A Voice-Controlled Mobile User Interface and Emergency System for Visually Impaired University Students

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***Abstract*—Visually impaired university students encounter numerous issues during their campus life as a significant portion of Universities are not equipped utilities that would help these students in time of need or emergencies. In this paper, we propose a stand-alone voice-controlled to address this issue. The proposed system aims to present the student with access instructors' and departments' information, office location and availability, in addition to an emergency system that can be triggered in case of a fire alarm or if he/she are facing any difficulty. We discuss in this paper the main components of the system with focus on the student application's Onboarding process where the user first enters his/her information and is familiarized with the features of the system, the search engine based voice recognition process and the positioning algorithm used in the emergency system. We also describe the results of a user evaluation field test that was performed.**

Keywords— visually impaired; user interface; voice control; postioning; bluetooth low energy; rsssi; index; emergency; university.

I. INTRODUCTION

Vision is taken for granted. Visually Impaired individuals face many situations in their daily lives where they cannot autonomously perceive or analyze information that is present in their surroundings. These issues have increased with the emergence of the Digital Visual Information age where all kinds of information is being presented constantly through a multitude of screens [1].

Visually Impaired university students encounter numerous issues during their campus life. From visiting an instructor during office hours to submitting a form to the Registrar's office. What may seem like trivial tasks to a regular student can be a hassle to a special needs students in certain environments. While navigation assistants like guide dogs and canes can help them in navigating their pre-known paths, in this age of visual information these solutions are not enough to provide the student with information regarding their surroundings or environment. A lot of Universities in the region currently still lack in terms of Visually Impaired friendly mobile application interfaces that would help students in time of need or emergencies [1].

Given that we are in the current age of IoT and smart devices where all entities are connected and data is constantly flowing, we aim to present visually impaired students with a user-friendly interface that will enable them to perceive and interact with the data presented to them when navigating through the university campus and to request assistance in cases of emergencies or difficulties.

II. RELATED WORKS

There have been recent multiple studies that have proposed navigation systems to assist the visually impaired with most studies revolving around indoor positioning or obstacle detection/avoidance with the help of mobile phones, beacons and image processing.

For example, A. Bhowmick et al. [2] presented a wearable navigation system named IntelliNavi that was built with Microsoft Kinect's on board depth sensor which extracts red, green, blue and depth information from the user's environment. The system then makes use of this data to reduce it to a machine learning problem that uses support sector machine classification to categorize obstacles in the user's path and to alert him through an earpiece about any object blocking his road. V. Filipe et al. [3] also used the Kinect's camera depth sensor to gather data about the user's environment. The data is then processed through a neural network that will then extract features from the scene which will enable the system to detect obstacles that are standing in the user's way.

S. Bilgi et al. [4] proposed a smartphone indoor navigation system called Loud Steps that serves as a guide to visually impaired users who are traveling on campus. The system uses Bluetooth Low Energy (BLE) beacons that are installed on campus to localize users and to guide through their chosen path. D.Ahmetovic et al. [5] also describe a similar system to one mentioned previously. The system is called NavCog and uses a similar approach where BLE beacons localize the user through his smartphone with an approach that is based on the K-nearest neighbour algorithm. The system also contains a pre-built map server that encompasses all required information about the environment that the user is in.

S. Chumkamon et al. [6] developed a system that uses Radio-Frequency Identification (RFID) to inform users about their location. The system then tries to find the shortest path to the user through a General Packet Radio Server network.

As for Visually Impaired user friendly mobile interfaces, J. Sierra et al. [7] introduce in their study the concept of "Low Vision Mobile App Portal", which provides a way to access mobile apps specifically designed for low-vision users. The paper revolves around the idea of designing an application that contains multiple utilities that could be of use to the user. The application data and interface would be visualized in a manner that a low-vision user would be able to interact with. In other words, the font and color of the text would be increased and organized in a certain way that would be easier for low vision users to read.

R. Swathika et al. [8] propose an approach to recognize emergency exit signs using the user's mobile phone. This approach uses edge and region detection to identify Exit signs. The system works by employing region filtering to check the existence of the word 'EXIT'. The system then tries to detect the direction of the arrow on the sign by template matching, with the direction of the sign being sent to the user as audio.

Based on previously developed systems and the current need of universities in the region, we are proposing a system that will focus on presenting the student with access instructors' and departments' information, office location and availability through a completely voice controlled interface. The system will also provide the user with an emergency system that will locate him/her using RSSI based positioning from BLE enabled guider devices and call for help in cases of a fire signal or need of help. We are aiming to provide universities with a system that will enable them to provide a better experience for their students and that will converge their existing campus buildings towards smart buildings with our proposed IoT technology. Our implementation will focus on providing the user with a solution that is simpler to interact with and that focuses on enabling access to information that is not easily available to him/her Moreover, we are looking to offer users with an emergency system that calls for help in time of difficulties or need. All in all, the system contains four main components and is described in the section that follows.

III. PROPOSED SYSTEM

This section presents the four main components of our system:

A. Information Database

All information describing instructor offices locations, office hours, statuses and other department related information are stored in this database. The database will act as a university directory. We chose to use Google's Firebase [9] as it provided us with a real-time database that was compatible with the application interfaces that were developed for the system. Moreover, Firebase includes a Cloud messaging service (FCM) that allows sending notifications and messages between mobile devices. For testing purposes, the Lebanese American University's instructor and department directory was used in this study.

B. Instructor Application:

This mobile application interface allows the instructor to update his office hours and his current status e.g. In class, Not on Campus, Meeting and etc. in real-time which will be displayed on the Guider device (discussed in the next section) that is placed near his office door. The application allows the instructor to send a fire signal alarm in case of fire in a building. Moreover, the application notifies the instructor whenever a special needs or visually impaired student is coming to his office (this feature is further discussed in the Student application section). This application was developed using Android.

C. Guider Devices:

Guider devices are to be installed near the door of the office of each instructor or faculty members. These devices display the instructor's name, office number, office hours and current status. These devices also continuously advertise their device name through BLE. The advertised data will then be used for user positioning in the Student application. For this study, Android devices were used as Guiders. Figure 2 shows the interface of the Guider device.

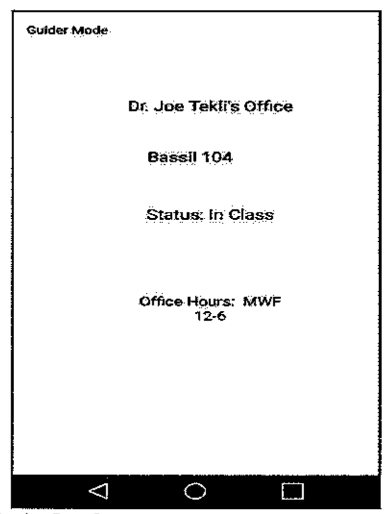

Fig.1. Guider Device Interface

D. Student Application

The Student Application's main purpose is to facilitate his/her daily university life. With visually impaired individuals in mind, we have developed an application that can be completely controlled through voice commands. This type of application interface is unfortunately currently not available in most academic institutions. The application's Onboarding process where the user is first asked to enter his/her information and is then familiarized with the features of the system is also completely voice controlled. The app enables the student to search a university's directory with his voice by saying certain commands followed by an instructor's or department's name. The student will then have access to the chosen instructor's office location, office hours and current status which are set through the instructor application. Moreover, the student will be able to notify an instructor that he/she will visiting his office in case he/she needs any type of assistance. Evidently, information will be conveyed to the student through voice audio.

The system also acts as an emergency system in case he/she needs any help or if he/she is facing any difficulty as the student interface allows him through voice commands to either directly call the university's emergency hotline or to send a notification to nearby instructors or faculty members that he/she is in need of assistance. The application will determine the user's location from the BLE data that is being advertised by the Guider devices. Based on the scanned data the application can determine the building floor that a user is on and the office that is nearest to him. In the case that the data is not available or is not deemed enough to determine the location of the student, the BSSID of the WIFI-Router that the mobile phone is currently connected to will be used to at least determine the building that the user is located in. The Student Application can also be used by any student that has any other type of special need as its instructor notifying and emergency alert features can be helpful to anyone who is facing any difficulty on campus.

At the time of the writing of this paper the user can choose the following disabilities during the onboarding process: Visually Impaired, Wheelchair Bound and Amputee. The application was developed for Android and uses the Android Speech API [10] for voice recognition . Moreover, the Algolia [11] search engine platform add reference was used to improve the performance of the speech recognition API when it comes to instructor/department names and to voice commands. The following section will discuss in more depth some of the main components of the Student Application and the techniques that were employed to improve them.

IV. Student Application Components

This section discusses and describes some of the main components of the Student Application:

A. User Onboarding Process

An application's Onboarding process is one of its main success factors as it is the first point of contact with the user. A successful Onboarding process should familiarize the user with the application and allow him/her to register his/her user information. Most university applications have their Onboarding process as a series of screens which in turn is not helpful for a Visually Impaired user as he/she would not be able to read the information and would need another individual to enter the required user information for him/her. The application that we developed aims to provide the user with a smooth voice controlled Onboarding process that will allow him/her to enter his/her user information autonomously and to start getting familiar with the app's features.

The user will first be asked by voice audio to spell his/her first name. The application will then pronounce the letters of his first name and ask him/her to confirm if they are correct by saying "yes". If the user does not confirm he will be prompted to repeat the process. The second step is then for the user to spell his/her last name and to confirm it following the logic of the previous step. The system will then inform the user the list of numbered disabilities that he/she can chose from and will then wait for his choice. For example, the user would hear "One Visually Impaired, Two Wheelchair Bound, Three Amputee", then based on his/her disabilities will say its number. Therefore, in the case that the user wants to choose Visually Impaired he/she will only need to say "One". The system will then inform the user of the choice that was made and will ask for confirmation similarly to the prior step.

After all required information has been entered, the system will start informing the user of all of the application's features and about what each voice command does. Voice commands are discussed in depth in the following section.

After the system finishes familiarizing the user with the features, it will ask if he/she is ready to go to the main interface or if he/she wants the familiarization part to be repeated. The user can if needed to restart the Onboarding process or to re-listen to the app's features by saying two certain voice commands in the main interface. Figure 3 shows a flowchart that describes the Onboarding steps.

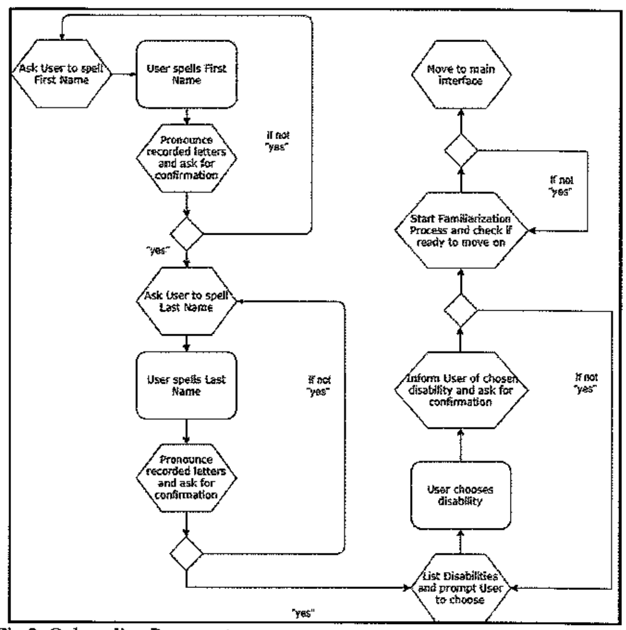

Fig.2. Onboarding Process steps

B. Improving Voice Recognition with a Search engine platform

To provide the user with a better experience, we used the Algolia Search Engine API to improve the results of the Android Speech API. Whenever the user provides a voice command or instructor/department name the speech API results will be passed through the search engine indexes to return the best found hit. Therefore, we first created an index for voice commands on Algolia. After testing the speech API on each command and on multiple devices we took note of its correct results and the errors that we got. Based on the errors that were perceived, we added similar sounding words to each voice command as an alternative in their respective object element in the Algolia Index. For example, the voice command "Urgent Help" was being misinterpreted as "Urgent App" or "Urgent Hip" on multiple occasions and therefore we added them as alternatives.

We also created an instructor/department Index that mirrors the main directory database of the proposed system. This Index was created to account for any typos or misinterpretations that the speech API might have returned. For example, the name "Joe Tekli" was being interpreted as "Joe Tekly"; seeing that Algolia allows typo-tolerance to be enabled, giving "Joe Tekly" as a search input would have returned its correct form. Moreover, the speech API was having problems correctly interpreting Arabic names. To solve this we instruct the user to spell non-English names as the search engine will handle finding the required instructor name even if the spelled name is not completely accurate. Also whenever there are more than one hit in the search, the user will be prompted to choose one of the returned instructor names similarly to when he/she is asked to choose from the disabilities in the onboarding process.

Given that we decided to allow the student to search by department, we added alternatives to department names to make it easier for the user. For example, instead of saying "Electrical and Computer Engineering Department" in full, the user can say "Electrical", "Computer", "ECE" or "Electrical Engineering" and etc. to search for the required instructors.
The system currently has the following voice commands:

- "Instructor": This command starts the search by instructor feature. The user will be prompted to say or spell the instructor name. If there one or multiple matches the user will be asked to confirm or choose his choice before being relayed with the instructor related information. The student will be then asked if he/she would like to notify the instructor that he/she will be coming to his office. In the case there are no instructor matches, the user will be asked if he/she would like to search by department.
- "Department": This command starts the search by department feature. The user will be prompted to say the department name. If there are one or multiple matches the user will be asked to confirm or choose his choice before being relayed with the list of instructors that are available in the chosen department. After choosing the instructor the steps become similar to those of the searching by instructor feature.
- "Emergency Call": Will directly call the university's emergency hotline. In the case that the hotline is not available the user can resort to the "Urgent Help" command.
- "Urgent Help": Will start the positioning process (discussed in the next section) and send a help notification that includes the student's floor location and nearest office to nearby instructors or faculty members.
- "Change Data": Will take the user to the Onboarding process to enable him to re-enter user related information.
- "Repeat Features": Will repeat the familiarization process of the Onboarding phase by describing the voice commands and features of the application.
- "Reset": Allows the user to stop any ongoing search and to go back to square one.

Figure 4 describes the complete search by Instructor or Department process:

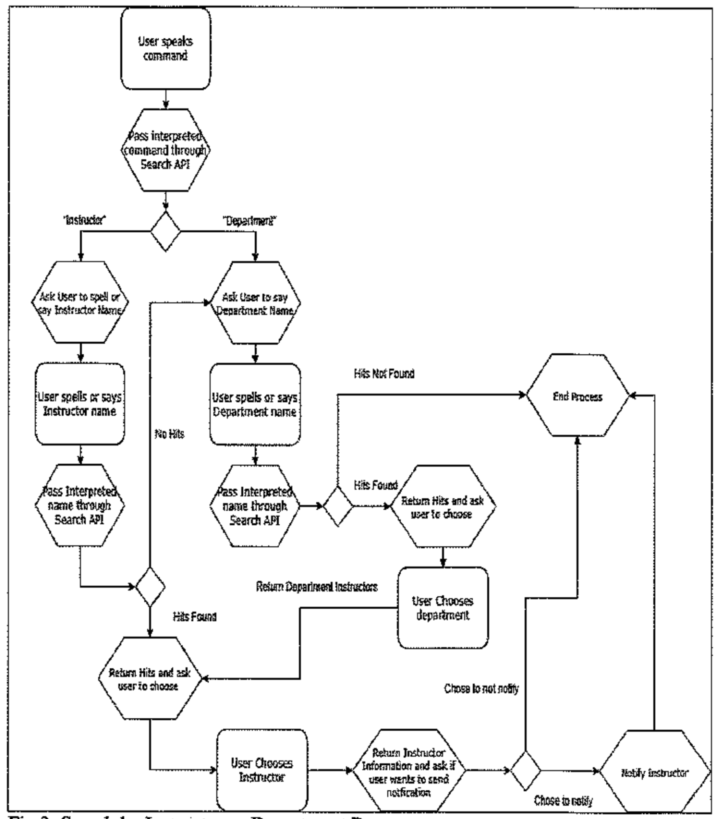

Fig.3. Search by Instructor or Department Process

C. Emergency System Positioning Algorithm

The Emergency system aims to help a student in case of a fire alarm or in the case of he/she needs any type of urgent assistance. When the application receives a fire notification (which also includes the location of the building where the fire is located) it will directly open the main interface of the application, start the positioning process which will try to determine the building, the floor and the nearest office to the user. Then the application will check if the user located in the building where there is a fire. If this is asserted the application will send a notification to faculty members and instructors that are positioned at the building and who are available that there is a special needs student that needs help. The notification will include the name of the student and if available the floor that the student is on and the nearest office to him/her. In the case that the user asks for help through the "Urgent Help" voice command, the system will start the positioning system and directly send a notification to nearby faculty.

We used a similar indoor positioning process to that described in the study that was written by S. Chai et al. [12]. As mentioned earlier in the Proposed System section, the Guider devices that are installed on the walls are always advertising their device name through BLE. When the positioning algorithm starts, the application will scan for all available BLE devices data and will store each detected RSSI and device name. The algorithm will then compute the mean (*Rssi_mean*) and the standard deviation (*Rssi_std*) of the recorded RSSIs. The algorithm will then proceed to remove any outliers from the scanned devices by filtering out any RSSI value that is below the value in (1).

$$Rssi\_mean - 2 * Rssi\_std \quad (1)$$

The algorithm will then compute the average of the remaining RSSI values and if the average is found to be between [-55,-35] dBm we find the device that has the closest RSSI value to the computed average. This device will be considered as the closest to the user and from the name of the device the building, the floor and the office number will be retrieved from the directory database. We decided on the range of the [-55,-35] dBm range to ensure that the average RSSI is considered as a strong signal which would in turn mean that the devices on the floor have a good RSSI signal to the student's mobile phone.

In the case that BLE data is not available or is not deemed enough to determine the location of the student the BSSID of the WIFI-Router that the mobile phone is currently connected to will be used to at least determine the building that the user is located in and a notification that only includes the name of the student and the building will be sent.

V. User Evaluation

For the purpose of evaluating the usability and accessibility of our student application, we performed a series of tests with 8 students from the Lebanese American University. Two of these participants were very experienced (VE) with the system, two were somewhat experienced (SE) with it and four of them had no prior experience with it (NE). The participants tested the application's search by instructor or department functionality. change through the features familiarization process, each one of them was asked to search for an instructor with an English name, we added instructors with English names to the database for testing purposes. In the case that the tester failed to find the English instructor by his name, he/she would then have to try to find the instructor by Department name. The second phase of the test was for the participant to search for an instructor with an Arabic name once by trying to say the instructor's full name and once by trying to spell it. The evaluation was done in the following Search Stages:

- Successful "Instructor" Voice Command (SIVC)
- Successful English name search by Instructor (SENSBI)
- Successful English name search by Department (SENSBD)
- Successful Arabic full name search by Instructor (SAFNSBI)
- Successful Arabic spelling name search by Instructor (SASNSBI)

TABLE I. TEST DATA

Search Stage	**Participants**			
	VE	***SE***	***NE***	***Total***
SIVC	2	2	4	8
SENSBI	2	1	2	5
SENSBD	0	1	2	3
SAFNSBI	1	0	1	2
SANSBI	2	2	2	6

Based on the test data above, it can be concluded that the system has difficulties with recognizing full Arabic names as only 25% of the testers were able to successfully complete an Arabic full name search. The proposed solution to this problem which is to spell the Arabic name gave much better results as 75% of the users were able to successfully find the instructor using this method. As for the results in other stages, they were more positive as 100% of testers were able to get through the "Instructor" Voice command successfully and all of them were also able to find the English named Instructor successfully. 62.5% of testers were successful directly through saying the instructor name and the remaining 37.5% through saying the department name which in turn listed the needed instructor.

From the data results discussed above, we can see that one of the ways to improve our system would be to ameliorate the voice recognition process in the student application. To do this, we should either replace the Android Speech API which were are currently using with a better one or/and we should try to add alternative names to instructors in their search engine Index based on the user usage and tests.

VI. Conclusion

In this paper, we proposed a system that aims to facilitate a Visually Impaired student's daily university life. The system focuses on presenting the student with access instructors' and departments' information, office location and availability through a completely voice controlled interface. In addition to providing the student with an emergency system in case of a fire alarm or if he/she are facing any difficulty. We also discussed all the four components that constitute the system after discussing some of the related previous implementations that were proposed in recent years.

We also discussed in details the Onboarding process of the student application and how it is suitable for our target audience. Moreover, we explored how we improved the recognition of voice commands and names through adding a search engine platform to our system. We discussed the positioning algorithm that we used to determine the location of the user when the emergency system is triggered.

We also included a testing evaluation section where the search by instructor or department feature of the student application was evaluated by 8 university students. The testing data allowed us to further recognize which components of the system should be improved in the future to ameliorate its quality.

Following the tests that were done, we are aiming to improve the voice recognition component of the system by adding more training data and by replacing the currently used Speech API with a better performing one. We also are looking into how we can develop our own Guider devices instead of using Android phones as we are looking into porting/developing the Guider application with Android Things which is better suited for production with embedded devices. Moreover, we are always trying to implement new features that will increase the usability of the system. We are also looking to implement our system in different establishments such as corporations, school campuses and government buildings as the system that was developed can be easily tailored to function in different types of environments.

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