

VisiBuy : An Accessible Online Shopping Platform for Visually Impaired

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Abstract:-Visually impaired individuals encounter numerous challenges in their daily lives, many of which are often overlooked by those with regular vision. One notable challenge involves the shopping process, during which individuals encounter difficulties in recognizing packaged products and deciphering labels to find essential details such as expiration dates, prices, and discounts. Consequently, they require help from store employees or a companion, and these circumstances limit their independence and infringe upon their privacy. This research paper introduces an innovative mobile solution to address this problem. The proposed solution leverages modern technologies, utilizing device cameras for product identification and enabling full control through voice commands. This approach aims to empower visually impaired individuals to shop independently and with privacy. To validate its effectiveness, the solution will be rigorously tested against popular modern e-commerce applications. This research endeavors to enhance the daily lives of visually impaired individuals by bridging the accessibility gap in the realm of shopping.

Keywords: *visually impaired, partially blind, online shopping, accessibility, inclusiveness, differently abled.*

1. Introduction

In the digitally interconnected world, there is a growing awareness of the obstacles encountered by people with various disabilities. The advancement of technology holds great promise in improving the quality of life for these individuals, particularly in domains that have traditionally presented difficulties. Among these difficulties, shopping emerges as a crucial domain that requires inclusive solutions. This research paper introduces VisiBuy, an online shopping application tailored to meet the unique shopping requirements of individuals with visual impairments. The VisiBuy solution is designed to empower individuals who are visually impaired to participate in autonomous shopping experiences, eliminating the necessity for physical store visits through the use of an accessible mobile application.

Visual impairment has been a subject of concern all over the world, with research and studies invariably highlighting its impact on different aspects of individuals' lives. For instance, A survey conducted in Sri Lanka in 2016, reported a prevalence of blindness at 1.7% among the population aged 40 and above, accompanied by severe visual impairment at 1.6% and visual impairment at 15.4% within the same demographic [1]. Globally, it's approximated that 1.1 billion people worldwide had some form of visual impairment in the year 2020 and out of those, approximately 43 million were considered legally blind [2]. These statistics highlight the significance of addressing the challenges encountered by visually challenged individuals in their daily activities, including shopping.

Visually impaired shoppers encounter numerous challenges when navigating a retail setting. Locating items, interacting with store personnel and the emotional discomfort of seeking assistance are recurring obstacles for them when shopping physically. Despite there being digital shopping platforms, they often lack the accessibility characteristics for this particular demographic. Elements such as inadequately described product images and descriptions, complex navigation, lack of compatibility with screen readers and challenging checkout process. Hence there is an imperative need for an inclusive solution that enables visually challenged shoppers to engage in independent and convenient online shopping experiences.

This paper aims to address the following research questions to comprehensively explore the challenges and propose effective solutions:

- How can a mobile application be designed to address the shopping needs of individuals with visual impairments, enhancing their online shopping experience, independence, and emotional well-being?
- What are the specific challenges and difficulties that visually challenged individuals encounter when using existing online shopping platforms?
- What features and functionalities should the mobile application possess in order to effectively address the challenges faced by visually challenged individuals and provide a usable and empowering shopping experience?
- How can the effectiveness and usability of the developed mobile application be assessed in improving the online shopping experience for visually challenged individuals?

The significance of this study lies in its potential to bring about substantial changes to the existing e-commerce options available to individuals with visual impairments. By supporting accessibility and equality in consumer environments, this will benefit the well-being of those who are afflicted with visual impairments, legally blindness, or partial blindness. The following objectives are intended to be achieved by this research paper:

- Propose an innovative mobile application solution to empower visually challenged individuals in overcoming shopping obstacles and enhancing their online experience.
- Analyse the challenges and difficulties faced by visually challenged individuals when using existing online shopping platforms.
- Identify and define a comprehensive set of features and functionalities for the mobile application, driven by an in-depth understanding of visually challenged individuals' preferences and requirements.
- Evaluate the impact, effectiveness, and user satisfaction of the developed mobile application through rigorous user testing, quantitative assessments, and qualitative feedback analysis.

The literature review underscores the pressing need for accessible and empowering solutions. The methodology section outlines the approach taken to design a purpose-built mobile application, addressing the deficiencies of existing platforms and emphasizing inclusive features. Moving forward, the results section will reveal the effectiveness and usability of the application through a rigorous evaluation framework, followed by a discussion of the implications and potential enhancements. This study not only seeks to enhance the independence and convenience of individuals with visual impairments but also contributes to a more inclusive digital landscape. The future work section outlines avenues for further exploration and development in this critical domain.

2. Literature Review

Numerous previous initiatives have been devoted to tackling the obstacles encountered by individuals with visual impairments. These efforts have focused on improving accessibility in both physical retail experiences and the sphere of online shopping, involving a variety of stakeholders. Within this context, a variety of initiatives have emerged, each employing very unique solutions. While certain initiatives have focused on the creation of intricate and costly physical devices, others have sought to leverage existing infrastructure. However, despite these commendable efforts, certain implementations have demonstrated deficiencies in terms of comprehensiveness and key feature coverage. This literature review explores the scholarly landscape surrounding these initiatives, critically examining their methodologies, strengths, and limitations, thereby contributing to a more profound understanding of the evolution of solutions designed to improve the shopping experiences of individuals with visual impairments.

Incorporating W3C Accessibility Principles

In the digital landscape, the W3C accessibility guidelines [3] set the standard for ensuring equitable online experiences. These guidelines offer a framework to create digital platforms that cater to diverse user needs, including individuals with visual impairments. However, it's regrettable that a significant portion of e-commerce platforms have struggled to effectively integrate these guidelines. This oversight has led to a regrettable exclusion of visually impaired individuals from the online shopping sphere.

Aligning with these guidelines is not only an ethical imperative but also a legal requirement in many jurisdictions. This underscores the urgency for e-commerce entities to embrace comprehensive accessibility measures.

Research Initiatives and Innovative Avenues

The field has witnessed the emergence of several research projects aimed at bridging the accessibility gap for visually impaired consumers. A prominent example is iShop [4] where Bluetooth beacons were used to mark locations inside a supermarket to guide the visually impaired users. In the realm of online shopping, a prominent study is the "BrowseWithMe" project [5]. This initiative, born from a thorough study, is committed to improving the online clothing shopping experience for individuals with visual impairments. Utilizing the capabilities of Artificial Intelligence, "BrowseWithMe" identifies the underlying structure of web pages and transforms them into understandable voice outputs. Another commendable pursuit in this demographic is "HABOS," [6] an experimental online furniture store enriched with haptic and audio features. Furthermore, S. Rallabhandy et al. [7] conducted a study focusing on enhancing online shopping for the visually impaired and they introduced speech-driven, keyboard-less interactions using AI, NLP, face recognition, and web scraping to navigate through the entire shopping process. These initiatives underscore the industry's commitment to innovation and enhancing the digital shopping landscape for the visually impaired.

Addressing Mainstream App Limitations

While mainstream applications such as Be My Eyes, Aira, TapTapSee, Google Lookout, and Seeing AI have made notable strides in offering real-time environmental insights, their effectiveness is constrained when it comes to optimizing the shopping experience. These applications lack the customized features necessary for smooth shopping experiences, especially in physical retail settings.

VisiBuy Solution

Responding to these gaps, VisiBuy emerges as a holistic solution, effectively fills the gaps identified in research initiatives and mainstream applications. By combining the best qualities of these efforts, the app goes beyond limits, providing an unmatched shopping experience for individuals with visual impairments. Table 1 presents a comprehensive comparative analysis, spotlighting the unique attributes and benefits of the app in comparison to existing solutions.

Table 1 The System Comparison

Features	BrowseWith Me	HABOS	Rallabhandy et al. solution	VisiBuy
Voice Navigations	Yes	Yes	Yes	Yes
Mobile Friendly	No	No	No	Yes
No Special Equipment Needed	Yes	No	Yes	Yes
Localized Product Identification	No	No	No	Yes
Secure Authentication	No	No	Yes	Yes

3. Methods

The authors conducted an interview with local supermarket employees and managers to learn about the shopping experience of visually impaired customers in urban areas. The interview data indicated that it is extremely rare to have visually impaired customers and on these rare occasions, they come with a friend or family member to help them. Thus, it would be more beneficial to provide an online solution for the users rather than an onsite solution.

The authors have identified two key functional requirements that need to be implemented. They are,

1. Local Product Identification

2. Virtual shopping assistant

As the interviewed employees have stated, visually impaired people almost never visit the supermarket on their own. Another crucial aspect to consider is that many local areas are not easily navigable for individuals with visual impairments, making the journey not only challenging but also exposing them to environmental hazards. Hence the decision was made by the authors to find an online solution for the aforementioned problem. In order to achieve this goal, it was decided to create a mobile shopping application with extensive accessibility features to accommodate the needs of the targeted users. The authors will be integrating the key features into the mobile application as shown in Fig. 1.

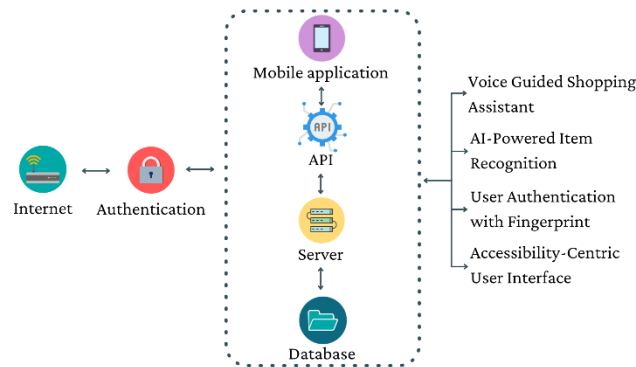


Fig. 1. The system overview

Voice Guided Shopping Assistant

The accessibility features of the Mobile operating system allow visually impaired users to make use of the built-in text to speech feature to identify the elements displayed on the screen. Although this is a good initial solution, it requires much time and effort to tap each individual element on the screen and identify what the user is looking for. According to a lab test conducted by Berglind F. et al. [8], they concluded that users needed to learn complex gestures and needed to receive necessary training, to use screen readers efficiently. To counter this, the application will be fully guided by a virtual assistant to heavily minimize the need for the user to interact with the screen. Fig. 2 shows the different voice commands accepted by the assistant. The authors will implement all the necessary commands such that the user can achieve all their shopping activities with minimal interactions with the screen. This feature will handle all the shopping list management functions via voice commands.

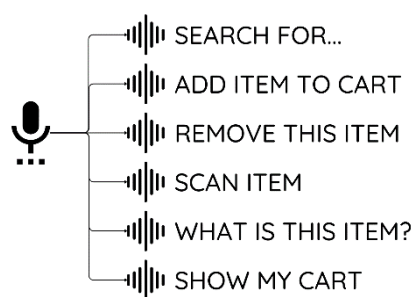


Fig. 2. Supported voice commands.

AI-Powered Item Recognition Model

Apart from the virtual shopping assistant, the authors will implement an image recognition model trained to meet the requirement to identify local products. Specifically, this model will identify local packaged products and canned goods, as for visually impaired people, these are the hardest items to identify by their shape and texture [9]. Users can point the camera towards the object they need to identify. After identifying the object, the user has the option to either search for similar products or add the item to their shopping cart if it's available. As shown in Fig. 3, after the item has been added to the user's shopping list, the delivery agents will be notified and will start the delivery process. When they reach the user's location, the delivery agent will mark the items as delivered. The

user will receive the items and scan them with the item recognition feature. Then the identified items will be marked as delivered by the user. When both the user and delivery agent have marked the item as delivered, the delivery will then be complete, and the item will be removed from the shopping list.

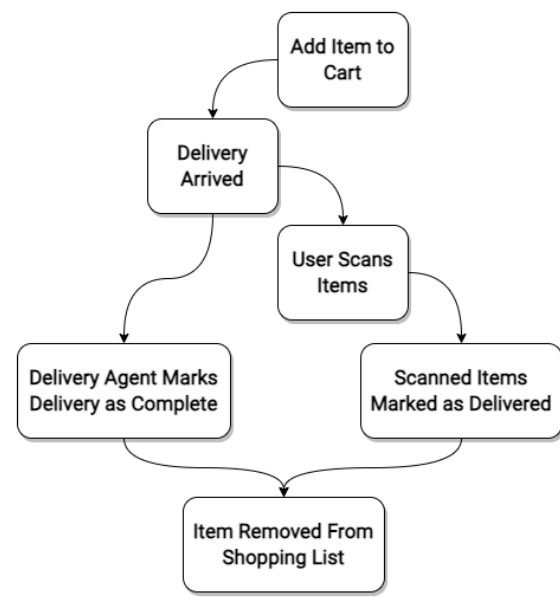


Fig. 3. The lifecycle of the shopping list item.

Accessibility-Centric User Interface and User Management Features

The user interface will contain highly contrasting themes and suitably large typography to ensure that users with partial vision can get some visual feedback. The user can save their general information in the application to conveniently reuse recurring information such as delivery address and payment information. The items sold through the application will be stored inside a database and these items will all be identifiable by the developed item recognition model. For the purpose of adding new items to this database, the authors will be creating a separate “Admin App” for the use of sellers.

User Authentication with Fingerprint and Face Recognition

To further minimize the screen interactions, the application will use fingerprint and face recognition features provided by the operating system to authenticate the users whenever necessary instead of using passwords.

Module implementation and technologies

The authors decided to use React native for the front-end implementation of the VisiBuy mobile application due to the cross-platform features of this technology. This will allow users across many platforms to make use of the provided services. For the development of the backend, Node.JS and Express were used as these technologies are very convenient for the development of web services and allow for very easy implantation of APIs. The backend involves two main web services. Two important technologies that were crucial for the development of the backend were Google Cloud services and Voiceflow platform. Using these technologies, two web services were created.

- Vision Product Search Service

Google Vision AI Product Search API [10] was used to implement the main feature, local product identification. This API utilizes the power of Google Vision AI to create an index of items based on the products that have been added. This process is much more efficient than a traditionally trained AI model, as this allows users to dynamically add new products without training a new model each time. Google product search service automatically creates indexes every 1-2 hours. After this period, the newly added item can be scanned with the camera and identified. A separate “Admin App” was developed for the purpose of adding new items. This application uses a Node.JS based Express web server to handle API calls to the Vision product search API. This

web server is hosted on the Google Cloud Run service and it is open to the public. As such the APIs can be invoked by both the Main app and Admin app.

- Voice Guided Services

The voice only mode is implemented using “Voiceflow” [11], a platform used to create AI assistants. The Voiceflow app is built using their development platforms and trained using Voiceflow’s Natural Language Understanding (NLU) model. The voice guided services of the VisiBuy application’s backend are connected to the Voiceflow assistant for data manipulations and retrievals. The Voiceflow assistant is integrated to the VisiBuy app and VisiBuy users can use natural language to issue commands to the application via voice only mode. These commands will be processed by the Voiceflow assistant and converted into commands understood by the web services and perform the necessary data manipulations or retrievals.

4. Results

The VisiBuy application was developed based on a user-centred design approach, with the ultimate objective of improving accessibility and usability for visually impaired users. The key features and functionalities introduced by the solution were able to achieve the goal. They are:

- *AI-powered item recognition model:* A crucial feature of VisiBuy is identifying local packaged and canned goods using smartphone cameras.
- *Voice-guided shopping assistant:* This feature allows users to interact with the system by giving voice commands throughout the application until the order is placed successfully. The voice assistant is more focused on legally blind users to complete the tasks with minimal screen interactions.
- *Accessibility-centric user interface:* The application is designed to provide more user-friendly and inclusive user interfaces by implementing features such as large typography and simplifying interface components. Each interface element will also be equipped with accessibility labels to enhance usability for individuals with visual impairments.

The following testing processes and comparisons were conducted to analyse the various aspects of the application:

Usability Testing

To assess the efficiency and the usability of the VisiBuy application authors conducted a usability test. The test was conducted as a two-part testing process. The authors evaluated the usability of the Voice-Guided Shopping Assistant feature and the usability of the Accessibility-Centric User Interface separately using two different types of users.

The Voice-Guided Shopping Assistant features’ usability testing was conducted with blindfolded users with an Android mobile. The blindfolded users were given the task of placing an order for a list of 3 items. The testing determined how well the users could navigate through the process, search available products, add products to the shopping cart, and place order with the voice assist. The results of the usability testing are as follows:

- *Order Placement Success Rate:* 100% of the blindfolded users successfully completed the order placement process with the guide of voice assist.
- *Obstacles Faced:*
 1. User needed a few minutes to become familiar with the voice-guided commands and the overall structure of the application.
 2. The user acknowledged that the voice-guided shopping assistant to be a helpful feature but acknowledged that it took some time to learn and remember the specific voice commands. They stated that, once familiarized with the commands, the feature proved to be accurate as well as useful in enhancing their engagement with the application.
 3. Cart management: The user mentioned that there was some initial confusion in handling the shopping cart and confirming the order.

All blindfolded users were able to successfully complete order placement process using voice-guided shopping assistant of the application. The overall user experience was positive, despite some initial navigational challenges and slight learning curve for voice commands.

The authors conducted the usability testing of the Accessibility-Centric User Interface, with the help of partially blinded individuals as test participants. Participants were tasked with the same testing steps that were assigned for voice-guided feature participants which is adding 3 items to the cart and place the order. This scenario allowed authors to evaluate the user experience with accessibility features with the devices' accessibility features and the AI-driven product identification feature.

Participants were allowed to choose the option to use regular browsing functionality or the product identification feature. Authors evaluated the overall usability, accessibility, and user satisfaction with the VisiBuy Accessibility-Centric User Interface through success rates, and qualitative insights gathered from participant feedback and observation.

The outcomes of the usability testing are as follows:

- *User Experience with accessibility features:* Most users were satisfied with the accessibility features. They stated that it provided clear and informative audio feedback which helped them with product selection and navigation.
- *Positive feedback on Product identification:* Participants who used the product identification feature found it extremely useful when adding products that they already have on their household, which spared them the time to browse for those products in the application. Users are satisfied with the accuracy of the feature even though it may produce inaccurate results on rare occasions.

All the users were able to complete the order placements without any major challenges.

Comparison of Order Placement Time of VisiBuy

As the next step of the evaluation process, authors have compared the time it took for visually impaired users to place an order using VisiBuy compared to a control group of users without visual impairments. Authors considered two categories while testing visually impaired users: blindfolded users simulating legally blind individuals were given the voice-guided feature, while users with partial blindness or low vision were provided with the accessibility-centric user interface. Testing includes adding 3 items to the shopping cart and placing the order. The average time taken to place orders for the testing are as follows:

- Blindfolded users with VisiBuy Voice Guided Assistant: 5 minutes
- Partially blind/ low vision users with Accessibility-centric interface: 8 minutes
- Control user group with regular vision: 3 minutes

These results demonstrate that VisiBuy provides a similar experience despite the visibility of the users while improves the independence of visually impaired users when placing orders. However, depending on the degree of the visual impairment and the specific features included in the solution, various periods of time may be recorded.

Comparison with Leading Shopping Apps

The authors recorded the average time consumed to search for and add 3 different products to the cart in leading shopping apps with the help of blindfolded users. Table 2 shows the time consumption for the given task using only the talkback features of the mobile devices.

Table 2 Average Time Taken By Leading Shopping Apps

App name	Average Time with Talkback feature
Amazon	15 minutes 51 seconds
E-bay	10 minutes 43 seconds
AliExpress	10 minutes 32 seconds
Cargills	7 minutes 14 seconds
Keells	Doesn't support accessibility features
Daraz	Doesn't support accessibility features

The above-mentioned testing processes and comparisons were conducted with the following assumptions:

- Cash on delivery payment: Since the research is focused on improving the shopping experience of visually impaired people, VisiBuy does not provide online payment methods, and the testing assumed the use of cash on delivery payment method.
- Blindfolded user: Test users were blindfolded to simulate the experience of visually impaired users. Although this method offers insightful information, it could not exactly reflect the experience of a visually impaired individual who may have varying levels of visual impairments.

5. Discussion

The feedback from the test users regarding the usability of the VisiBuy app was positive. Although the voice-guided shopping assistant supports natural language processing, the users were still required to understand the supported commands through the voice assistant and provide clear instructions accordingly. This did not pose a major issue, since as long as the user manages to say the correct commands, the application will handle all the necessary actions correctly through the backend.

The comparison between users with different levels of visual impairments showed interesting results. The blindfolded user group got a much faster complete time compared to partially blind users who used the accessibility centric user interface. This proved that the voice guided shopping assistant is very successful in improving the shopping experience, as intended by the authors. Although, a small gap still exists between the time taken by users with normal vision and blindfolded users.

The comparison with leading shopping apps clearly revealed that VisiBuy excels in terms of the speed at which orders can be completed through its accessibility features. The compared apps are vastly popular among the users with regular vision, but do not focus solely on accessibility. As such, they fall short in some areas due to having too much information on screen and compatibility issues with the screen readers functionality. Some applications had no accessibility support. When comparing the time taken to complete an order, in terms of accessibility, due to the voice guided assistant and product identification abilities, VisiBuyfar surpasses the other apps.

6. Conclusions and Future Work

The Authors intended to improve the quality of life of visually impaired people, specifically legally blind and partially blind demographics. The goal was to enhance the shopping experience of this demographic and to achieve this, the authors proposed to create a mobile application that facilitates full control over the application through voice commands, utilizing modern natural language processing AI models. Additionally, the authors proposed to further improve the process of identifying items, specifically local packaged goods by utilizing modern image recognition AI models. As proposed, the authors successfully finished implementing the VisiBuy application using versatile technologies. Since React Native technology was used to develop the frontend, the software is accessible to many operating systems and the app is even compatible with web browsers. The design architecture of the backend utilizes web services, as such the backend is highly scalable and available.

After analysing the test results, the authors concluded that the application was mostly successful in achieving the goal of enhancing the shopping experience of legally blind and partially blind people. As the results indicated, the accessibility centric design is very intuitive and convenient for legally blind users as the VisiBuy app significantly improves the efficiency of the ordering process when comparing to other major e-commerce platforms. But as the other tests indicated, this time is still slower than the time taken by users with regular vision. As such, there is still a gap between a visually impaired user and a user with regular vision in time taken to complete the shopping process. The research can be continued to seek ways to further decrease this gap.

Though the application is successful in achieving the main goal of the authors it still has some limitations. In Google Vision Product Search API, the newly added items cannot be scanned until they are indexed by Google's systems. This process may take up to 2 hours. Apart from this limitation, the solution can be further improved in a few other areas. Though the application heavily reduces the screen interactions required by the user, some interactions still exist. Tests indicated that these rare occasions cause the most delays in completing an order. Furthermore, an improved payment system and delivery methods could be introduced. Currently, the

application is only available in English. More localization options will further increase the accessibility of the application.

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