A Survey on Assistive Technology for the Visually Impaired

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Abstract - *This paper outlines the various recent developments in assistive technologies for the visually impaired. The currently existing technology enables its users to detect and differentiate between objects, navigate, recognize text and provide vibrational and audio feedback to the user. The technologies make use of various techniques such as text-to-speech and speech-to-text translation, various sensors, image and video processing and recognition, natural language processing and generation and binaural image mapping. Assistive technologies are available for various platforms like android and iOS. Most of these applications take images as input and produce audio output to assist the user. However, some applications have dived into video processing and wearable technologies too. The technologies mainly focus on providing a user-friendly interaction and ease of access so that the user can get the knowledge of the objects in front of him or instructions to navigate in an easy and hassle freeway. This goal of this paper is to provide an overview of these recent advancements especially in the field of application development for the assistance of the visually impaired. Using this overview as a foundation, we plan to overcome the various shortcomings that exist and provide the users with even better interface and quality of knowledge of the surroundings around them leading to them getting a "feel" of what is around them in a cost effective way.*

Key Words: **Assistive technology, blind, visually impaired, image processing, computer vision, mobile applications, machine learning.**

1. INTRODUCTION

Assistive technology is a term used for any form of technology that might provide any kind of assistance to its user. The term focuses on being a mobile or wearable assistant in the case of visually impaired and blind users. Assistive technology for the blind, in recent research and development, have been mobile applications that can identify the objects in front of them from a captured image, categorize objects and differentiate between products. Recent developments include applications that are able to provide instructions for navigating blind people indoors. The safety of the users has to be kept in mind while navigating them hence these are primarily wearable devices with loads of sensors making them costly. Research has been done in the areas of both wearable technology and mobile applications but development exceeds in applications due to availability of APIs and its cost effectiveness. Artificial neural networks are the major computing systems used for recognition and classification of images and generation and recognition of speech. Neural networks have to be trained on a dataset. In case of object recognition in images, the system learns to identify and classify objects based on various images that were previously fed to create the model. Similarly, voice recognition needs training data has to be fed initially. Although with the advent of APIs like Google Vision[1], Google Speech[2] and Amazon Rekognition[3], the task of image and voice recognition is reduced to mere API calls and the developers can focus more on providing more features and helping the visually impaired out with better interaction and ease. This paper aims at providing an overview of the existing technologies: theoretical and practical that focus on providing the visually impaired with assistance in their day to day problems. Section II elaborates the types of assistive technologies that are globally present today. Section III describes various assistive applications that have been developed. Section IV contains a mention of various shortcomings in the existing applications as well as various future improvements that could be brought about in the assistive technologies to aid the visually impaired leading them to a better perception of the world around them.

2. TYPES OF ASSISTIVE TECHNOLOGIES

2.1 OPTICAL AIDS

The basic optical aids are eyeglasses, magnifiers, telescopes and CCTV (closed-circuit television) which is a device that can magnify things and display them on a television screen. They aid subjects with low-vision. Contrast enhancement, edge and contour enhancement, background simplification are some of the image enhancing techniques also used for visual assistance.

2.2 SYSTEMS BASED ON HAPTIC/TACTILE FEEDBACK

State-of-the-art applications include haptic-feedback shoes[4] to guide blind walkers and haptic-based walking stick[5] such as the GuideCane[6], UltraCane[7] and LaserCane[8].

GuideCane looks like the traditional white cane but is a robotic device that detects obstacles and often contains wheels to steer away from the obstacle in front of the user. It also has a braking system which is triggered if a situation arises where the obstacle cannot be avoided by steering away. The UltraCane is a patent protected electronic mobility aid which consists of a device attached to a cane. It works by emitting waves of ultrasonic frequencies to detect obstacles in the environment. It is inspired by the echolocation system used by bats and dolphins. It has greater reliability and robustness compared to the GuideCane. LaserCane is similar to UltraCane but uses pulses of infrared light which is reflected by the obstacles and received by a photodiode attached to the cane.

Braille is a tactile technology that allows visually impaired people to do tasks such as reading, writing and working on a computer. Refreshable braille displays that electronically raise and lower different combinations of pins in braille cells allow blind users to read text outputs while braille keyboard allows them to type inputs.

2.3 SYSTEMS BASED ON AUDITORY FEEDBACK

Besides talking calculators, dictionaries, and audio books that are available in digital format, various other technologies are being researched on. One such example is the NAVI [9] technology. The system consists of small vision sensors that capture images and process them to achieve stereo vision. The details of the environment are then transformed into stereo sound patterns.

3. CURRENT RESEARCH AND DEVELOPMENTS

The recent spark in development of assistive technology for the visually impaired started off with the technology being able to detect and identify objects for the user. Efforts have been made to provide help the blind find their way in indoor environments. One such effort is to detect signage and stairs using saliency map and bipartite graph matching. The proposed system 'Object Detection and Recognition for Visually Impaired People' was able to detect stairs, the distance between the person and stairs, pedestrian crosswalks, upstairs and downstairs using an RGBD camera.[10] Another step in the same direction is 'Context-based indoor object detection as an aid to blind persons accessing unfamiliar environments' system to help blind people access indoor unfamiliar environments. The proposed system aids its users to find rooms, elevators, etc by using image detection and optical character recognition.[11] Along came the developments in using binaural sound to detect objects which were applied to assist blind people too. The Stanford based project called 'Let Blind People See' was able to convert detected objects around it into 3D binaural sound to assist blind people identify location and proximity of objects around them using the You Only Look Once Model[12].

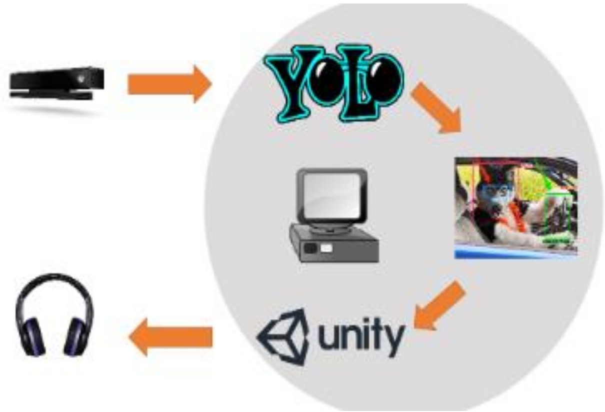

Figure 1. YOLO Model

Another audio based navigation system is '3D CMOS sensor based acoustic object detection and navigation system for blind people' suggested by researchers from the Polytechnic University of Valencia. This system presents us with the prototype of an Electronic Travel Aid for Blind People. The system gains information about its surroundings using an array of 1×64 CMOS Time-of-Flight sensors. The information is converted into binaural signals output to the blind users via the wearable aid. Tests show that it was able to work with precision in the range of 15m and 64 degrees in azimuth which is a significant improvement over the existing Electronic Travel Aids [13]. Developments have also been made in the area of using smartphones as an assistive tool for the blind. Headsets fitted with smartphones that can detect objects around the user and help them navigate and perceive things around them in detail. In the proposed system 'A Cloud and Vision-based Navigation System Used for Blind People' users can interact with the system using voice and navigate and inquire about the environment around them.[14] This is one of the major groundbreaking developments in assistive technologies for the visually impaired as it helps them to live as much like a normal person. Taking a parallel step, the navigation system proposed by researchers at National Institute of Electronics and Information Technology, Aurangabad helps navigate the visually impaired using moving object tracking. The aforementioned system uses ultrasonic sensors, raspberry pi and camera to track moving objects around its users and inform them of any obstacles by means of sounds such as beeps.[15] Another such suggested system that uses smartphones is 'ANDROID BASED OBJECT RECOGNITION INTO VOICE INPUT TO AID VISUALLY IMPAIRED' from Agni College of Engineering, Chennai. This system combines the techniques of image processing with text-to-speech using android as the platform. The image processing module detects the objects present in the image snapped by the smartphone and the text-to-speech module informs the user about it as an audio output. [16]

The researchers at MIT have created an automatic body worn system 'Camera-based object recognition aids navigation for the blind' that has a 3D camera worn on the neck which gathers images, the images are processed and navigational signals are given using the processed information to the blind users via a belt with vibrational motors attached to it. It also contains an 'an electro-mechanical Braille interface' to provide object information to the users. [17]

The system proposed in 'VOCAL VISION For VISUALLY IMPAIRED' [18] acts as a vision substitute designed to assist the visually impaired in navigation by detecting objects in the user's path. An image sensor captures the image of the surrounding and sends it to a computer for processing. The authors have used MATLAB which is the tool of choice for image enhancement and noise reduction. After pre-processing, edge detection and edge linking algorithms are applied. The processed image is sent to the microcontroller (ARM7) where it is compared with a database of various colored objects. The matched object name and its color is conveyed to the user through headphones. However in this system, the distance between the user and the object is not computed. It is said that with extensive use and experience, the user can perceive distance.

RFID (radio frequency identification) is a wireless system that uses radio waves to identify and track tags. In the field of wearable technology, RFID solutions have numerous benefits. In 'Wearable Object Detection System for the Blind' [19], an RFID device is designed to assist the blind in identifying objects; in particular, it has been developed to perform tasks such as searching for medicines in a cabinet. The tags can store information which is advantageous for this particular use. The reader can access this information and identify the object that contains the tag. The RSSI (Received Strength Signal Indicator) value, which is the power present in the received radio signal from the tag, is used to measure the distance between the reader and the object.

Another wearable device [20] supports navigation and mobility of visually-impaired people in an unknown environment using vision sensors, machine learning and computer vision techniques. Input data is received from multiple ultrasonic sensors and a phone camera. All processing is done on the smartphone. It is remarkable that the device was able to recognize objects in both indoor and outdoor environments continuously and gave audio feedback to the user. The two components of the computer vision system were obstacle detection and object recognition. The obstacles detected in the scene were recognized and the user was informed through audio feedback about the position and distance of the object compared to the user's position.

3. CONCLUSIONS

System	Indoor Navigation	Outdoor Navigation	Cost Effectiveness	Ease Of Use
Image Detection and Identification	No	No	Yes	Yes
3D Camera Based Navigation	Yes	Yes	No	Wearable, Could Be Uncomfortable
Binaural Assistance	Yes	Yes, not efficient	No	No
Smartphone Platform Based Assistance	No	No	Yes	Yes

Figure 2. Comparison Table Of Assistive Technologies

In retrospect we find that although the research and development in the field of assistive technology for the visually impaired has definitely evolved into something aidful but as seen in Figure 2, which is an evaluation of some of the proposed systems, none of the systems is truly satisfactory from an engineering and all round help perspective. Researchers have been able to get information from the surroundings using sensors, camera and various other equipment but many if not all of these equipment have a great cost and aren't affordable by the common man. Android based applications show promise. The idea of using a commonly affordable device such as the smartphone to aid the visually impaired is truly remarkable and cost effective. The proposed systems basically apply image processing to recognize the objects and then use it to navigate or tell the blind users about the objects around them. This system has clear shortcomings like it depends on the image quality from the smartphone, images cannot cover the area all around the user and interface issues. We're still a few steps away from the envisioned system of assistance that would be easy to interact, price-effective and robust. The developments in cloud and vision technology are continuously bringing us closer to feeding the entirety of the captured ambient data into the system. We also now have the power and resources to compute complex moves, extract minute features and predict things from it. This development is going to be the key to unlocking a perfect assistant for the blind that would understand the user's needs and would be able to extract data from the user's environment and convert it into useful information, helping them perceive the world better and aiding in day to day activities easing their lives.

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