K.H.U. Faculty of Engineering and Natural Sciences

FENS402 DESIGN PROJECT
PROPOSAL

WEARABLE SMART DEVICE FOR VISUALLY IMPAIRED PEOPLE

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ABSTRACT:

This project will enable visually impaired individuals to travel safely and move comfortably using a wearable smart device. Main functions of this smart device are identifying obstacles and responding to the user, tracking activity and alarming with location information in case of emergency such as falls. Therefore, the system provides obstacle detection, activity and location tracking with a highly functional microcontroller, advanced sensor and camera. With machine learning integrated into the system, the device can guide visually impaired individuals through vibration feedback. In addition, the wearable smart device allows the user to track physical activities such as walking and falling. In case of possible emergencies such as falling on the user's side, it is ensured that the desired people are notified. In addition, the device facilitates the detection of the user's location using GPS technology. This project offers a cost-effective and safe design for the user. In this way, visually impaired individuals can move more independently and comfortably. The project is intended to be an innovative technology and user-oriented system offered to visually impaired individuals.

AIM:

People with visual impairments are a part of our society. According to data from the World Health Organization (WHO), around 285 million people worldwide are visually impaired, including 39 million who are classified as “blind” and 246 million who are classified as “low vision” [1]. In Türkiye, approximately 215,076 visually impaired individuals make up about 0.26% of the total population [2]. The majority of visually impaired persons have long used the conventional white cane as a useful but constrained navigation tool; while it is reasonably priced and can identify obstacles up to knee level, it offers very little insight into the surrounding area. The classic white cane used by the blind and visually impaired is inadequate for modern needs. An alternative option is to use a guide dog, which acts as a navigation aid and helps the blind avoid dangers. It takes many years to train a guide dog effectively, making it costly and rare. These devices are often inadequate for a constantly changing urban environment in daily life, which includes dynamic variable obstacles and complex situations, making visually impaired people more vulnerable in their daily lives and having limited mobility and freedom. To address these problems that visually impaired people face in the contemporary environment, we will create a smart guide for them using wearable sensors.

The goal of this project is to create a wearable, AI-powered system for real-time environmental obstacle detection and physical activity monitoring by using wearable sensors. During mobility, the system will track the user's body movements and detect environmental obstructions. Various sensors and a microcontroller-based control unit will be used to achieve these two main goals in the project. The design of this control unit will ensure that it is wearable and can be attached to the body. The data collected by the sensors will be processed by the microcontroller and the necessary data will be stored. In addition, in the event of a possible emergency, a warning notification will be sent to the desired persons. The data from the sensors will be used to provide real-time warnings for obstacle detection and to provide the user with sound and vibration input about the location and distance of obstacles. The microcontroller will receive the data gathered from the sensors and evaluate it in real time. The system will use machine learning techniques to detect abnormalities (such as falls) and to predict the user’s physical activity status (such as sitting, lying, walking, and running). These algorithms will analyze sensor data and categorize predefined actions. Along with the user’s location, the system aims to inform registered persons (such as family members, caregivers, or appropriate authorities) about any risk scenarios.

Collecting real-time data through wearable devices and processing it using machine learning algorithms presents a multi-layered engineering challenge. It requires an interdisciplinary approach, combining hardware design - such as sensor selection, microcontroller integration, and power management with software development, including sensor data synchronization, signal processing algorithms, and wireless communication protocols. There are several multi-layered and analytical engineering challenges in collecting real-time data with wearable technology and analyzing it with machine learning algorithms. A multi-disciplinary approach that integrates software development (including wireless communication protocols, signal processing techniques, and sensor data synchronization) with hardware design (such as sensor selection, microcontroller integration, and power management) is required. Additionally, the user’s body movement and the location and distance of the surrounding barriers will be analyzed using machine learning techniques. Managing signal processing issues is one of the main engineering challenges as sensor data can be noisy and require precise fusion to obtain reliable findings. Critical tasks that require low-latency data processing, such as obstacle and fall detection, require real-time processing. Another important aspect is energy efficiency, as wireless connectivity and ongoing data collection have a major impact on battery life. Furthermore, to ensure synchronous and significant interpretations, multi-sensor integration requires combining data from multiple types of sensors. Finally, ergonomics and user comfort are critical, as the device must be small in size for long-term use, lightweight and comfortable for user comfort. As a result, the project needs a complete technical solution that combines knowledge in data science, software, electronics and user-centered design.

Project Objectives

1. **Real Time Obstacle Detection and Alerts:** The wearable smart device uses information from sensors to detect obstacles around the user in real time (distance, direction) and provide feedback to the user in the form of vibration or voice warning.
2. **Activity Recognition and Analysis:** Categorize bodily activities (such as sitting, lying, walking, and running) and detect anomalies (such as sudden falls) using machine learning techniques and sensor data.
3. **Location Tracking and Emergency Notifications:** Use GPS to notify the user's location and registered persons such as family members, caregivers or relevant authorities in the event of a fall or other potential danger.

Parameters for Objectives

Performance of Machine Learning Models

To evaluate the effectiveness of machine learning models used for obstacle detection and body activity determination, a large number of metrics need to be evaluated [3]. Common metrics for categorization models are as follows:

Accuracy: The ratio of properly predicted cases to the total number of forecasts. It's computed as:

$$Accuracy = \frac{(TP + TN)}{(TP + TN + FP + FN)} \quad (1)$$

- True Positives (TP): Correctly predicted positive cases.
- True Negatives (TN): Correctly predicted negative cases.
- False Positives (FP): Incorrectly predicted positive cases.
- False Negatives (FN): Incorrectly predicted negative cases.

The 80% accuracy target for obstacle recognition ensures that the system reliably recognizes obstacles and transmits directional inputs such as distance and location with the same accuracy. The standard target for physical activity identification is 85% accuracy; This demonstrates the system's ability to successfully categorize behaviors such as walking, running, and falling [3].

Precision: The percentage of optimistic forecasts that are really right. It assesses the model's ability to correctly categorize positive cases.

$$Precision = TP / (TP + FP) \qquad (2)$$

Recall: The percentage of real positive cases properly detected by the model:

$$Recall = \frac{TP}{(TP + FN)} \qquad (3)$$

F1 Score: The harmonic mean of precision and recall:

$$F1\, Score = 2 * \left(\frac{(Precision * Recall)}{(Precision + Recall)}\right) \quad (4)$$

An F1 score of 0.8 for obstacle detection provides a compromise between recognizing obstacles and minimizing false alarms. To ensure accuracy and reduce false alarms, a target F1 score of 0.85 is recommended for identification of body activity, especially for detecting falls [3].

Response Time and Feedback Latency

Response time is the time between an event, such as detecting an obstacle, and the system notifying the user. Reducing latency is crucial for both security and usability. For obstacle detection, the time between detecting an obstacle and transmitting an audible or haptic signal should not exceed 2 seconds, giving users sufficient time to respond. This is calculated by taking timestamps at the detection point and alarm emission locations. To ensure timely notification and capture relevant data, event detection delay should be less than 3 seconds. Developers measure this by comparing the time it takes to make a transition (for example, from walking to falling) to the system's response time.

Energy Efficiency

Energy efficiency is critical to ensure wearable system portability and use over time. Continuous data collection, processing, and communication can drain the device's battery.

To solve this, the equipment must maximize power consumption while maintaining performance for a minimum of 1.5 hours of operation under normal conditions.

Detection Range

The detection range is the largest distance at which sensors can effectively identify obstacles, giving users plenty of time to respond. The minimum detection range for this project is 2.5 meters. Longer ranges increase user awareness but may lead to higher power consumption and false positives due to ambient noise or distant objects. It is very important to strike a balance between range, sensitivity and energy efficiency.

Location Precision

Location accuracy evaluates the extent to which the system's stated location corresponds to the user's actual location; This is critical in situations where caregivers rely on accurate coordinates. The acceptable error tolerance for GPS in outdoor conditions is approximately 10 meters. To ensure accuracy, the system's reported positions are compared to established reference positions and the average deviation is determined. Reliable location tracking ensures essential information is accurate and actionable.

Research Questions

RQ1: What is the optimal sensor combination for accurately classifying user activities?

This topic discusses the difficulty of selecting and integrating several sensors, such as accelerometers, gyroscopes, and pressure sensors, to accurately capture a wide variety of user motions. Choosing the most efficient sensor combination is crucial for improving classification accuracy and lowering computing overhead in wearable devices. Such insights can considerably improve fall detection and activity tracking, hence improving user safety and well-being.

RQ2: How do ultrasonic sensors, LIDAR, and infrared sensors compare in terms of accuracy and energy consumption for obstacle detection, and which sensor is more effective?

This question examines the trade-offs of several sensor systems for identifying environmental impediments. Energy efficiency is a major problem in wearable devices, and accurate obstacle detection has a direct influence on user safety. Addressing these trade-offs is vital to design a dependable system that combines battery life with accurate obstacle identification, therefore aiding individuals, such as those with visual impairments, who require powerful real-time awareness of their environment.

RQ3: What accuracy can machine learning algorithms achieve in real-time activity prediction, and obstacle detection and which models are more suitable?
Investigating the efficiency of different machine learning algorithms tackles the fundamental challenge of making timely and accurate predictions about user behavior. Different algorithmic techniques offer different benefits and disadvantages in terms of processing resources, latency, and complexity of the models. Determining which models are suitable for real-time applications on wearable devices may lead to more effective, responsive, and easy-to-use alternatives.

RQ4: How do the placement of sensors and device dimensions impact user comfort? What ergonomic or technical issues arise with long-term use?
Wearable devices should be pleasant and convenient for long-term use. This research aims to identify design principles that limit pain, enable reliable data collection, and reduce user fatigue by examining various sensor locations, form factors, and ergonomic concerns. Overcoming these human-cantered challenges is critical to practical acceptance and long-term happiness with the system.

METHODOLOGY:

This section describes the methodology and techniques that will be used to achieve the goals of the "Wearable Smart Device for the Visually Impaired" project. This methodology aims to enable the creation of a reliable system for real-time obstacle identification, activity tracking and location detection. The main goal is to create and build a wearable sensor system that aids visually impaired people by using machine learning to predict behavior and detect possible obstacles.

The project takes an organized, multi-phase approach combining hardware design, software development, machine learning and real-time communication to create useful supportive equipment for visually impaired people. The project will be implemented in phases in work packages, each focusing on a key aspect of the conceptualization and implementation of the system. These work packages cover initial research and planning, system architecture and design, hardware implementation, testing and optimization. Additionally, the project will require the assembly of various hardware and software components.

Literature Review

Studies and Applications in Assistive Technologies for the Visually Impaired:
Advances in computer science and medical technology now focus on solving the problems experienced by visually impaired and blind people. These people need new equipment to navigate and interact with the environment as easily as sighted people. Although current technologies aid in tasks such as reading, writing, and

navigation, there is still much to improve, especially in terms of precision and reliability [4]. Navigating unknown indoor and outdoor spaces remains a significant challenge. Although many navigation systems are available, they often cannot provide the degree of precision required for visually impaired users due to limitations in positioning systems and road directions.

Outdoor navigation systems such as GNSS, field strength measurements, and pedestrian dead reckoning (PDR) have been investigated. Indoor navigation systems often rely on installation infrastructures such as Bluetooth Low Energy beacons, radar, sonar, lasers and motion sensors. However, since many buildings do not have the necessary connection infrastructures, infrastructure-free alternatives are critical. The research emphasizes sensor fusion, or localization, and the use of multiple approaches to improve tracking accuracy. Combining these technologies can improve navigation systems by providing accurate guidance both indoors and outdoors, thus meeting the demands of visually impaired users [4].

Studies have also shown that contemporary localization and tracking technologies, such as GPS and BLE beacons, make it easier for visually impaired people to traverse both limited and open settings. These technologies increase both sense of place and independence, making them essential components of assisted navigation systems. A sophisticated navigation system for visually impaired users ought to include exterior and indoor localization approaches to provide infrastructure-independent, dependable, and accurate guiding [4].

Prema et al. [5] investigated a smart stick designed for visually impaired people, combining various sensor modules and modern technology. Ultrasonic sensors detect obstacles at a distance of one meter and warn the user with voice guidance through the headset. Extra sensors, such as fire and liquid detectors, increase safety by detecting potential threats in the environment. The device combines GPS and GSM functions for location tracking and emergency communication and sends information to healthcare personnel when necessary. The panic button allows users to report crises and get immediate help. The device also uses the Raspberry Pi board to analyze data and manage hardware components, demonstrating the possibility of portable and adaptable designs. Additionally, voice assistance via a voice module aids navigation by providing clear and concise information. Despite these gains, the system has certain detection range limits and needs to be better integrated into the hardware. This approach highlights the value of sensor-based technology in improving the mobility and safety of visually impaired people.

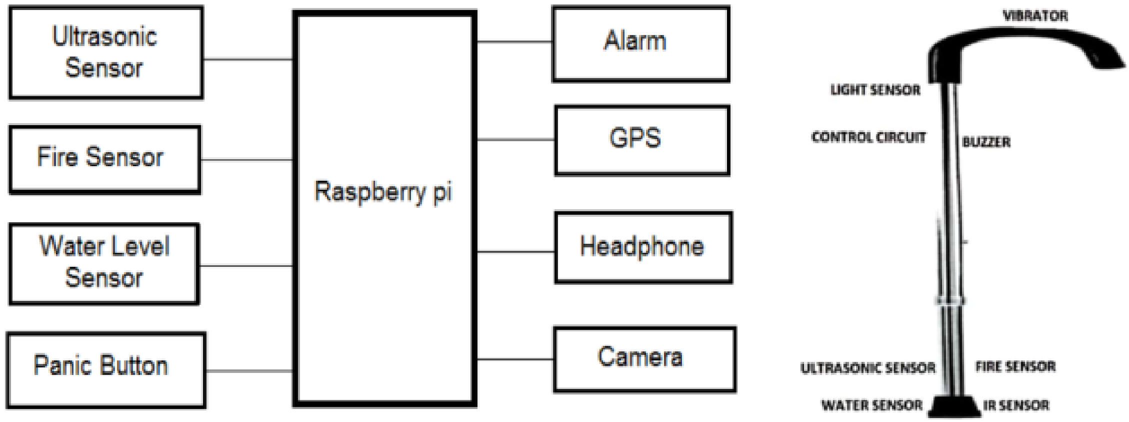


Fig. 1 Block Diagram and Stick Model [5]

Li Jasim Ramadhan [6] created the wearable smart system, a wrist-worn device that detects obstacles and provides notifications to visually impaired users. The device uses an ultrasonic sensor to detect obstacles within a 4-meter range and provides audio and vibration alerts that get stronger as the user approaches them. Those who have hearing problems or are in noisy environments benefit from the vibration feature that effectively communicates possible threats. In the event of an emergency, such as if the user stumbles, the device instantly sounds an alert and sends SMS messages to caregivers informing them of the person's current location. Additionally, speech recognition allows users to ask for help by saying “Help,” which triggers both local alarms and caregiver notifications [6].

The main parts of the setup include an ATmega328 microprocessor combined with an Arduino Uno board, allowing for fast processing and programming. The ultrasonic sensor detects obstacles, the accelerometer detects falls, and the voice identification module analyzes spoken instructions. Stimuli are delivered via a buzzer for auditory feedback and a vibrating motor for tactile sensation, ensuring consistent performance in changing situations. GSM and GPS modules provide real-time communication and tracking, allowing caregivers to find the person they need. High-capacity power supply and solar panel provide long life with low power usage. This lightweight, low-cost device promotes ease of use and real-time operation, making it ideal for daily use by visually impaired people [3]. Combining modern sensors with communication technologies, this device increases user safety and freedom while also eliminating significant challenges faced by this group.

Obstacle Detection Methods:

Obstacle detection is critical for assistive technologies for visually impaired people. This project will use Raspberry Pi and OpenCV, which provide real-time image processing and artificial intelligence integration, as well as a camera and depth sensor for image-based detection. Lee et al. [7] demonstrated the effectiveness of integrating artificial intelligence and visual processing to detect obstacles in autonomous wheelchairs. Their method used MobileNet SSD, a lightweight CNN model, to perform real-time object identification with good accuracy on pre-trained datasets such as COCO and PASCAL VOC. They also used adaptive thresholding to dynamically identify obstacles and enable direct movement control; They showed how pixel density and spatial location can improve obstacle avoidance. Built on this basis, the proposed system will use comparable approaches to provide a reliable and effective obstacle identification solution.

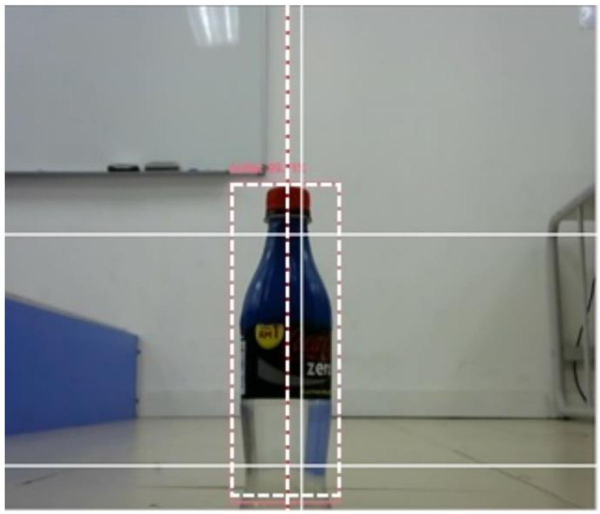


Figure 2 Center of obstacle detection output with Python and OpenCV [7].

YOLOv5 and COCO

YOLOv5 is an updated deep learning model for object identification. This is an improved version of the "You Only Look Once" technique, which analyzes an image in one step, determining the position (bounding box) and class of elements within it (e.g. person, car, cat). This type is designed for speed and precision and is ideal for real-time applications. Built on the PyTorch framework, YOLOv5 is easy to use and customize. Integration of YOLOv5 with the COCO dataset is a critical component of the training process, allowing the model to learn efficiently and adapt to object identification tasks [8].

The COCO (Common Objects in Context) dataset is a commonly used dataset for training object identification algorithms such as YOLOv5. It offers 80 types of common items found in different locations and conditions, including people, animals, cars, and furniture. One of the key benefits of the COCO dataset is that it not only gives named items, but also provides context for how these things show up in everyday situations. This information allows models like YOLOv5 to recognize objects with higher precision. Additionally, the high resolution and diverse images of the COCO dataset make the model adaptable to changing environmental conditions.

YOLOv5 includes pre-trained models based on the COCO dataset that can be used as the basis for a variety of object identification tasks. For example, a person creating an alarm system could use a YOLOv5 model trained on the COCO dataset to create an application that recognizes individuals and cars. These pre-trained models can be easily transformed into customized datasets through transfer learning; It allows users to precisely define the object classes required for their application and maximize the performance of the model.

Using YOLOv5 and the COCO dataset together provides a successful approach to identifying object tasks. This pair has a wide range of applications, including security systems, medical imaging, production lines and robotics. The richness of the COCO dataset and the adaptability of YOLOv5 allow object recognition algorithms to run quickly and accurately. Powered by the COCO dataset, YOLOv5 is well suited for real-time applications and can solve a wide range of problems encountered in daily life.

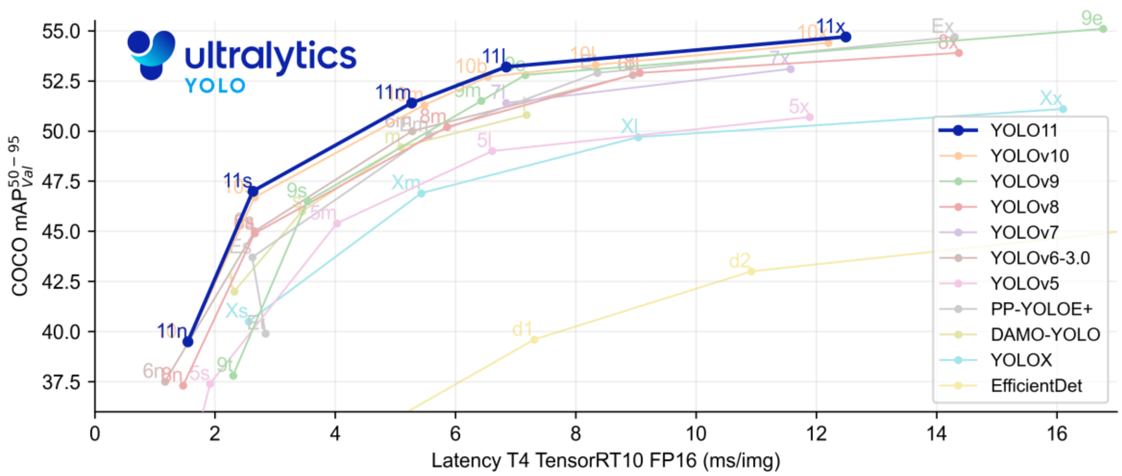


Figure 3 Comparison of object detection models [8].

This project aims to help visually impaired people by detecting things around them and sending alerts through audio and vibration feedback. The system will take real-time photos of the environment using the Raspberry Pi and camera and process them with the YOLOv5 object detection method. Detected items will be transmitted to the user via headphones or a wearable device that provides haptic feedback. This strategy increases spatial awareness and mobility by allowing users to receive timely and intuitive signals about elements in the environment. The project aims to develop an inexpensive and portable solution that uses the lightweight and efficient YOLOv5 model to provide excellent accuracy and fast response times even in complex environments.

Python and Libraries

Python was chosen as the main programming language for this project due to its flexibility, simplicity and extensive library support. Python is an excellent choice for building applications in areas such as machine learning and computer vision, making it a key component in implementing the YOLOv5 object recognition method to be used in this project. Python's open-source status and support from a large developer community make it an attractive choice for both personal and enterprise-level projects. Python's versatility will allow many phases of this project to be executed smoothly, such as object recognition, hardware integration, and user feedback.

Python's comprehensive library ecosystem significantly simplifies development efforts. For example, **OpenCV** will be used to process and analyze images acquired by the camera. OpenCV can effectively perform tasks such as image optimization, noise removal, and object detection. **Pandas** will be used for data analysis and management, as well as organizing and managing the data obtained from the system. **PyTorch** will be used to train and infer deep learning models as it provides a dynamic computational graph structure that allows the model to quickly adapt to various datasets and system constraints.

Additionally, Python's clarity and easy-to-use syntax is a significant advantage, especially during rapid development and debugging phases. Being able to express complex algorithms and system components in an accessible way not only makes the development process more efficient, but also allows early detection of possible errors. Python's seamless connection with hardware such as the Raspberry Pi allows real-time processing of data from peripheral devices and rapid response to the user. In this project, the camera will detect objects and transmit them to visually impaired individuals through auditory warning or tactile feedback, thus increasing their environmental awareness. To summarize, Python was chosen for this project because it is a strong language that can handle all of the technical needs.

OpenCV

In this project, OpenCV (Open Source Computer Vision Library) is widely used to process and evaluate the visual input generated by the camera. OpenCV is an open-source framework that offers a variety of capabilities for image and video processing. Its versatility and effectiveness were ideal for the development of the object detection system used in this project; This system is intended to help visually impaired people by detecting objects around them and providing real-time feedback.

OpenCV will serve various functions in this project. First, the Raspberry Pi will handle image pre-processing tasks, including resizing, filtering, and enhancing raw photos taken by the camera. These preparation processes ensure that photos are clean and ready to be examined by the YOLOv5 object recognition algorithm. For example, reducing noise and changing colors can significantly increase detection sensitivity.

Second, OpenCV will be used for real-time video stream processing. The optimized functions of the library enable efficient processing of continuous video input, guaranteeing fast and lag-free processing of frames. This functionality is especially important in real-time applications where rapid feedback is required. OpenCV's interaction with hardware such as Raspberry Pi ensures smooth operation even on systems with low processing capacity.

OpenCV will also be used to display bounding boxes for discovered elements. When YOLOv5 finds elements in an image frame, OpenCV creates bounding boxes and labels surrounding them. While this visualization is mostly for testing and troubleshooting purposes, it verifies that the detection system is operational as planned. Additionally, OpenCV's capabilities allow for estimating how close objects are to the user, allowing for better prioritization of feedback based on the user's environment.

OpenCV is also required for integration with other parts of the project. Python compatibility allows easy integration with libraries such as PyTorch (used in YOLOv5) and hardware components such as Raspberry Pi. For example, OpenCV can take camera frames and send them directly to the YOLOv5 model for detection. This close integration simplifies the entire process from input to output.

In summary, OpenCV is a critical component of this project; It provides fast image preparation, real-time video processing and seamless integration with the YOLOv5 algorithm. Its adaptability enables the system to operate smoothly even in resource-limited contexts, and its capacity to deal with real-time activities makes it critical in the development of a responsive and reliable assistive technology option for visually impaired people.

OpenAI-API

In this project, visually impaired people will be provided with information about the objects and people around them using an OpenAPI-based virtual assistant. The system will use a Raspberry Pi and a camera to take real-time photos, which will then be analyzed using the YOLOv5 object detection method. Recognized items and people will be transmitted to the user via the headset using audio feedback. OpenAPI will form the basis of efficient communication between the object recognition system and the voice assistant, providing smooth and fast user experience.

OpenAPI will serve as the underlying mechanism for the integration of voice assistants with the object detection system. Scalability and maintainability are achieved by providing an integrated interface between system elements such as the detection module and the voice assistant. Additionally, OpenAPI's automated API documentation will make it easier for developers to implement future system changes or extensions.

The system works like this: The camera takes real-time photos of the user's surroundings, which are then analyzed by the YOLOv5 model to recognize objects and people. The observed data is then transferred to the voice assistant system using API endpoints created by OpenAPI. The voice assistant translates this information into natural language sentences and presents it to the user. For example, it might tell the user, "There is a chair two meters away" or "There is someone to your left." Additionally, objects or individuals can be ordered based on consumer preferences or environmental conditions. For example, the system can issue an emergency alarm when an approaching vehicle is detected.

The usage of OpenAPI and the voice assistant assures that the system is real-time, scalable, and easy to use. This framework not only raises the user's environmental awareness, but it also keeps the system accessible to future enhancements and additions. Finally, this initiative seeks to equip visually impaired people with a dependable and unique technological solution.

Activity Monitoring Methods:

This project will employ an LSTM (Long Short-Term Memory)-based AI system to recognize the user's movement indicates, including walking, falling, or lying down, as well as identify any possible discrepancies. Information from a 3-axis accelerometer (angle sensor) will be processed as a series of times, enabling the model to derive distinct properties related with various motions. LSTM is especially well-suited for processing time-series data because of its capacity to learn consecutive patterns, making it a good choice for discriminating between normal and pathological motions.

The 3-axis accelerometer will continuously capture the user's movements in three axes and record the movements of activities such as walking, falling, and reaching. For example, after a fall, data from the accelerometer may show a sharp increase followed by a long period of low activity. To effectively identify dips, the LSTM model can evaluate these patterns by distinguishing between sudden changes and subsequent steady states. Additionally, the system will have anomaly detection capabilities. An LSTM model based on typical motion information classifies deviations from expected patterns as anomalies. For example:

- **Fall Anomaly**: A sudden and considerable increase in acceleration, followed by a period of stillness, signaling the start of a fall.

- **Irregular Movements**: Unusual movement patterns or excessive vibrations that differ from typical walking behavior.

When such anomalies are noticed, the device quickly warns the user with audio notifications, ensuring that they are aware of possible dangerous situations.

During the training phase, labeled datasets depicting walking, falling, and reaching will be used to teach the LSTM model to distinguish different patterns of each movement type. For anomaly identification, the model will rely heavily on “normal” movement data to recognize deviations as anomalies when trends fall outside the learned range.

This system design guarantees reliable monitoring of 3-axis sensor data, continuous monitoring of user movements and real-time notifications of possible dangers. LSTM's capacity to evaluate time series data, together with its anomaly detection feature, ensures consistent and efficient operation of the system. This technology increases safety and encourages independence by providing real-time feedback.

Data Collection for Activity Monitoring:

This project will collect and store 3-axis accelerometer data in time-series format to reliably characterize human movements and detect any anomalies. The method of data collection will be meticulously planned to ensure accurate labeling and classification of various mobility conditions. At this stage, various user behaviors will be collected as well as acceleration data collected along the x, y and z axes. Each data point will be labeled according to the type of movement required for accurate model training, such as “walking,” “falling,” or “reaching.”

The resulting data will be stored in CSV format and organized as time series data. Each element in the CSV file will contain a timestamp, recorded velocity values for the x, y, and z axes, and the motion label. For example, the file will include the start and end times of a movement, accelerometer measurements taken throughout the activity, and a label indicating the type of movement. This standardized style will make data easier to interpret and manipulate.

In order to increase the diversity of the data set and the generalization capacity of the model, data will be collected from many people under different situations such as different surfaces, speeds, body angles. This comprehensive dataset will be used to train and test the LSTM-based time series model as well as the anomaly detection system. This method of data collection and triangulation will better equip the model to handle real-world conditions.

These data collection, labeling and storage stages in CSV format form the basis of this project, ensuring the creation of a reliable and efficient system.

User Experience and Accessibility:

The accessibility features offered by mobile applications of wearable devices designed for visually impaired individuals increase the quality of life of visually impaired individuals. Some of these features offered by mobile applications have great importance in the lives of disabled individuals. These accessibility features are quite effective on mobile applications. The most important of these are as follows.

1. Audio prompts and feedback

Audio prompts and feedback used in mobile applications make it easier for visually impaired individuals to use the devices. In addition, these audio prompts and feedback they receive from the device are among the most important auxiliary tools for visually impaired individuals. Thanks to these methods, a visually impaired user can perceive objects around them without using their hands or easily sending messages.[9]

In addition, thanks to audio feedback, the mobile application menu can be used more easily. They can reach information they want to research much faster through the application. As seen in the prototype given below, the device processes the data it receives with the help of sensors on the system appropriately and gives the necessary feedback to the user with sound output [9] [10].

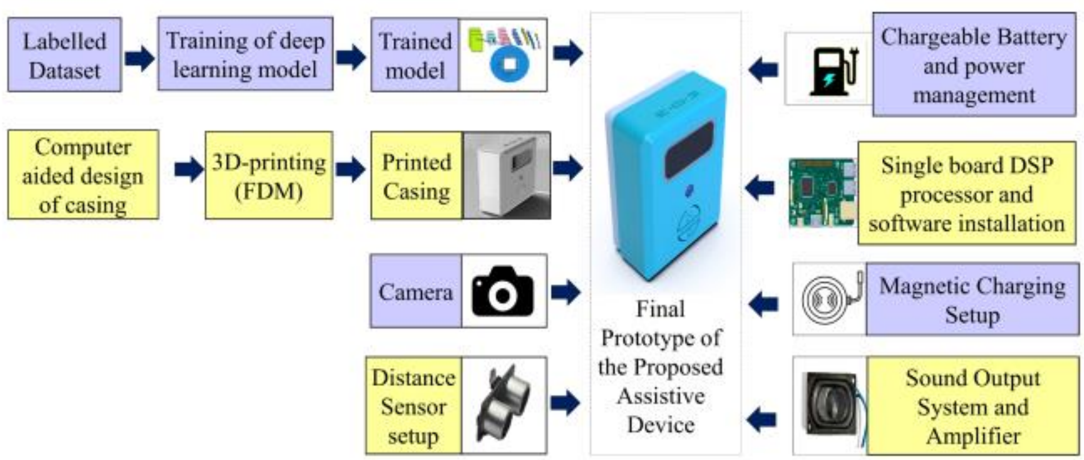


Fig. 4 Development of the final prototype for the proposed assistive device [9].

2. Vibration feedback

Giving feedback with vibration is a very applicable and easy to use method. It is very useful for visually impaired individuals to perceive objects around them and to find the right direction while traveling with vibration. Audio and vibration feedback methods are used in many projects. This method can be perceived by the user very quickly and the user does not need to use their hands while using this system. Another feature is that it works in noisy environments compared to audio feedback, allowing the user to use it easily in many areas. In addition, it is suitable for use in quiet environments since it does not make any sound [9].

When we look at the disadvantages of vibration feedback, it is possible that it can disturb the user in long-term use. It can make it difficult for the user to distinguish in situations containing multiple messages. In addition, the vibration sensation may not be sufficient, and situations may occur that are difficult to perceive by the user [9][10].

3. User feedback

The feedback given by the user during the device development tests has a great impact on the development process of the device. In addition, the user's feedback makes it easier to understand the possible errors that the device has. Another important effect is that it determines the habits of the users while using this system and the finalization of the position of the device on the design and the user. [6]

Energy Efficiency and Power Management:

Effective power consumption control in wearable devices for the visually impaired is very important as it directly affects the usability and reliability of the device. A low-efficiency device may require regular charging, which can be inconvenient for consumers and limit the usefulness of the system in daily life.

Wearable devices for visually impaired people require a delicate balance between usefulness and energy savings. Increasing battery life while meeting the real-time data processing needs of these systems also poses a significant problem. Existing research suggests numerous approaches to overcome these challenges.

Sensor selection and use in obstacle identification systems is critical for energy saving. For example, although an RGB camera can help recognize barrier types, it uses much more energy than ultrasonic sensors. Similarly, while infrared cameras outperform RGB cameras at night, they consume twice as much power. To solve this, an efficient system must use a combination of sensors and reactive control techniques. This technique allows sensors to be triggered based on their context and achieve a balance between energy usage and performance [11].

For example, a low-power ultrasonic sensor can constantly detect obstacles. When it detects potential risks, more energy-intensive sensors or computing processes, such as RGB or infrared cameras, are activated only when needed. Additionally, adaptive systems can determine when lighting is required and turn on infrared LEDs accordingly. This adaptive control technique not only provides consistent performance but also significantly reduces energy usage [11].

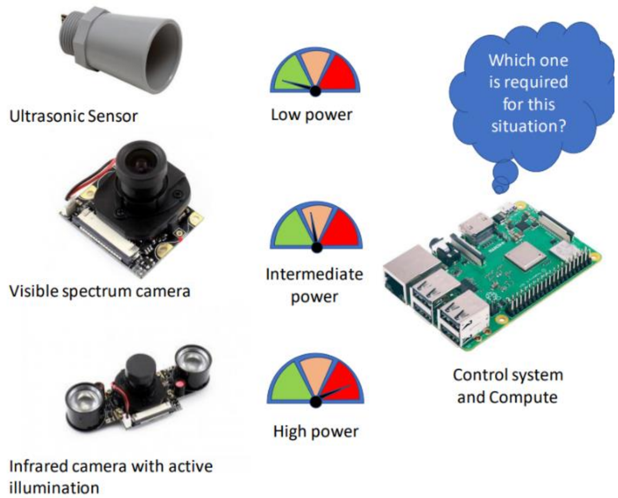


Fig. 5 Common obstacle detection sensors have varying energy consumption patterns and performance in specific settings [11].

Nanotechnology and wearable device microsensors are making progress towards self-powered sensing systems. Developments in recent years have enabled the development of high-performance, multi-purpose systems that can collect and manage their own energy. These networks include adaptive technology that can link environmental exposure to health outcomes such as the onset of chronic diseases such as asthma or heart disease. Low-power electronics for sensor interfacing, data processing, energy storage, and wireless communications are critical elements in such systems. However, a major limitation is that most commercially available off-the-shelf electronics used in wearable devices consume excessive power and require high duty cycles to operate continuously on the harvested energy [12].

Although such cutting-edge technologies offer significant advances in wearable sensor array, they are better suited to sophisticated health and environmental process devices than obstacle detection devices for visually impaired people. However, it highlights possibilities for future developments that can be applied to improve the energy economy of wearable devices designed for guidance and security [12].

In our project, we plan to use efficient power management using low-power sensors in addition to the camera as the primary obstacle detection mechanism. Adaptive control techniques can be used to activate specific sensors or features only when certain conditions are met. Additionally, building the system using energy-efficient processors and sensors can help extend battery life. Setting priorities for lightweight, energy-efficient batteries will not only increase device uptime but also improve users' experience.

Limitations of Current Systems:

Despite advances in technology, current guidance and safety devices for the visually impaired have many disadvantages. For starters, environmental conditions can affect the accuracy of the sensors used in these systems. For example, ultrasonic sensors can produce false positive or negative results in narrow places or depending on surface roughness. While GPS-based location-finding devices perform well outdoors, they lack signal and have limited accuracy indoors. While BLE beacons are useful, they can cause problems in large-scale applications due to their high cost and installation difficulties. Additionally, most existing solutions lack customization options to meet unique user demands, limiting the user experience as a whole. In addition, concerns about energy efficiency and low battery capacity make regular use of these devices difficult.

Reading and Discussions

In this section, we conducted research to find and evaluate potential component options for our project. After comprehensively reviewing various technologies, we developed a comparative review of sensors, microcontrollers, communication protocols, and location tracking systems. The benefits and limitations of each component were evaluated to determine its suitability for wearable applications, resulting in an ideal blend of performance, energy efficiency, and cost.

Sensors used for activity tracking must be small, lightweight, but energy efficient as they will be incorporated into wearable devices. They need to be able to accurately identify and categorize human movements, allowing real-time data collection. However, to ensure optimal operation and user experience, some constraints such as noise in the signal or power consumption need to be addressed. As a result, we can use one or both of the sensors listed below:

Component	Advantages	Disadvantages
Accelerometer	Small, lightweight, energy efficient. High accuracy in detecting acceleration.	Noisy data requires signal processing. It can't classify all movements on its own.
Gyroscope	High accuracy in rotation/orientation detection. Complement accelerometer data.	Higher energy consumption. Requires calibration for accuracy.

Sensors used for obstacle detection should be accurate and reliable in a variety of situations, such as dynamic and crowded areas. The chosen sensors need to be able to identify barriers of various materials and sizes while being energy efficient and small for wearable installation. We have multiple opportunities for obstacle detection; thus, we prefer to combine more than one sensor or component. We've listed our top choices below.

Component	**Advantages**	**Disadvantages**
Ultrasonic Sensor	Affordable, energy efficient. Performs well on various surfaces.	Struggles on soft/absorbing surfaces. Needs proper angle placement.
Lidar Sensor	Highly accurate and fast. Suitable for complex environments.	Expensive. High energy consumption.
Infrared Sensor	Low cost, compact. Ideal for short-range detection.	Reduced accuracy under bright light. Less precise than ultrasonic sensors.
Waveshare Laser Sensor	Long-range detection. Compact and lightweight design.	Relatively expensive. May require additional processing power for data handling.
Camera with Image Processing	Provides detailed visual data. Effective in dynamic environments.	Requires high processing power. Poor performance in low light.

The microcontroller needs will do multiple jobs simultaneously, such as analyzing sensor data and maintaining communication protocols. To make wearables easier to use, they need to have minimal power usage and be adaptable enough to include a variety of sensors. Real-time data transfer may also require connectivity options such as Wi-Fi or Bluetooth. Having easily accessible modules is an attractive feature for us. So, our options are:

Component	**Advantages**	**Disadvantages**
ESP32	Dual-core processor. Integrated Wi-Fi/Bluetooth. Cost-effective.	Limited for complex algorithms. Energy optimization required.

Arduino Nano	Compact, BLE for low power use. Easy to develop.	Limited processing power. No Wi-Fi support.
Raspberry Pi	High-performance dual core. Affordable with many I/O pins.	No wireless communication (requires external modules). Less energy efficient.
STM32	High processing power, energy efficiency. Versatile for many applications.	Complex development. Needs external modules for Wi-Fi/BLE.

The communication protocol is critical for data transmission between sensors, processing units, and external devices. Protocols for wearable devices must be reliable and able to operate throughout the ordinary personal range of motion. A short latency is also important to provide real-time feedback.

Component	Advantages	Disadvantages
Bluetooth Low Energy	Low energy consumption. Compatible with most mobile devices.	Not suitable for high-speed data. May face interference in crowded areas. Shorter range.
Wi-Fi	High-speed data transfer. Long-range communication.	High energy consumption. Complex pairing with devices. Long range.

Location tracking is essential for functions like navigating and activity monitoring. The approach adopted must be accurate while minimizing power usage. GPS is a reliable alternative for outside navigation and BLE Beacons provide precise inside localization in areas. Because we will be utilizing it outside, GPS is our preferred option, but as technology advances, outdoor BLE technologies may potentially serve the same purpose with infrastructure installations.

Component	Advantages	Disadvantages
GPS	High accuracy outdoors. Wide global coverage.	Ineffective indoors. High energy consumption with continuous use.
BLE Beacon	Accurate for indoor localization. Low power consumption.	Requires hardware for beacon placement. Accuracy depends on deployment.

Feasibility and Limitations

The project is feasible given time, resource and information constraints. The RGB camera will be developed using an organized process that includes research, design, prototyping, testing and improvement with commercially available components such as sensors, accelerometers and microprocessors. Existing technologies such as Wi-Fi networking and machine learning frameworks provide a strong foundation for the project.

Although the project is possible, it is not unlimited. Environmental factors may affect sensor accuracy, requiring calibration. Real-time data processing and power management must be established to ensure accurate alerts and long battery life. Machine learning models may require repeated adjustments to account for user variability and improve prediction accuracy. Additionally, relying on third-party components can cause supply issues. Despite these limitations, the project's organized approach and its potential impact on mobility and safety for visually impaired users justify its implementation.

Potential Impact and Significance

This project has the potential to significantly improve the mobility and safety of visually impaired people by combining real-time obstacle alerts and activity tracking. Technology will allow users to navigate their environment with greater confidence and independence, reducing the likelihood of incidents such as falls or collisions.

The startup helps develop wearable health technologies by combining artificial intelligence and machine learning. It will assess activity patterns and predict abnormalities, providing useful information for preventive care and ongoing health monitoring. The invention also helps caregivers as it allows for real-time alerts and remote monitoring, enabling faster emergency responses.

The project adheres to inclusive design principles on a larger scale and demonstrates how AI can solve real-world problems for disadvantaged people. It has the ability to shape future assistive technology and help create smarter, more accessible communities.

Standards and Ethical Concerns

Wearable smart devices for visually impaired individuals were prepared in accordance with IEEE 1471 standards during design and production. At the same time, it is aimed to carry out this project by considering the protection of personal data, its impact on the environment and the health of the individual. The requirements of the system in terms of security have been determined and implemented. While determining the design of the device and its location on the body, it is very important to minimize the harmful effects on the individual's health and to make the user comfortable with an ergonomic design [12].

In addition, the data collected by the system will be processed securely and used only in accordance with its task. It is aimed at obtaining the individual's explicit consent and act in accordance with the provisions of the KVKK in the collection of data. In addition, the negative effects of the system on the environment are minimized and an environmentally friendly device design will be provided. In addition, it is desired that the system can operate for a longer period of time and that the energy efficiency of the device is kept as high as possible due to sensitivity to the environment. As a result, the design process will be sensitive to the environment and society in addition to its engineering aspect [6, 12].

RISK MANAGEMENT

Effective risk management ensures that additional options are available if initial alternatives do not meet the desired objectives. This section discusses possible risks in the selection of components, algorithms, and requirements, as well as alternative ways to mitigate them.

Sensor Selection:

- Obstacle Detection:
  Our obstacle identification method involves combining camera-based image processing with a depth detection sensor such as LiDAR. However, if the image processing does not work as expected, for example due to poor light or computational complexity, instead of image processing we will use sensor fusion to increase the reliability of obstacle detection by combining multiple sensors.

- Activity Monitoring:
  We plan to use a multi-axis accelerometer and gyroscope for activity tracking. If the sensor data becomes too complex for our system to learn or manage successfully, we will simplify the configuration by reducing the number of sensors to a single accelerometer.

- Location Tracking:
  GPS sensors are our primary option for location tracking due to their excellent accuracy in outdoor environments. However, if GPS sensors vary greatly or fail to meet our standards, we will switch to BLE beacons that can also provide strong outdoor performance, yet a more complicated localized change need.

Microcontroller Solution:

Our original idea is to use an advanced Raspberry Pi model that can handle all system functions, including data processing and transfer. If problems develop, such as processing delays or transmission inefficiencies, we may consider employing two microcontrollers. This alternate strategy will slightly increase the device's weight and use of power but allowing us to assign one microcontroller to tracking activity and the other to obstacle recognition, resulting in better real-time functioning.

Requirement Changes for Plan B:

If achieving the initial requirements proves infeasible, we have the following backup options:

Requirement	Initial Aim	Risk Adjustment
Detection Range	2.5m	1.2m
Detection Accuracy	Accuracy 80%, F1 score 0.8	Accuracy 65%, F1 score 0.65
Response Time	2 seconds or less	5 seconds or less
Activity and Location Reporting Time	3 seconds or less	10 seconds or less
Battery Time	1.5 hours	30 to 45 minutes
Device Weight	Less than 1 kilo	Less than 2 kilos

This proactive strategy ensures that the project can adjust to problems and continue functionality even if its initial objectives are not completely accomplished.

In case of Short Budget:

If the allocated budget is insufficient to procure specified components, we will choose lower cost alternatives. For example, sensor quality may be reduced in favor of more costly alternatives. Similarly, we can use entry-level Raspberry Pi models or replace some components with cheaper alternatives. However, it is clear that this tweak will have an impact on the overall system accuracy and performance. We will adjust the system requirements to reflect these changes. For example, accuracy limits for obstacle detection and activity tracking can be adjusted to meet the capabilities of the new hardware.

WORK PACKAGE DESCRIPTION

Number and name of the package: Phase I – Requirements Specification

Start date: January 1, 2025

Finish date: January 20, 2025

Short description: Initial research, literature review, defining the complex problem, reviewing existing studies; determining the materials, equipment and algorithms to be used in the project based on user requirements which will be collected according to the design thinking principles.

Methodology: Literature survey, scanning resources and academic papers, design thinking (emphatize and problem definition stages)

Outputs: Literature research, Project requirements, Project Structure and Outline.

Relations to other packages: With this phase, the road map of the entire project will be determined, and preliminary information will be gained before starting each work package.

Working team members (with contributions as percentages of the work packet):
Berkay Sarı (%25), Berke Kaya (%25), Hakan Çanakçı (%25), Samet Kartlar (%25).

WORK PACKAGE DESCRIPTION

Number and name of the package: Phase II – System Architecture and Design

Start date: January 20, 2025

Finish date: February 28, 2025

Short description: In this phase, the two functions of our project, obstacle detection system and activity monitoring system will be designed.

Methodology: We will develop the two systems simultaneously but separately by applying the software and algorithms we mentioned in the report.

Outputs: a. An obstacle detection and response system design document
b. An activity monitoring system design document with response of current location and activity

Relations to other packages: This phase is divided into two subpackages according to our project's functions. Before hardware implementation, we will design both systems independently of each other in this phase.

Working team members (with contributions as percentages of the work packet):
Berkay Sarı (%25), Berke Kaya (%25), Hakan Çanakçı (%25), Samet Kartlar (%25).

WORK PACKAGE DESCRIPTION

Number and name of the package: Phase III – Hardware Integration and Prototyping

Start date: February 24, 2025

Finish date: April 18, 2025

Short description: In this phase, the product will be physically designed and built. A prototype will be obtained by combining obstacle detection and activity monitor systems with hardware integration.

Methodology: First, we will build the outer frame and physical body of the product. Then, we will create prototypes by combining our ready systems into a single hardware.

Outputs: Device Prototype

Relations to other packages: All designs and software implementations made in previous stages will be combined with the hardware.

Working team members (with contributions as percentages of the work packet):
Berkay Sarı (%25), Berke Kaya (%25), Hakan Çanakçı (%25), Samet Kartlar (%25).

WORK PACKAGE DESCRIPTION

Number and name of the package: Phase IV – Testing, Validation, and Optimization

Start date: April 1, 2025

Finish date: May 15, 2025

Short description: User testing, verification of requirements, optimization and improvements in the product we obtained as a result of hardware and software integration. Validation of the final product.

Methodology: We will test each function of our final product and ensure that it works properly. If we encounter a problem we will optimize and solve it. Finally, we will check whether the product meets the requirements.

Outputs: A fully functional device that meets the requirements we set.

Relations to other packages: Testing of the prototype obtained after hardware implementation, necessary improvements if there are deficiencies that were not made in the previous work packages.

Working team members (with contributions as percentages of the work packet):
Berkay Sarı (%25), Berke Kaya (%25), Hakan Çanakçı (%25), Samet Kartlar (%25).

WORK PACKAGE DESCRIPTION

Number and name of the package: Phase V – Documentation

Start date: January 1, 2025

Finish date: May 15, 2025

Short description: Documenting the project from start to finish. Results obtained at each stage, improvements made, test results, etc. recording.

Methodology: We will report all our progress and keep records in a word file.

Outputs: Project Report

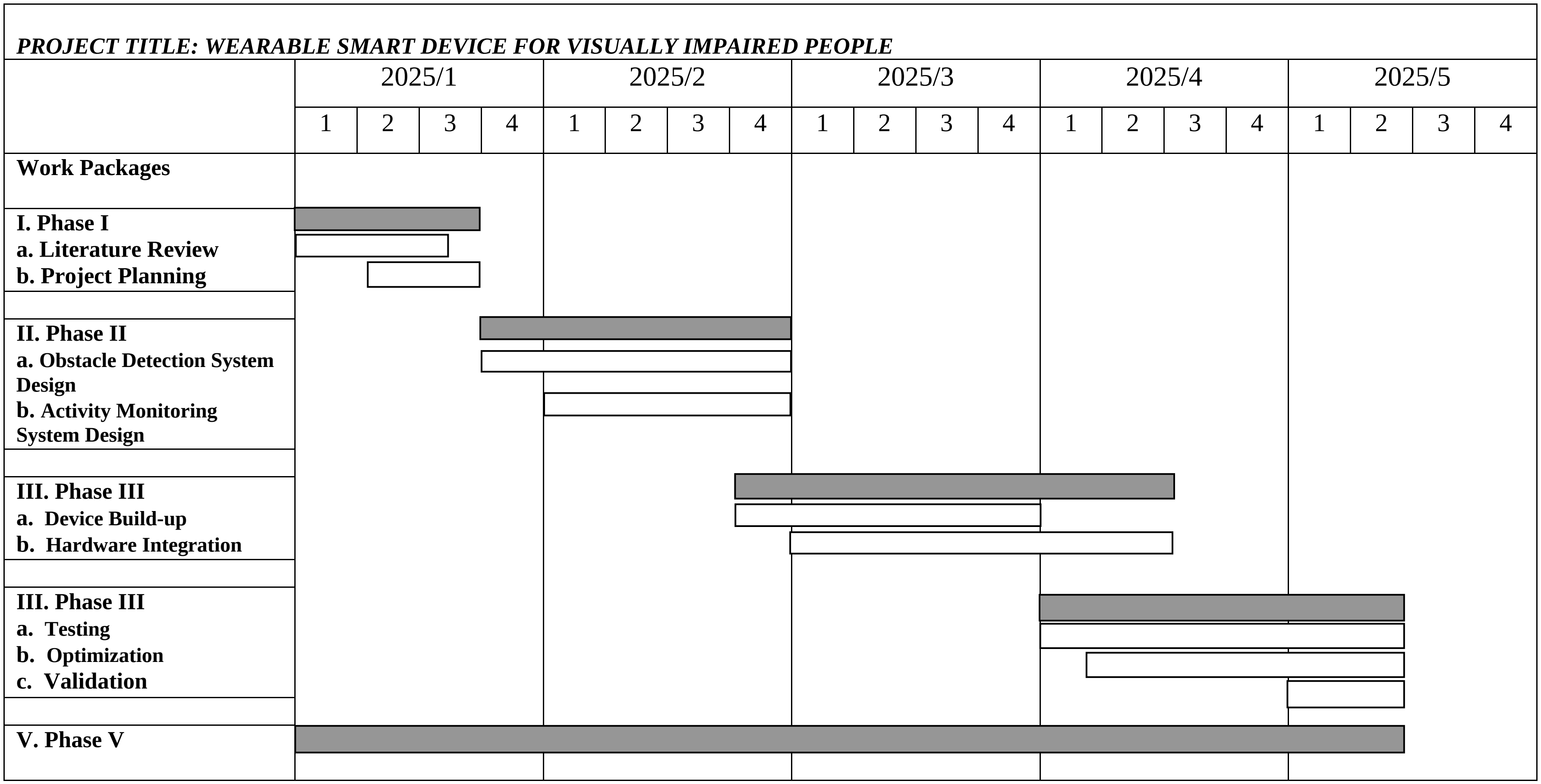
Relations to other packages: We will have a written report of what we have done in each work package, and the progress of the project from start to finish will be recorded.

Working team members (with contributions as percentages of the work packet): Berkay Sarı (%25), Berke Kaya (%25), Hakan Çanakçı (%25), Samet Kartlar (%25).

CONTRIBUTIONS OF THE TEAM MEMBERS:

Name, Surname	Work Packages								Total	
	I		II		III		IV			
	h	%	h	%	h	%	h	%	h	%
Berkay Sarı	10	1.6	40	5	60	10	50	8.3	**150**	**25**
Berke Kaya	10	1.6	40	5	60	10	50	8.3	**150**	**25**
Hakan Çanakçı	10	1.6	40	5	60	10	50	8.3	**150**	**25**
Samet Kartlar	10	1.6	40	5	60	10	50	8.3	**150**	**25**
Total	40	6.6	120	20	240	40	200	33.3	**600**	**100**

PROJECT CALENDAR



INFRA-STRUCTURE REQUIREMENTS:

Laboratory:

Kadir Has Electrical and Electronics Lab (Phase II - III and IV)
We will need to use the Lab for building the prototype and tests.

Equipment:

Lab Components (Phase II and III):
DC Source
Oscilloscope
Multimeter
Soldering Machine

3D Printer (Phase III)

We will need to use DC source and oscilloscope in the Lab for prototyping, testing and optimization. If we choose to design the physical body of the product, we will print it with a 3D printer.

Computer(s):

Phase II-III-IV:

Individual Laptops (Provided by team members) for coding, hardware integration and testing.

Personnel:

-

PROJECT BUDGET:

	Work Packages					
	I	**II**	**III**	**IV**	**V**	**TOTAL**
Equipment	-	₺14000	₺400	-	-	₺14400
Consumable goods	-	₺700	₺1800	-	-	₺2500
Publications/Software	-	-	-	-	-	₺0
Transportation	-	-	-	-	-	₺0
Services	-	-	₺1500	-	-	₺1500
TOTAL	₺0	₺14700	₺4000	₺0	₺0	₺18400

Equipment:

Main Components:

- Raspberry Pi Model 4 or 5 8GB - ₺4000
- Rechargeable Battery - ₺1800
- Cables: Power cable and USB Cable - ₺700

For Obstacle Detection

- Raspberry Pi Camera - ₺1800
- Depth Sensor or LiDAR - ₺3500
- Coin-Type Vibration Motor x4 – ₺400
- Speaker + Wired Headphones for response - ₺550

For Activity Monitoring Purpose

- Multi-axis Accelerometer, Gyroscope - ₺900
- GPS Module - ₺1050

Consumable goods:

- All necessary cables - ₺400
- Solder, tape, glue, and other small assembly items. - ₺1800

Publications/Software:

- Python**,** OpenCV, YOLOv5 and COCO, Pandas, Pytorch, OpenAPI, MATLAB, SolidWorks for CAD design.

Transportation:

-

Services:

- 3D Printing Service – To print the designed CAD - ₺1500

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