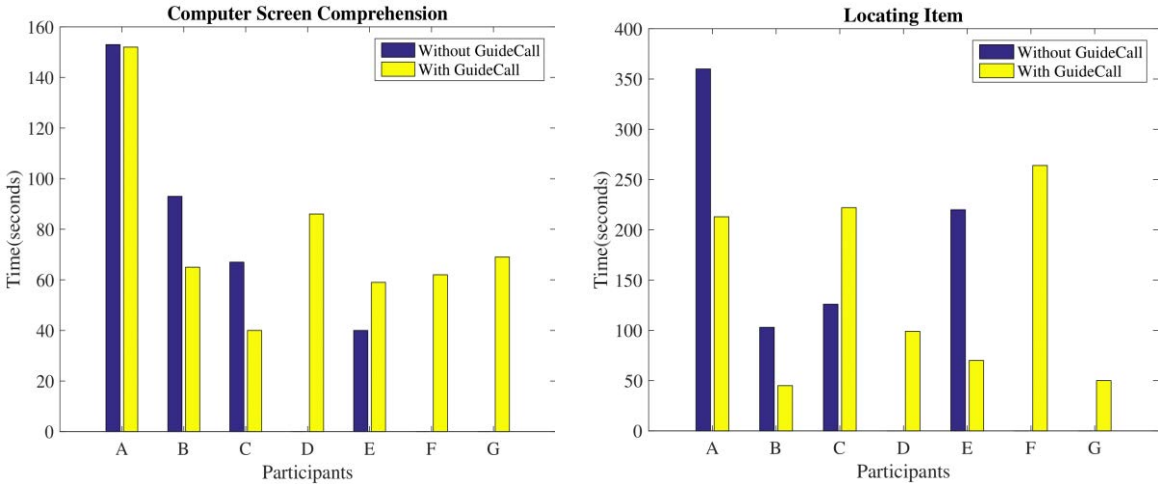


c) Steps for outdoor wayfinding

d) Steps for indoor wayfinding

Figure 4: Task completion time and number of steps for wayfinding tasks

The greatest benefits of using GuideCall were seen for the indoor wayfinding task as evidenced in Figure 4b. There were significant benefits in using GuideCall for participants A, E, and G with smaller benefits for participants C and F. The lower benefits, we believe, was due to the fact that participant C had some useful vision that was utilized in conjunction with a smartphone magnifier app to way find indoors. Participant F's speech impairment in addition to the unfamiliarity of the helper used for that person may have contributed to the result. Participants B and D, testing with only GuideCall, took very little time to get to their destinations. The benefits of GuideCall is greater (a roughly 50% reduction) in terms of number of steps that needed to be taken to arrive at the destination which is because there is rarely any guidance available for indoor environments that BVI users can currently use. A system like GuideCall utilizing existing indoor wayfinding technology can make a major difference in unfamiliar environments through real-time location updates.



a) Time for computer screen comprehension b) Time for locating item

Figure 5: Task completion time for computer and location tasks

For the computer screen comprehension task (Figure 5a) GuideCall still seemed useful at interpreting screen information for many users, especially those that did not typically use any smartphone apps. The results for participant E was an anomaly; this was due to the user

being very adept at using the KNFB app [5] which did not have the overhead of calling someone first. Participants D, F, and G used GuideCall only and completed the task fairly quickly. In general, the computer screen resolution and size as viewed through a smartphone's video camera posed some issues and the helper had to request repositioning the BVI user phone a few times. Finally, for the locating an object (document) task (Figure 5b), only participant C was able to accomplish the tasks faster without GuideCall. This was primarily due to their residual vision which just required a magnifier to complete the task. Participants D and G accomplished their tasks fast with GuideCall, but participant F had trouble accomplishing the tasks due to low video quality as result of a poor Wi-Fi connection at the time of the test.

7.2 Qualitative Results

User feedback about their experience with GuideCall is presented in Table 4. Interesting aspects to be gleaned include comparisons to BeMyEyes and Aira from those who have used them, and overall effectiveness of GuideCall to accomplish tasks. The feedback seems to suggest that GuideCall can reduce costs on Aira, while being more trustworthy than BeMyEyes. Users even felt that for situations at work, GuideCall is a better option than Aira and BeMyEyes in using colleagues' group. Those who have not used such a remote video assistant before liked the human touch in receiving assistance and how it enabled them to complete tasks which they may not have attempted before without having someone in proximity assist them. The ability to get assistance to navigate indoors was a major feature difference with BeMyEyes with some even found wayfinding assistance in general to be easier to receive.

7.3 Helper Experience

Three different helpers were used during our evaluations. None of them had undergone any training or had experience with orientation and mobility guidance for BVI individuals. The

same helper was used for participants A, B, D, E, and G and this person had used GuideCall before and was somewhat familiar with the geographic area (indoor and outdoor) we tested in. Helper for participant C knew the geographic area but was using GuideCall for the first time. The helper for participant F was unfamiliar with both GuideCall and the geographic vicinity.

TABLE 4

USER FEEDBACK

User Label	**Effectiveness Score**	**Positives**	**Possible Improvements**
A	OW = 10, IW = 10, CSC = 6, LI = 7	As an Aira and BeMyEyes user, I can say that this will be very useful if sensitive data is involved; will be useful when danger is possible, and for subjective tasks in general; indoor wayfinding is way better than of even Aira	An iOS version is necessary; can place burden on friends and relatives
B	OW = 9, IW = 9, CSC = 9, LI = 9.5	GuideCall can be very useful to reduce my costs on Aira; did not face any lag in getting assistance when crossing street which is better than what I have faced with Aira and BeMyEyes	Camera focus seemed choppy for remote helper at first in locating item; had to ensure I keep camera steady for text-based assistance
C	OW = 9, IW = 10, CSC = 9, LI = 9	Found the user interface and entire application simple to use; was nice to have someone offer assistance, will be really helpful if free to use	Need to get used to receive remote assistance for some of the tasks, where in the past I may not have attempted the task at all

Notes: User information and subjective scores (1-10, 10 being best) and feedback. IW and OW signify the indoor and outdoor wayfinding tasks respectively. CSC and LI signify the computer screen comprehension and locating item tasks respectively.

TABLE 4 (continued)

User Label	Effectiveness Score	Positives	Possible Improvements
D	OW = 8, IW = 7, CSC = 7, LI = 7	Does give a person confidence in manoeuvring, do not have to ask a stranger, gives independence; helps find items in a pile; a human touch is better for me than just technology by itself	Helper was not able to see beforehand which direction the building entrance is; video resolution can vary with Internet connection sometimes
E	OW = 8, IW = 10, CSC = 9, LI = 9	Quick feedback, can communicate how to assist best, help them help you best; if you are lost and miserable, you are not alone; you constantly get new information both indoors and outdoors, unlike BeMyEyes; in my profession confidentiality is important a work group will be perfect	A wearable glass like Aira has will be useful at sometimes; cane users will enjoy this more as with a dog I have to deal with three brains (dog's, mine, and helper's)
F	OW = 6, IW = 7, CSC = 8, LI = 7	Was easy to locate document and do computer screen recognition (because I generally do not use any smartphone apps for such tasks)	Indoors it took some time for the helper to understand where I wanted to go; outdoors I was nervous crossing the street as I generally have someone go with me
G	OW = N/A; IW = 10; CSC = 10; LI = 10	Calling a group was faster and efficient in getting someone to help me; indoor navigation became very less stressful	A ringtone to say call is placed will be useful

Notes: User information and subjective scores (1-10, 10 being best) and feedback. IW and OW signify the indoor and outdoor wayfinding tasks respectively. CSC and LI signify the computer screen comprehension and locating item tasks respectively.

From the quantitative results, it can be observed that unfamiliarity to GuideCall and its features can have some impact on the outcomes for participants; time taken to complete tasks with participants C and F could be considered as on the higher side. All helpers found GuideCall easy to use and connect to a BVI user. The second helper had some trouble

determining where the entrance to a building was using just the satellite view of Google Maps. The speech impairment of participant F made the third helper's job difficult in terms of verbal communications through the app. The third helper also needed some time to learn how to use the split screen of BVI user's camera and their location. All helpers felt that poor video quality due to bad network connectivity can make it difficult to identify small fonts through the video camera.

With greater familiarity to the application, due to repeated use of the same group of helpers over time, it is expected that outcomes with GuideCall will only improve. A longitudinal study of the effectiveness of friends, family, and colleagues as helpers with GuideCall is a task for future work.

CHAPTER 8

CONCLUSION

This research presented the GuideCall remote video-based assistance system that allows a BVI user to seek and get assistance from a trusted set of known individuals through a free smartphone-based application. GuideCall allows the user to populate and create trusted groups for specific life scenarios (such as work, personal) and reach out simultaneously to all members of a group when assistance is needed. This research provided a detailed description of the design and implementation of the proposed GuideCall app and its unique features such as customized group-calling, indoor wayfinding capabilities, and tools for helpers. An extensive evaluation showed that GuideCall was effective in helping complete challenging tasks for BVI individuals. Additionally, a user study of BVI individuals posing questions about habits and preferences of using remote video-based assistance and ascertaining who they trust in various life and work situations, helping establish appropriate motivations towards designing GuideCall.

GuideCall is still very much a preliminary prototype. Future work with GuideCall will include developing an iOS version and integrating additional indoor wayfinding mechanisms as they become available. Releasing the app to be used more widely by the BVI population will allow gathering longitudinal data over many months of use with various helpers for different tasks, some beyond what this research tested for. It is expected that as helpers get used to providing assistance (many of whom already do with FaceTime, Skype etc. in one-on-one sessions), they will better understand the needs of BVI individuals.

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APPENDIXES

APPENDIX A

FLOW CHART OF USER SETUP

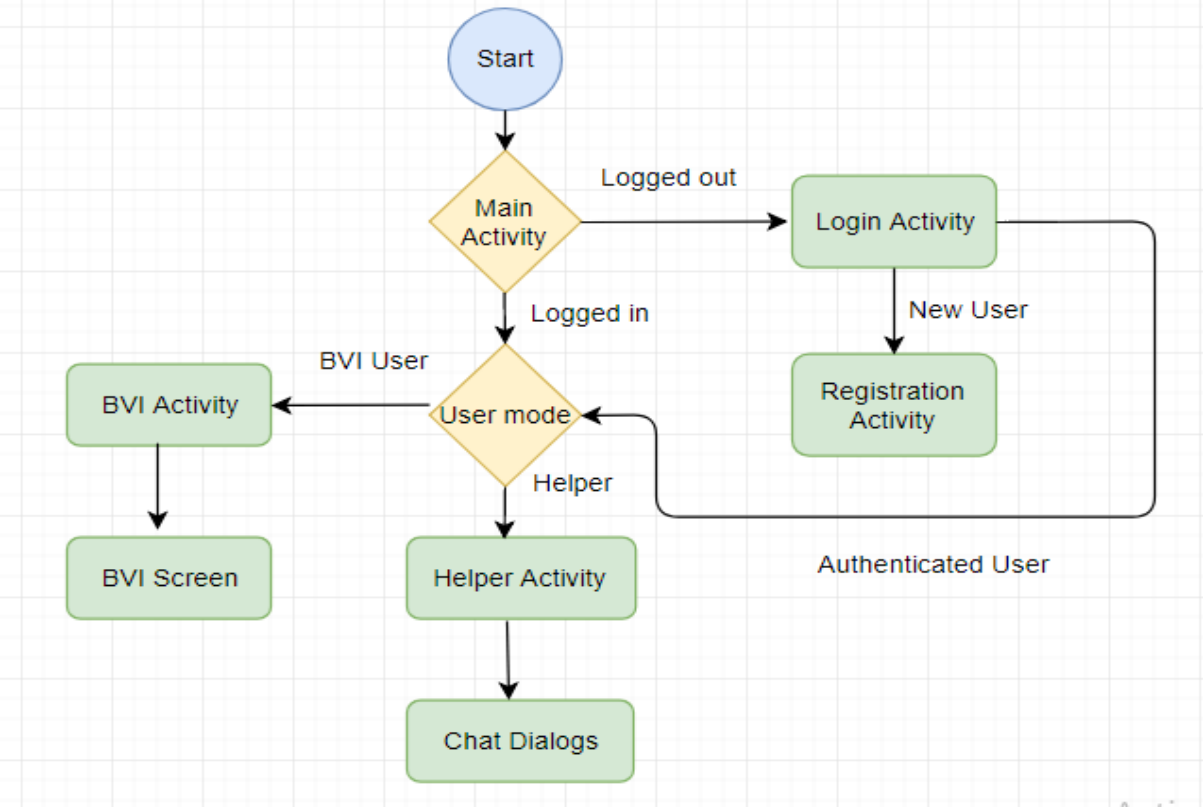

Figure 6: Flowchart of User Setup

When GuideCall application is initiated, the first activity to load is Main Activity. This activity consists of user authentication, displaying logo and setting application permissions. Once application permissions are set, the activity connects to Quickblox cloud to check for user credentials stored temporarily in device. If not found, the activity forwards to Login Activity where the user is asked to enter credentials. If the user does not have an account, the activity will be forwarded to Registration Activity. After successfully log in to the application, User mode interface will check whether the user is registered as BVI or Helper. If BVI, it will forward to BVI activity, else it will forward to Helper Activity showing Chat Dialogs screen.

APPENDIX B

FLOW CHART OF BVI ASSISTANCE

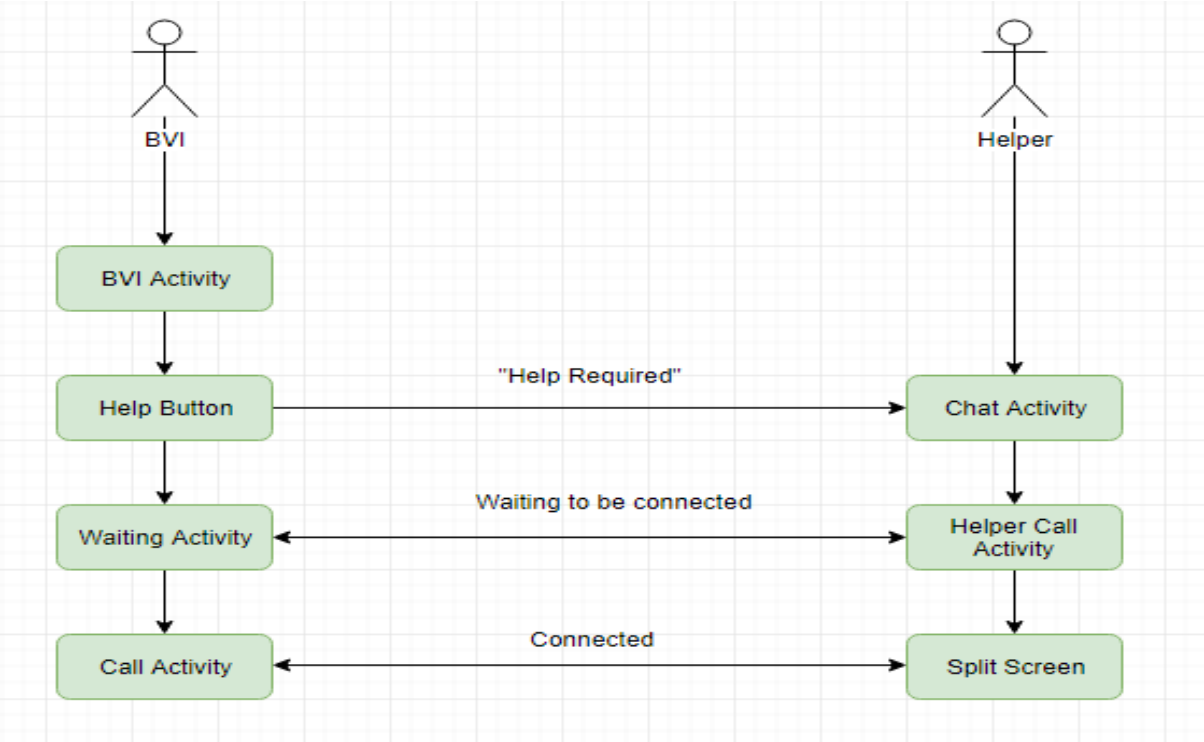

Figure 7: Flowchart of BVI Assistance

When BVI needs assistance, BVI will select Help button from BVI Activity. This activity will broadcast the message “Help Required” to group of trusted helpers from Chat Activity. After sending the message and notification to the group, the context will forward to new activity called as Waiting Activity. In this activity, the user will wait for a trusted helper to call. A helper will initiate the call from Helper Call Activity and wait for both the users to be connected. Once the call is connected, the BVI will be shown the camera of helper in Call Activity and BVI’s camera, flashlight, microphone will become accessed on helper’s side in Split Screen Activity.

APPENDIX C

FLOW CHART OF SPLIT SCREEN ACTIVITY

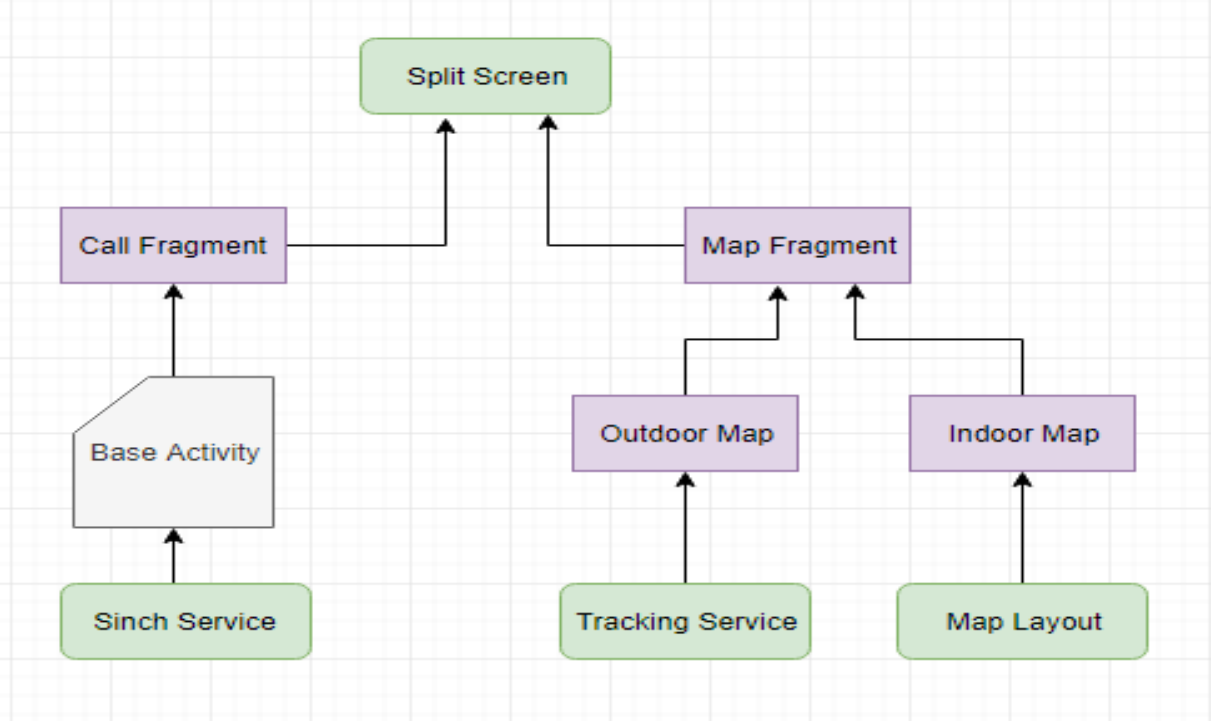

Figure 8: Flowchart of Split Screen Activity

Split Screen activity consists of may fragments, interfaces and activities. In order to display both the video call and maps (indoor and outdoor), the respective functions and classes are called from Split Screen activity. Call Fragment contains Base Activity interface which runs as a background service throughout the call duration analysing the data and quality of call. Base Activity extends the functions and properties of Sinch Service activity for video call. There are two fragments with one for outdoor and another for indoor map. Outdoor Map fragment extends Tracking service which updates real time location on Google Maps. Map Layout displays and marks the real time coordinates of BVI user in an indoor space. BVI's location will be updated in cloud instantly which will be sent by Tracking Service. Map Layout sends indoor coordinates to cloud with BVI user's movements.