Southeast Europe Journal of Soft Computing ISSN 2233 – 1859
Available online: http://scjournal.ius.edu.ba

Vol 9, No. 2, September 2020, pp. 15-23

"Visory" Mobile Application for the Visually Impaired

[1*]Zahiriddin Rustamov and [2]Jaloliddin Rustamov

[1,2]Faculty of Computing and Information Technology,
Tunku Abdul Rahman University College,
Jalan Genting Kelang, 53300 Kuala Lumpur,
Malaysia
**Corresponding Author*: [1]zakisher@gmail.com
[2] jaloliddin.rus@gmail.com

Article Info

Article history:

Article received on 1 September 2020

Received in revised form 7 September 2020

Keywords:

Mobile application; Object detection; Image recognition; Video calling; Visually impaired; Volunteer;

ABSTRACT: Unquestionably, visual impairment severely affects the quality of life and has an impact on many daily activities of the visually impaired individuals. Visory is a mobile application that aims to assist the visually impaired individuals with visual support, through human and automated visual support. Mobile phones are a norm; thus, solutions need to be created to assist the visually impaired while lessening the chances of discrimination against these individuals. With the help of volunteers, who opt to spend their valuable time helping others, the visually impaired individuals are able to connect via video calling and inquire for visual assistance using their device camera. Visory is also equipped with three vision APIs to ease further the life of these individuals, which includes object detection, text, and image recognition. Considering the limited time and budget of the project, Agile methodology is utilized to ensure the successful development of each of the modules within the stipulated deadline. Wide range of extensive testing techniques ensured minimal crashes, and uncovered bugs rectified. Ultimately, the objectives of the project were achieved. However, there is still room for improvement that needs to be addressed in future development for further stability and performance.

1. INTRODUCTION

The number of visually impaired people is more substantial than ever, and it has an undeniable impact on the economy of any country [1]. According to the report published by [2], it is estimated that in 2019 at least 2.2 billion people globally have a visual impairment or blindness. Visual impairment and blindness are often far more significant in people living in rural areas, those with low incomes, women, older people, people with disabilities, ethnic minorities, and indigenous populations. Traditionally, blind and visually impaired (BVI) individuals used tools such as white canes to avoid objects when walking or their hands to identify items [3, 4]. However, these techniques and tools are not sufficient in the era of technological advancement. Computer vision technologies, especially convolutional neural networks (CNNs) [5, 6], which have been rapidly developed in recent years, can also be used to ease the challenges the BVI people face. The CNN models can be integrated with mobile phones, which are today have become versatile than ever, initially built for communication. Mobile phones now can do so much more than just communicating, be it for entertainment, messaging, or calling [7]. It is safe to say mobile phones have become a must-have device for everyone. Although mobile phones include accessibility features available for visually impaired users, most mobile applications are designed for sighted people and are not accessible for non-sighted ones [8]. Through the help of technology, solutions can be created to ease the lives and have a positive impact on the day to day life of the BVI individuals.

2. PROBLEM STATEMENT

Undoubtedly, visual impairment may severely affect the quality of life and have an impact on many daily activities, including interacting with and understanding the surrounding environment, wayfinding, and socializing with people outside of the families and inner circle of friends [9 – 13]. Sometimes, BVI individuals need the help of people around them to do their daily tasks, even though it may be simple for many, it may be of a challenge for them [1]. There are various challenges where BVI individuals come across in their daily life. One of them is undoubtedly in the difficulty of recognizing objects [4]. It may vary from identifying what item they are holding, the expiry date of a particular product, or even the color of the shirt they are holding. Typically, BVI individuals recognize objects using their hands [4, 14]. However, it can be difficult in some cases where it requires to wanting to know more information regarding the item. They are unable to identify the color of the object or understand more regarding the product, such as the nutrition of tuna can. Usually, people around them are the ones that assist them with these obstacles. Thus, often people consider them a burden while some simply ignore their presence and leave them to take care of themselves [1].

Consequently, this may create a feeling of loneliness and demotivation in them. Moreover, lose confidence in themselves due to the feeling of burden in always being dependent on someone. Such that there are numerous tools are available for the visually impaired to assist them in some of the challenges in their life [1, 4, 15]. However, there is yet to be a tool developed in helping BVI individuals with visual support using their mobile phones, which implements automated artificial intelligence (AI) and human-powered visual assistive technologies.

The main objective of this paper is to develop the model of a mobile application which provides visual assistance for the BVI individuals by using of automated- and human-powered technologies. Thus, we propose a software model, called as “Visory”, which aims to provide visual support for the BVI individuals via various object detection and recognition technologies that allow for the use without internet connectivity, as well as through video calling to generous volunteers which provide help in real-time.

3. BACKGROUND

A considerable amount of applications or systems have already been developed over the years to assist the BVI individuals. The literature focuses on two primary models of camera manipulation for visual support: automated and human-powered visual assistive technology; their properties, strengths and limitations.

3.1 Automated Visual Assistive Technology

Paper [16] showcased the development of an Android application for the visually impaired called “iSee”. iSee allows the user to tap on the screen and outputs the name and description of object in the field of view of the smartphone camera. As stated by [16], experimentations were performed to verify the correctness and accuracy of the algorithm used in the application. It was tested on two platforms, Samsung Note 3 and MacBook Pro. iSee was able to recognize an object within 1.8 seconds on the Samsung Note 3 whereas iSee recognized an object within 0.8 seconds. The author argues that processor speeds of the devices played a huge role in the numbers mentioned earlier: users with low end devices will receive feedback slower than users with faster processor device.

Work [17] demonstrates an application, called “TapTapSee”, available on iOS and Android. It features a minimal interface with just four buttons and a preview of the video. By double-tapping the screen to take an image of anything, at any angle, the BVI individual will hear the application speak the received result. The application uses the method of crowd-sourcing, where the captured images are sent to a database server via the internet and compared with the existing data. Then the result is sent back to the user via text describing the scene found in the images. Consequently, “TapTapSee” will not work when an internet connection is unavailable. “TapTapSee” produces swift and accurate results and is designed especially for accessibility. However, it is unable to recognize most branded or labeled objects. Also, it only allows for repeating the most recent result. One of the limitations of this application is that it is not in real-time and can take some time to receive the results, and this may not be ideal in a fast-paced environment [18].

Paper [19] introduced another smartphone application, named “PictureSensation”, that was designed to enable the visually impaired to gain direct perceptual access to images using acoustic signals. In other words, assist the visually impaired individuals by allowing images to be explorable. Acoustic signals are noises animals produce in response to stimulus or situation [20]. Once the captured image is loaded, objects are detected. The application classifies each object using object recognition algorithms. These recognized objects are represented by musical instruments (such as drums). Upon testing with visually impaired participants, one participant pointed out difficulty in distinguishing magenta and cyan. Following with more experiments, shadowing effects or different light sources could be an obstacle when classifying colors during object recognition [19].

A mobile assistive technology application that allows BVI individuals to point their phone cameras at objects they would like to get information about is considered in [21]. The application uses Google Lookout that describes objects in the scene by giving audio descriptions such as “spoon”, “12- o’clock”. Unfortunately, it allows the user extremely little freedom to explore a visual scene in an interactive way [22].

The application developed in [23] is slightly more sophisticated, augmented with the ability to recognize texts, people, scenes, money, etc., and give illumination descriptions (color, brightness) and convert visual feed into speech. However, it is unable to provide navigational support to BVI individuals, as it is considered one of the main tasks in their daily lives [24]. Besides, the application is only available on the iOS platform. As a result, many BVI individuals are unable to access the application due to financial reasons, with almost 90% of blind and visually impaired people living in low- and middle-income countries [25]. Moreover, the application is unable to accurately identify faces and guess emotional states [26, 27].

By implementing deep learning algorithms to the work [28] can also recognize objects, colors, currencies, text and is even able to identify animals and plant species and speaks out the result to the BVI individual. Besides, most of the features function without an internet connection, providing greater privacy. On top of that, the application learns all the time, based on the data provided by the users. However, it requires a monthly or yearly subscription to access most of the features, which may be expensive for some BVI individuals to pay regularly.

Unfortunately, automated visual assistive systems have their limitations. Results provided may be inaccurate or may lack comprehensive descriptions when required [29], and they do not allow BVI individuals to interact with images, in the same way, sighted individuals do [22]. For example, the BVI individual may want to know the expiry date of a juice box, whereas the application responds as a “juice box”. For this reason, BVI individuals may find communicating with a volunteer or a trained agent more reliable at such times [30].

4.1 Human-powered Visual Assistive Technology

“VizWiz” introduced in [31] is a mobile phone application that allows blind users to send images of their visual questions and receive answers through mechanical Turk solutions. One of the first research applications of “VizWiz” was the object recognition application. Users recorded their questions and chose to route it to anonymous crowd workers or automatic image processing (IQ Engines). They have used their initial findings to further develop and expand their work through VizWiz Social [32]. VizWiz Social connected the BVI individual to their social networks, such as their family members, for visual assistance. One of the limitations of “VizWiz” is the workers being biased towards providing an answer over feedback if they are unsure. Also, in some cases, the “VizWiz” workers did not listen to the questions, resulting in unhelpful responses. Moreover, answering long sequences and complex questions using single-image interactions can be time-consuming. BVI individuals were also concerned about being a burden to their relatives or acquaintances [33].

[34] is another example of a human-powered visual assistive application. The application connects the BVI individuals with untrained volunteers through a free of charge video calling service. According to a survey conducted by [30], users find the application useful for reading text, locating items, shopping assistance, and assisting at ticket machines. However, the application is found less useful when the hands are busy, as it requires the BVI individual to hold their mobile phones when interacting. Besides, users perceived navigation tasks and using ATMs to violate their privacy.

Work [35] considers another human-powered application. It is a subscription-based service that either uses smart glasses with a camera and a speaker connected to a smartphone or can directly use the camera of the mobile phone, to assist the BVI individuals through trained human agents. A BVI individual is connected to an Aira agent, especially trained representatives from Aira, and the agent will assist the individual in real-time. Agents have access to the video feed from the camera of the BVI’s mobile phone or smart glasses, as well as their GPS location. It assists the BVI individual in their daily tasks such as reading books, washing clothes, and navigating. However, Aira is a subscription-based service, individuals from low-income families may not be able to afford it, and as discussed earlier, people with visual impairment are at higher risk of unemployment and financial complications as compared to sighted individuals. Besides, with much more access to user information by Aira agents, the violation of user privacy is also far more significant.

Human-powered visual assistive systems are not without limitations, either. Privacy issues are the most pressing concerns with such systems, where the BVI individuals are exposed to sharing sensitive information mistakenly [36].

To address most of the limitations of the reviewed mobile applications, our model "Visory" combines automated and human-powered visual assistive technologies into a single application. As a result, it allows the BVI individuals to connect to volunteers when necessary and use the object detection technology whenever they desire, without internet connectivity and, retain their privacy. Moreover, provide for a user-friendly and cost-effective solution.

4. METHODOLOGY

The mobile application has been developed by the group of two individuals. Therefore, Agile Software Development (ASD) is used as the method of developing the solution. ASD methodologies are based on incremental and iterative development, and they utilized to produce a high-quality software in short period of time. In addition, ASD methodologies accept change even during the development stages as shown in Figure 1 which stands out when compared to other methodology [37]. We specifically use the scrum technique to develop the application as it is suitable for small and large projects. Scrum teams can handle smaller projects whereas larger projects can be broken down into smaller subprojects which are handled by scrum teams. It focuses on communication and cooperation between team members. In addition, scrum is lightweight, meaning, it is open to change in requirements even in development phase. Most importantly, scrum maximizes productivity as it breaks down work into series of "sprints". Sprint is a small release cycle. During sprints, team members meet up every day for a daily scrum meeting to check up on the status of the progress on assigned tasks. Moreover, it focuses more on management of development than coding techniques [38-40].

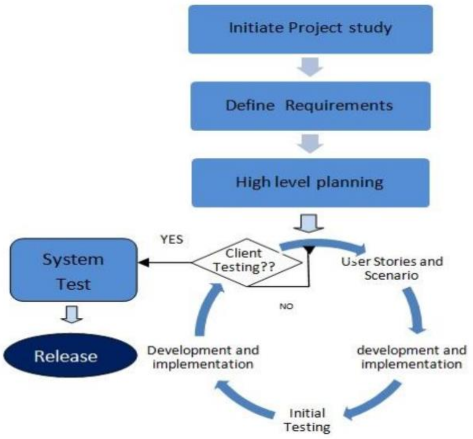

Figure 1: Phases of Agile Software Development [41].

5. DESIGN AND IMPLEMENTATION

The purpose of the application "Visory" is to integrate the many automated visual assistive technologies such as object detection with human-powered visual assistive technology to deliver them under a single application, for free of charge.

5.1 Human-powered Visual Assistive Technology

Figure 2 illustrates the workflow overview of human-powered assistive technology, *video calling*.

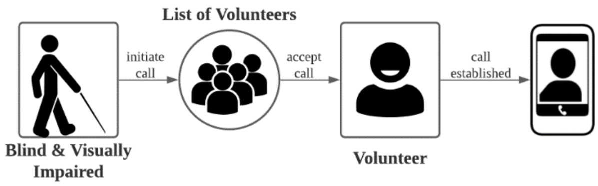

Figure 2: Video calling concept in Visory.

1. The BVI individual initiates a call to a list of volunteers, *x*.
2. Each volunteer in *x* receives a notification.
3. The first volunteer who opens notification will be connected with the BVI individual.
4. If the volunteer rejects the call after opening the notification, volunteers in *x* will still have the notification available. Only when the connection is established, all notifications are cleared.
5. The camera stream of the BVI individual will be displayed on the volunteer's screen.
6. After the end of call, both parties are able to leave a feedback.

QuickBlox will used as the video calling API. The details related to user, calls and locations will be stored in the Firebase Realtime Database along with Firebase

Cloud Storage. The application will be written in Kotlin programming language using Android Studio.

Automated Visual Assistive Technology

Under automated assistive technologies, three types of image analysis APIs are implemented: object detection, text recognition and image recognition.

Object Detection: Analyses the supplied image from the camera or the gallery and provides sound feedback for two objects with the highest matching percentage. Makes use of a local dataset to allow users with no internet connection to always be able to utilize it.

Text Recognition: Similarly, analyses the image from the camera or the gallery, and provide a sound feedback on any text that is recognized within the image. No internet connection is required.

Image Recognition: Provides a general theme for the image rather than identifying an object within an image. Likewise, analyses the image from the camera or the gallery, and provide a sound feedback on the objects that are recognized within the image. No internet connection is required.

Figure 3 shows the workflow overview of automated assistive technologies.

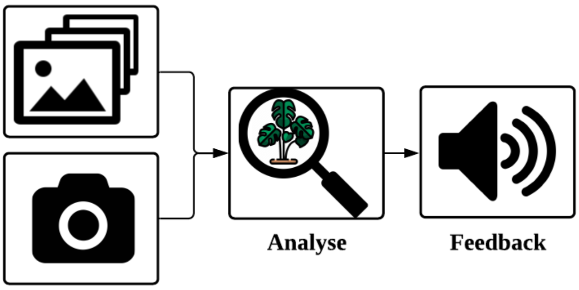

Figure 3: Object detection overview process in Visory.

1. The BVI individual either captures an image or selects an image from gallery in "Visory".
2. The image analysis is run on the background.
3. Once the image has been analyzed, the results are output as sound feedback.

The automated assistive technologies will be implemented using TensorFlow Lite.

6. RESULTS AND DISCUSSION

Figure 4 shows the Home Screen for the BVI individual. The call to a volunteer takes up most of the space for ease of access. The object detector menu is right under the call a volunteer button. The aim of the design is to be as simplistic as possible.

Figure 4: Home Screen for the BVI individual.

6.1 Automated Visual Assistive Technology

Figure 5 illustrates the menu for the automated visual assistive technologies in "Visory".

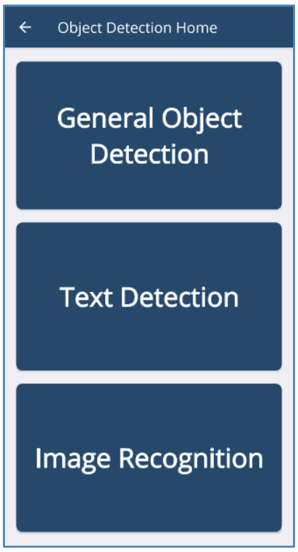

Figure 5: Object Detection Menu for the BVI individual.

1) Object Detection

Figure 6 shows the output example of Object Detection. The object detected in the captured image was a "Studio couch" with 94% reliance.

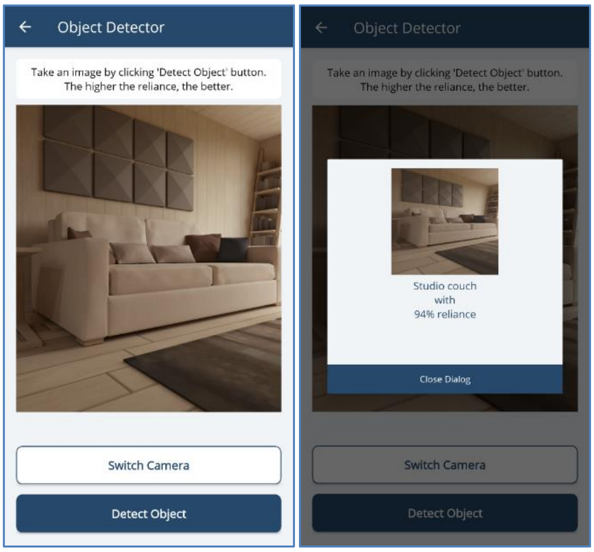

Figure 6: Example output for Object Detection.

2) Text Recognition

Figure 7 shows the output example of Text Recognition. The text from the supplied image was correctly recognized.

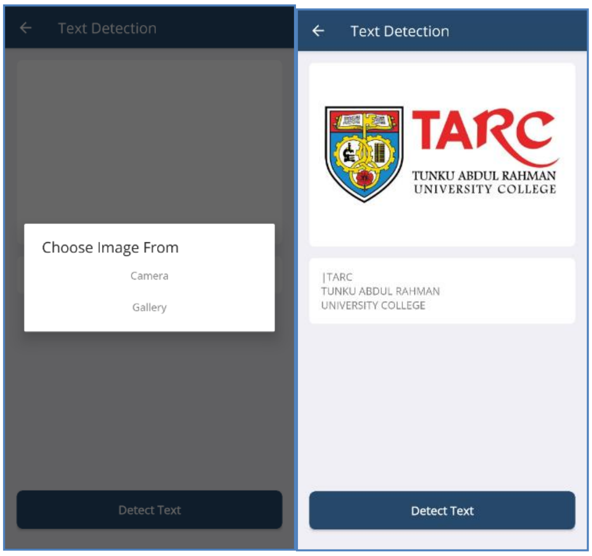

Figure 7: Example output for Text Recognition.

3) Image Recognition

Figure 8 shows the output example of Image Recognition. The image of various flowers in a garden is supplied, and the results are sorted from the highest to the lowest reliance and only those that match 50% and above. From the figure, all the matching options are relevant to the image supplied and it can be concluded the image has been correctly recognized.

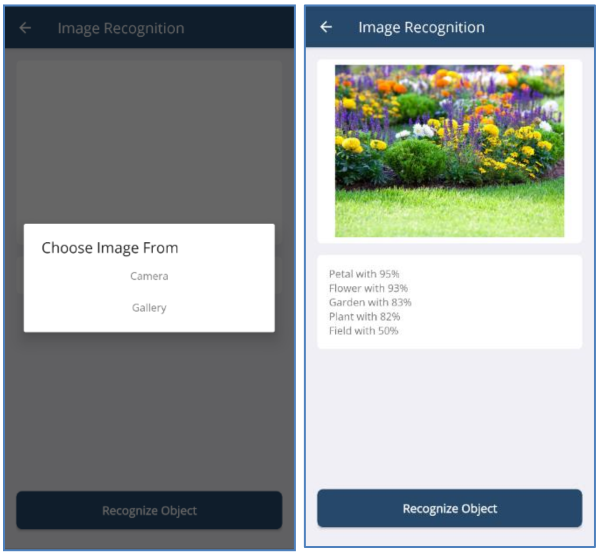

Figure 8: Example output for Image Recognition.

To note, the results displayed in the figures above are output as a sound feedback to the user.

6.2 Human-powered Assistive Technology

1) BVI Individual

Once the BVI individual initiates a call, a list of volunteers will receive a notification as shown in Figure 10. Once a volunteer opens the notification, a call will be started between the parties as shown in Figure 9.

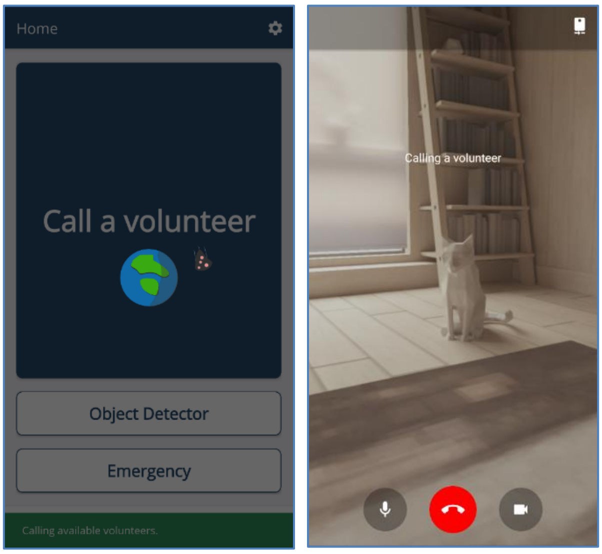

Figure 9: Initiating call screen for BVI individual.

2) Volunteer

Figure 10 shows the volunteer receiving a notification for help from a BVI individual. Once the notification is opened, incoming call will be displayed. The volunteer has the option to either accept or reject the call. In case the call is rejected, other volunteers will still have the notification to connect with the BVI individual. After the call is established, notifications are cleared from other volunteers.

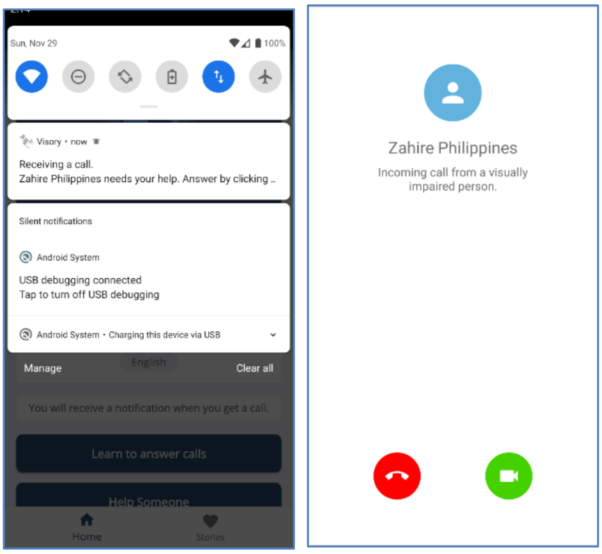

Figure 10: Notification and incoming call screen for volunteer.

Figure 11 shows the ongoing video call, with the left image belonging to the BVI individual whose camera stream is being presented. Hence, has more video control options compared to the volunteer, the right image. Both parties can end the call at any time.

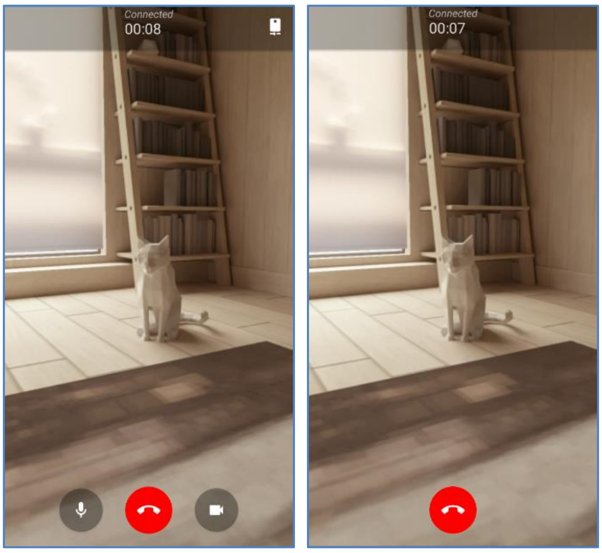

Figure 11: An ongoing video call between a BVI individual and a volunteer.

Following the end of the call, both parties are allowed to submit a feedback regarding the user and/or the call as shown in Figure 12. Comprises of pre-defined problems and the ability to write a custom feedback for comprehensiveness. The submitted feedbacks will be displayed on the administrator module for taking appropriate measures.

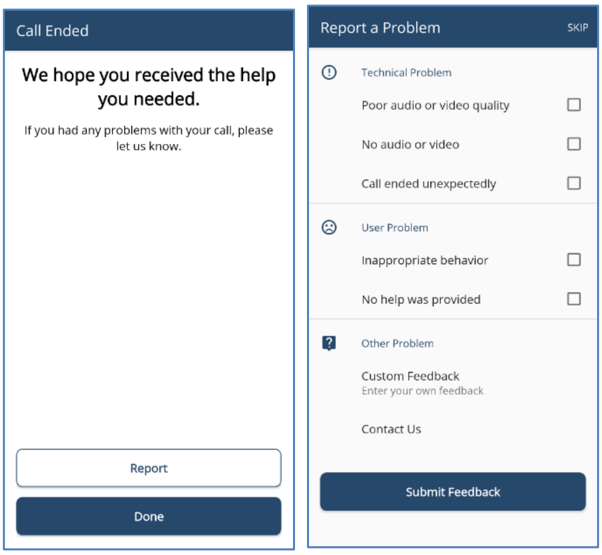

Figure 12: Call end screen following the video call session.

7. CONCLUSION

In this paper, we introduced "Visory" mobile application, that aims to ease the life of BVI individuals with the help of automated and human-powered assistive technologies. The user interface has been crafted for simplicity for the BVI individuals. In addition, the application is designed to function with accessibility features such as TalkBack. Results indicate a successful detection for all the integrated assistive technologies.

The application is not without faults, such that future improvements are mandatory. Comprehensive automated assistive technologies need to be implemented to further provide more options for detection. Besides, the conversations between parties need to be recorded for a definite measure by the administrator. Lastly, the application needs to be further optimized for ease of use by lower end device models.

REFERENCES

[1] I. Joe Louis Paul, S. Sasirekha, S. Mohanavalli, C. Jayashree, P. Moohana Priya, and K. Monika, "Smart Eye for Visually Impaired-An aid to help the blind people," *ICCIDS 2019 - 2nd Int. Conf. Comput. Intell. Data Sci. Proc.*, pp. 1–5, 2019, doi: 10.1109/ICCIDS.2019.8862066.

[2] World Health Organization, *World report on vision*,

vol. 214, no. 14. World Health Organization, 2019.

[3] Y. Shiizu, Y. Hirahara, K. Yanashima, and K. Magatani, "The development of a white cane which navigates the visually impaired," *Annu. Int. Conf. IEEE Eng. Med. Biol. - Proc.*, pp. 5005–5008, 2007, doi: 10.1109/IEMBS.2007.4353464.

[4] J. Sosa-García and F. Odone, "'Hands on' visual recognition for visually impaired users," *ACM Trans. Access. Comput.*, vol. 10, no. 3, 2017, doi: 10.1145/3060056.

[5] K. Potdar, C. D. Pai, and S. Akolkar, "A Convolutional Neural Network based Live Object Recognition System as Blind Aid," *arXiv*, 2018.

[6] Y. C. Wong, J. A. Lai, S. S. S. Ranjit, A. R. Syafeeza, and N. A. Hamid, "Convolutional Neural Network for Object Detection System for Blind People," vol. 11, no. 2, pp. 1–6, 2019.

[7] A. Hussain, E. O. C. Mkpojiogu, J. Musa, and S. Mortada, "A user experience evaluation of Amazon Kindle mobile application," *AIP Conf. Proc.*, vol. 1891, no. October, 2017, doi: 10.1063/1.5005393.

[8] M. Awad, J. El Haddad, E. Khneisser, T. Mahmoud, E. Yaacoub, and M. Malli, "Intelligent eye: A mobile application for assisting blind people," *2018 IEEE Middle East North Africa Commun. Conf. MENACOMM 2018*, pp. 1–6, 2018, doi: 10.1109/MENACOMM.2018.8371005.

[9] M. Langelaan, M. R. De Boer, R. M. A. Van Nispen, B. Wouters, A. C. Moll, and G. H. M. B. Van Rens, "Impact of visual impairment on quality of life: A comparison with quality of life in the general population and with other chronic conditions," *Ophthalmic Epidemiol.*, vol. 14, no. 3, pp. 119–126, 2007, doi: 10.1080/09286580601139212.

[10] R. Velázquez, "A. Lay-Ekuakille et al. (Eds.): Wearable and Autonomous Systems Wearable Assistive Devices for the Blind," pp. 331–349, 2010.

[11] E. Brady, M. R. Morris, Y. Zhong, S. White, and J. P. Bigham, "Visual challenges in the everyday lives of blind people," *Conf. Hum. Factors Comput. Syst. - Proc.*, no. i, pp. 2117–2126, 2013, doi: 10.1145/2470654.2481291.

[12] N. Arlappa, N. Balakrishna, A. Laxmaiah, and G. Brahmam, "Journal of Opthalmic Science Issn No : 2470 - 0436," *J. Ophthalmic Sci.*, no. 4, pp. 1–5, 2016.

[13] M. Khorrami-Nejad, A. Sarabandi, M.-R. Akbari, and F. Askarizadeh, "The Impact of Visual Impairment on Quality of Life.," *Med. hypothesis, Discov. Innov. Ophthalmol. J.*, vol. 5, no. 3, pp. 96–103, 2016, [Online]. Available: http://www.ncbi.nlm.nih.gov/pubmed/28293655%0Ahttp://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=PMC5347211.

[14] S. O'Modhrain, N. A. Giudice, J. A. Gardner, and G. E. Legge, "Designing media for visually-impaired users of refreshable touch displays: Possibilities and pitfalls," *IEEE Trans. Haptics*, vol. 8, no. 3, pp. 248–257, 2015, doi: 10.1109/TOH.2015.2466231.

[15] M. Hersh and M. A. Johnson, *Assistive Technology for Visually Impaired and Blind People*. Springer Science & Business Media, 2010.

[16] M. Ghantous, M. Nahas, M. Ghamloush, and M. Rida, "ISee: An android application for the assistance of the visually impaired," *Commun. Comput. Inf. Sci.*, vol. 488, pp. 26–35, 2014, doi: 10.1007/978-3-319-13461-1_4.

[17] TapTapSee, "Assistive Technology for the Blind and Visually Impaired," 2019. https://taptapseeapp.com/.

[18] B. Holton, "A Review of the TapTapSee, CamFind, and Talking Goggles Object Identification Apps for the iPhone," *AFB AccessWorld Magazine, 14*, 2013.

[19] M. Banf, R. Mikalay, B. Watzke, and V. Blanz, "PictureSensation – a mobile application to help the blind explore the visual world through touch and sound," *J. Rehabil. Assist. Technol. Eng.*, vol. 3, p. 205566831667458, 2016, doi: 10.1177/2055668316674582.

[20] "Acoustic Signals." https://www.encyclopedia.com/science/news-wires-white-papers-and-books/acoustic-signals.

[21] P. Clary, "With Lookout, discover your surroundings with the help of AI," *Google*, 2019. https://www.blog.google/outreach-initiatives/accessibility/lookout-discover-your-surroundings-help-ai.

[22] B. Fakhri and S. Panchanathan, "Haptics for Sensory Substitution," in *Haptic Interfaces for Accessibility, Health, and Enhanced Quality of Life*, Cham: Springer International Publishing, 2020, pp. 89–115.

[23] "Seeing AI App from Microsoft," *Microsoft.com*, 2021. https://www.microsoft.com/en-us/ai/seeing-ai.

[24] S. Real and A. Araujo, "Navigation systems for the blind and visually impaired: Past work, challenges, and open problems," *Sensors (Switzerland)*, vol. 19, no. 15, 2019, doi: 10.3390/s19153404.

[25] F. K. Al-Swailmi, "Global prevalence and causes of visual impairment with special reference to the general population of Saudi Arabia," *Pakistan J. Med. Sci.*, vol. 34, no. 3, May 2018, doi: 10.12669/pjms.343.14510.

[26] H. Reese, "Microsoft's new AI app to assist the blind could be a 'game changer' in accessibility,"

TechRepublic, 2017. https://www.techrepublic.com/article/microsofts-new-ai-app-to-assist-the-blind-could-be-a-game-changer-in-accessibility/.

[27] K. Bell, “Microsoft’s ‘talking camera’ app for the blind isn’t as magical as it sounds,” *Mashable*, 2017. https://mashable.com/2017/07/12/microsoft-seeing-ai-app-for-blind/.

[28] Aipoly, “Vision AI for the Blind and Visually Impaired,” *Aipoly*, 2019. http://aipoly.com.

[29] R. Jiang, L. Qian, and S. Qu, “Let Blind People See: Real-Time Visual Recognition with Results Converted to 3D Audio,” no. January, 2016.

[30] M. Avila, K. Wolf, A. Brock, and N. Henze, “Remote assistance for blind users in daily life: A survey about be my eyes,” *ACM Int. Conf. Proceeding Ser.*, vol. 29-June-2016, 2016, doi: 10.1145/2910674.2935839.

[31] J. P. Bigham *et al.*, “VizWiz: nearly real-time answers to visual questions,” in *Proceedings of the 23nd annual ACM symposium on User interface software and technology - UIST ’10*, 2010, p. 333, doi: 10.1145/1866029.1866080.

[32] D. Gurari *et al.*, “VizWiz Grand Challenge: Answering Visual Questions from Blind People,” in *2018 IEEE/CVF Conference on Computer Vision and Pattern Recognition*, Jun. 2018, pp. 3608–3617, doi: 10.1109/CVPR.2018.00380.

[33] W. S. Lasecki, P. Thiha, Y. Zhong, E. Brady, and J. P. Bigham, “Answering visual questions with conversational crowd assistants,” in *Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility*, Oct. 2013, pp. 1–8, doi: 10.1145/2513383.2517033.

[34] Be My Eyes, “Bringing sight to blind and low-vision people,” *Be My Eyes*, 2020. https://www.bemyeyes.com.

[35] Aira, “Aira,” 2020. http://aira.io.

[36] H. Xia and B. McKernan, “Privacy in Crowdsourcing: a Review of the Threats and Challenges,” *Comput. Support. Coop. Work*, vol. 29, no. 3, pp. 263–301, Jun. 2020, doi: 10.1007/s10606-020-09374-0.

[37] G. Kumar and P. Bhatia, “Impact of Agile methodology on software development process,” *Int. J. Comput. Technol. Electron. Eng.*, vol. 2, no. 4, pp. 46–50, 2012.

[38] J. Livermore, “Factors that impact implementing an agile software development methodology,” in *Proceedings 2007 IEEE SoutheastCon*, 2007, pp. 82–86, doi: 10.1109/SECON.2007.342860.

[39] S. Shivaleela and L. M. Rao, “Current State of Agile Methodologies and its extended practices in Software Development - A Review,” *Int. J. Adv. Res. Comput. Commun. Eng.*, vol. 7, no. 7, pp. 90–95, 2018, doi: http://doi.org/10.17148/IJARCCE.2018.7716.

[40] A. Ahmed, S. Ahmad, N. Ehsan, E. Mirza, and S. Z. Sarwar, “Agile software development: Impact on productivity and quality,” in *2010 IEEE International Conference on Management of Innovation & Technology*, 2010, pp. 287–291, doi: 10.1109/ICMIT.2010.5492703.

[41] S. Thakur and A. Kaur, “Role of Agile Methodology in Software Development,” *Int. J. Comput. Sci. Mob. Comput.*, vol. 2, no. 10, pp. 86–90, 2013, [Online]. Available: www.ijcsmc.com.