Smart and Guide Hat for Blind Persons in Smart Cities Using Deep Learning

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***Abstract*—In recent years, Artificial Intelligence (AI) technology has evolved significantly and is used in various fields including banking, email management, surgery, *etc*. The primary objective of the current study is to assist visually impaired (blind) individuals using AI technology. Blindness is a natural occurrence but it need not prevent blind people from experiencing the world similarly to sighted people. They must execute daily tasks such as walking with such precision so that various obstacles do not impede their progress. Typically, a blind individual uses a white cane as a guiding aid to navigate around obstacles. It is difficult, however, to design smart headgear that is both supportive and intelligent in order to provide numerous services that accurately and promptly anticipate obstacles at ground level and in traffic. Technological advances present an opportunity to develop intelligent headwear which helps its wearer to anticipate potential dangers. This paper presents a work-in-progress and analysis of the challenges blind people face when attempting to identify traffic signals, objects, plant types and QR codes on city maps. Through this endeavour, we hope to gain a better understanding of how blind individuals will be able to navigate smart cities.**

***Keywords*—visual impairments, disabilities, artificial intelligence, smart cities, deep learning, voice-activated personal assistant**

I. Introduction

Technology has changed the way we work, live, and communicate. People with visual impairments who lack a complete understanding of Artificial Intelligence (AI) are unable to access many websites and use their mobile phones. Most of the Internet features that we enjoy are unavailable to visually impaired people [1]. AI can read documents and understand structural elements such as headings, paragraphs, and lists, thereby allowing users to quickly navigate documents using voiceovers. It can also recognise photos from other applications. With the development of AI technology, it has become increasingly important to understand what the visually impaired want as part of their technical toolbox. Also, there is a growing body of literature concerning what people today perceive as a challenge [2].

Among the most notable innovations of the twenty-first century are self-driving and automatic vehicles which make it possible for blind people to transport themselves from one place to another and use technical gadgets on their own. These improvements have been supported by the enhanced degree of AI and a system that has the capacity to feel, process, react and adapt to external factors just like humans. In terms of safety, AI cannot be relied on entirely but it has the ability to save people and helps to mitigate the effects of collisions and roadblocks. It is anticipated that the coincidence charge will reduce the growth in human productiveness and enhance the same old of residing in society for the visually impaired and their households in particular [3]. AI simulates human conduct without the capacity to grasp it and is frequently performed via trial and error. As a computer machine, it learns the appropriate manner to carry out a task and develops human-like behaviours and responses to particular tasks. It is carried out to correctly understand the surroundings and make appropriate selections based on human actions.

A useful technology is one that is used to benefit society and humanity. Blind people have difficulty performing daily tasks, particularly when it comes to mobility, because their path may contain potentially hazardous obstacles. Typically, they use a white cane to help them navigate the terrain and find the safest route. A white cane is beneficial but it is difficult to detect obstacles close by that are above knee level, such as street barriers. In today's world where technology is becoming increasingly essential to human existence, the white cane can be made intelligent to enhance its function for the blind. The white cane represents assistance and mobilisation. Indeed, the equipment helps blind patients to overcome their dread of falling. It is also used as a verification instrument because it can point or hover over any object and determine its rigidity. Similarly, it assists in determining whether or not a particular route is obstructed. Moreover, the greatest advantage of a white cane is its portability.

Visual impairments are significant issues which affect many people worldwide and according to the National Council for the Blind of Ireland (NCBI), millions of blind people are unable to lead a normal lifestyle, as shown in Fig. 1. Visually impaired patients require significant assistance. With today's technologies and AI, these

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patients require special work and attention to develop innovative approaches to improve their lives. Visually handicapped people struggle to navigate familiar streets and they require life-enhancing technologies. AI-based solutions can improve visually impaired patients' lives and the current study proposes employing smart hats to help blind individuals cross the road and identify things in smart cities.

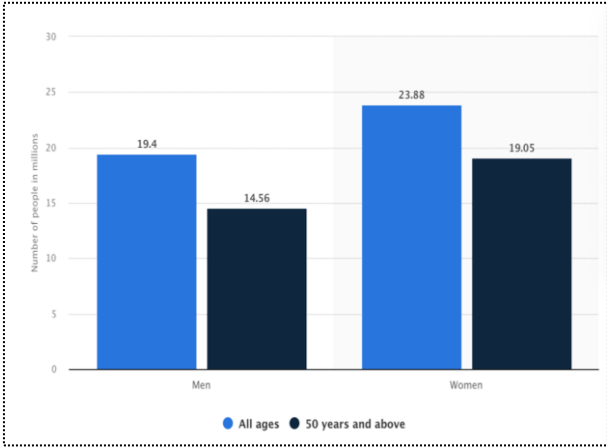


Figure 1. Number of people with blindness worldwide in 2020 according to the NCBI.

Smart cities could transform blind people's lives. Public space accessibility is a notable feature of smart cities for the blind. The proposed smart hat technology can help to create a disabled-friendly environment. Smart traffic lights with auditory signals can help blind people to traverse crowded junctions and blind people can plan their trips with real-time bus and train schedules for smart public transportation networks.

Smart cities provide information to the blind. Blind persons can use their smartphones to connect with the smart hat in order to scan QR codes and interact with digital information. This helps blind people to stay connected and access information. Smart cities also enable blind individuals to navigate indoor spaces. Blind persons can navigate unfamiliar buildings with audio directions and descriptions from indoor navigation systems which are voice-activated.

II. Literature Review

Visual impairment is a condition of impaired vision which limits the ability of an individual's vision to be used effectively and competently, thereby adversely affecting growth and performance. This impairment includes central vision and weaknesses and defects in visual function which is the peripheral vision. This is the result of anatomical deformities, illnesses or wounds affecting the eye [4]. According to the World Health Organization (WHO), a disability is a dysfunction which leads to a loss of function and the patient cannot perform it normally or is dysfunctional, incapacitated or unable to work properly. It is a limitation which can be physical, mental or both [5]. However, researchers have found that visually impaired people can lead their daily lives effectively.

Several studies have been conducted by numerous scholars concerning the adoption of AI-based solutions to assist visually impaired patients in overcoming the obstacles they face in life. AI represents a large area of computer science involved in developing intelligent machines which can perform functions that usually require human intelligence. It is considered an interdisciplinary science with multiple methods. However, the evolution of machine learning and deep learning has caused a paradigm shift in almost every area of the technology industry, whilst helping doctors and patients at the same time [6]. Most people are not very familiar with the convention of AI and its ability to transform and make our daily lives easier. People with disabilities often turn themselves negatively and freely. People with disabilities are often treated unequally and encounter stereotyped negative behaviours. In addition, they are often treated with fear, compassion, discomfort and/or guilt [7].

The smartphone is a powerful tool that is capable of helping visually impaired users. Many apps can also help users to maintain autonomy. For example, by placing documents under the camera of their smartphone, visually impaired people can read emails. AI technology is applied to all types of failure profiles. For example, virtual personal assistants such as Amazon's Alexa can help people with restricted mobility to control everything in their home using only their voice. "Seeing AI" is a free app narration tool for the blind and low vision community. It is the result of ongoing research project which harnesses the power of AI to open up the visual world by illustrating people, objects and texts that are nearby. Several solutions have been presented to help visually challenged persons design new technologies. Researchers have suggested social engagement, protection, independence, and navigation when creating new AI systems.

They use these social factors to help designers address users' social needs and wants when designing assistive technologies [8]. The use of ICT to empower special needs people was examined in another study [9]. This study used combination and a descriptive technique to reveal that empowerment (motivation, training) in that dimension improved information and communication technology. Disability, ethics, and AI were examined [10]. Two disabled people's narratives examined AI's promises, support, and disappointments in daily life. Autoethnography and reflection were used and it was found that AI can help disabled persons in numerous ways such as Alexa, Echo, Siri, and others which are the main vocal communication advancements. These enhancements improve speech controls with advanced equipment for those with visible disabilities. AI also helps visually impaired people by explaining pictures. However, AI's speech advances are not only for visually handicapped persons. Speech-to-text and text-to-speech technology allows patients recovering from brain injuries, including cerebral palsy, to interact more. AI provides closed captioning for impaired people. Furthermore, AI's dynamism has touched every industry, increasing comfort through vocal communication. Several AI technologies help visually impaired persons to recognise signs and landscape texts and live more comfortably with greater mobility. AI-powered self-driving cars like the 2020 Tesla Model S and BMW X7 have also been lauded and often discussed with regards to disabled individuals. The Concepti RIDE is not self-driving but it helps to make wheelchairs more reliable. AI technology's inclusivity in terms of handicap enhancement also helps people to buy homes and use new technology.

Disabled persons benefit from being able to go shopping and run other errands. Smart light outlets, garage door openers, attractive curtains and smart doorbells allow individuals to live freely with the assistance of AI. Voice control technologies turn lights on and off, change heating and air conditioning settings, and turn stoves on and off to make cooking easier. Several smart home hubs track routines and anticipate needs. AI can solve several daily problems. Home AI technology improves security and smart houses can notify family and emergency services in the event that someone collapses.

Several studies have developed ways to help those who are visually challenged. Haptic graphics [11], screen reader upgrades like concurrent audio [12] or charts [13], reading visual information with a finger camera [12], 3D printed tactile mapping [14], code navigation [8], and blind photos [15] have been studied recently. Object and picture identification have garnered attention, while image and object recognition have been crowdsourced [16]. Automatic captioning services have been developed to address social media image identification issues [17, 18]. Meanwhile, others have identified objects using a personalised object detector [19]. System builders have neglected social aspects of living but researchers have examined social assistants [20]. A camera and vibration band showed the interaction partners' positions, distances, and facial expressions. Systems and individuals were found to adapt in this study.

Other research has evaluated emotional valence and head nods to provide a particular response and described the limitations of context-sensitive categorical answers [17]. An earlier impact perception study used tactile feedback to communicate gaze direction. Only visually impaired people tested the system [21]. ASR converts voice to text. The ASR system creates video captions and live captions in augmented reality for the hearing impaired [22, 23]. Speech input helps disabled people to utilis their hands to manipulate traditional input devices [24].

The speaker analysis system identifies and verifies the speaker's qualities including their age, gender, and emotions. Speaker analysis systems are used for biometrics, to improve speech conversion and for personalisation [25–27]. Moreover, speaker analysis systems can help DHH people to visualise sound [28].

Visual aids include Electronic Travel Aides (ETAs) which require environmental information from a convenient user interface. Designing sensory systems, hardware configurations, physical construction, user interface-based visual aid systems, and data inference algorithms requires various strategies. Ultrasound, sonar, lasers, RGB CCD cameras, IR cameras, and GPS sensors are the most common. The user interface typically uses headphones or gloves with a buzzer or small vibration actuator. Computer vision has improved ETA design. Tapu *et al.* [29] tracked moving objects with a mobile telephone camera using multiscale Lucas Kanade feature-tracking.

Another study argued that Voice-Activated Personal Assistants (VAPAs) and text mining could make commendable contributions to help impaired students submit academic requests to their respective institutions. This study helps to ensure the successful development of a system that meets the academic communication and interaction requirements of blind students using VAPA [30].

III. Materials and Methods

A. Materials and Dataset

The current study aims to help impaired individuals identify various objects and utilise the benefits of smart cities in real time. The smart hat is equipped with a standard camera which supports VR technology, as well as a microphone and speaker. The model was trained with the Common Objects in Context (COCO) dataset and the objects can be identified in the following three steps, as shown in Figs. 2 and 3:

1. Connecting the camera, microphone and speaker to the app which was developed specifically for that function; the VR camera was able to capture the items in real time and identify them using a You Only Look Once (YOLO V3) algorithm which provided a high level of confidence.
2. The software application identified objects and utilised a Text-To-Speech (TTS) algorithm to recognise and convert the text. TTS algorithms employ Natural Language Processing (NLP) techniques to scrutinise, classify and construe written text, subsequently utilising speech synthesis to generate an auditory rendition of the text.
3. Voice-Activated Personal Assistants (VAPAs) can guide blind people through the communication process, helping to point them in the right direction and make decisions as they try to determine what it is that is in front of them.

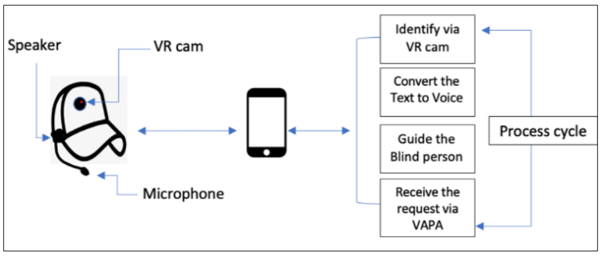


Figure 2. The proposed model.

B. Procedure

The COCO dataset includes more than 50 photos of various items, the majority of which need to be identified by a person. In the current research, the reliability of the images was evaluated using four different examples.

The dataset does not require any preparation processes other than categorisation to classify the images into different classes such person, objects, traffic, animals etc. Only three classes are examined, as follows:

(1) Traffic: This class contains all the traffic instructions such as traffic lights, road crossing signs, etc.
(2) Objects: This class contains different objects such as tables, chairs, etc.
(3) Animals: This class contains different types of animals such as dog, cat, etc.

This categorisation process is based on the standard of most objects' distribution in the COCO database. The Convolutional Neural Network (CNN) algorithm is able to classify the recognised image and store it for future retrieval. CNNs are a common form of deep learning algorithm used for image classification tasks. They are designed to autonomously learn and extract features from images which are then used to assign the images to various categories. CNNs have multiple layers including convolutional layers, pooling layers, and fully connected layers as their fundamental structure.

The network applies a set of filters to the input image in the convolutional layer to extract features such as edges, corners, and textures. The pooling layer then down samples the feature maps to reduce their size. In the fully connected layer, the network classifies the image into one or more categories using these features. To classify images with this algorithm, the CNN needs to be trained on a set of labelled images. During the training process, the network learns to identify image patterns that correspond to various categories. Once trained, the CNN can be used to classify new images by passing them through the network and determining their category based on the output. When implementing CNNs in deep learning frameworks such as TensorFlow and Keras, numerous libraries are available. These libraries provide pre-built models which can be trained on your own dataset or modified for particular tasks.

A CNN can be represented using Eq. (1):

$$y = f(W * x + b) \tag{1}$$

where y represents the output, x is the input, W refers to the weight matrix, b represents the bias vector, and f is the activation function. The * operator represents the convolution between W and x.

In a typical CNN architecture, this equation is applied multiple times with various weight matrices and biases in order to learn features at various levels of abstraction. The output of one layer serves as the input for the subsequent layer until the final output layer generates a prediction or classification.

IV. Results and Discussion

Experiments were conducted with Python employing our integrated dataset of different objects based on three classes, as follows:

- Traffic
- Objects
- Animals

Virtual Reality (VR) cameras are gaining popularity in the technological world. They can capture 360-degree recordings and images which can be used for a variety of purposes including gaming, tourism, and education. One of the most notable features of VR cameras is their ability to confidently identify various objects. Object recognition in VR cameras is accomplished using advanced algorithms and machine learning techniques.

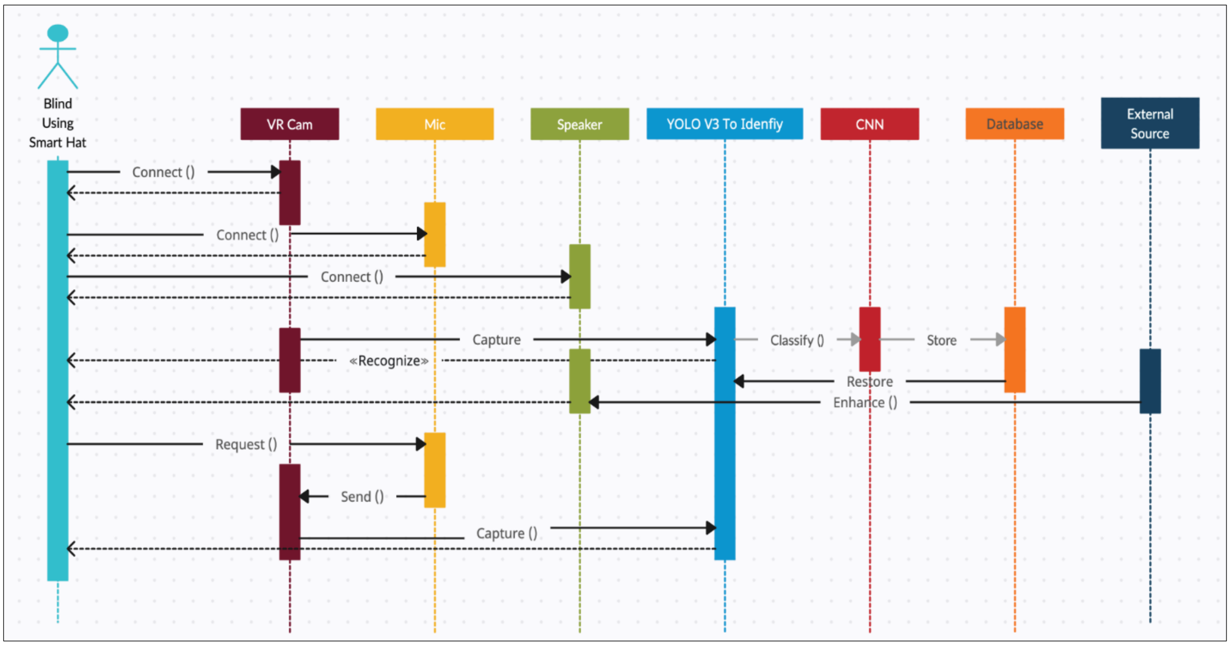


Figure 3. Sequence diagram events of smart hat.

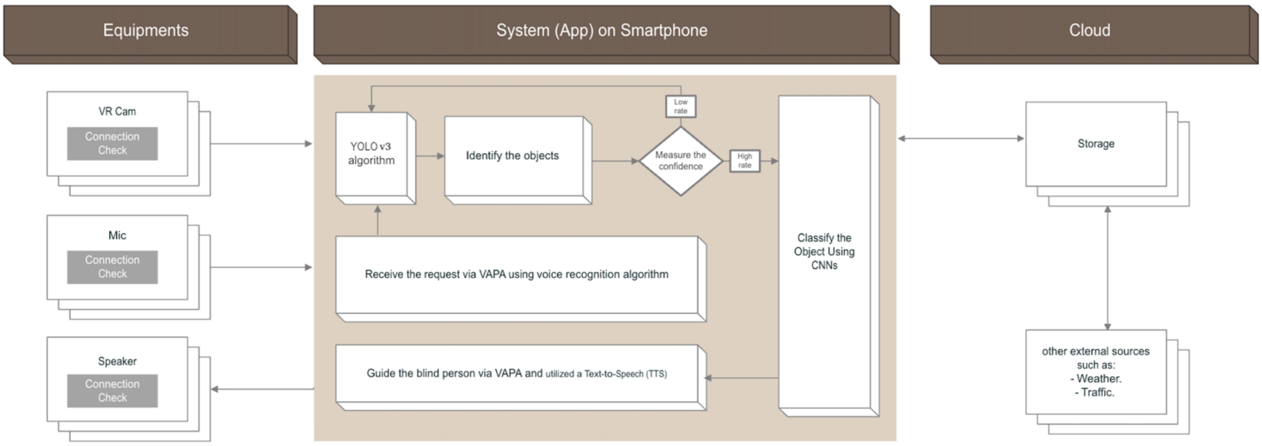
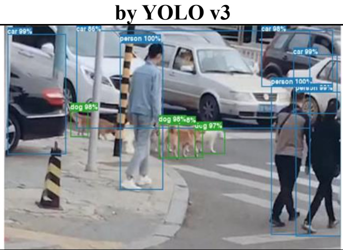
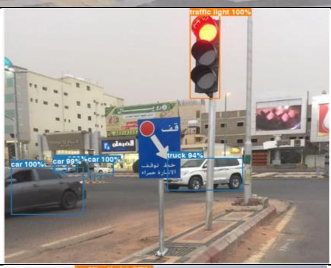


Figure 4. The architecture of the smart hat.

As shown in Figs. 3 and 4, in order to recognise objects, the VR camera starts by recording an image and measuring the confidence using the YOLOv3 algorithm. If the confidence rate is low, the resolution of the image will cause the recognition process to restart in an effort to increase the confidence level. The VAPA device, which includes a microphone and speaker, is then used to communicate with requests from blind individuals using voice recognition and a TTS algorithm to help them complete their tasks. To improve measurements, create and restore databases, and classify items into distinct categories, CNN is utilised. To maximize the use of the system, the suggested framework can interface with external sources relating to the weather and traffic.

TABLE I. RESULTS FOR RUN TIME FOR IDENTIFYING VARIOUS OBJECTS

No.	Image capture via VR camera and identified by YOLO v3	Time/confidence	Class
1		4.5 seconds/High	**Traffic; Animals**
2		3.7 seconds/High	**Traffic**
3		3.2 seconds/High	**Traffic**
4		7.8 seconds/High	**Objects**

These algorithms analyse the collected images and videos to determine the shape, size, colour, and texture of various objects. To improve their accuracy, the algorithms also take into consideration the context in which the objects appear. In the current study, the YOLOv3 algorithm was applied to assess impaired individuals in their normal lives.

When a VR camera identifies an object with high confidence, as shown in Table I, there is a high likelihood that the object is what it appears to be. This high level of assurance enables users to interact with the identified object in a variety of ways. If a VR camera detects a chair in a room, for instance, users can interact with it by sitting on it or moving it. However, there are situations in which Identhis could occur when an object is partially obscured or when multiple objects have similar appearances. In such situations, the VR camera may be unable to accurately identify the object.

If the level of identification confidence is insufficient, there are several actions that can be taken. Utilising additional sensors or cameras to collect more information about an object is one option. This additional information can then be used to enhance identification accuracy.

VR devices have revolutionised our ability to capture and interact with the environment. Their ability to confidently identify various objects has created new opportunities for the traffic, object, animals, and other categories. While there may be instances in which the confidence level for identification is low, there are options available to increase the accuracy and ensure that users can interact meaningfully with their environment. Overall, the experimental results have found that the CNN classifier is the best, offering considerable reliability and performance in terms of classifying various objects in the correct class. In addition, the results have shown that YOLOv3 is able to more quickly identify different objects in one image compared to the previous version of the YOLO algorithm.

The confidence of the prediction has been measured using the high/low scale. Predictions with low confidence are reprocessed to enhance the prediction or recapture the image if the resolution is weak. Table I illustrates the images that were captured using VR and recognized with the time and confidence of prediction.

V. Conclusion

This manuscript introduces an ongoing study and a comprehensive examination of the obstacles encountered by visually impaired individuals in terms of recognising traffic signals, items, botanical species and QR codes depicted on an urban smart city map. This initiative sought to enhance our comprehension of the means by which visually impaired individuals can effectively traverse smart urban areas. The current study has validated the efficacy of a proposed methodology for object recognition which can help individuals with impairments to carry out their daily activities in a natural and seamless manner. The results demonstrate that the combination of CNN and YOLO V3 using VAPA equipment is able to recognise objects, offering fast and reliable results. In order to enhance the calibre of forthcoming outcomes, it may be prudent to contemplate the involvement of human intervention. In future research, the option to utilise human feedback presents itself as a viable means of object identification. In the event that a virtual reality camera is unable to accurately recognise an object, it is possible for a human operator to manually assign a label to the object, thereby enabling its identification in subsequent captures. This could expand the use of AI in the human interaction field.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

T. Almurayziq developed and examined the methodology, collected and analysed the data and wrote the paper. S. Almobla collected the sources, revised the paper and approved the final version. Gharbi Alshammari's contribution was project administration, resources, validation and assisting with writing the original draft. Abdullah Alshammari and Mohammad Alsaffar were responsible for data curation, formal analysis, resources, reviewing and editing, and validation. All authors had approved the final version.

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