Mobile Phone Navigator for fully and partially visually impaired

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***Abstract*—Many of us nowadays rely on mobile apps to help us navigate. However, these touch-screen apps are not user-friendly for visually impaired people. Furthermore, because the most widely used apps are not specifically designed for the visually impaired, they cause a lot of confusion and have a bad user experience. The rapid advancement of mobile technology initially hampered the accessibility of device functionalities for visually impaired people, increasing their digital exclusion. This paper describes the current state of mobile technology development from the perspective of visually impaired people. It lists and evaluates the suitability of various functions available in modern devices, as well as the various innovative solutions facilitating the use of mobile devices by people with special needs. First and foremost, the article describes specific problems encountered by people with disabilities when using applications designed for mobile devices and suggests solutions. The paper discusses the use of basic assistive tools that come with mobile operating systems, such as voice reading labels, voice commands. The findings from the analysis of the problem of mobile application accessibility were used to create an original concept of universal, sound, and tactile interface design. This concept is predicated primarily on the ability to customise the interface. A visually impaired person can freely configure and run a set of applications available on a mobile device using touch, gestures, voice commands, and audio feedback. Because of the proposed interface template's ease of use and universality, any mobile desktop application that uses it can be a useful solution for all users, regardless of their visual disability. We have incorporated certain features like making calls through voice commands, instant messaging through the same and battery status display and time are also given in similar manner. Moreover the user can read Indian currency notes through the app with the help of in built camera of the mobile phone being used.**

I. Introduction

Touch interfaces have become significant in today's technologically advanced world and are an essential component when designing any new interface for users. This vital interface is used by ATM machines, personal computers, smartphones, and other devices. Smartphones, in fact, have become an essential part of our daily lives. A smartphone combines the features of a traditional mobile phone with those of other devices such as a media player, a camera, GPS, and so on. Many devices' functionalities are available within a single device, so it is critical that it is accessible to all types of users. The blind are at a loss here, so novel approaches are required to provide these functionalities to these users.The touch interface can be improved so that it can be used effectively by the blind. The traditional touch and locate paradigm that they adhere to is incompatible with smartphone touch interfaces. To improve a blind user's usability, haptic and audio feedback can be provided for each touch on the interface. The interface design had to be intuitive, simple to learn, and simple to use, which necessitated analysis and insight.Because it was assumed that the blind could use the smartphone's edges as bearings to locate targets on the screen, the interface's targets were designed to be easily locatable. The menus such as the caller app,messaging app,battery status and time,currency recogniser were all located on the four corners of the smartphone screen. The app's layout, aims for larger target sizes and fewer targets. The targets must be easily identifiable. There are four large buttons along the phone's edges: caller app,messaging app,battery status and time,currency recogniser. The user can initiate text entry by touching a large area. The user is never forced to pinpoint an exact location on the screen in this manner. Although the layout is not aesthetically comparable to that of mainstream apps, this project is much more accommodating to the needs of blind users.From any point in the navigation, the user can return to the home screen. The app's layout is consistent throughout the application so that the user can quickly become acquainted with it.The user is free to experiment with the interface without fear of making a mistake. When a user touches a screen element, the name is read aloud to them. Long press is used for selection. Buttons functionality are even announced as they appear on the screen. The combination of an easy-to-find target and audio feedback enables the user to quickly adapt to the interface and explore with confidence.Navigation is accomplished in two ways: by touching the appropriate button or by speaking commands. The app captures the voice command and moves to the corresponding activity after a long press of the audio button. This dual navigation method is intended to provide the user with the most convenient method of interaction based on the situation. A partially impaired user, for example, can use the touch method of navigation, and the blind can use only verbal commands.Thus ,the goal of this research endeavor was to make technology and services practical and effective for blind users which was successfully achieved in our mobile app navigator for partially and fully impaired people.

II. Literature Survey

Through [1] we learnt about adding voice commands efficiently to the android applications. Voice commands that are effective and also does not get triggered unnecessarily. Through [2] we learnt about the effective feedback commands that are simple to understand and importance of keeping the mode they are delieverd consistent throughout the application. Through [3] We learnt about incorporating the user interface layout with voice based feedback effectively. We also learnt about the impact of size of components of layout on user experience. Through [4] We learnt about how the design for mobile application is different from the regular desktop based applications that are available for people who need voice based assistance. Through [5] we learnt about the various designs available for messaging application for visually impaired people. We learnt about the layouts that provide good user experience. From [6] we learnt about various audio based styles of providing the feedback to the users. We came to know about how effective one type was with respect to the others. From [7] we learnt about designing applications that are audio based. Even feedback to users through these application is provided with the help of voice commands. From [8] we learnt about accessing various application programming interfaces in android based applications. From [9] we learnt about speech to text conversions in various applications and how the obtained text can be further usage. From [10] we learnt about what are the challenges visually impaired people faces while using technology. All the present work lacks user interface that is research backed we have tried to gain knowledge about various impairments and what are the color combinations that should be avoided or that should be used in user interface to make application universal in nature.

III. Problem Statement

"Mobile Phone Navigator for fully and partially visually impaired"

A. Objectives

- To develop a fully functional mobile application to help the partially and fully visually impaired in navigating through the mobile phone.
- To provide a user-friendly and supportive UI for the partially and fully blind people by following the HCI principles(Ben Shneiderman's Eight Golden Rules).
- To provide features such as :
  1) Messaging
  2) Calling
  3) Info about basic phone details(date, time and battery status)
  4) Currency Recognition using phone camera

IV. Methodology

The aim of developing a mobile phone navigator for partially and fully visually impaired is to enable them to use one of the most common and essential technologies of today's world to the fullest. The hardships faced by this community with the advent of touch screen phones have not been much addressed. Voice-based assistants are becoming popular in recent years. The basic psychological shortcoming of these assistants is that the user doesn't feel that he/she is in full control of the phone as he is unable to use the most basic component, i.e, the touch screen. To fill this gap, we have innovated to combine touch and voice-based navigation for easier use by the visually impaired community. The three basic use cases of mobile phones for visually impaired users and other users, in general, are calls, messaging and checking the date, time and battery percentage. Another useful feature of currency detection is also provided so that the users can distinguish among different denominations of currency.

The inclusion of a touch-based navigation component was done to improve the user experience and overall ownership feeling of the user . However while designing the UI for the special category of visually impaired users, along with the HCI guidelines, special guidelines are to be considered targetted for different types of visual impairment.

A. Home Page

The layout of the main page consists of 4 large buttons covering the 4 quadruple of the screen real estate. The reason for choosing the positioning of these buttons is that, user can acess them by approaching the 4 corners of the screen. The buttons occupy most of the part of the screen to prevent invalid taps. The text size used is 14pts which is backed by research conducted by NRB in 2014. Usually larger text size is directly proportional to readability. The 4 buttons named Messages, Call Manager, Battery Status and Currency Recognition are colored in purple, yellow, red and blue respectively. The colours and their combination is chosen are research-backed and aids readability in various kinds of visual impairment like Dichromacy(can not distinguish between red and green), Protanopia(can not distinguish dark colours (12.5% of the population)), Tritanopes(cannot distinguish light colours and greys (13% of the population)), and Deuteranomalous(partial loss of green colour vision (62.5% of the population)).

The coloured background was also used in order to set up the colour associativity of each colour with different functions so that users every time don't need to read the text on the button, they can either remember the position associativity or the colour associativity. Sufficient padding is provided to ensure proper distinction among the UI elements. Elevation has been provided to distinguish the elements from

TABLE I: Summary of Literature Survey

Authors	Methodology	Merits	Limitations
S. Jiang, X. Ding, F. Chen, E. Tan, and D. Zhang	Voice commands in android apps	Voice commands and feedback defined	Not defined for visually impaired
M. Abrams, C. Standridge, G. Abdulla	Design and development of UI	UI principles	Visually impaired principles not covered
P. Andersen and N. Petersen,	voice based system in desktop and mobile	Voice commands in mobile applications	Principles of viually impaired apps not covered
C. Siriopoulos and P. Tziogkidis	Aiding specially abled people with app	Visually impaired principles for UI design	Voice commands not defined

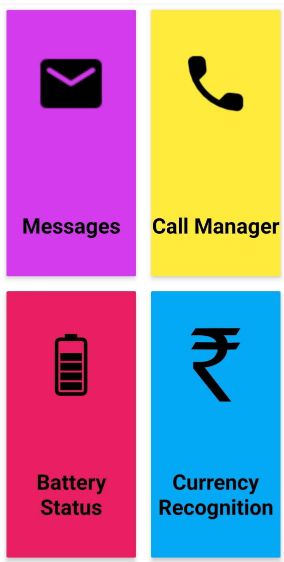


Fig. 1: Home Page User Interface

their background. These were all the UI features designed to improve readability but for a high level of visual impairment, voice-based cues and feedback are also designed and added to the app for greater accessibility.

The voice-based assistance provided in the app is designed in such a way that the HCI guideliness are well followed to improve the user experience and satisfaction. When the user opens the application, they are greeted with a welcome message which also servers as a feedback that they have successfully opened the application. Following which, the basic instructions to use the app are spoken. The positions of the respective buttons on the screen is instructed. “There are 4 buttons present near the 4 corners of the screen. Messages on top left, Call manager on top right, Battery Status on bottom left, Currency Recognizer on bottom right” . When the user taps on any of the four buttons, a voice based feedback stating which button is pressed along with instruction on how to open it is spoken. Ex - “You clicked messaging, Long press to open”. These verbal cues are designed in such a way that the app is convenient to use for both new and experienced user. An experienced user will directly long press the button he wants to open, thus skipping the verbal hint. When the user long presses the button the particular module/activity is opened.

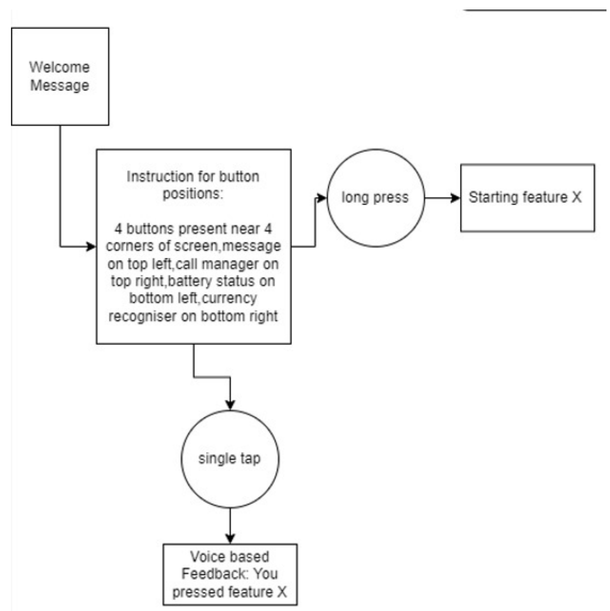


Fig. 2: Verbal Cues flow for home page

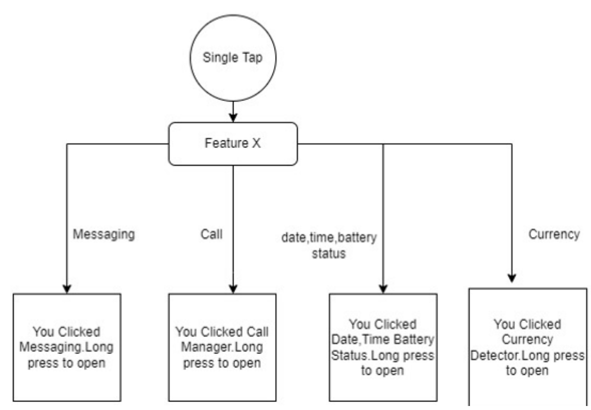
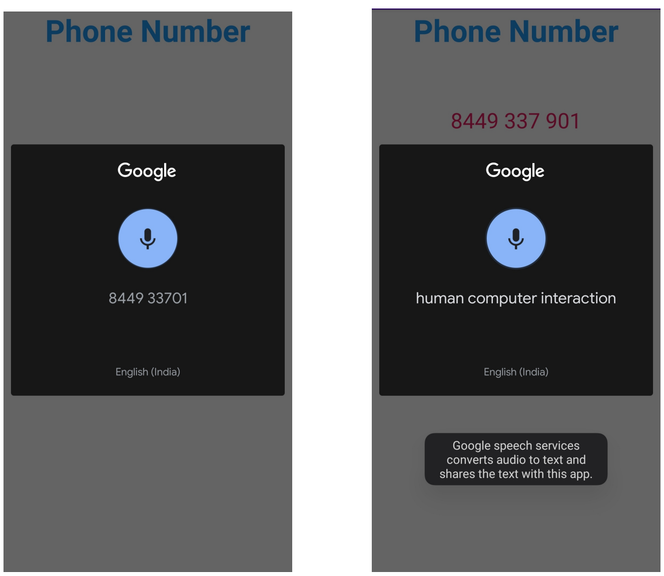


Fig. 3: Voice command on single tapping buttons present on home page.

For every action performed by the user, proper feedback is provided in order to inform the user that they have successfully performed the action they were intending to do. To avoid user mistakes, the app is designed such that directly tapping the button does not open the particular activity. Easy reversal of mistakes is also taken care of.

B. Messages

Messaging is one of the most important functionality of a mobile phone but designing a messaging interface for visually impaired community is a challenging task. In initial version of the app, we included a talk back keyboard using which the user can enter the number of message recipient but the chances of error were very high in that design and it was time consuming for the users to enter number using that keyboard. Second disadvantage of that layout was that user needed to find the respective buttons to perform the task. Thus innovating over that, a new simple to use layout was used without any buttons.



(a) (b)

Fig. 4: Entering recipient's phone number and message using voice command.

When user enters the messaging activity, a feedback and welcome message stating "Messaging box opened". Thus the user knows that they have successfully entered into messaging module. The next voice cue is "Tap anywhere on the screen to enter recipient's number". Instead of using buttons for a specific task, the whole screen is programmed to do a task whenever tapped. When the user taps the screen, a feedback stating "Enter Recipent's phone number after the beep" . Then the number is inputted as the user speaks it. It is followed by a message "Tap again to speak the message". When user taps, "Enter the message after the beep". After inputting the message, a command stating, "Tap again to send the message" is stated.The messaging API of android is used to send the message after collecting data from the user. Once message is sent. "Message sent successfully, you will be redirected to home screen now." The complete user interface is designed in such a way that there are minimal user errors and maximum satisfaction.

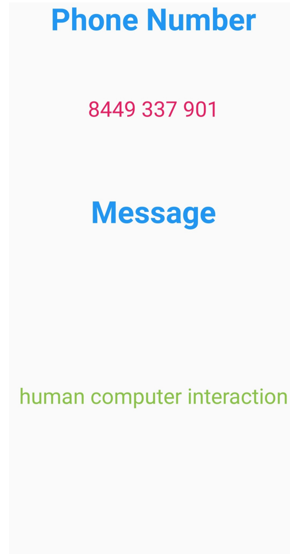


Fig. 5: Finally tap anywhere on the screen to send the message.

C. Calling

The other important feature of a mobile phone, calling. It is one of the most fundamental usecase of a mobile phone. The user interface design in this module is similar to that of the messaging module. The user taps once to enter the mobile number using voice command. Once phone number is entered successfully, a command stating "Tap again on the screen to start the call" is spoken. Once the user taps again, the phone number of the recipient is spoken for confirmation and call is placed to that respective person. All the voice commands, hints and feedback in this and messaging activity are depicted in Fig. 6.

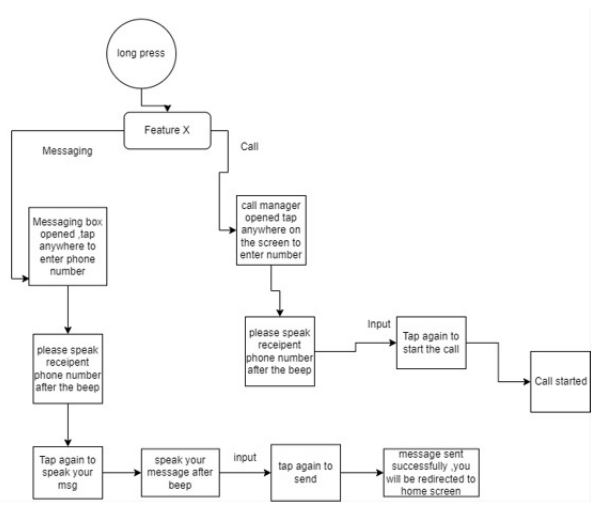


Fig. 6: Voice-based instructions, feedback for calling and messaging.

Intent.ACTION_CALL api function of android is used to arrange the phone call. The contacts saved in the phone can also be used to make the call using this api.

D. *Time, Date and Battery Status*

This is a comparatively simpler module. This requires no inputs from the user. Once the user enters this activity, he is greeted with the message, "You opened time date and battery status. Tap anywhere to know the details". Here care is taken that too much information is not given to user in a short time in order to not challenge their short term memory. Once the user taps the screen, then the information such as current date, time are told to the user in text and voice based also. The UI of all the activities are designed keeping in mind the HCI principles like being consistent, offering significant feedback, reducing the amount of information to be remembered in between actions, yielding closure, reduce short term memory load.

Fig. 7: Time, Date and Battery Status

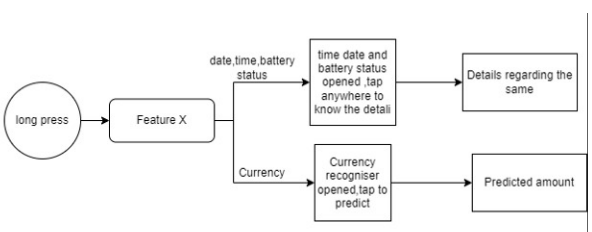


Fig. 8: Voice-based instructions, date, time and battery status and currency recognizer.

E. *Currency Recognition*

This is an extra feature provided to assist people with visual impairment to distinguish between Indian currency of different denominations. Here pretrained model, Mobilenet is used to extract features and predict the denomination of the currency. For this, camera of the phone is used pointed to the currency note and the model extracts the features and makes prediction and same are viewed on the screen and user can tap the screen to know the prediction.

Fig. 9: Currency Prediction

V. Human Computer Interaction Principles Used

Our project follows eight guidelines proposed by Shneiderman which are universal for all types of Human Computer Interaction design. These are applicable for both the normal and the interface designs.The guidelines followed are as follows : consistency, universal usability, providing well informative feedback, feature for proper closure, prevention of errors, easy reversal of actions thus ensuring easy recovery from errors, reduction in memory load of the user, easy control and most of the control given to the user with very few restrictions. In order to ensure consistency we followed a simple intuitive layout throughout our application meanings of functionalities remain consistent throughout the application thus creating less confusion and making application easy to use. To ensure universal usability of the application we have researched about various types of visual impairments and tried coming out with the color combinations that can be clearly distinguished by the users irrespective of visual impairments. We have also made sure that user is given proper feedback since our application is for visually impaired people we have provided voice based feedback which is consistent in nature throughout and helps in easy recovery from the errors.We have also provided swipe based reversal to actions thus if on recieving error message user can return back. In order to reduce the memory load of the users we provide voice based instructions about the positions of cards corresponding to the various features and we have tried keeping application completely voice based where instructions are given to user at each step. Thus users need not to remember anything to use our application. Apart from covering general issue i.e, weakening of eyesight for both moderate and extreme loss, some other visual disorders were considered while designing the application

1) Red and Green : People suffering from Dichromacy (person who can distinguish two colors) can not distinguish

between red and green.
2)Extreme Dark Colors : People suffering from Protanopia (colour blindness resulting from insensitivity to red light, causing confusion of greens, reds, and yellows) can not distinguish dark colors (12.5 percent)
3)Light colors and greys : People suffering from Tritanopes (inability to distinguish between blue and yellow) cannot distinguish light colors and greys. (13 percent)
4)Green Colors : People suffering from Deuteranomalous exhibits partial loss of green color vision.(62.5 percent)
Apart from this we have also kept in mind few other research based guidelines used are as follows 1)Padding of 0.62)Text size has been sufficiently large to support easy reading.
3) Contrasting colors have been used to support the color blind people in navigation through the app.
4) Elevation has been provided to distinguish the icon from it's background.
5)Audio support has been provided to aid the fully blind in navigation.

VI. Experiments, Results, and Analysis

For experimental analysis, to simulate the real world case of visually impaired community, we took help of or 10 friends and blindfolded them while they tried to use the app. Fig. 10 shows the questions that were framed for taking the user feedback. Likert scale was followed for the survey.

Questions	1 Very poor	2 Poor	3 Fair	4 Good	5 Excellent
1)How easy was to navigate through the app?					
2)How easy was to recover from the mistakes committed by you?					
3)How intuitive was app ?					
4)How good was the feedback on your successful completion of action?					
5) How correct were results?					

Fig. 10: Survey Questions for real time user feedback.

Fig. 11 shows the response of the participants regarding the questions asked. After taking feedback from the participants previously, many changes were made in the UI to make it feel more intuitive and easy to use for visually impaired. Ex - instead of using buttons, complete screen was provided to the user and he can tap anywhere on the screen to do a task. Manual entry of phone number through talk-back keyboard was replaced with entering phone number through voice based speech-to-text conversion.

Fig 12. shows the time taken by the 10 users starting from opening the app to using all the features of the app. User 3 is an experienced user who has used the previous and this version 2-3 times. Fig 13. shows the same analysis in graphical form. As evident from the graph, all the users found it easier to use Version 2 of the app as compared to version 1.

User No.	Question 1	Question 2	Question 3	Question 4	Question 5
1	4	4	4	5	3
2	4	4	4	5	4
3	5	4	4	4	4
4	5	5	4	4	5
5	3	4	3	5	4
6	4	3	3	5	5
7	5	4	5	4	4
8	5	4	5	4	4
9	4	3	4	4	3
10	3	5	4	4	5
11	3	4	4	4	4
12	4	5	5	3	4
13	3	3	4	4	5
14	5	5	5	5	5
15	3	4	5	5	5
16	4	4	4	5	3
17	4	4	4	5	4
18	3	4	4	5	4
19	5	4	4	4	5
20	4	4	4	5	4
21	4	4	4	5	5
22	5	3	3	4	4
23	5	5	5	3	4
24	4	4	4	4	4
25	4	5	3	4	5
26	3	4	4	4	4
27	4	4	4	3	5
28	5	4	4	4	5
29	5	5	4	3	5
30	5	5	4	4	4

Fig. 11: Likert Analysis - Rating by the users for the different survey questions.

ANOVA Test was performed on the data collected. P value came out to be '0' which is significantly less so we can reliably reject the null hypothesis.

VII. Conclusion

With the technology we can solve various problems prevailing in our society. Some problems which cannot be solved still we can aid or provide assistance to those facing particular problem with the technology. Through this project we by following various human computer interaction guidelines we try to provide assistance to visually impaired people in using phone. The guidelines being followed are the consistency which implies all the features present are accessible by following the same approach, voice commands are kept in same way to avoid confusion of any form. Layout is also kept Constant throughout to avoid confusion.Other guideline followed is Universal Usability. We tried keeping color combinations in such a way that people suffering through various types of visual impairment can use our application with ease. We also tried to provide an informative feedback to the user which will assure him that action which he is trying to perform is completed successfully. This will also help him in recovery from the error performed by him. After successful completion of application user is taken to main page of the application as well as user is given complete liberty in reversal of the application by performing simple gestures like swipe actions

Version 1	Version 2
627	451
606	444
673	478
607	400
580	407
610	394
703	359
633	409
609	440
673	478
599	400
583	407
611	397
707	367
540	307
569	338
700	298
654	305
567	357
603	368
588	451
606	394
673	337
719	400
580	277
619	384
703	359
633	409
609	440
655	378

Fig. 12: Analysis of time taken by users to navigate and use all functions of the app.

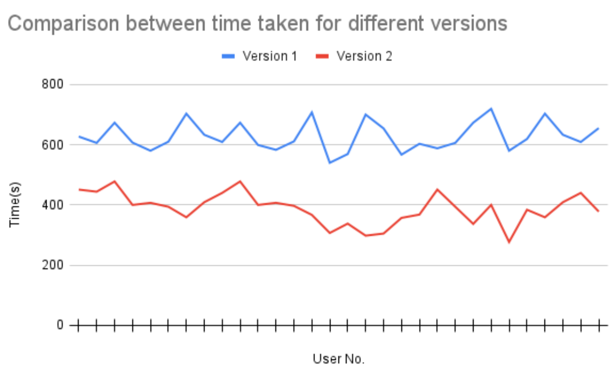


Fig. 13: Time taken by 30 users to use all the features in different versions of the app

on the screen. Other guideline being followed is reduction is short term memory load. From the start itself user is given proper instruction about the location of various cards corresponding to each feature of our application. This makes it easier for user. We have also focused on shortening of task structures. We have focused on enriching user action by providing proper voice based commands and that too with optimal number of steps involved. For help on a single tap voice based instructions are provided to user, if he/she cant get a proper understanding of the feature in the first attempt.

The feature provided to users are as follows simplified phone calling, simplified messaging, phone and battery status and currency detection. For making phone calls user has to

Anova: Single Factor						
SUMMARY						
Groups	*Count*	*Sum*	*Average*	*Variance*		
Version 1	30	18839	627.9666667	2274.378161		
Version 2	30	11633	387.7666667	2670.391954		
ANOVA						
Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	865440.6	1	865440.6	350.0428048	0	4.006872653
Within Groups	143398.3333	58	2472.385057			
Total	1008838.933	59				

Fig. 14: Anova Test

follow voice based command to locate the position of phone call card on main screen, On single tap he get verification that he has pressed at right place or not. Then user is required to long press to use the feature. Then a voice based instruction is given to the user and after the beep he need to speak a phone number to which he wants to make call. After call user is taken to main page of the application. Similar method is used to access other features like messaging, phone and battery status, currency detector. Our currency detector is capable of detecting both old and new denomination of Indian currency. As part of our future scope and reach of our application we will extend our application to have support for more languages and currency. Our application on being tested come out as a tool that really helps visually impaired people.

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Individual Contribution

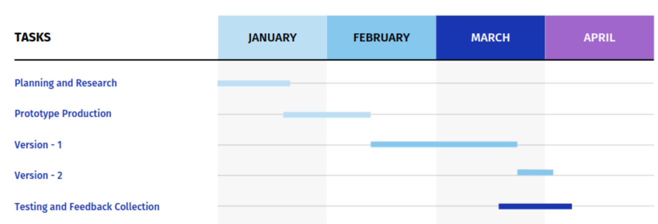

Fig. 15: Gantt Chart

- Rishit, Sarthak and Yash - The UI design following the studied HCI guidelines, flow of the application
- Yash and Rishit - Designing and implementing Calling module
- Sarthak and Yash - Designing and implementing Messaging module
- Rishit and Sarthak - Designing and implementing Currency Recognizer and battery, date details module.

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