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Shopping Aid Device for the Visually Impaired Using Arduino Mega and Barcode Module

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Abstract

Over the past five years, the number of blind and visually impaired (BVI) individuals in Indonesia has reached approximately 3.6 million in 2023. Based on interviews with Indonesian Union for the Visually Impaired (PERTUNI), it was found that blind and visually impaired (BVI) individuals often face limited independence, leading to reduced self confidence. A common challenge is daily grocery shopping, where they frequently require companions, and the absence of such support makes it difficult to ensure that the selected products are correct. PERTUNI also highlighted that assistive devices for this kind of problem are rarely developed, despite being urgently needed by almost all BVI individuals. To address this gap, we developed Drishti, a compact and portable assistive system specifically designed to support shopping activities by detecting product names through barcode recognition and providing audio feedback. Unlike most existing assistive devices that rely on camera based systems, Drishti employs a dedicated barcode sensor. In addition, the system is designed to be lightweight and operating without internet connectivity, ensuring usability anytime and anywhere. Drishti also functions as a validator, aiming to enhance the confidence and comfort of BVI individual during shopping. The prototype demonstrated a 67% accuracy rate in detecting products with EAN type barcodes under various lighting conditions and product states, while maintaining clear audio feedback across all trials. These results position Drishti as a promising prototype that can be further developed to enchance the shopping independence of BVI individuals.

Keywords: Assistive device; Barcode; Product identification; Visually impaired;

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1. Introduction

Human life is fundamentally sustained by five basic sensory systems, among which vision is arguably the most essential for perceiving the surrounding environment and facilitating independent interaction with the world. Blind and Visually Impaired (BVI) refers to a significant reduction in visual acuity or field of vision that cannot be corrected through conventional means such as eyeglasses or contact lenses, often resulting in substantial challenges for individuals in maintaining safe and autonomous mobility both indoors and outdoors, as well as in navigating independently and managing daily life activities [1, 2, 3]. According to the report by the World Health Organization, approximately 2.2 billion people globally suffer from some form of visual impairment, with cataracts remaining the leading cause [4, 5]. The etiology of visual impairment and blindness is multifactorial, including preventable causes such as delayed medical treatment, chronic diseases like diabetes, and unexpected trauma or accidents [6, 7]. The Social Affairs Ministry of Indonesia reported a 15% increase in the number of BVI individuals over the past five years, reaching approximately 3.6 million people in 2023 [8]. The report data underscores the urgent need for the development of accessible, innovative assistive solutions aimed at supporting independent living.

Over the past decade, extensive efforts have been devoted to developing wearable assistive devices for BVI individuals, with the aim of enhancing BVI cognition during navigation in both familiar and unfamiliar indoor and outdoor environments, ultimately improving their quality of

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life [9]. A substantial body of research has been devoted to designing wearable and portable devices that utilize both conventional sensor systems and emerging technologies such as artificial intelligence (AI) to assist BVI individuals [2, 10]. These assistive devices ranging from hardware based tools to software driven applications, are developed to enhance the daily living experience of BVI Individuals by supporting navigation, reading, object recognition, and interaction with digital information [11, 12]. Despite these technological advances, the adoption and usability of such solutions remain inconsistent. For example, Remillard et al. [13], in their study on aging individuals with vision impairments, highlighted that users often struggle with the default visual design of mainstream digital tools, such as insufficient font size and contrast settings on smartphones. This raises a critical question regarding the effectiveness and inclusiveness of assistive technologies, especially when implemented for individuals with total blindness.

Although assistive technology innovations have advanced, they often overlook essential aspects of independent living. Insights from Persatuan Tunanetra Indonesia (PERTUNI) or Indonesian Union for the Visually Impaired indicate that while mobility aids are widely adopted within the BVI community, there remains a significant lack of dedicated tools for autonomous object recognition in daily scenarios such as grocery shopping. Furthermore, the limited solutions available are predominantly based on camera and image recognition technologies [1], which typically require internet connectivity, highly sensitive to environmental conditions, and may encounter issues when product packaging changes. These limitations reduce their practicality and may even become burdensome for users.

In response to these problems, this study proposes the design of a barcode-based assistive device that integrates a high performance barcode scanner module with a text-to-speech (TTS) audio output system, aimed at enabling BVI Individuals to recognize physical objects through auditory feedback. The design prioritizes usability and operational simplicity by implementing a one-touch interaction model, allowing users to activate the scanning and feedback process with a single button press eliminating the need for complex navigation, multi step operations, or visual cues [14, 15]. Barcodes, being universally present on product packaging, offer a practical and standardized means of identification. The system works by prompting the user to scan a product's barcode, after which the device retrieves and verbalizes the associated item name or relevant information stored in its local memory. This approach offers a distinct advantage over smartphone-based solutions, which often require navigating menus, aligning camera views, or relying on screen readers, factors that can introduce substantial barriers BVI Individuals.

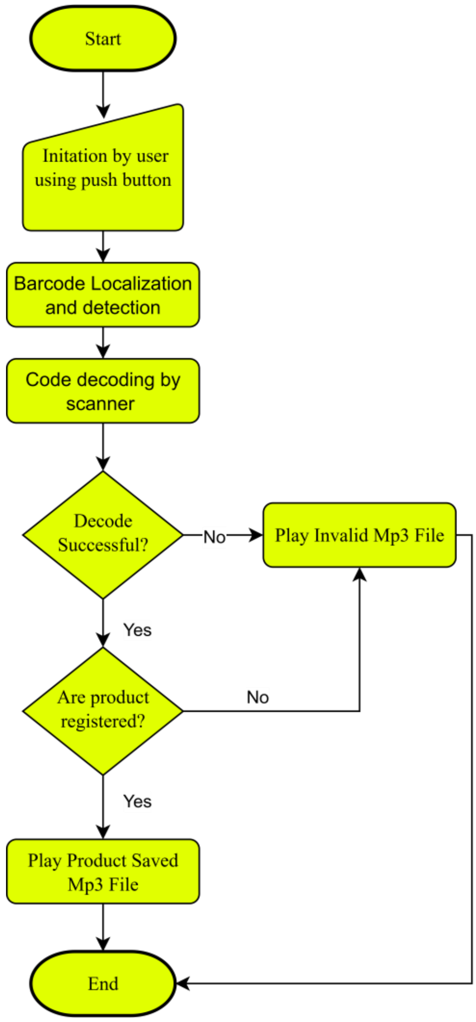

Fig. 1. Flowchart of proposed system.

2. Research Method

2.1 Proposed System

The proposed assistive device was developed as a portable, embedded system designed to support object recognition for BVI Individuals by providing auditory feedback via barcode scanning. Its core is the Arduino Mega 2560, chosen for its extensive I/O ports, multiple UART serial communication lines, and sufficient memory for integrating various peripherals. The Arduino platform offers simplicity in programming, affordability, and the ability to execute scripts stored in EEPROM without requiring continuous external interfacing, enabling fully autonomous operation in daily environments [16].

Object recognition is facilitated using the GM720 barcode scanner module, capable of

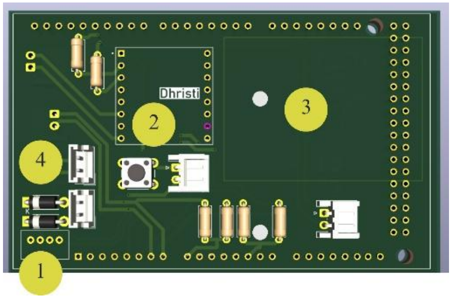

Fig. 2. PCB Design and component placement.

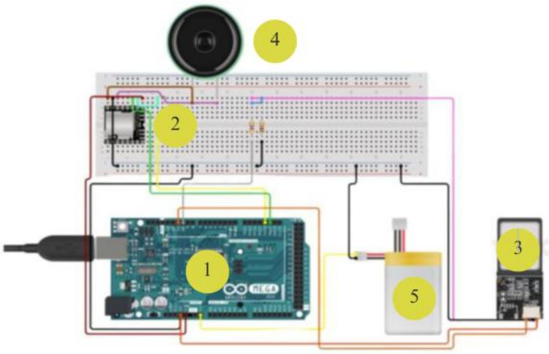

Fig. 3. The electronic hardware configuration.

decoding both 1D and 2D barcodes with high accuracy using an embedded image recognition algorithm. The scanner connects to the Arduino via UART and demonstrates reliable performance under diverse lighting conditions, making it ideal for identifying products in retail or domestic settings. A single tactile push-button interface is implemented to initiate scanning, enhancing accessibility. Upon receiving barcode data, the Arduino performs a local lookup in its internal memory and, upon a successful match, triggers the DFPlayer Mini MP3 module to play a corresponding pre-recorded audio file from a microSD card. These audio files are linked to each product using a consistent file naming convention, ensuring clear voice output through the speaker. Fig 1 shows the flow diagram of proposed system.

2.2 Hardware Design

To optimize size and integration, this device employed to custom printed circuit board (PCB) designed in KiCad, consolidating the microcontroller, sensors, and power circuitry into a single compact board measuring 9 × 6.5 cm. This integration significantly reduced the physical footprint and improved internal reliability by eliminating excess wiring and modular connections. Fig. 2 shows the 3D rendered PCB layout, comprising: (1) a charging module for charging the battery, (2) a DFPlayer MP3 module for audio playback, (3) a barcode module for scanning and identification, and (4) a JST connector for connecting the battery to enable the step-down process. Fig. 3 illustrates the corresponding wiring schematic developed in the software, consisting of: (1) an Arduino Mega 2560 microcontroller as the central processing unit that manages system operations and data flow, (2) a DFPlayer MP3 module responsible for audio output, (3) a module used to scan and decode product barcode, (4) a speaker that delivers the audio output from the MP3 module, and (5) a battery that serves as the primary power source for the entire system.

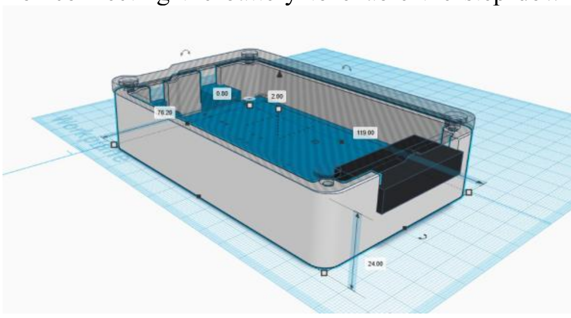

Fig. 4. 3D Case Design for electronic hardware.

The outer casing of the device was 3D printed using flexible TPU95 filament (Shore 95A), selected for its elasticity, toughness, and low weight, enhancing both comfort and durability. The final enclosure measures 13 × 7.5 × 2.5 cm, offering a compact and ergonomic form factor suitable for handheld use. Unlike rigid plastics, TPU95 can flex to absorb impact and adapt to the user's grip, ideal for assistive applications [17]. Additionally, TPU exhibits excellent fatigue resistance and long term wear durability [18], while its soft, skin friendly surface reduces the risk of irritation during extended contact [19]. The 3D modeled casing design is shown in Fig 4.

The system is powered by a set of four 3.7 V, 2000 mAh lithium batteries, with two cells dedicated to the microcontroller and audio playback modules, and two reserved exclusively for the barcode scanner. This dual power allocation ensures stability and extends operational time, supporting prolonged daily usage without compromising performance or reliability.

Table 1. Room and Light Specifications

Specification	Value
Room Size	5 x 3 meters
Light Distance	2.5 meters
Light Type	LED
Power	9 Watt
Color Temp.	3500 K
Brightness	900 lumens

Fig. 5. Final prototype after assembly.

2.3 Device Testing

To evaluate the performance of the developed system, testing was conducted in a controlled indoor environment with specific room conditions, as outlined in Table 1. Quantitative metrics were collected during the evaluation phase, including the percentage accuracy of barcode detection and subjective ratings of audio clarity. These metrics were used to assess the functional reliability and usability of the prototype. Table 1 provides detailed specifications of the room and lighting conditions used throughout the testing process.

Each hardware component in the assistive device underwent individual functional testing. For the barcode sensor module (GM720), evaluation was carried out using standard EAN-type barcodes under various conditions. These included differences in lighting environments (bright and dark) as well as barcode print conditions. The objective was to assess the robustness and decoding accuracy of the sensor under realistic usage scenarios.

Meanwhile, the DFPlayer Mini MP3 module and integrated speaker were tested by triggering audio playback corresponding to stored mp3 files on a microSD card. Each audio file was linked to a specific barcode value previously programmed into the Arduino's logic. Playback tests were conducted at three volume levels 80%, 60%, and 50% to evaluate the clarity, intelligibility, and responsiveness of the audio output in varying ambient conditions.

3. Result and Discussion

The final assembly prototype of the developed assistive device is illustrated in Fig 5, showcasing the final integration of all hardware components within the custom-designed casing.

3.1 System Testing and Durability

Comprehensive testing was conducted to evaluate the system's functionality and durability. A single EAN-format barcode was scanned repeatedly under two different lighting environments to assess detection performance, with a fixed distance of 5 cm between the scanner and the barcode. In the bright lighting scenario, conducted in an enclosed room with the lights turned on, the device successfully recognized 7 out of 9 scans (77.78%). In contrast, under the dark scenario, performed in the same room with the lights turned off, the system successfully detected 5 out of 9 scans (55.56%). These results yield an overall accuracy rate of 66.67%. All percentages were obtained using the following accuracy calculation:

$$Accuracy\ (\%) = \frac{Successful\ Scans}{Total\ Scans} \times 100 \quad (1)$$

$$Accuracy_{bright} = \frac{7}{9} \times 100 = 77.78\% \quad (2)$$

$$Accuracy_{dark} = \frac{5}{9} \times 100 = 55.56\% \quad (3)$$

$$Accuracy_{overall} = \frac{12}{18} \times 100 \approx 67\% \quad (4)$$

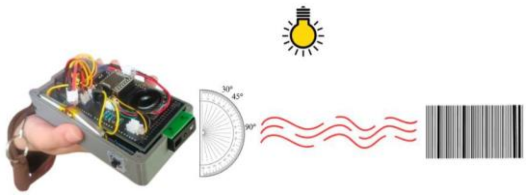

Fig. 6. Illustration of the degree-based testing setup.

Fig. 7. Documentation taken during the testing process.

Fig 6 illustrates the testing setup, while Fig 7 presents documentation captured during the testing process and Table 2 presents the results of successful barcode scans under varying lighting conditions and scanning angles.

Table 2. System Function Test Result

Lighting Cond.	Angle	Success	Observations
Bright	30°	1/3	Barcode can't be read
Bright	45°	3/3	Barcode read clearly
Bright	90°	3/3	Barcode read clearly
Dark	30°	0/3	Barcode can't be read

Lighting Cond.	Angle	Success	Observations
Dark	45°	2/3	1 failed scan; low light
Dark	90°	3/3	Barcode read clearly

Additional trials were conducted at varying distances. The farthest effective scanning range was observed at 10 cm, with 5 cm proving to be the most reliable distance for consistent detection. Further evaluations showed that the scanner performed optimally under standard room lighting conditions and at scanning angles of 45° and 90°, utilizing only the module's built-in illumination. These results emphasize the system's reliance on sufficient ambient lighting and precise alignment for optimal barcode recognition, underscoring the importance of environmental factors in future system improvements.

3.2 Ergonomics and Portability

The ergonomic evaluation of the prototype was conducted based on the ISO 9241-210 [20] guidelines, which emphasize user-centered design and usability principles in interactive systems. The device, with physical dimensions of 13.7cm × 6.7cm and an average measured weight of 224.17 grams (based on three weighings), was confirmed to be portable and ergonomically appropriate for handheld use. To further assess the device's comfort and familiarity, a comparative analysis was carried out against commercially available portable devices, such as the Xiaomi Power Bank and Anker PowerCore Slim. This comparison demonstrated that the assistive device's size and weight fall within the range typically considered acceptable for daily handheld use.

User feedback was collected through structured questionnaires completed by participants with normal vision. Although BVI Individuals were not involved due to time constraints and the absence of ethical clearance, this preliminary evaluation provides early insights into usability. A total of 83% of respondents rated the device's comfort and handling as 4 (four) on a five-point likert scale, indicating a generally positive perception. These initial results suggest that the device design meets general user expectations, though further validation with the target user group is essential.

In addition, this device offers a novel approach to supporting visually impaired individuals in their daily activities by employing a simple system that can be used in various settings. Unlike previous prototypes [1] that relied on Raspberry Pi as the main controller and image identification algorithms approaches that introduce challenges when product packaging changes, require multi-step operations that may complicate user interaction [13], the proposed system adopts a more straightforward and practical design. Although earlier prototypes may appear more advanced, they generally incur higher costs, whereas the system presented in this study can be developed at an approximate cost of only IDR 600,000, with potential cost reductions through mass production. Despite these advantages, several limitations remain and warrant further investigation. Future work should focus on improving system accuracy, conducting direct trials with BVI participants to obtain authentic user feedback, refining the device into a more compact form factor, and performing extensive testing in real-world environments such as shopping centers.

4. Conclusions

The developed device, named Drishti (derived from the Sanskrit word meaning 'vision') demonstrates significant potential as an assistive tool to support BVI Individuals in independently performing grocery shopping and validating purchased goods, thereby enhancing autonomy, safety, and self-confidence. By integrating a barcode scanning module, Arduino Mega 2560, and a TTS system, the device enables effective product identification through audio feedback, achieving an overall accuracy of 67%. While the prototype successfully meets its targeted specifications, including portability and ease of use, it still faces limitations under low-light conditions. Future work should prioritize improving system accuracy, enhancing sensor sensitivity, and refining the case dimensions for better user experience. Ultimately, Drishti represents a promising, simple, and reliable system that is easy to use, cost effective to produce, and directly suitable for adoption by the visually impaired community.

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Additional Information