Camera & Sensors-Based Assistive Devices For Visually Impaired Persons: A Systematic Review

Preetjot Kaur, Roopali Garg

Abstract— Assistive Technology has led to the removal of numerous navigation barriers for visually impaired individuals. It promotes more freedom by empowering such people to perform tasks that were formerly challenging, such as Obstacle Detection, indoor/outdoor Navigation, finding lost objects etc., with more ease. This paper provides a wider scope for researchers in the field of Obstacle detection for blind/partially sighted persons. This paper discusses several techniques contributed by numerous researchers to serve this purpose. These techniques are reviewed and categorized according to the criteria of taking visual information and then the research gaps in those techniques have been detailed. The critical challenges faced by visually impaired users in using Assistive systems based on smartphones, IoT devices, sensors, etc have been discussed along with future directions. In this paper the advancements and research done in this field is surveyed. Further, the various research gaps are included.

Index Terms — Assistive systems, Computer Vision, Camera-Based, Obstacle Detection, Sensors-Based,Visually Impaired;

1 INTRODUCTION

Vision is among one of the key sensory modalities that humans possess & loss of vision makes the human lives' more challenging. The White Cane & Guide dogs [1] are primary navigational aids used by blind persons or partially sighted ones. Both of them are reliable tools used by blinds since past years, but these have certain drawbacks. The White Cane cannot detect obstacles coming from far range such as moving vehicles & that they don't guide the user in an unfamiliar situation or in the emergency situations. Guide dogs itself have certain challenges associated to it [85]. The problem with Guide dogs is that they are costly & demand care as shown by the survey of great British dogs in [2]. The Probing Cane [3] comes in many flavors nowadays, such as Folded Long Cane, Guide Cane, Green Cane [4], smart cane [5] & many more variations (e.g. [6], [7], [8], [9]). Since very long years, researchers have been trying to improve this very trusted tool of visually impaired persons.

As per the latest Global Vision database, it has been found that there is an increase in the number of blind persons by 6 million and that of moderately and severely impaired people by 56.7 million in the year 2015 from year 1990 [10]. The term blindness is actually a part of term Visual impairment. The term legally blind refers to the persons having visibility less than 20/200 in a normal eye. Such persons are eligible for all the legal benefits provided by governmental agencies.

Retinal Detachment, cataract, Head Injury, Glaucoma and overgrowing population are the major factors responsible for blindness among individuals. The current epoch in which we are living is of Information Explosion, where everyone needs variety of information on variety of topics to take decisions. People with visual impairments have difficulty in accessing some information that sighted people take for granted in [11], [12], [13]. Götzelmann and Winkler in [14] improved the already existing Braille labels, keeping in view the restricted discriminability of tactile sense of humans. Researchers have been using several tools & techniques to build systems that would add help to the community of blind persons. Nicoletta Noceti suggested using glasses equipped with webcam [80]. Although some of the systems were even successful in making a blind person, board the bus independently [81]. Some of these systems have been rejected by this community due to heavy sets of wearable clothes or because of complex methods of operating tools or because of their costs or because they overwhelm the users with unnecessary information. Also, it is difficult to insist visually impaired person to switch to newer technology from traditional tools, for detecting obstacles during navigation in unfamiliar situations. Building trust is the most difficult part here. To be acceptable by this community, assistive devices have to be more effective & should detect obstacles that are beyond the reach of Canes. Within no time, the domain of computing will outgrow and cross the limits of long-established desktops [15]. IoT has taken respectable status in the lives of differently abled peoples, especially visually disabled. The computer through the help of sensors, actuators, cameras & some wearable on the body, alerts the people about the obstacles in front of them [16]. Assistive technologies in collaboration with IoT have been designed to assist such people & now, it has become a powerful tool to improve freedom & build interest among them [17]. Many systems succeeded in satisfying the users based on stereovision technology such as in [18] & [19] but lagged behind due to the reasons such as these doesn't provide information of holes on the road or get heated up during operation respectively.

We audit the research and advancements within this field, also highlighting various research gaps. Till now, several techniques have been devised or used to help people with visual disabilities. Some of them are categorized below.

- *Preetjot Kaur is currently pursuing PhD in Information Technology in UIET Panjab University, Chandigarh, India.*
  E-mail: reetjotkaur20@gmail.com
- *Dr. Roopali Garg is presently serving as Associate Professor, Panjab University, Chandigarh. She is former Coordinator of Department of IT, UIET, Panjab University, Chandigarh. She is an active Life Member of several International and National technical organizations like ISTE, IETE, IEE*
  E-mail: roopali.garg@pu.ac.in

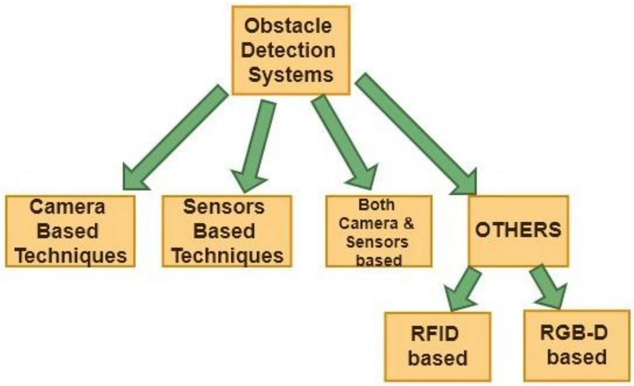

Fig.1 Flowchart showing obstacle detection techniques on the basis of criteria of taking input.

The rest of the paper is organized as follows: In section-II, the review of different techniques proposed by several researchers on the basis of different input criterions is presented. It also discusses the open challenges and future directions. Section-III is devoted to Evaluation Metrics and comparison charts of different techniques. The concluding remarks of paper are given in section-IV.

2 OBSTACLE DETECTION TECHNIQUES WITH DIFFERENT WAYS OF TAKING INPUT

2.1 *Camera Based Techniques:*

Adriano Mancini (2018) et al. developed a heavy size embedded system based on small camera and image processing algorithms to assist visually impaired individuals during walking and running [20]. The system comprises of vibrators, robotic-like controllers and gloves equipped with motors. There are 3 main components of the system such as Camera (global-shutter monochromatic), Processing Unit (image processing algorithms) and charging haptic feedback device (gloves). The system is observed efficient in guiding right directions to the user while navigation. Jamming should be reduced by the use of RADAR and compact RTK L1 GPS receiver.

Bogdan Mocanu (2018) et al. introduced a system DEEP-SEE FACE to help visually impaired individuals communicate with social environment, based on the integration of computer vision techniques with Convolution Neural Networks (CNNs) [21]. The system uses video camera of the smartphone and the whole processing unit is carried in backpack of the user. The battery of the smartphone remains a major concern here. The ultrabook computer carried in backpack is expensive. The output is provided by the bone conduction headphones, which also consume much energy. An accuracy of 92% is observed even with different light and position conditions.

Nawin Somyat (2018) et al. introduces an app NavTU for visually impaired persons in Thai based on GPS and camera based technologies [22]. It encourages the use of android smartphones having GPS trackers, compasses, maps, and digital cameras in it. This app is made while considering electric poles on the sidewalks as emergency warning for blind users, thereby ensuring the safety of users. NavTU fails to detect dynamic objects and stairs. It does not operate properly in low light regions. User must hold WhiteCane even while using this app.

Jindal (2018) et al. presented a cost effective system to guide visually impaired users based on camera using an alogorithm - Speeded-Up-Robust-Features (SURF) [23]. The proposed framework is composed of many phases which are as video pre-processing (removing non-linear camera motion by using Feature Point matching & ROI searching); ground Plane Removal (using thresholding & region growing), Extracting Localized Points (by using SURF), Region Of Interest Segmentation (active Contour Model), Calculating Textile Features (such as Gray-Level Co-occurrence Matrix) and ROI Classification

$$Accuracy = \frac{TP + TN}{image\_size} \quad (1)$$

where TP is *True Positive* & TN is *True Negative*.
In order to accurately detect changing Ground planes, Machine Learning can be used.

S.Meers & **K.Ward (2017)** introduced a stick framework based on 3D vision using head mounted camera & electro-tactile gloves [24], which utilizes AI to assist the visually handicapped individuals with navigating their environment autonomously. The user has to keep hands in the direction viewed by his camera, allowing him 3d perception of the environment. After 5 minutes of training in unknown environment with the proposed system, the users were comfortably able to use it. The stereo cameras used here are not able to clearly detect the featureless/texture less walls/surfaces. Infrared sensors can be used to resolve this limitation.

Delahoz(2017) et al. proposes work for the detection of floors using Smartphone's camera [25]. The system contains 5 modules like:

- smoothing for the removal of noise from image,
- edge detection to detect edges in an image,
- line detection to detect lines of different types (horizontal, vertical),
- Floor wall boundary detection to remove
- Lines not part of the boundary of floor wall.
- Floor detection actually selects the floor area in an image.

The system received an accuracy of 82%, a precision and recall of 90.3% and 75% resp. This work can be further extended to detect objects lying on the floor & tripping hazard analysis.

R. Tapu (2017) et al. introduces a new framework called DEEP-SEE, based on the integration of computer vision algorithms & CNNs for visually impaired users [26]. It is based on the principle of alternating between tracking by using motion information & modifying the predicted location on the basis of visual similarity. The proposed method attains an accuracy of about 90% in recognizing both static & dynamic obstacles. The system could be extended to detect crossings on the road. Several features such as Face detection and shopping assistance could be incorporated into it.

Rumin Zhang (2017) et al. presents a real-time depth-data based technique by using binocular camera, for helping visually impaired users in detecting obstacles [27]. The system is based on the algorithm in which Region of Interest (ROI) is captured by stereo cameras, whose calibration is discussed in Eq. 1, & disparity maps are generated & through segmentation techniques as discussed in Eq. 2, the obstacles are detected. The accuracy is acceptable for visually impaired users.

$$P = A(RW + t) \quad (2)$$

where P is projection to W & m; W is word coordinate as : W= $[X, Y, Z]^T$, M is image coordinate as: m= $[u,v]^T$, A is camera intrinsic matrix; R is orthonormal matrix of 3x3 size. The distance between baseline & 3D point is:

$$Z = \frac{Bf}{X_L - X_R} = \frac{Bf}{d} \quad (3)$$

where d is disparity [ranging from 0-255] is: d= X_L - X_R
f is rectified Focal Length; B is baseline of Camera;
Color & depth information can be integrated into it to make it a reliable assistive system.

Kang (2017) et al. gives the improved version of obstacle detection technique based on Deformable Grid (DG) [28]. In this technique, following steps are performed as:
Step-I : A vertex deformation function is defined using Perspective Projection geometry.
Step-II : The collision risk is measured based on this DG.
The obstacles within the range of 2m from the user are treated as risk of collision. 3 different cases were considered to obtain the ground truth data. The system fails when it gets closer to the non-textured obstacles such as walls, doors, etc. This can be resolved by using image segmentation techniques. On comparison with other systems, it is found that the proposed DG version gives better and more accurate results & also more précised information of risks.

Zhang (2017) et al. presents a new framework, based on 6-DOF Pose estimation method & 3D camera & involves 2 graph SLAM processes for reducing accumulative pose errors in the device [29].
Step-I At first, the floor plan is extracted from 3D camera,
Step-II Then wall lines are extracted.
Based on this PE method, a navigational system is built that helps in finding ways for blind persons in an indoor environment. The concept of RNA, which is an enhanced WhiteCane with 3d camera, is introduced here. Experimental results proves that the proposed system provides more accurate poses & in lesser time. The runtime of the proposed strategy is 59.4ms, while that of planar SLAM is 77.6ms for one frame data. Several errors are observed in SLAM algorithm that can be reduced by employing loop-closure detection algorithm mentioned in [30].

Trung-Kien Dao (2016) et al. introduced an indoor navigation prototype for visually impaired users [31]. The proposed system includes several multimedia technologies integrated into it. It consists of 4 layers as Physical, Functional, logical and Application layer. After modeling the environment, user's location is determined through the combination of Wi-Fi & vision information. The system interacts with user in their local Vietnamese language through voice synthesis. The deployed version of this system in schools revealed its effective nature. But accuracy of 97% is ineffective in real-time situations, thus, it is only good for safe environments.

Chan (2016) et al. proposed a modified sigmoid function (MSF) framework that is based on the IMU (inertial Measurement Unit) [32]. As camera in smartphone is moving, topological structure of MSF is estimated & IMU estimates the blur levels to adapt to MSF. The concept of Artificial Intelligence is also used. Through this technique, not only the number of errors, but also computation time got reduced as compared to other techniques such as using Guide Dogs or WhiteCanes.The system needs to be checked on public database consisting of more blurred images (video sequences) for its effectiveness.

Al-Khalifa (2016) et al. described an Arabic navigational aid, namely Ebsar for partially sighted users [33]. It consists of wearable devices furnished with sensors & cameras. The application develops indoor maps from the movements of the blind person & produces QR code area markers & provides voice guidance to its users in Arabic language. The application demonstrated satisfactory results. The system can be improved in many ways like using Wi-Fi & reducing dependency on QR codes to track blind persons' movements.

Khenkar (2016) et al. proposed ENVISION, a navigational aid for visually impaired smartphone users [34].. It is based on the fusion of *GPS technology*, *supervised learning* & uses new ways to detect obstacles (both static & dynamic). The system is robust & works accurately by taking real-time video made using smartphone & takes intelligent decisions. The results were recorded in terms of four models, which are PMhigh with recall of 70% & precision of 85%, PMlow with recall of 78% & precision of 83%, PMleft with recall of 72% & precision of 85% & PMright with recall of 77% & precision of 79%. The system needs to be improved to imbibe the concepts of obstacle detection and for the clearer understanding of the environment around blind users.

Mohane (2016) et al. proposed a system having 1 camera & using the features of SIFT algorithm [35]. The movement based technique is used to extract obstacles of the moving objects from the video made by camera by using K-means clustering technique. SIFT Algorithm is used to extract features from the object image. The extracted features are compared with the features extracted from the data set images & if there is a match, then output is given in the form of speech. The system is robust, easy to use and slow. It is not suitable for emergency situations in real-time environment.

Aravinda S.Rao (2016) et al. stresses on the lack of devices for detecting potholes & uneven pavements during night or in dark [36]. The framework incorporates projecting laser designs, recording the patterns via monocular video, & then observing patterns for extracting features and after that giving way signs to the visually impaired client. The HOI (Histogram of Intersections) descriptor is used to detect potholes & uneven areas. The proposed technique attained an accuracy of 90% in detecting potholes. It works only in night time or in dark areas.

Lukas Everding (2015) et al. proposed a wearable prototype that captures the visual information through a unique Dynamic Vision Sensor (Camera) and outputs audio through headphones [37]. DVS camera has many alluring features over normal camera such as less power consumption, lesser storage requirements etc., which make it highly encouraging camera for applications where power (battery) is of high concern. The system attained a success rate of close to 100%. However, it is only good for static subjects and fails in case of moving subjects. Moreover, it performs better only after a user is trained for 50-100hrs.

R.Tapu (2014) et al. introduced a new framework based on feature extraction [38]. At first, features are extracted based on image grid & tracked based on Lucas-Kanade algorithm. Then, the background & other types of movements are identified using homographic transforms & RANSAC algorithm and agglomerative clustering technique respectively. The distance of the user from an obstacle determines the situation as normal or urgent. The advantage of the approach is that it is robust in nature & doesn't require any previous information about the obstacle. The average time required for its execution was 18ms/frame on Windows 7 platform, while it was 130ms/frame on Samsung Galaxy S4. Voice module can be incorporated into it for better output.

Praveen (2013) et al. proposed depth estimation technique on the basis of local depth hypothesis [39]. An image is captured by camera and is further resized for computational efficiency & obstacles are extracted using edge detection and then by morphological image processing operations & their depth is compared to the estimated depth measured by local depth hypothesis & obstacles are realized. This system doesn't require any prior information of the user's space & can be used in both known & unknown environments, thereby making it compatible for real-time environment. No Ultrasonic sensors have been used in this system. The system failed to detect the depth discontinuity between sub segments in the same obstacle itself. This can be resolved using graph-based segmentation. The paper highlights the deviations of the proposed system in terms of 8 bands.

R.Tapu (2013) et al. introduced a real-time obstacle detection system for visually impaired persons based on smartphone Camera [40]. Interest points are selected by HoG descriptor from an image & tracked using Lucas-Kanade algorithm. Homomorphic Filtering techniques are used to detect camera & background motion. Obstacles are classified as urgent or normal on the basis of distances. These obstacles are sent to the Classifier BoVW (Bag of Visual Words). The technique is computationally efficient, effective & achieves high accuracy rates with an average recall of 83.75%, Average precision of 91.5% & average F1 of 87%. User alerting system needs improvement as Bone induction headphones can be used instead of normal headphones.

Ali Israr (2012) et al. introduces a visuo-tactile assistive device for helping visually impaired users, explore the world around them [41]. The system is comprised of Webcam camera, capacitive touch panel, touch-panel USB driver, tesla touch driver, USB hub and connector. Several computer vision and color extracting techniques are used to build a prototype. Experiments conducted reveal that training is required to operate the prototype. But it should also be able to extract more features like edges, contours and contrasts and detect small items like keys, coffee mug, etc.

Lee (2012) et al. proposed a depth based technique for visually impaired [42]. By analyzing the depth map, techniques such as segmentation & noise elimination are applied & obstacles are extracted. Time Of Flight (TOF) Camera has been used for the generation of depth & color images. The proposed system detects all the moving & standing obstacles within the range of 1-2m from the user. Although the practical implementation of the system is still in progress, the system achieved the detection rate of 96.17% in indoor & 93.7% in outdoor environments.

Liyanage (2012) et al. proposed a navigational system based on optical flow estimations [43]. A prototype comprising of virtual reality world was designed, using 2 stereo cameras headset, portable computer & GPS, to demonstrate the concept. It uses auditory & tactile feedback to guide visually impaired persons. Existing optical flow algorithm is also used along with other image processing techniques. The simulation of the technique shows its efficiency in controlled environment but awaits real-time implementation.

Fazli (2011) et al. proposed an algorithm for detection of negative obstacles [44]. It is a fusion of Stereo vision techniques & 2 stage Dynamic Programming technique. The paper also discusses several algorithms used for matching features. The camera collects images during navigation & the algorithm depicts important terrain features of the obstacles that are below the level of ground such as holes, drop-offs etc. On comparison with algorithms such as Belief Propagation & random Growing Correspondence Seeds (GCS), it performs better in terms of (lesser) time taken, accuracy of disparity map and also lower RMS errors. Also, the proposed method is 28% times faster than the GCS method, but focuses only on the negative obstacles in the environment.

Chen (2011) et al. proposed a technique based on dynamic fuzzy logic & Musical Instrument Digital Interface (MIDI) & its conversion from images of roads to help visually impaired guide through roads while moving [45]. In this technique, a low-cost camera is mounted with 18degree pitch down, on the scooter. The paper also defines the concept of RGB ration according to the reference colors of an image. The obstacle information includes the information about an obstacle such as Normalized Image size, Image co-ordinates of obstacle center and Lowest Obstacle pixel. Although the system is not tested on large databases, in 96.8% cases, users could detect the number of obstacles correctly, in 90.6% cases, the users detected the orientation of obstacles correctly & in 97.3% cases, the users could correctly depict the size of the obstacles.

Costa (2011) et al. proposed a new algorithm to perceive landmarks placed on sidewalks [46]. The new algorithm is composed of fusion of Peano-Hilbert Space Filling Curves, which is used for reducing dimensions in the image, captured by camera & Ensemble Empirical Mode Decomposition (EEMD), which is used to pre-process the image. The evaluation of the results provide that proposed algorithm leads to fast results & efficient method for assisting visually impaired in obstacle recognition. Certain improvements are required as disparity maps can be used and PH-EEMD image analysis can be used.

En peng (2010) et al. devised a real time obstacle detection mechanism implemented on a smartphone [47]. It is used to help visually impaired individuals in detecting any low height object lying on the floor by combining three techniques, which are as:

- color histograms,
- edge cues
- Pixel–depth relationship.

The paper also discusses several issues faced by the participants in holding the smartphone, etc. The proposed system has an accuracy of 94% in all the cases & a speed of only 7ms is required to execute it. But the system has failed in the detection of complex floor patterns and the objects lying on such floors.

Critical Challenges:
The critical challenges faced by using camera based techniques are as:

In some cases, the system fails in the detection of complex floor patterns. The objects lying on such floor are not detected by the system. It should be able to extract more features like edges, contours, contrasts etc. Some systems are found to execute at very low rate. This might be due to the computer vision algorithm used to calculate the distance between user and obstacle. There are systems that use laser patterns, which operate only in night time or dark areas. So, suitable laser source is required, which may detect patterns in both day as well as night. The accuracy of most obstacle recognition systems should be improved either by using more powerful GPUs (Graphical Processing Units) or other feature extraction tools. Buying GPUs is itself very expensive. In most of the cases, results are not completely accurate. This may be due to random sampling as not always the samples have equal probability of being chosen. Accuracy of 97% is ineffective in real-time situations, thus, some systems are only good for safe and protected environments. High Resolution cameras are very expensive. Size of the system becomes too big and heavy for a user to carry. Some devices require long training time. Heavy & expensive components should be replaced by light and cheaper ones. It should be able to detect small daily routine things such as keys, coffee mug, etc. However, it is only good for static subjects and fails in case of moving subjects. Certain camera based assistive systems perform better only after a user is trained for 50-100hrs. Detecting concave objects such as holes & downward steps is very complex.

Future Directions:
In order to accurately detect changing Ground planes, Machine Learning algorithms such as Naive Bayes classifiers, Support Vector Machines, etc. can be used. The systems need to be checked on large public databases consisting of more blurred images and video sequences. Camera-based systems can be practically implemented on smartphone, tablet or wearable device. Some obstacle detection algorithms can be further extended using object classification algorithms & also voice can be incorporated into it. Ultrasonic sensors detect even in dark surfaces, where infrared sensors fail and therefore can be used as required along with cameras. The systems should be extended for detecting crossings on the road, faces and providing assistance in shopping thereby improving its accuracy in real-time environments. Bone Induction headphones can be used instead of normal headphones, so as to allow user to listen environment sound as well sound from the device. Improvements in speed can be made by using PH-EEMD (Peano-Hilbert Ensemble Empirical Mode Decomposition) image analysis for pre-processing the images. Disparity maps need to be integrated into the obstacle detection modules, for depth sensing. Disparity map refers to the difference in pixels between a pair of stereo images. Jamming can be reduced by using RADAR and compact RTK L1 GPS receiver.

2.2 Sensors Based

Nur Syazreen Ahmad (2018) et al. proposes a multi-sensor based obstacle detection system implemented on a White Cane [48]. The system is based on the model-based state-feedback control strategy, which controls the detection angle of sensors; thereby reducing false detection results. It uses 3 Ultrasonic sensors (detecting left and right side) and 1 Infrared sensor (detecting holes and stairs) along with vibrotactile and audio feedback systems for the visually impaired user. The system performs best with an accuracy of 97.95% on an average. A wearable system can be made to promote hands-free movement. Also, a survey must be done to ensure the usability of proposed system among visually impaired users.

R K. Katzschmann (2018) et al. presents hands-free wearable device as Array of Lidars and Vibrotactile Units (ALVU) for visually impaired users based on Time-Of-Flight (ToF) sensor [49]. The device comprises of Sensor Belt and Haptic Feedback device (strap). ALVU creates a map by sensing the environment and projects it on the user's body through haptic feedback. An overall accuracy of 82% with ALVU is observed in the system. The viewing range of ALVU needs to be adjusted according to speed of the user. Also, its performance can even be enhanced by using turn-by-turn navigation.

R. K. Megalingam (2018) et al. introduces an intelligent navigation system for visually impaired individuals that is based on robotics and is using Ultrasonic and infrared sensors [50]. It also comprises of Buzzer, vibration motor, motor driver, and power source, ISD 1820Voice Module, Arduino Mega (ATMEGA1280) and Keypad. There are 3 modes such as Learning, retrace, free-moving module. Joystick directs the movement of robot. The most suitable feature in the system is that a user can stop in between while walking and can again restart. It provides multiple warnings to the user, hence ensures safety.

Gonzalo Baez (2018) et al. proposes a 3d artificial vision system that converts 3d depth information into 3d sound using Head Related Transfer Function (HRTF) and Light Structured Sensors [51]. Microsoft Kinect is used to register 3D point cloud from environment. Directional spatial Interpolation is most important feature of HRTF. Although the system shows an accuracy of 97%, but it is ineffective in real-time situations due to its big size and external power requirements. Thus, it should be either embedded on a smartphone or should be made wearable technology.

Nabila Shahnaz Khan (2017) et al. introduces an assistive system for helping visually impaired users in walking based on Ultrasonic sensors & GPRS module [52]. The framework consisting of Arduino Uno, sensors, buzzers, switch buttons & battery, is used to detect obstacles & manholes. An opening for sending sound pulse & another one for receiving signal are located on the sensor & distance is calculated as mentioned in Eq. 4.

$$\text{Distance} = \text{Time} \times \text{Speed\_of\_sound} / 2 \quad (4)$$

Sensor doesn't get affected with dust or water & covers large range of distance by holding it while walking. Arduino Digital Magnetic Compass can be used to help users in detecting right directions & by including audio notifications to it.

Tayla Froneman (2017) et al. developed a wearable prototype for the detection of obstacles in an unfamiliar environment by using low-cost Ultrasonic sensors for visually impaired persons [53]. Sensors were worn on users' waist as it is considered the least moving part of body. The detection distance ranges from 0.02m to 7m. 100% obstacle detection sensitivity & 100% object discrimination was observed on testing the system. System yields inaccurate results for objects like table & chair. Cost of the prototype can be reduced by using microcontroller instead of expensive computer.

Van-Nam Hoang (2017) et al. presents a wearable obstacle detection and warning system for visually impaired users on the basis of matrix of electrode and a mobile Kinect [54]. The system uses the techniques such as maging technique, segmentation technique, Euclidean distance measurement and Watershed algorithm. Other hardware includes laptop in backpack, RF transmitter and belt. It shows 50% accuracy in real-time and 82% in controlled environment. It is a simple, portable, hands & ears-free prototype. It gives many warnings at the right time. But bulky prototype makes it difficult for a user to wear it on body for continuous long time. Also, it requires training before using.

Desar Shahu (2017) et al. presents a low cost obstacle detection system by using 2 Ultrasound sensors along with GPS & GSM module for visually impaired users [55]. The system is based on the principle of estimation of TOF (Time of Flight) of transmitted pulse from the obstacle sensed by the proposed framework. Several scenarios such as typical indoor & outdoor environment are considered to test the efficiency of system. It is observed that system is light-weight & obstacles of different material & shapes are successfully detected by the system. But the system fails to detect inclined doors. Also, the reliability of a system can be improved by using Microwave sensors instead of Ultrasound sensors.

Bruno Andò (2017) et al. presents wearable active assistive system to help visually impaired persons navigate in indoor environment based on multisensory technologies [56]. The system uses Ultrasound sensors and wireless sensor network along with advanced trilateration paradigm (MTA), signal processing algorithms, UEI and UEC functionalities, Nelder–Mead nonlinear to perform real-time localization. Audio output is given through Bluetooth audio feedback device. Mispositioning of environment nodes has also been compensated. MTA needs more time, so there is a trade-off between localization performances and processing time.

Karimi (2017) et al. presented a context-aware smartphone based approach to help visually impaired in in-door environments [57]. The approach uses 2 consecutive frames, computes the optical flow & track texture features to detect the obstacles in front of blind users. The frames are set based on the fusion of sensors & using the concept of machine learning. The algorithm is more precise as compared to other comparable algorithms & has an accuracy of 79%, precision 82%, recall 69% & F-Measure of 72% in comparison to the other techniques (sparse point's dataset & predefined grid). In case of lamps, reflective surfaces such as floors, inaccurate results are observed.

Zhou (2016) et al. proposed a novel technique by combining ultrasonic sensors to sense the environment, GPS & Google maps to determine the current location, Bluetooth devices for data flow utilizing smartphone, Voice commands [58]. This software has 2 parts. One is wearable smart sensor & another is app running on smartphone. The prototype is built on Android platform in the Eclipse IDE. The sensor data is relayed to the device & reads distance from 1 to 10 feet, making users enjoy a hand-free interaction with the device. The system has an average standard deviation of 0.448 and can be improved to detect objects more than the range of 10 feet in a controlled environment.

Jee-Eun kim (2016) et al. introduces a new solution - StaNavi, to address the problem being faced by blind travelers at railway stations [59]. This system uses Bluetooth Low Energy (BLE) & built-in compass of smartphone. BLE is a localization module that is considered as the most accurate, low cost ($5 per unit) & low power consumption module (runs several years). It provides voice instructions & was tested at one of the busiest railway stations of Tokyo. No external hardware was required. It encouraged feeling of independence & confidence among users. 38 deviations occurred in 32 trials, requiring users re-route their paths. Large number of deviations should be improved by integrating StaNavi with other positioning methods.

Chaitali Kishor Lakde (2015) et al. proposes a wearable navigational assistance system for visually impaired persons based on Infrared (IR) sensor and RGB sensor [60]. The system is made up of AVR 8/l6 development board, Headphone, Voice Recording IC, Power supply and Vibrator. Several pattern matching algorithm are used along with fusion of sensing & voice based guidance. It is simple, portable & low-cost system and user friendly. It doesn't require training. Some measures should be suggested in case of unfortunate situations such as fast moving vehicle or in case of accidents etc.

B. Ando (2015) et al. introduces a haptic device which aims to guide visually impaired users in daily-routine tasks [61]. It comprises of 2 Ultrasonic sensors and array of strain gauges sensors. It is based on codification strategy, Detection simulation and threshold algorithms. It has Contactless cane along with vibrating actuators to warn user about the obstacle. It provides natural codification of obstacles and improved user confidence. Handlers should be made keeping in consideration left-handed persons as well. Results need to be improved by using more sensors.

Uddin (2015) et al. proposes a system that has 2 modules as providing direction and Obstacle detection [62]. Direction is provided by smartphone over voice command & sensors detect obstacles & finds minimum distance based on Dijkstra's algorithm. The data is transmitted through Bluetooth. 100%

accuracy was obtained in case of detection of obstacles, 84% in detection of holes & 93% in case of detection of turns with an overall accuracy of 92.33%. Accuracy depends upon weather and changing weather leads to inaccurate results. Microsoft Bing map is not updated.

Zhe Wang (2014) et al. observes the need of designing a robust system for detecting obstacles for blind persons & uses *scene segmentation* & *labeling* to design an obstacle avoidance system [63]. The prototype uses a multiscalevoxel technique for reducing noise effects & improving segmentation. The results are then combined with depth & color data. Then, a decision tree is trained to be able to classify different segmental types. On testing this method on NYU Data sets & it is observed that the system is fast, robust & effective in nature. The proposed technique has been compared with other techniques and the significant results have been shown. The method can be extended to apply on sequence of images & videos & detect more area.

Cheng-Lung Lee (2014) et al. proposes an obstacle detection device based on automobile parking sensors in [64]. It consists of 3 modules:

- Sensing module (transmitting & receiving unit)
- Processing module (control host)
- Warning module (buzzer)

Several experiments are conducted and efficiency of the device is compared with WhiteCane & the combination of proposed device with WhiteCane. It is observed that the combination (of proposed device with WhiteCane) showed 0% collisions and the best results. Sample data used for testing is very small; thereby lacking the trust of users in it.

Nakajima (2013) et al. put forth a navigational system for blind users in Indoor environments [65]. The system uses Visible LCT (light Communication Technology) using LED lights & geomagnetic sensors facilitated in a smartphone. The author claims the system performs effectively for some VI users. But the biggest problem here was an error in the direction is equivalent to 1 hr. clock difference. Moreover, for the faster moving users, the spoken navigation doesn't match. Azimuth accuracy is not detected by the system.

Wai L. Khoo (2012) et al. uses Microsoft Robotics Developer Studio to create a virtual environment for evaluating multimodal sensors that are used for assisting visually impaired users [66]. It uses multimodal sensors, laser sensors, ultrasonic sensors, laser sensors and sonar sensors. The outcome is a wearable system which uses segmentation-based stereo vision algorithms, Microsoft Robotics Developer Studio, stereo cameras, XBOX controller, Brainport and Braille. It is Easy-to-use XBox controller than using mouse & keyboard. Also, Laser sensors are more accurate to range distance & angle up to 80m. Different combination & placements of sensors along with user's learning curve will provide research platform in making different assistive tools for VI.

B. Mustapha (2012) et al. proposes a system which is composed of ultrasonic and optical sensors to detect wide range of obstacles for visually impaired persons [67]. It uses ultrasonic (SRF10), Infrared (GP2Y0A21YK), Laser range and Ultrasonic range (sonar) sensors. It uses the concept of correlation distance measurement and Bluetooth technologies along with microcontrollers, Smart transceivers and warning units for the user. IR sensor works perfect than ultrasonic senor in terms of speed, all types of material & sizes. The sensor is attached to the shoe tip of user and gives many warnings on detecting obstacle. It detects small, large objects on walkways, stairs, and uneven surfaces. Same experiments can be conducted using Proximity sensor to check its efficiency.

Atif Khan (2012) et al. proposes a wearable obstacle and human detection system for visually impaired users by using depth information acquired by Kinect sensor - Xtion Pro Live [68]. The system utilizes OpenNI framework, Xtion Pro Live, the Laptop, Bluetooth and USB power cord. It provides an efficient and robust algorithm that can identify up to 3 people at a time. But it fails if the object is in motion. Also, SAPI feature used here reduces the efficiency of output.

Gallagher (2012) et al. presents an indoor positioning system that runs on a smartphone & is based on Kalman Filter that collects the information from all the sensors present on a smartphone [69]. The earlier part of this paper mentions the requirements of blind or visually impaired users for an indoor/outdoor environment. On comparison of the system with most advanced Wi-Fi & NN algorithms, it was found that the system shows an improvement of 35% over Wi-Fi algorithm & 50% over classical NN algorithm respectively. Large numbers of errors were detected due to the presence of metallic structures in a room. The system can be improved further by the choice of relevant noise covariance matrixes of Kalman Filter.

Mounir Bousbia-Salah (2011) et al. presents a wearable navigational aid to help blind persons in their vision by using ultrasonic sensors on user's cane and mounted on shoulders [70]. It consists of 2 vibrators, ultrasonic cane, microcontroller, accelerometer, footswitch, speech synthesizer, hexadecimal keypad, mode switch, an ultrasonic cane and power speech. The system detects obstacles within 6m range. It warns the user about obstacles through vibrations & voice. The proposed system is low cost & effective in real-time. But the efficiency can be improved by using GPS to track user's position information.

Bruno Andò(2011) et al. suggests a new platform to help visually impaired interact with the environment by using smart distributed sensor [71]. The Decision Support System (DSS) tool uses data from sensor probe. The Management Tool (MT) manages interaction. Bluetooth audio interface conveys messages about environment to the user. The system provides continuous perception of both environment & user. It is a Flexible system and can even assist deaf people. Performance can be enhanced by increasing complexity of DSS.

A. M. Kassim (2011) et al. proposes a wearbale warning system called 'MY 2nd EYE' for visually impaired individuals based on distance measurement and-infrared sensors [72]. It consists of H-bridge Motor driver, Pulse Width Modulation (PWM) and a vibration motor along with PIC Microcontroller, Rechargeable battery, Glove and Wheel. It is a low cost system. Here, user only needs to wear gloves. It vibrates on detecting obstacles._But there is a need to improve system to be able to operate at crowded areas such as supermarkets. And deal with high-speed obstacles such as cars.

Mitsuhiro Okayasu (2010) develops two systems to help visually impaired people in visualizing environment things by using Thermographic camera (Infrared sensor camera) along with Ultrasonic sensor [73]. One is implemented on White Cane and other one is a wearable wrist-band. The system uses depth data and 3D view using array of pins. It also consists of vibrator and tooling apparatus to guide the user. White cane is able to detect high as well as low level objects ranging between 0.5 m to 5.5 m. 3D visual system provides information on shape & distance of obstructions ranging up to 7.5m. Certain collisions were observed while its execution. It is unable to detect concave object such as holes & downward steps.

Critical Challenges:
Some of the critical challenges faced while using sensors as input device to assistive systems:

Some systems do not detect objects more than the range of 10 feet. There are systems that do not yield accurate results in case of lamps, reflective floors or highlighting surfaces. In most cases, accuracy depends on weather and changes in weather makes results highly unpredictable. Some System yields inaccurate results as table is detected as chair and vice-versa. Detecting inclined doors is still a complex task. There is high need to improve systems for crowded areas such as supermarkets. Users are not warned of emergency obstacles such as high-speed cars. Some Trialteration algorithms such as MTA provide very accurate results but take much time. So there is a trade-off between localization performances and processing time. Many sensors make the prototype bulky for user to wear it on body for continuous long time. Users require training before using some prototypes. Lack of confidence in using and adapting to newer technology is often observed among visually impaired users.

Future Directions:
Arduino Digital Magnetic Compass can be used to help users in detecting right directions & including audio notifications to it, makes it more user-friendly. System performances can be improved further by the choice of relevant noise covariance matrixes of Kalman Filter. Large number of deviations in results of StaNavi could be improved by integrating it with other positioning methods (such as DR). The systems should be further extended so as to be able to detect azimuth accuracy. Reliability of some systems can be improved by using Microwave sensors instead of Ultrasound sensors. GPS can be used to track position related information and should be incorporated into navigational devices. Some systems use smart sensors along with Decision support systems. Increasing the complexity of such systems will yield good performance. Proximity sensors can be used to perform experiments while testing the efficiency of prototype. Some measures should be suggested in case of unfortunate situations such as fast moving vehicle or in case of accidents etc. Sensors should be able to adjust themselves according to the speed of the user. Different combination & placements of sensors along with user's learning curve will provide research platform in making different assistive tools for VI. Those sensor based systems that contain handlers, should consider left-handed people also. Increasing the number of sensors will provide accurate results, but will make the system very heavy; therefore the trade-off between accuracy and bulky system to be prioritized.

2.3. *Both (Camera & sensors)*

Maria Cornacchia (2018) et al. proposes a small and low-cost obstacle detection assistance system for visually impaired users based on camera and patterned light field sensor [74]. The system helps the users in navigating indoor and outdoor environments and detects obstacles along their way. It uses the concept of deep learning, especially Convolution Neural networks (CNNs) to classify different frames of obstacles. Long Short Term Memory (LSTM) is used to smoothen the frames so as to enhance better detection and gives the accuracy of 98.37%. Real-time performance can be improved by using better shape detection algorithms and also detecting different colors.

M.Vanitha (2018) et al. has designed a smart walking stick by using 4 Ultrasonic sensors & 1 Camera for assisting the blind users & helping them in detect obstacles [75]. Three sensors have been put on use for detecting obstacles, while the 4^{th} sensor detects potholes. Camera also recognizes objects & text & works like virtual eye to blind users. The system is successful in detecting obstacles from 360 degree view with respect to smart stick. Inclusion of GPS system into this framework will help guardians of blind person to know their exact location at any time. Framework should be extended to recognize faces.

W.Elmannai (2018) makes use of fuzzy logic in guiding visually impaired about the obstacles in their way & ensures 100% results [76]. The proposed technique is based on the integration of sensors & cameras using BRIEF (ORB) for obstacle detection with an accuracy rate of 98%. The proposed technique doesn't detect all the obstacles in the image. This may be due to the large sized obstacles & needs an improvement

D-R.Chebat (2017) et al. provides a review on advanced technologies based on neural correlates & sensory substitution for visually impaired persons & suggested sensorimotor loop as the basis for plastic changes in the brain [77]. This paper is a review on sensory substitution devices, which are using cameras & sensors in them. The paper reviews neural correlates of the route finding in sighted & blind persons.

Ramirez (2017) et al. identifies the problems being faced by visually impaired users due to autonomy of cities & urban areas [78]. The paper presents previously designed traveling aids & enhances them using IoT. The proposed architecture uses haptic feedback that comprises of both tactile & auditory feedback. The major improvements were done in Electronic Long Cane Project by minimizing power consumption, utilizing recyclable elements in it & many more. The results obtained were adequate & satisfactory with an average precision of 4.59 & average repeatability of 2.80. A central server is required to be developed to allow even more services through IoT. The unfortunate situations such as failed obstacle detection cases should be addressed. Solar batteries can be used for the improvement of autonomy & sustainability of smart cane.

P. Kumar (2017) et al. proposed navigation system that provides brief & quick audio messages to visually impaired persons based on neural networks & neural learning [79]. The proposed technique consists of 2 modules. These are Intelligent Navigation Module (that uses Ultrasonic sensors, compass, Arduino Studio & Arduino SDK) and Face Recognition Module (uses smartphone camera, Artificial Neural system, and voice enabled interface). The system provides an accuracy of 90% for face recognition & 95% for obstacle detection. But it works only for static faces. Integration with IoT can make it more effective.

S. Chinchole (2017) et al. presents a low-cost stick that uses the concept of artificial intelligence to detect obstacles for visually impaired persons [80]. It uses a smartphone camera, Bluetooth & several sensors for the perception of user environment. The system was successful in performing the task of obstacle recognition, obstacle detection & independent navigation. Beep sound is produced as a warning when any obstacle comes out of the safe distance set in the system. Hands-free assistance is required as hands of the user are always occupied due to smartphone holding.

Muneshwara (2017) et al. builds a portable product, which is worn as a cap by visually impaired users [81]. Raspberry Pi processes the obstacles data' & inform the users through headphones. The device is simple & robust. The special point about this device is that it is also helpful for the persons with other disabilities such as legs. The paper also discusses about the advantages & disadvantages of Electronic Travelling Aids (ETAs) being used by persons with disability. The device can be paired with GPS for improved detection of obstacles & to analyze the environment more properly. Audio Feedback can be provided in regional languages and accuracy can be improved by using high level cameras.

Rabia Jafri (2016) et al. presents a depth based obstacle detection system to help visually impaired users navigate in indoor environments [82]. The system is utilizing Google Project Tango Tablet Development Kit along with processors (NVIDIA Tegra K1) and sensors such as infrared based depth sensor and ambient light sensor. The application uses computer vision techniques and is based on cutting edge technology. The other hardware includes processor (NVIDIA Tegra K1 with 192CUDA cores), accelerometer, barometer, compass, GPS and gyroscope. The system is real-time, affordable, aesthetically acceptable and mobile assistive stand-alone application that helps users in unfamiliar situations. Errors in data & noise were observed in point cloud scans. It only detects obstacles, but doesn't identify them.

Daniel Koester (2016) proposes an approach for detecting zebra crossings in aerial images by using geospatial database, which will help in the navigation of visually impaired persons [83]. The framework naturally takes in an appearance model from accessible geospatial information for an analyzed region. The feature recognition algorithms such as HOG, LBPH are used in combination with SVM classifier on different sets of data. This leads to the formation of efficient datasets, which can be further used for building navigational systems for blind users. Practical application of such a guidance system, based on this approach is required for both local & urban areas.

Mocanu(2016) et al. suggests a wearable assistive device that uses the ultrasonic sensors, mobile camera & machine learning techniques (SVM Support Vector Machines) to identify objects for visually impaired objects [92]. Munoz et al. proposes an indoor staircase detection assistive system for visually impaired based on RGB-D camera & SVM based multi-classifier in [84]. The system observed an F-score of 82% & an accuracy of more than 90%. The system does not give accurate results for some classes of objects such as bicycles. Also, it does not provide navigational information, which is necessary for a user to reach specific location. Enhancing features such as face detection could be used to improve performance.

Parra (2015) et al. reviews all the published proposals that uses sensors like the accelerometer, gyroscope or light, multimedia sensor [85]. The design & deployments of such proposals in making applications for visually impaired especially elderly people, such as AAL (Ambient Assisted Living) & e-Health, is shown here. The collected information is grouped into several categories & compared. There is a need to develop such systems that have both microphone & camera in them.

Shripad Bhatlawande (2014) et al. has proposed a wearable assistive system for helping visually impaired individuals in navigation by using the combination of camera & ultrasonic sensor [86]. A user understands his environment by using waist-belt & bracelet along with WhiteCane. The waist-belt is made up of fabric & Velcro material, having battery & camera attached to it. The manufacturing cost of the system is $300. In order to test the reactions of users towards the system, System Capability & Utility Score (SCU) was calculated & it was observed that using WhiteCane, the score was 20.93, while using the prototype, the score was 26.20. It should also include Object categorization. System needs to be made portable. Testing in large sample space is required.

Dunai (2014) describes a new system named CASBliP(Cognitive Aid System for blind persons) based on artificial vision, that uses acoustic sounds & helps blind users while walking or travelling [87]. The initial part of the paper presents a review on Electronic Travel Aid Systems (ETAs), which are classified into 3 categories as, Input Interface (ultrasound,GPS,laser & artificial vision), Processing Interface (contains techniques & software required for processing information), Output Interface (to give output to the user). The paper discusses about 2 under development prototypes:

- TANIA (Tactic Acoustical Navigational & information Retrieval) – uses MTx inertial sensors and
- SWAN (System for Wearable Audio Navigation) – uses 4 cameras & light sensors.

The objects are detected within the area of 5 to 15m & the user is warned. White Cane users were highly satisfied with this prototype. Heavy wearable helmet is a major drawback of this prototype.

Fuzzy logic, the subset of AI has also been used extensively in this field.

Jin-Hee Lee (2014) et al. proposes a wearable assistive system for visually impaired persons by utilizing Camera, GPS receiver, magnetic compass & multiple ultrasonic sensors [88]. All the data taken by these inputs is sent to the embedded computer. This paper presents 2 modules of navigation system. One is Indoor navigation system & other is Outdoor Navigation system. By using magnetic compass & GPS receiver, the proposed system shows accuracy of 55%. System shows inaccurate results if the user walks faster, thus the system only fits the environment that has fixed obstacles. Also, the system should be lightweight.

Hotaka Takizawa (2013) et al. proposes a novel system for helping visually impaired persons detect objects in the environment. The system is implemented on Cane. The kinect has 3-axis accelerometer, infrared sensor and RGB camera [89]. It uses depth data and 3D computer vision techniques along with White cane, Keypad type, controller and tactile device. It recognizes 3d objects in lesser time than normal WhiteCane and provides only brief & necessary information to the user. Prototype size is too big & can cause fatigue, so downsizing of the system is necessary. System is not executed in real-time.

Pundlik (2013) et al. developed a real time collision detection system that uses body mounted camera & gyro-sensors [90]. The system uses videos made by camera & computes sparse optical flow, uses gyro-sensors to predict & issue warnings and estimates collision risk based on motion estimates. This system has been implemented using generic laptop as well as on embedded OMAP-3 compatible platform. This approach is successful in estimation of collision risk for obstacles. Out of 4 test sequences, the proposed technique had false rate of 2.05% & 2.56% in sequence 1 & 2 resp. Collision warnings can be refined for better risk estimation Also, using the concept of positional tracking can improve performance.

Brian F. G. Katz (2012) et al. presents a wearable architecture of Navigation Assisted by artificial VIsion and GNSS (NAVI) - head and backpack, for helping visually impaired users in navigation purposes [91]. The system is based on Global Positioning System (GPS sensor), 2 head mounted cameras and BumbleBee stereoscopic camera. The prototype is build using real-time embedded vision algorithms, fusion algorithms and bio-inspired vision along with laptop, ANGEO GPS, XSens orientation tracker, headphones, microphone, and a notebook computer. High precision geolocalization is achieved. It allows to user to select routes on pedestrians. 3D synthesis of relative location can be more helpful. This purpose can also be served by white canes, guide dogs.

Amit Kumar (2011) et al. presents a wearable navigation aid to help blind persons in their travelling by using USB camera along with ultrasonic sensors [92]. Face detection and cloth texture analysis is used to identify human faces. The system is composed of sonar, USB camera and eBox 2300™ Embedded System. It detects obstacles up to 300cm & humans within 120cm & uses beep sound. The accuracy of 95.45% is achieved. It is easy to carry, small, lightweight & convenient to user. User needs to carry eBox 2300™ along with sensors having weight of 500gm.

Angin (2010) et al. presents a traffic light detector as an initial component of context aware model [93]. The approach is based on available resources by Cloud computing suppliers & location specific resources present on internet. The aim of this approach is to build a system that has limited dependence on infrastructure. The experiments done using this approach shows that there is a need to build robust obstacle detection system. Camera mounting position is still an issue that needs to be addressed.

Critical Challenges:

Certain challenges faced while using sensors along with cameras are as:

Objects should be categorized so that they can be effectively detected and informed to blind user. But Object categorization is missing in some systems. Some techniques work only for static objects such as faces, etc. In most of the smartphone based systems, hands of the user are always occupied due to smartphone. Hence, hands-free assistance is required. System shows inaccurate results if the user walks faster, thus the system only fits the environment that has fixed obstacles. The size of prototype becomes too large on combining camera and sensors together (such as eBox 2300™). This can cause fatigue, so downsizing of the system is necessary. Camera mounting position is still an issue that needs to be addressed in most cases. A central server should be developed to allow more services through IoT. The unfortunate situations such as failed obstacle detection cases should be addressed. Heavy wearable helmet is a major drawback in some prototypes. In some cases, the proposed technique doesn't detect all the obstacles in the image. This may be due to the large sized obstacles and needs an adjustment of the system, which is difficult for blind user. Some systems do not give accurate results for some classes of objects such as bicycles. Errors in data and noise are observed in point cloud scans. Some systems only detect obstacles, but do not identify (classify) them. This purpose can also be served by white canes, guide dogs. Thus, it is difficult to motivate users to use new technology systems.

Future Directions:

Inclusion of GPS system into this type of frameworks will help guardians of blind person to know their exact location at any time. Frameworks should be extended to recognize faces. All systems need to be portable so that they can operate at all places. Collision warnings need to be refined for better risk estimation. Using the concept of positional tracking through GPS can improve system's performance and analyze the environment more properly. Real-time performance of such systems can be improved by using better shape detection algorithms and also detecting different colors. IoT can be embedded into such systems to make them more effective. Practical application of such guidance system is required for both local & urban areas. Audio Feedback can be provided in regional languages also. Accuracy can be improved by using high level cameras (HD). 3D synthesis of relative location is helpful for object classification and detection. Solar batteries can be used for the improvement of autonomy & sustainability of smart cane

2.4 Others

- ***RGB-D based:***

Kailun Yang (2018) et al. proposed an effective wearable framework that is composed of smart glasses & path-finder (waist-worn) by using RGB-D sensor to guide visually impaired persons in detecting obstacles [94]. The proposed system aims to achieve 2 goals i.e. providing Long-term traversability to blind users and detecting Low-lying obstacles. Navigation system can be improved by making it achieve higher perception levels & offering more independence to its users.

Jinqiang Bai (2017) et al. presents a low-cost and novel Electronic Travel Aid (ETA) in the form of smart glasses based on RGB-D sensors for visually impaired persons [95]. The system acquires depth information through depth sensor (RGB-D), which comprises of CMOS (Complementary Metal Oxide Semiconductor) image sensor. An accuracy of 98.93% is observed without using ultrasonic sensor with frosted glass, but shows inaccurate results with pure transparent glass. The system produces promising results in comparison to WhiteCane, by informing user through beep sound in crowded areas such as supermarkets.

W. C. SIMÕES (2016) et al. presents an audio assistive system based on visual markers, Ultrasonic sensors & Camera for blind persons [96]. It consists of a pair of glasses with RGB Camera & Ultrasonic sensors & a low cost mini-PC is used for storing database & Haar Cascade classifier. It was observed that an accuracy of 94.92% obtained in the recognition of markers & 98.33% in detection of obstacles. The system needs many improvements such as low-light detection and it should allow different languages for people of different regions. Better camera (Infrared Camera) should be used.

Vítor Filipe (2016) et al. proposes a real-time navigation system to help visually impaired individuals avoid obstacles on their path by using Microsoft Kinect sensor and accruing RGB-D images of the object [97]. It uses visual recognition of markers, RGB-D images, depth information, C# programming and neural networks in coordination with FANN, an open source library NyARToolklit. Proper detection of wall-mounted markers within the range of 1-4m & vertical field in range of 0.8-4m in front of user is observed. The system is not portable, so it is difficult for the user to carry it. Sometimes the system yields false results, which needs to be improved by using NFT markers. Also, there is no need of such a system as blinds themselves follow path along walls.

Bing Li (2016) at al. presents a novel wearable navigation system ISANA, based on depth sensor (RGB-D) & cameras for visually impaired persons [98]. The framework incorporates an indoor map editor & Tango device app on multiple modules. It also supports multi-floor navigation by defining graphs connections between floors, stairs, escalators or elevators. The system does not detect dynamic obstacles. Also, it should focus on complete environment understanding.

Hoon Lee (2016) et al. presented an indoor navigational application based on RGB-D camera & IMU sensors [99]. Real-time ego motion estimation (both sparse features and dense point clouds), mapping, path planning & smartphone form the basis of this system. In order to attain real-time frame estimation, FOVIS (Fast Odometry from VISion) is used. The proposed method provides much accurate results in terms of errors on an average of 0.88m on 13.93m trajectory. The comparison of the system with white cane shows progress of about 57% over cane. Inaccurate results were obtained in some cases due to severely blur images. Also, further plans are being made to adapt real time image based localization algorithm. It is observed that few places are being visited multiple times by a user.

Huy-Hieu Pham (2016) et al. presents a wearable support system for visually impaired individuals to help them detect obstacles in the indoor environment based on Kinect sensor and RGB-D 3D-image processing [100]. The system is comprised of personal computer (PC) and Tongue Display Unit (TDU). An accuracy of 90.69% is observed. It detects 4 types of obstacles- walls, floor, door & stairs by measuring distance between user & obstacles. No satisfactory performance is observed while detecting downstairs. Also, the kinect sensor does not detect things in case of strong lightning, which can be resolved by using combination of color & depth information. High Execution time can be reduced by using fusion of 4 algorithms & applying probabilistic approaches.

Aladren (2016) et al. presents a NAVI (Navigational Assistance for Visually Impaired) based on RGB-D camera, its range & visual information [101]. A range sensor provides depth information & differentiates between wild terrain & solid obstacles. The range camera is worn on neck & the laptop is carried in backpack. Real-life implementation of the system implies a precision of 99% & recall of 95%. But it does not work in direct sunlight. Also, it can accurately measure distance up to 3.5m only. These limitations can be improved by using better color segmentation & floor segmentation techniques.

Perez-Yus (2016) et al. presents a wearable method for detecting stairs based on chest-mounted **RGB-D Camera** for visually impaired persons [102]. 3d point cloud is computed by sensor & depth images are retrieved. The paper deals with detecting staircases in indoor environments. On comparing the results of proposed technique with other techniques, it was observed that proposed system has 0% False Positive (FP) & False Negatives (FN). The system should be extended for outdoor environments as well. Also, it should also include information such as count of stairs & color of the obstacles.

M.Poggi & S.Mattoccia (2016) proposes a technique based on 3d computer vision & deep learning techniques to guide the visually impaired users [103]. RGB-D Sensors sense images & embedded CPU board processes them & deep learning techniques are used to categorize the detected obstacles. The proposed technique has an accuracy of 98% in obstacle detection & an accuracy of 72% in object categorization. The system needs to be trained on larger datasets in order to improve its categorization capability.

Wang (2014) et al. developed a framework based on RGB-D (Red, Green, Blue & depth) images to detect pedestrians & crosswalks [104]. At first, Hough Transform is applied to extract features based on RGB channels and then the depth transform is used to identify stairs, crosswalks & pedestrians. The identification of stairs going up or down is also done along with the measurement of distance between user's camera & stairs. The system attained accuracy of more than 90% in the identification of crosswalks, stairs & pedestrians. This technique can be improved to detect several types of obstacles & from different projections.

Critical Challenges:

Some challenges being faced by individuals using systems based on RGB-D sensor are listed as below:

Some depth-based systems are non-portable and cannot be carried by the user. Low-light detection is a problem for many systems. Better camera such as Infrared Camera should be used for systems such as smart glasses. Prediction of dynamic obstacles is also required along with static obstacles and the system should focus on complete environment understanding, rather than just focusing on big obstacles in an image. Inaccurate results were obtained in some cases due to severe blur images. Some RGB-D based systems do not work in direct sunlight. NAVI system can accurately measure distance up to 3.5m only. Systems do not give satisfactory performance while detecting downstairs and upstairs.

Future Directions:

The further plans need to be made to adapt real-time image based localization algorithms as few places are being visited multiple times by a user. Some limitations can be improved by using better color segmentation and floor segmentation techniques. Kinect sensor does not detect in case of strong lightning. It can be resolved by using combination color and depth information. High execution times can be reduced by using fusion of 4 algorithms & applying probabilistic approaches on it. The systems should be extended for outdoor environments as well. Also including information such as count of number of stairs and color information is required. The system needs to be trained on larger datasets in order to improve its categorization capability. This technique can be improved to detect several types of obstacles and from different projections. False results can be improved by using NFT markers.

- **RFID Based:**

Chumkamon (2008) et al. builds a blind navigation system for Indoor environment using RFID tags [105]. The system uses RFID tags to store location information, user's destination place & a routing server to measure user's current location from destination by using GPRS. The specialty of the system lies in the fact that it cannot be used by blind persons only, but also tourists, or fire fighters to enter a room full of smoke. The system shows promising results. The proposed device operates on rechargeable battery of 9V (6 hrs.). There are some delay problems such as communication delay due to GPRS modem and voice delay due to file transfer delay from MMC module. These problems can be improved by adding some common words to ROM and preloading them.

Mathankumar (2013) et al. proposed a framework that gives direction to visually impaired users to recognize and buy their items in the grocery store without anybody's help [106]. The system uses RFID for identification of products and audio instructions are used to assist them further inside supermarket, thereby eliminating queuing headaches. Zigbee transceiver is used for sending & receiving information leading to formation of convenient environment for blind users. The technique needs to be built on portable device along with trolley. Also, there is a need of ultrasonic sensors to avoid collisions among blind users in a supermarket.

Tsirmpas (2015) et al. presents a navigation system for visually impaired elderly individuals in [107] in helping them navigate indoor environments. An RFID-based model of an indoor navigation framework, having able to navigate a sightless disabled senior person with safety in a natural real-time environment, is presented. More specifically a "mapping" process by interpreting the blueprints of a building is proposed along with an innovative localization and obstacle avoidance algorithm. In addition a proper antenna circuit is built so as to enhance the properties of the proposed framework. 99% success rate is not considered efficient due to other resource limitations. The system needs many improvements, taking into account the limitations of time & human resources and should be able to accommodate different scenarios multiple times.

Kumar Yelamarthi (2010) used Robots to build navigation system to detect obstacles for visually impaired users [108]. The input is given through Ultrasonic & Infrared sensors & output through speakers & vibrating motors. The concepts of RFID reader, GPS & analog are used in building the prototype. The pilot study of the result shows effectiveness of the system. The time to reach certain destination is different every time the system is operated & is unpredictable. This loosens the interest of user & demands attention towards resolving the technique.

Domingo (**2012)** provides an overview of usage of IoT in the field of Obstacle detection for visually impaired persons [109]. He also proposed architecture based on RFID databases. Benefits of using IoT & different scenarios & challenges being faced by visually impaired persons is highlighted here. The proposed framework is divided into 3 layers as Perception, Network and Application layer. Various challenges represented in this paper provide scope the researchers working in this field.

Rosen Ivanov (2010) developed a low cost indoor navigation system based on technology of mobiles, NFC (Near Field Communication), Java Program& a low cost RFID [110]. It enables users to imagine the map of a room & stores this info in RFID tags in WBXML format. The audio messages are recorded in RFID tags in AMR format and build a voice enabled guidance system for visually impaired users. This application has many advantages such as low cost, easily accessible, simple, user-friendly, audio-enabled, & many more. The mean time to complete the task of finding some room is 136s at 1.5km/hr. Navigational data must be adjusted if the client moves away from the path between two reference focuses or get lost. This can be improved by using a mobile phone that supports electronic compass and accelerometer.

M. Nassih (2012) et al. develops an obstacle recognition system for visually impaired people based on RFID and also gives overview of RFID based techniques used in this field [111]. The paper presents how DGPS (Differential Global Positioning System) has lacked in localizing people and objects and mentions the rise of techniques using RFID. The proposed system uses RFID along with very traditional cane equipped with Braille & builds smart canes. It is difficult to implement this system.

Critical Challenges:

Several challenges being faced by using RFID based systems are discussed below:

Communication delay is observed in some systems due to GPRS modem. The voice delay is seen due to file transfer delay from MMC module. The time to reach certain destination is different every time the system is operated & is unpredictable. This loosens the interest of user & demands attention towards resolving the technique. Difficult implementation of RFID based systems is also a common issue.

Future Directions:

Different types of delays can be improved by adding some common words to ROM & preloading them. The systems using RFID techniques need to be built on portable device along with trolley. There is a need of ultrasonic sensors to avoid collisions among blind users in a supermarket. Navigational data must be adjusted if the client moves away from the path between two reference focuses or get lost. This can be improved by using a mobile phone that supports electronic compass and accelerometer.

3 EVALUATION CRITERIA

Evaluation is an endeavor to appraise the quality of proposed technique. It is important to evaluate techniques because it becomes easier to decide the suitable one among many works. Also, the user gets to know how the existing work can be improved based on certain parameters discussed below & it leads to further expansion of research in that area. There are many metrics to evaluate obstacle detection based techniques. Some of them are listed below:

Null Hypotheses is a general assumption about anything. Testing of Null Hypotheses is done to accept it or reject it. A contrasting statement to null hypotheses is called as Alternate Hypotheses. There are 2 types of errors called as Type 1 & Type 2. Rejecting correct Null Hypotheses leads to Type 1 Error, which is also called False Positive (**FP**). False Positives rate (FPR) is the extent of existence of certain condition, which actually doesn't exists. False Negatives rate **(FNR**) is the extent of absence of certain condition, which actually exists. True Positives rate (**TPR)** is the extent of real positives that have been correctly identified. True Negatives rate **(TNR**) is the extent of real negatives that have been correctly identified. Sensitivity, also known as Recall is defined as:

no. of TP/no. of (TP + FN)

and Specificity is the no. of TN/ no. of (TN + FP). Precision is the quality of being completely correct and is defined as:

$$TP/\,(TP\ +\ FP)$$

Accuracy is the nearness of the measured value to the expected value.

While there are many criteria's as discussed above to check the efficiency of the proposed techniques for obstacle detection for blind persons, we have evaluated few techniques on the basis of accuracy observed in them as shown in Fig. 2, Fig. 3, Fig. 4 and Fig. 5.

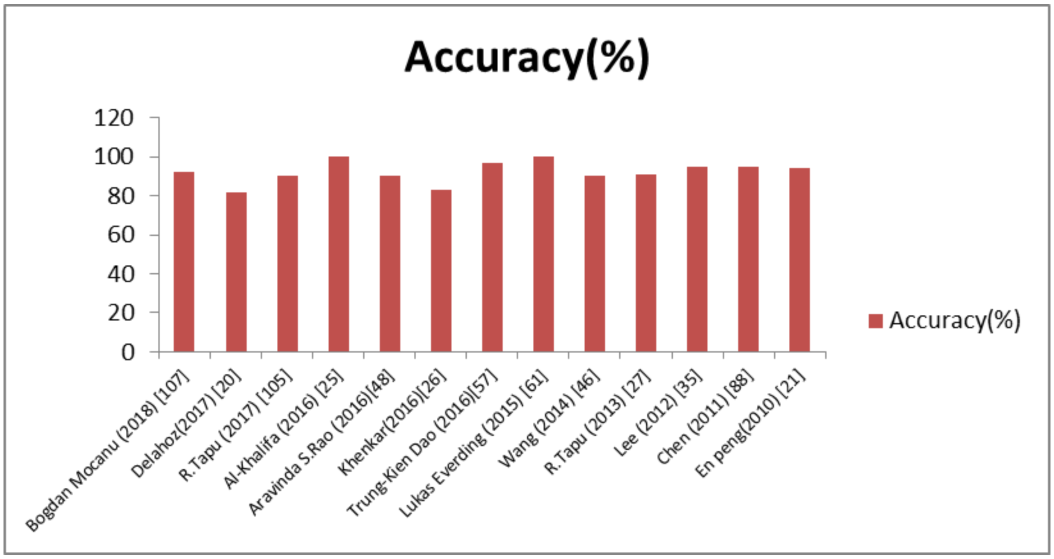

Fig. 2 Percentage-wise accuracy evaluation of different techniques based on using camera for taking input.

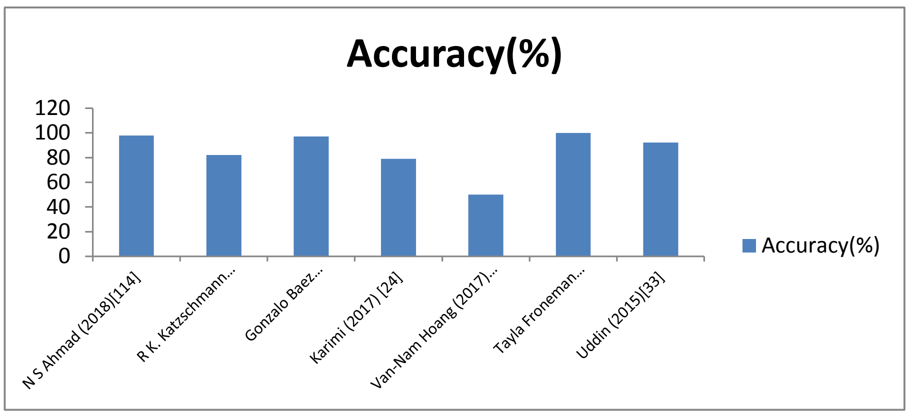

Fig. 3 Percentage-wise accuracy evaluation of different techniques based on using Sensors for taking input

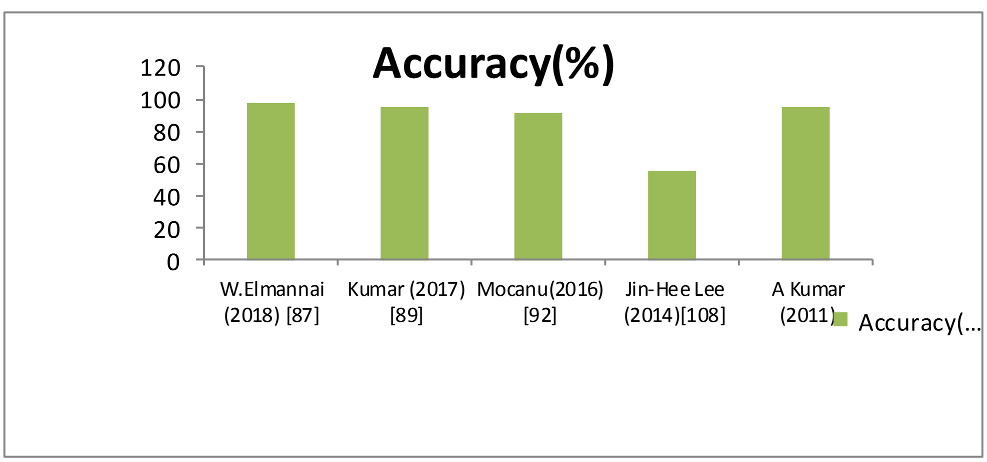

Fig. 4 Percentage- wise accuracy evaluation of different techniques based on the fusion of Camera & sensors

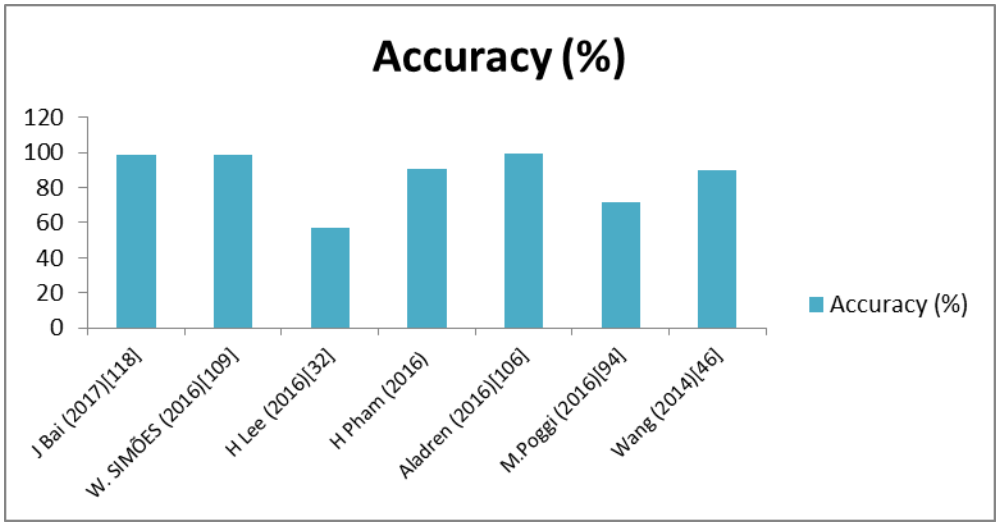

Fig. 5 Percentage- wise accuracy evaluation of different techniques based on RGB-D Camera sensors

4 SUMMARY

In this paper, several technologies used for detecting obstacles for blind persons have been reviewed. The advantages and disadvantages of previous work have been studied thoroughly along with their critical challenges and future directions. The analysis and comparison of several techniques have been done, which may serve as research Gaps for upcoming researches in this field.

After reviewing many papers on this work, it is observed that major improvements are required in existing systems, so that they can operate accurately in crowded areas such as supermarkets, hospitals, airports etc. Also, some techniques yield accurate results but takes more time during execution, thereby making the systems unfit for real-time situations. Different combination and placements of sensors along with user's learning curve will provide research platform in making different assistive tools for Visually Impaired (VI) users. Motivating blind users towards new technology itself impose a big challenge. This paper will help in the ongoing research on this topic.

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REFERENCES

[1] Whitmarsh, L. "The Benefits of Guide Dog Ownership." (2005): 27-42.
[2] "Dogs Monthly." Great British Dog Survey 2016: 1-28.
[3] What Type of Cane Should I Use?" n.d. American Foundation for the Blind: Leading the Vision Loss Community. [Online] http://www.visionaware.org/info/everyday-living/essential-skills.
[4] Eugene A. Bourquin, Robert Wall Emerson, Dona Sauerburger, and Janet Barlow. "The Effect of the Color of a Long Cane Used by Individuals Who Are Visually Impaired on the Yielding Behavior of Drivers." Journal of Visual Impairment & Blindness (2017): 401-410.
[5] Do Ngoc Hung, Vo Minh-Thanh, Nguyen Minh-Triet, Quoc Luong Huy, Viet Trinh Cuong. "Design and Implementation of Smart Cane for Visually Impaired People." *6th International Conference on the Development of Biomedical Engineering in Vietnam* (BME6). Vietnam: Springer, Singapore, 2017. 249-254.
[6] Sung Yeon Kim, Ki Joon Kim, S. Shyam Sundar, Frank Biocca. "Electronic Cane for Visually Impaired Persons: Empirical Examination of Its Usability and Effectiveness." Human Centric Technology and Service in Smart Space (2012): 71-76.
[7] Kozak, Roman. ""Virtual Cane" for the Blind, Powered by Arduino and Android." 2014. www.romanakozak.com. [Online] https://www.romanakozak.com/virtual-cane/
[8] Sonda Ammar Bouhamed, Jihen Frikha Eleuch, Imen Khanfir Kallel. "New electronic cane for visually impaired people for obstacle detection and recognition." *IEEE International Conference on Vehicular Electronics and Safety* (ICVES 2012). Istanbul, Turkey: IEEE, 2012.
[9] VARSHINI, G.PRIYA. "SMART MOBILITY STICK." International Journal of Scientific & Engineering Research 6.10 (2015): 89-94.
[10] Rupert R A Bourne*, Seth R Flaxman*, Tasanee Braithwaite, Maria V Cicinelli, Aditi Das, Jost B Jonas, Jill Keeffe, John H Kempen, Janet Leasher,Hans Limburg, Kovin Naidoo, Konrad Pesudovs, Serge Resnikoff, Alex Silvester, Gretchen A Stevens, Nina Tahhan,. "Magnitude, temporal trends, and projections of the global prevalence of blindness and distance and near vision impairment: a systematic review and meta-analysis." The Lancet Global Health 5.9 (2017): e888-e897.
[11] Kirsty Williamson, Steve Wright, Don Schauder, Amanda Bow. "The Internet for the Blind and Visually Impaired." Journal of Computer-Mediated Communication 7.1 (2001).
[12] Tella Adeyinka, James Abedayo Ayeni, and Olukemi Titilola Oleniyi. "Assessment of Information Seeking Behaviour of Physically Challenged Students in Selected Nigerian Tertiary Institutions." Journal of Balkan Libraries Union 5.2 (2017): 24-33.

[13] Kirsty Williamson, Don Schauder, Louise Stockfield, Steve Wright & Amanda Bow. "The role of the internet for people with disabilities: issues of access and equity for public libraries." The Australian Library Journal (2001): 157-174.

[14] Winkler, Timo Götzelmann and Klaus. "SmartTactMaps: a smartphone-based approach to support blind persons in exploring tactile maps." PETRA '15 *Proceedings of the 8th ACM International Conference on PErvasive Technologies* Related to Assistive Environments. Corfu, Greece: ACM, 2015.

[15] Nicoletta Noceti, Luca Giuliani, Joan Sosa-Garciá, Luca Brayda, Andrea Trucco, Francesca Odone. "Designing audio-visual tools to support multisensory disabilities." Recognition, Computer Vision and Pattern. Multimodal Behaviour Analysis in the Wild. Academic Press Elsevier, 2019. 79-102.

[16] Dr.P.C.Jain, K.P.Vijaygopalan. RFID and Wireless Sensor Networks. CDAC Noida: Proceedings of ASCNT, 2010.

[17] Domingo, Mari Carmen. "An overview of the Internet of Things for people with disabilities." Journal of Network and Computer Applications 35 (2011): 584-596.

[18] Alberto Rodríguez, J. Javier Yebes, Pablo F. Alcantarilla, Luis M. Bergasa, Javier Almazán and Andrés Cela. "Assisting the Visually Impaired: Obstacle Detection and Warning System by Acoustic Feedback." SENSORS New Trends towards Automatic Vehicle Control and Perception –Systems (2012): 17476-17496.

[19] Senem Kursun Bahadir, Vladan Koncar, Fatma Kalaoglu. "Wearable obstacle detection system fully integrated to textile structures for visually impaired people." Sensors and Actuators A: Physical 179 (2012): 297-311.

[20] Adriano Mancini, Emanuele Frontoni, Primo Zingaretti,. "Mechatronic System to Help Visually Impaired Users During Walking and Running." IEEE Transactions on Intelligent Transportation Systems 19.2 (2018): 649 - 660.

[21] Bogdan Mocanu, Ruxandra Tapu, Titus Zaharia. "DEEP-SEE FACE: A Mobile Face Recognition System Dedicated to Visually Impaired People." IEEE Access 6 (2018): 51975 - 51985.

[22] Nawin Somyat, Teepakorn Wongsansukjaroen, Wuttinan Longjaroen, Songyot Nakariyakul. "NavTU: Android Navigation App for Thai People with Visual Impairments." 2018 *10th International Conference on Knowledge and Smart Technology* (KST). Chiang Mai, Thailand: IEEE, 2018.

[23] A. Jindal, N. Aggarwal, S. Gupta. "An Obstacle Detection Method for Visually Impaired Persons by Ground Plane Removal Using Speeded-Up Robust Features and Gray Level Co-Occurrence Matrix." Pattern Recognition and Image Analysis 28.2 (2018): 288-300.

[24] Simon Meers, Koren Ward. "A Vision System for Providing 3D Perception of the Environment via Transcutaneous Electro-Neural Stimulation." *Proceedings of the Eighth International Conference on Information Visualisation* (IV'04). IEEE, 2004.

[25] Yueng Delahoz, Miguel A. Labrador. "A Real-Time Smartphone-Based Floor Detection System For The Visually Impaired." 2017 IEEE International Symposium on Medical Measurements and Applications (MeMeA). Rochester, MN, USA: IEEE, 2017.

[26] Ruxandra Tapu, Bogdan Mocanu, Titus Zaharia. "DEEP-SEE: Joint Object Detection, Tracking and Recognition with Application to Visually Impaired Navigational Assistance." Sensors 17.11 (2017).

[27] Rumin Zhang, Wenyi Wang, Liaoyuan Zeng, Jianwen Chen. "A Real-Time Obstacle Detection Algorithm for the Visually Impaired Using Binocular Camera." 2017 *International Conference in Communications, Signal Processing, and Systems.* Springer, Singapore, 2018. 1412-1419.

[28] Kang, Mun-Cheon, et al. "An enhanced obstacle avoidance method for the visually impaired using deformable grid." IEEE Transactions on Consumer Electronics 63.2 (2017): 169 - 177.

[29] He Zhang, Cang Ye. "An Indoor Wayfinding System based on Geometric Features Aided Graph SLAM for the Visually Impaired." IEEE Transactions on Neural Systems and Rehabilitation Engineering 25.9 (2017): 1592 - 1604.

[30] Kin Leong Ho, Paul Newman. "Loop closure detection in SLAM by combining visual and spatial appearance." Robotics and Autonomous Systems 54.9 (2006): 740-749.

[31] Trung-Kien Dao, Thanh-Hai Tran, Thi-Lan Le, Hai Vu, Viet-Tung Nguyen, Dang-Khoa Mac, Ngoc-Diep Do, Thanh-Thuy Pham. "Indoor navigation assistance system for visually impaired people using multimodal technologies." *14th International Conference on Control, Automation, Robotics and Vision* (ICARCV). Phuket, Thailand: IEEE, 2016.

[32] Kit Yan Chan, Ulrich Engelke, Nimsiri Abhayasinghe. "An edge detection framework conjoining with IMU data for assisting indoor navigation of visually impaired persons." Expert Systems With Applications (2016).

[33] Gaurav Kumar, Pradeep Kumar Bhatia. "A Detailed Review of Feature Extraction in Image Processing Systems." *Fourth International Conference on Advanced Computing & Communication Technologies*. Rohtak, India: IEEE, 2014.

[34] Shoroog Khenkar, Hanan Alsulaiman, Shahad Ismail, Alaa Fairaq, Salma Kammoun Jarraya, and Hanêne Ben-Abdallah. "ENVISION: Assisted Navigation of Visually Impaired Smartphone Users." Procedia Computer Science (2016): 128-135.

[35] Mohane, Vikky and Chetan Gode. "Object recognition for blind people using portable camera." World Conference on Futuristic Trends in Research and Innovation for Social Welfare (Startup Conclave). Coimbatore, India: IEEE, 2016.

[36] Aravinda S. Rao, Jayavardhana Gubbi, Marimuthu Palaniswami and Elaine Wong. "A vision-based system to detect potholes and uneven surfaces for assisting blind people." IEEE *International Conference on Communications* (ICC). Kuala Lumpur, Malaysia: IEEE, 2016.

[37] Lukas Everding, Lennart Walger, Viviane S. Ghaderi, and Jorg Conradt. "A Mobility Device for the Blind with Improved vertical resolution using dynamic vision sensors." IEEE *18th International Conference on e-Health Networking, Applications and Services* (Healthcom). Munich, Germany: IEEE, 2015.

[38] R. TAPU, B. MOCANU and T. ZAHARIA. "Real time static/dynamic obstacle detection for visually impaired persons." 2014 IEEE International Conference on Consumer Electronics (ICCE). Las Vegas, NV, USA: IEEE, 2014. 394-395.

[39] R. Gnana Praveen, Roy P Paily. "Blind Navigation Assistance for Visually Impaired Based on Local Depth Hypothesis from a Single Image." International Conference on DESIGN AND MANUFACTURING, IConDM 2013. ELSEVIER, 2013. 351 – 360.

[40] Ruxandra Tapu, Bogdan Mocanu, Andrei Bursuc, Titus Zaharia. "A Smartphone-Based Obstacle Detection and Classification System for Assisting Visually Impaired People." *International Conference on Computer Vision Workshop*s. Sydney, NSW, Australia: IEEE, 2013. 444-451.

[41] Ali Israr, Olivier Bau, Seung-Chan Kim, Ivan Poupyrev. "Tactile feedback on flat surfaces for the visually impaired." CHI EA '12 CHI '12 Extended Abstracts on Human Factors in Computing Systems. Austin, Texas, USA: ACM New York, NY, USA ©2012, 2012. 1571-1576.

[42] Lee, Chia-Hsiang, Yu-Chi Su and Liang-Gee Chen. "An intelligent depth-based obstacle detection system for visually-impaired aid applications." *13th International Workshop on Image Analysis for Multimedia Interactive Services*. Dublin, Ireland: IEEE, 2012.

[43] D. K. Liyanage, M. U. S. Perera. "Optical flow based obstacle avoidance for the visually impaired." 2012 IEEE Business, Engineering & Industrial Applications Colloquium (BEIAC). Kuala Lumpur, Malaysia: IEEE, 2012. 284-289.

[44] Saeid Fazli, Hajar Mohammadi Dehnavi, Payman Moallem. "A robust negative obstacle detection method using seed-growing and dynamic programming for visually-impaired/blind persons." Optical Review 18.6 (2011): 415–422.

[45] Chieh-Li Chen, Yan-Fa Liao, Chung-Li Tai. "Image-to-MIDI mapping based on dynamic fuzzy color segmentation for visually impaired people." Pattern Recognition Letters 32.4 (2014): 549-560.

[46] Paulo Costa, Hugo Fernandes, Verónica Vasconcelos, Paulo Coelho, oão BarrosoLeontios Hadjileontiadis. "Landmarks Detection to Assist the Navigation of Visually Impaired People." Human-Computer Interaction. Towards Mobile and Intelligent Interaction Environments 6763 (2011): 293-300.

[47] En Peng, Patrick Peursum, Ling Li & Svetha Venkatesh. "A Smartphone-Based Obstacle Sensor for the Visually Impaired." *International Conference on Ubiquitous Intelligence and Computing. Lecture Notes in Computer Scienc*e. Springer, Berlin, Heidelberg, 2010. 590-604.

[48] NUR SYAZREEN AHMAD, NG LAI BOON and PATRICK GOH. "Challenged, Multi-Sensor Obstacle Detection System Via Model-Based State-Feedback Control in Smart Cane Design for the Visually." IEEE Access. vol. 6 (2018): 64182-64192.

[49] Robert K. Katzschmann, Brandon Araki, Daniela Rus. "Safe Local Navigation for Visually Impaired Users With a Time-of-Flight and Haptic Feedback Device." IEEE Transactions on Neural Systems and Rehabilitation Engineering 26.3 (2018): 583 - 593.

[50] Rajesh Kannan Megalingam, Souraj Vishnu, Vishnu Sasikumar, Sajikumar Sreekumar. "Autonomous Path Guiding Robot for Visually Impaired People." Cognitive Informatics and Soft Computing.Advances in Intelligent Systems and Computing,. Springer, Singapore, August 2018. 257-266.

[51] Gonzalo Baez, Pablo Prieto and Fernando A Auat Cheein. "3D vision-based handheld system for visually impaired people: preliminary results on echo-localization using structured light sensors." Biomedical Physics & Engineering Express 4.4 (2018).

[52] Nabila Shahnaz Khan, Shusmoy Kundu, Sazid Al Ahsan, Moumita Sarker, Muhammad *Nazrul Islam. "An Assistive System of Walking for Visually Impaired." 4th International Conference on Computer, Communication, Chemical, Material and Electronic Engineering* (IC4ME2-2018). Bangladesh: IEEE, 2018.

[53] Tayla Froneman, Dawie van den Heever, Kiran Dellimore. "Development of a wearable support system to aid the visually impaired in independent mobilization and navigation." 2017 39th *Annual International Conference of the IEEE Engineering in Medicine and Biology Society* (EMBC). Seogwipo, South Korea: IEEE, 2017.

[54] Van-Nam Hoang, Thanh-Huong Nguyen, Thi-Lan Le, Thanh-Hai Tran, Tan-Phu Vuong, Nicolas Vuillerme. "Obstacle detection and warning system for visually impaired people based on electrode matrix and mobile Kinect." Vietnam Journal of Computer Science 4.2 (2017): 71-83.

[55] Shahu, Desar, et al. "A low-cost mobility monitoring system for visually impaired users." International Conference on Smart Systems and Technologies (SST). Osijek, Croatia: IEEE, 2017.

[56] Bruno Andò, Salvatore Baglio, Cristian O. Lombardo, Vincenzo Marletta. "Smart Multisensor Strategies for Indoor Localization." Mobility of Visually Impaired People (2017): 585-595.

[57] A.Karimi, PedramGharani & Hassan. "Context-aware obstacle detection for navigation by visually impaired." Image and Vision computing 64 (2017): 103-115.

[58] david Zhou, yonggao yang, and hanbing yan. "A Smart Virtual Eye- Mobile System for the Visually Impaired." IEEE Potentials 35.6 (2016): 13-20.

[59] Jee-Eun Kim, Masahiro Bessho, Shinsuke Kobayashi, Noboru Koshizuka, Ken Sakamura. "Navigating Visually Impaired Travelers in a Large Train Station Using Smartphone and Bluetooth Low Energy." SAC *'16 Proceedings of the 31st Annual ACM Symposium on Applied Computing.* Pisa, Italy: ACM New York,USA, 2016. 604-611.

[60] Chaitali Kishor Lakde, Dr. Prakash S. Prasad. "Navigation system for visually impaired people." 2015 *International Conference on Computation of Power, Energy, Information and Communication* (ICCPEIC). Chennai, India: IEEE, 2015. 93-98.

[61] 82B. Ando, S. Baglio, V. Marletta, A. Valastro. "A Haptic Solution to Assist Visually Impaired in Mobility Tasks." : IEEE Transactions on Human-Machine Systems 45.5 (2015): 641 - 646.

[62] Md. Ashraf Uddin, Ashraful Hug Suny. "Shortest Path Finding and Obstacle Detection for Visually Impaired People Using Smart Phone." 2nd *Int'l Conf. on Electrical Engineering and Information & Communication Technology* (ICEEICT) 2015. Dhaka, Bangladesh: IEEE, May 2015.

[63] he Wang, Hong Liu, Xiangdong Wang, Yueliang Qian. "Segment and Label Indoor Scene Based on RGB-D for the Visually Impaired." *International Conference on*

Multimedia Modeling, MMM 2014. Springer, Cham, 2014. 449-460.
[64] Cheng-Lung Lee, Chih-Yung Chen, Peng-Cheng Sung, Shih-Yi Lu. "Assessment of a simple obstacle detection device for the visually impaired." Applied Ergonomics 45.4 (2013).
[65] Haruyama, Madoka Nakajima and Shinichiro. "New indoor navigation system for visually impaired people using visible light communication." EURASIP Journal on Wireless Communications and Networking (2013).
[66] Wai L. Khoo, Eric L. Seidel, and Zhigang Zhu. "Designing a Virtual Environment to Evaluate Multimodal Sensors for Assisting the Visually Impaired." ICCHP 2012.Computers Helping People with Special Needs 7383 (2012): 573-580.
[67] B. Mustapha, A. Zayegh, R.K. Begg. "Multiple sensors based obstacle detection system." *4th International Conference on Intelligent and Advanced Systems* (ICIAS2012). Kuala Lumpur, Malaysia: IEEE, 2012. 562-566.
[68] Hotaka Takizawa, Shotaro Yamaguchi, Mayumi Aoyagi, Nobuo Ezaki and Shinji Mizuno. "Kinect cane: Object recognition aids for the visually impaired." 2013 *6th International Conference on Human System Interactions* (HSI). Sopot, Poland: IEEE, 2013. 473-478.
[69] Gallagher, Thomas, et al. "Indoor positioning system based on sensor fusion for the Blind and Visually Impaired." *2012 International Conference on Indoor Positioning and Indoor Navigation*, 13-15th November 2012. Sydney, NSW, Australia: IEEE, 2012.
[70] Mounir Bousbia-Salah, Maamar Bettayeb, Allal Larbi. "A Navigation Aid for Blind People." Journal of Intelligent & Robotic Systems SPRINGER 64.3-4 (2011): 387–400.
[71] Bruno Andò, Salvatore Baglio, Salvatore La Malfa, and Vincenzo Marletta. "A Sensing Architecture for Mutual User-Environment Awareness Case of Study: A Mobility Aid for the Visually Impaired." IEEE Sensors Journal 11.3 (2011): 634-640.
[72] A. M. Kassim, M. H. Jamaluddin, M. R. Yaacob, N. S. N. Anwar, Z. M. Sani and A. Noordin. "Design and Development of MY 2nd EYE for Visually Impaired Person." IEEE Symposium on Industrial Electronics and Applications (ISIEA2011). Langkawi, Malaysia: IEEE, September 25-28, 2011. 700-703.
[73] Okayasu, Mitsuhiro. "Newly developed walking apparatus for identification of obstructions by visually impaired people." Journal of Mechanical Science and Technology 24.6 (2010).
[74] Maria Cornacchia, Burak Kakillioglu, Yu Zheng, Senem Velipasalar. "Deep Learning-Based Obstacle Detection and Classification With Portable Uncalibrated Patterned Light." IEEE Sensors Journal 18.20 (2018): 8416 - 8425.0.
[75] M.Vanitha, A. Rajiv, K. Elangovan, S.Vinoth Kumar. "A Smart walking stick for visually impaired using Raspberry pi." International Journal of Pure and Applied Mathematics 119.16 (2018): 3485-3490.
[76] Wafa M. Elmannai, Khaled M. Elleithy. "A Novel Obstacle Avoidance System for Guiding the visually impaired through the use of fuzzy control logic." 15th *IEEE Annual Consumer Communications & Networking Conference* (CCNC). Las Vegas, NV, USA: IEEE, 2018.
[77] Daniel-Robert Chebat, Vanessa Harrar, Ron Kupers, Shachar Maidenbaum, Amir Amedi and Maurice Ptito. "Sensory Substitution and the Neural Correlates of Navigation in Blindness." Mobility of Visually Impaired People (2017): 167-200.
[78] Alejandro R. García Ramirez, Israel González-Carrascor, Gustavo Henrique Jasper, Amarilys Lima Lopez, Jose Luis Lopez-Cuadrado, Angel García-Crespo. "Towards Human Smart Cities: Internet of Things for sensory impaired individuals." Computing 99.1 (2017): 107-126.
[79] Priyan Malarvizhi Kumar, Ushadevi Gandhi1, R. Varatharajan, Gunasekaran Manogaran, Jidhesh R., Thanjai Vadivel. "Intelligent face recognition and navigation system using neural learning for smart security in Internet of Things." Cluster Computing (2017): 1-12.
[80] Sandesh Chinchole, Samir Patel. "Artificial intelligence and sensors based assistive system for the visually impaired people." International Conference on Intelligent Sustainable Systems (ICISS). Palladam, India: IEEE, 2017. 16-19.
[81] Mr. Muneshwara M S, Dr. Lokesh A, Mrs. Swetha M S3, Dr. Thunagmani M. "Ultrasonic and Image Mapped Path Finder for the Blind People in the Real Time System." IEEE International Conference on Power, Control, Signals and Instrumentation Engineering (ICPCSI-2017). Chennai, India, sept 2017. 964-969.
[82] Rabia Jafri, Marwa Mahmoud Khan. "Obstacle Detection and Avoidance for the Visually Impaired in Indoors Environments Using Google's Project Tango Device." ICCHP 2016: Computers Helping People with Special Needs 9759 (2016): 179-185.
[83] Daniel Koester, Björn Lunt, Rainer Stiefelhagen. "Zebra Crossing Detection from Aerial Imagery Across Countries." *International Conference on Computers Helping People with Special Needs*. Springer, Cham, 2016. 27-34.
[84] Rai Munoz, Xuejian Rong, Yingli Tian. "DEPTH-AWARE INDOOR STAIRCASE DETECTION AND RECOGNITION FOR THE VISUALLY IMPAIRED." *IEEE International Conference on Multimedia & Expo Workshops (ICMEW*). Seattle, WA, USA: IEEE, 2016 . 1-6.
[85] Lorena Parra, Sandra Sendra, José Miguel Jiménez, Jaime Lloret. "Multimedia sensors embedded in smartphones for ambient assisted living and e-health." Multimedia Tools and Applications 21 (2015): 13271–13297.
[86] Shripad Bhatlawande, Amar Sunkari, Manjunatha Mahadevappa, Jayanta Mukhopadhyay, Mukul Biswas, Debabrata Das & Somedeb Gupta (2014): Electronic Bracelet and Vision Enabled Waist-belt for Mobility of Visually Impaired People, Assistive Technology: The Official Journal of RESNA, DOI: 10.1080/10400435.2014.915896.
[87] Larisa Dunai Dunai, Ismael Lengua Lengua, Ignacio Tortajada, Fernando Brusola Simon. "Obstacle detectors for visually impaired people." 2014 International Conference on Optimization of Electrical and Electronic Equipment (OPTIM). Bran, Romania: IEEE, 2014. 809-816.
[88] Lee, JH. Kim, D. & Shin, BS. Multimed Tools Appl (2016). Springer US. HYPERLINK "Multimedia Tools and Applications" Multimedia Tools and Applications 75: 15275. https://doi.org/10.1007/s11042-014-2385-4.
[89] Hotaka Takizawa, Shotaro Yamaguchi, Mayumi Aoyagi, Nobuo Ezaki and Shinji Mizuno. "Kinect cane: Object recognition aids for the visually impaired." 2013 *6th*

International Conference on Human System Interactions (HSI). Sopot, Poland: IEEE, 2013. 473-478.
[90] Shrinivas Pundlik, Matteo Tomasi, Gang Luo. "Collision Detection for Visually Impaired from a Body-Mounted Camera." 2013 *IEEE Conference on Computer Vision and Pattern Recognition Workshops*. IEEE, 2013. 41-47.
[91] Brian F. G. Katz, Slim Kammoun, Gae ¨tan Parseihian, Olivier Gutierrez, Adrien Brilhault , Malika Auvray , Philippe Truillet, Michel Denis, Simon Thorpe, Christophe Jouffrais,Simon Thorpe ,Christophe Jouffrais. "NAVIG: augmented reality guidance system for the visually impaired." Virtual Reality 16.4 (2012): 253-269.
[92] Amit Kumar, Rusha Patra, M. Manjunatha, J. Mukhopadhyay and A. K. Majumdar. "An Electronic Travel Aid for Navigation of Visually Impaired Persons." *Third International Conference on Communication Systems and Networks* (COMSNETS 2011). Bangalore, India: IEEE, 2011.
[93] Pelin Angin, Bharat Bhargava, Sumi Helal. "A Mobile-Cloud Collaborative Traffic Lights Detector for Blind Navigation*." Eleventh International Conference on Mobile Data Management*. Kansas City, MO, USA: IEEE, 2010. 396-401.
[94] Kailun Yang, Kaiwei Wang, Luis M. Bergasa, Eduardo Romera, Weijian Hu, Dongming Sun, Junwei Sun, Ruiqi Cheng, Tianxue Chen, Elena López. Sensors (Basel) 2018 May; 18(5): 1506. Published online 2018 May 10. doi: 10.3390/s18051506.
[95] Bai, Jinqiang, et al. "Smart guiding glasses for visually impaired people in indoor environment." IEEE Transactions on Consumer Electronics 63.3 (2017): 258 - 266.
[96] W. C. S. S. Simões, V. F. de Lucena. "Blind user wearable audio assistance for indoor navigation based on visual markers and ultrasonic obstacle detection." 2016 *IEEE International Conference on Consumer Electronics* (ICCE). Las Vegas, NV, USA: IEEE, 2016.
[97] Vítor Filipe, Nuno Faria, Hugo Paredes, Hugo Fernandes, João Barroso. "Assisted Guidance for the Blind Using the Kinect Device." DSAI 2016 *Proceedings of the 7th International Conference on Software Development and Technologies for Enhancing Accessibility and Fighting Info-exclusion*. Vila Real, Portugal: ACM, 2016. 13-19.
[98] Li B., Muñoz J.P., Rong X., Xiao J., Tian Y., Arditi A. (2016) ISANA: Wearable Context-Aware Indoor Assistive Navigation with Obstacle Avoidance for the Blind. In: Hua G., Jégou H. (eds) Computer Vision – ECCV 2016 Workshops. ECCV 2016. Lecture Notes in Computer Science, vol 9914. Springer, Cham.
[99] Young HoonLee, GérardMedioni. "RGB-D camera based wearable navigation system for the visually impaired." Computer Vision and Image Understanding 149 (2016): 3-20.
[100] Huy-Hieu Pham, Thi-Lan Le, Nicolas Vuillerme. "Real-Time Obstacle Detection System in Indoor Environment for the Visually Impaired Using Microsoft Kinect Sensor." Journal of Sensors (2016): 1-13..
[101] A. Aladrén, G. López-Nicolás, Luis Puig, Josechu J. Guerrero. "Navigation Assistance for the Visually Impaired Using RGB-D Sensor With Range Expansion." IEEE Systems Journal 10.3 (2014).
[102] Pérez-Yus A., López-Nicolás G., Guerrero J.J. (2015) Detection and Modelling of Staircases Using a Wearable Depth Sensor. In: Agapito L., Bronstein M., Rother C. (eds) Computer Vision - ECCV 2014 Workshops. ECCV 2014. Lecture Notes in Computer Science, vol. 8927. Springer, Cham.
[103] Matteo Poggi, Stefano Mattoccia. "A Wearable Mobility Aid for the Visually Impaired based on embedded 3D Vision and Deep Learning." IEEE Symposium on Computers and Communication (ISCC). Messina, Italy: IEEE, 2016.
[104] Shuihua Wang, Hangrong Pan, Chenyang Zhang, Yingli Tian. "RGB-D image-based detection of stairs, pedestrian crosswalks and traffic signs." Journal of Visual Communication and Image Representation 25.2 (2014): 263-272.
[105] Sakmongkon Chumkamon, Peranitti Tuvaphanthaphiphat, Phongsak Keeratiwintakorn. "A blind navigation system using RFID for indoor environments." 2008 5th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology. Krabi, Thailand: IEEE, 2008. 765-768).
[106] M. Mathankumar, N.Sugandhi. "A low cost smart shopping facilitator for visually impaired." 2013 I*nternational Conference on Advances in Computing, Communications and Informatics* (ICACCI). Mysore, India: IEEE, 2013. 1088-1092.
[107] Charalampos Tsirmpas, Alexander Rompas, Orsalia Fokou, Dimitris Koutsouris. "An indoor navigation system for visually impaired and elderly people based on Radio Frequency Identification (RFID)." Information Sciences 320 (2015): 288-305.
[108] Kumar Yelamarthi, Daniel Haas, Daniel Nielsen, Shawn Mothersell. "RFID and GPS integrated navigation system for the visually impaired." 2010 *53rd IEEE International Midwest Symposium on Circuits and Systems*. Seattle, WA, USA: IEEE, 2010.
[109] CarmenDomingo, Mari. "An overview of the Internet of Things for people with disabilities." Journal of Network & Computer Applications 35.2 (2012): 584-596.
[110] Ivanov, Rosen. "Indoor navigation system for visually impaired." CompSysTech '10 *Proceedings of the 11th International Conference on Computer Systems and Technologies and Workshop for PhD Students in Computing on International Conference on Computer Systems and Technologie*s. Sofia, Bulgaria: ACM New York, NY, USA, 2010. 143-149.
[111] M. Nassih, I. Cherradi, Y. Maghous, B. Ouriaghli and Y. Salih-Alj. "Obstacles Recognition System for the Blind People Using RFID." *Sixth International Conference on Next Generation Mobile Applications, Services and Technologies*. Paris, France: IEEE, 2012. 60-63.

Preetjot Kaur is currently a PhD research scholar at UIET, Panjab University Chandigarh. She received her M.Tech degree in Computer Engineering from Punjabi University Patiala in 2016. She is a B.Tech in Computer Science Engineering from GNDEC Ludhiana in 2014. Ms. Kaur has a teaching experience of 2.5yrs as an Assistant Professor in the School of Computer Science Engineering at Chitkara University Punjab. She has published high impact factor technical papers in International Journals. Also, she has presented her research work at various conferences of

National and International repute. Her current research interests include Digital Image Processing, Deep Learning, and Cognitive radios.

Roopali Garg is presently serving as Associate Professor, Panjab University, Chandigarh. She is former Coordinator of Department of IT, UIET, Panjab University, Chandigarh. She is PhD in Electronics and Communication Engineering. She did her M.Tech in Electronics and B.Tech in Electronics & Electrical Communication Engg from PEC University of Technology, Chandigarh. She has been in academics for 15 years and is armed with rich teaching and research experience. Dr. Garg has over 60 technical papers published in indexed high impact-factor International Journals and International Conferences. She has authored two books, namely Polarization Mode Dispersion and Digital Electronics.
In addition she has several book chapters to her credit.Her focused research area is Wireless communication, Optical communication, and Cognitive Radio. She is in active research by supervising PhD and M.tech research scholars. She has guided nearly 20 M.Tech Thesis. In addition she has delivered talks and lectures at various conferences, workshops at different institutes. She has reviewed many research papers for varied reputed journals. She is an active Life Member of several International and National technical organizations like ISTE, IETE, IEE. She has been awarded Administrator's Gold medal by Chandigarh Administration in 2000 for her supreme performance in curricular, co- curricular and extra- curricular activities.