Design and Development of an Autonomous Smart Stick Framework for Assisting Visually Impaired People

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Abstract. Visually Impaired People (VIP) face numerous obstacles and troubles like physiological, psychological, social, and economic outcomes in their daily life. This work brings an intelligent and comprehensive stick framework aimed to assist VIP and navigate where to go. To increase sensing mechanisms wireless network is used to communicate between system components, enhance battery life. Global Positioning System (GPS) with General Packet Radio Service (GPRS)/Global System for Mobile communication (GSM) plays a vital role to get the location of visually impaired people with a short message service to rescuer them and adding buzzer timer to activate a buzzer in a specific duration with control buttons. It has a high range of obstacle detection, meticulous information conveyed, endowed sensor alert notification, sustainable power supply, short and multimedia messaging service (MMS), face and voice recognition, wireless system component connection, and its foldability gave the smart stick easy to keep and comfort for the VIP when they hold in addition to its robustness.

Keywords: GPS · GPRS · GSM · Navigation · Smart stick · VIP

1 Introduction

Visually Impaired People (VIP) performing many activities by navigation and mobility. To navigate unknown places, VIP brings family members or friends for support. Thus, they are relying on their families for mobility and financial support [1, 2]. Exploiting state-of-the-art technology for improving people's everyday life is always a compelling challenge, especially when the people in question are impaired in some way. In recent years, the rapid evolution of color acquisition devices and computing hardware and their affordability have spawned several solutions to assist blind people in indoor and outdoor mobility. Most of the edge-breaking technologies have been applied to assist or train them. Assistive technology permits people with disabilities to accomplish daily tasks and assists them in communication, education, work, and recreational activities. In general, it helps to attain larger independence and enhance their overall quality of life [3]. From completely different helpful technologies accessible, a special focus was placed on people who enhance the quality of VIP [4] as a result of "Vision is that the

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most significant a part of human physiology as eighty three of data person gets from the atmosphere is via sight" [5]. In 2018, World Health Organization (WHO) estimates that there square measure 1.3 billion individuals within the world with visual impairment, thirty six million of that square measure blind, 188.5 million individuals have a gentle vision impairment, 217 million have moderate to severe vision impairment and 826 million individuals support visual modality impairment however now adays in 2021 this number rise to 2.2 billion [6]. Blindness affects 11.7 million people in South Asia, 6.2 million people in East Asia, 3.5 million people in South East Asia, more than 4% of the population in parts of sub-Saharan Africa and less than 0.5% of the population of Western Europe [7]. Therefore, this study helps the VIP walking confidently guide by the smart stick that communicates with the user through voice alert and vibration [8].

In this research work we proposed a system to provide a smart walking stick to the VIP that enables them to navigate the indoor and outdoor environment, move safely, and passed lots of hurdles which faced in their daily life without any assist of the sighted people. The proposed solution is very cost-effective, user-friendly, ease of use navigational aid, sizeable and comfortable to carry along. Also, it can be used to analyze the surrounding of a person without any human intervention. As a methodology, we applied Design Science Research (DSR) and the system has five main units (i.e., sensing, communication, recognition, alerting, and notification) with controlling button and power supply unit and developed using APL, Prolog, Python, Arduino, SWI-Prolog, PyCharm, and Proteus.

As it has been discussed in the results and discussions section the objective of the work is achieved in a wide range of obstacle detection, by conveyed adequate information of VIP, sensor alert notification, recognition and messaging, system component connection, and in supplying of sustainable power which used to run the integrated circuit and mad the system functions work properly. This is achieved by the aimed combination of several working sub-systems (i.e., water, holes, flame, ponds, staircase, temperature, location…) makes a time demanding system that monitors the environmental scenario of static and dynamic objects and provides necessary feedback forming navigation more precise, safe and secure. We were including some local languages and face recognition system so that several VIP can use this stick to overcome the mobility and navigation problem in daily life and it avail VIP to recognize the person standing in front of him/her and also make it work day and night by using light sensor at the night.

The system has four different output devices which are speech pedagogue, vibrator, buzzer, and torch that area unit accessed assortments relying upon different inputs state. Depending on the distance of the obstacle from the person five zones (i.e., very far (safe) zone, fare zone, middle zone, near zone, very near zone (danger zone) are formed. If obstacles which were small in size and cannot be detected by the Ultrasonic sensor is detected by IR sensor.

If VIP wants to know their current location, they can press the switch assigned for that purpose and audio regarding the current location is heard by the VIP with the help of a speaker. And when VIP is around places like hotels, squares, religious

organizations, universities and schools didn't wait until VIP press the button it told automatically where there is current location and also the VIP wants some help during some emergency, the GPS and GSM modules are successfully operated in sending the location of VIP to caregivers via SMS.

If blind people need any help, they can trigger an emergency button which is mounted on the stick and the GSM sends the location information to the predefined contact numbers. A GPS module will offer the period location of static objects in out of doors navigation which will be mapped via satellite. It also can be used in conjunction with voice feedback that might alert the user once the obstacle was found in its path, employing a combination of GPS and also the web. A voice in practicality can be accustomed to input the destination into the stick and also the stick would be able to chart the trail to the destination from the supply exploitation the shortest path for the VIP to follow. Hence voice output is a great benefit to VIP when it comes to independent mobility. This could also be considered a crude way of giving the VIP a sense of vision. Using smart stick is unquestionable because smart stick for blind people is one of the self-operating robots and that minimizes numerous human labors [9].

To use know-how for the well-being of the society, which includes VIP, is the main motivation of this study. This study noticed that normal VIP sticks used by VIP have certain limitations like detecting water, heat, holes, stairs, distant objects, above knee obstacles, etc. At the same time currently, available sensor-equipped sticks are very costly and unaffordable for most people. This study takes a lot of inputs from disable people and comes up with the idea of design and development of an autonomous obstacle-free path indication and navigation framework for assisting VIP via a foldable smart stick which is an economical sensor-equipped stick capable of assisting VIP to navigate easily. The final design of this study is quite cheaper than existing alternatives and warns the person via vibratory and auditory signals. And also make them navigate directions easily.

2 Related Works

Six types of canes are most commonly used. A popular straight vogue cane is created of fiberglass that is ultra-light, provides legion sensory feedback, and bends slightly if it slides below an automobile or similar obstacle. Cane tips are developed for travel in geographical region areas and farms and a large form of cane tips currently give sander operation and additional sturdiness. Every tip has its execs and cons. Generally, a support cane and an inquiring cane area unit designed otherwise and serve terribly completely different functions. Advances in laptop technologies, intelligent sticks, and up to date developments within the field of wireless communications, together with Wi-Fi, Bluetooth, ZigBee, multi-hop wireless computer network, and therefore the international wireless technologies like GPS, GSM, GPRS, 5G, and satellite systems have created a large array of latest potentialities for today's society. Once these technologies

began to be employed in conjunction with a stick a new smart stick framework emerged and also because of the improvements in technology the conventional sticks are being replaced with smart blind sticks [10, 11]. Thus, researchers aim to design and implement an intelligent and cheap stick with GPS for visually impaired peoples [1].

In [8] a prototype that can detect objects or obstacles in front of users and feeds warning back in the forms of voice messages and vibration is proposed. In this study, the authors recommended that a power supply meter reading could be installed to monitor its power status. A device can also be incorporated to be used during a scenario of very engorged areas and replace Polyvinyl Chloride (PVC) with steel so it will be additional sturdy and sturdy. Also, a buzzer timer may be added that the buzzer can activate at a particular length.

In [12], the proposed system helps to detect obstacles with the use of infrared, ultrasonic, and water sensors. Also, use GPS modules to give positioning and navigating the stick and GSM modules to give notification when the visually impaired peoples feel a threat. The downside of this planned stick is that it will be troublesome to stay as a result of it absolutely was not designed to be foldaway. Also, running this integrated set of hardware needs another to the battery, A Braille device to administer the visually handicapped person associate degree uncomplicated technique to supply the destination address for navigation.

The proposed device was aimed to help the VIP people to move independently in the unfamiliar environment and to navigate with ease by using advanced technology. Majorly these blind sticks were integrated with the ultrasonic sensor along with temperature, water, dump, label, heat sensor, etc. On sensing obstacles, the sensor passes this data to the Micro Controller (MC). The MC then processes this data and calculates the obstacle is close or far and also if water, heat, the dump is there in the path the microcontroller sends a signal to sound a buzzer, vibrate or voice message. However, hasn't a sustainable power source, nothing to describe stick is it easy to keep or not, doesn't show the finest path by calculating data comes from GPS. This study didn't describe multimedia messaging but using GPRS and doesn't have integration of GPS & GSM module to communicate relative caregiver [13, 14].

Today technology is rising daily in several aspects to produce versatile and safe movement for the VIP who strive to live independently by developing smart stick to give personal independence so that they can move from one place to another easily and safely hence the stick has GPS/GSM modules which help the VIP in navigating even unknown areas independently as the same time if the VIP felt too lost they can communicate with their relative or caregiver by sending short SMS including their location. Almost all papers referenced with [15, 16] number majorly give emphasis on the communication part and faced to such limitation like charge capacity of the device, hadn't flame detector sensor to alert them to escape from the fire accidents, range of sensing mechanism, detecting pits, staircase, holes, label sensor and also easiness of the stick to keep.

3 System Model and Methodology

Based on the research goal, this research has adopted Design Science Research Methodology (DSRM) process model as shown Fig. 1.

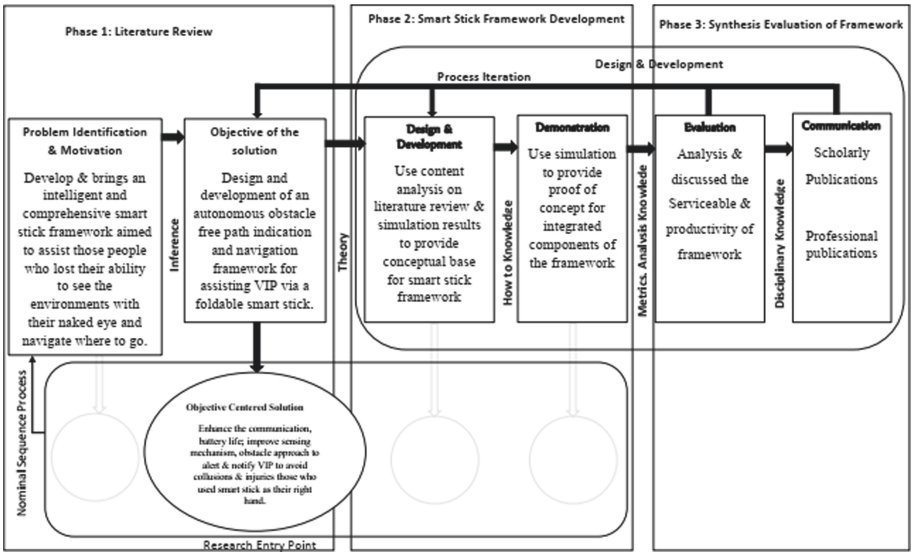

Fig. 1. Research design framework

When an influential person is walking, if any massive obstacles like human, car, animal, tree, and wall appeared ahead of them high-frequency acoustic wave transmitted from ultrasonic sensors, area unit collected across the receiver then theses received waves are going to be sent to the processor in a sort of electrical impulse for the obstacles like holes, stairs or stone that area unit little in size area unit detected exploitation IR detector then the IR detector sends signals to the processor; whereas just in case of the massive obstacle detection passive infrared (PIR) sensor check the motion of the obstacle because human or animal emit heat energy in the form of IR and sending signal to the processor. The processed gives alert the existence of obstacles to VIP using a combination of sound instruction, vibrator or buzzer that helps the VIP to take the right action according to the received notification in order to avoid the possibility of accident or collision occurrences [17]; the overall algorithms of the proposed obstacle detection methodology were illustrated in Fig. 2 and Fig. 3.

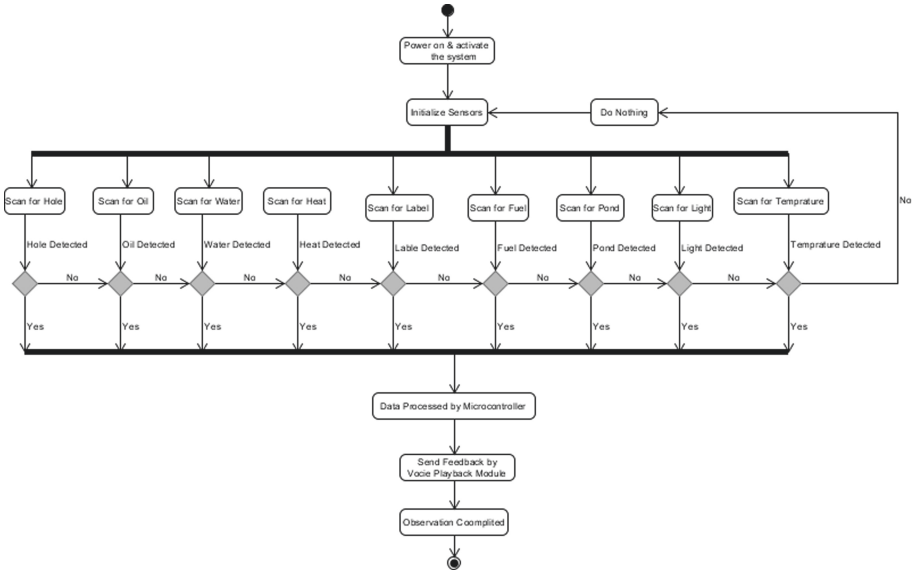

Fig. 2. Small object detection methodology

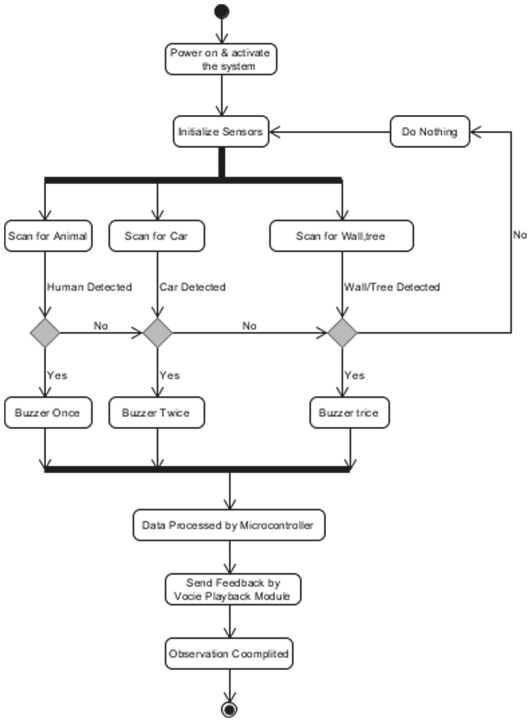

Fig. 3. Large object detection algorithm

The proposed system consists of a camera which is used to capture the face of people around the VIP regularly at an interval of two seconds and send it to the microcontroller. Then the face recognition unit is used to analyze this captured face in the use of morphological analysis. As a producer first chooses a set of training image from any directory under various situations to get the required image whose information is required for training purposes. Secondly the binary images from the original images are found because morphological operations bank solely on the relative ordering of pixel values, not on their numerical values, and particularly suited to the process of binary pictures. Next morphological operations on the training set of images are done to calculate the average intensity value. We also calculate the minimum and maximum values from the set values of the training images. The information is stored for further processing of the face recognition, capture an image of people around VIP then face recognition of the input image are done and newly calculated average intensity value is compared with stored images finally the mostly matched image is used to identify the name of the person [4, 16, 18]. The overall algorithm of the face recognition methodology is illustrated in Fig. 4.

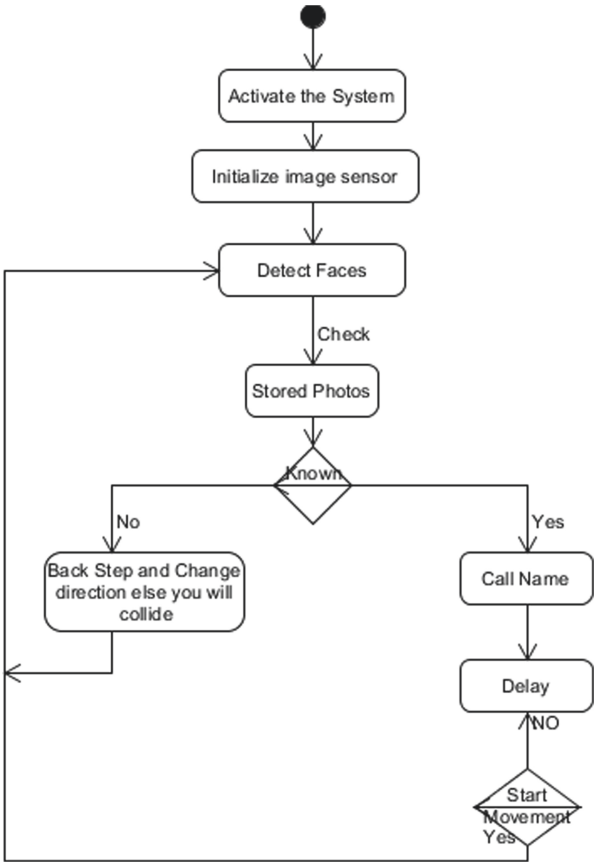

Fig. 4. Face recognition methodology

The GPS tracer is a system that uses the GPS signal to identify the exact location of the vehicle, person, or any other object. It's associated and location information can be sent via a simple text message using GSM/GPRS leading provider of a mobile network. The device offers several advantages some functionalities are the reception of a single location by making a simple phone call to the GPS Tracker which will respond via SMS sending all the information needed to establish its correct localization, latitude, altitude, longitude, speed, degree, satellites, date and time, reception of information about the battery level with the possibility to set/unset the sleep mode (energy saving) and so on. The locator is designed to offer maximum reliability even in extreme conditions, such as high-temperature variation, humidity, moisture and vibration [11]. The GPS module provides a location to the voice module to alert the VIP of his/her destination area. The GPS receiver obtains the data as a whole National Marin Electronics Association

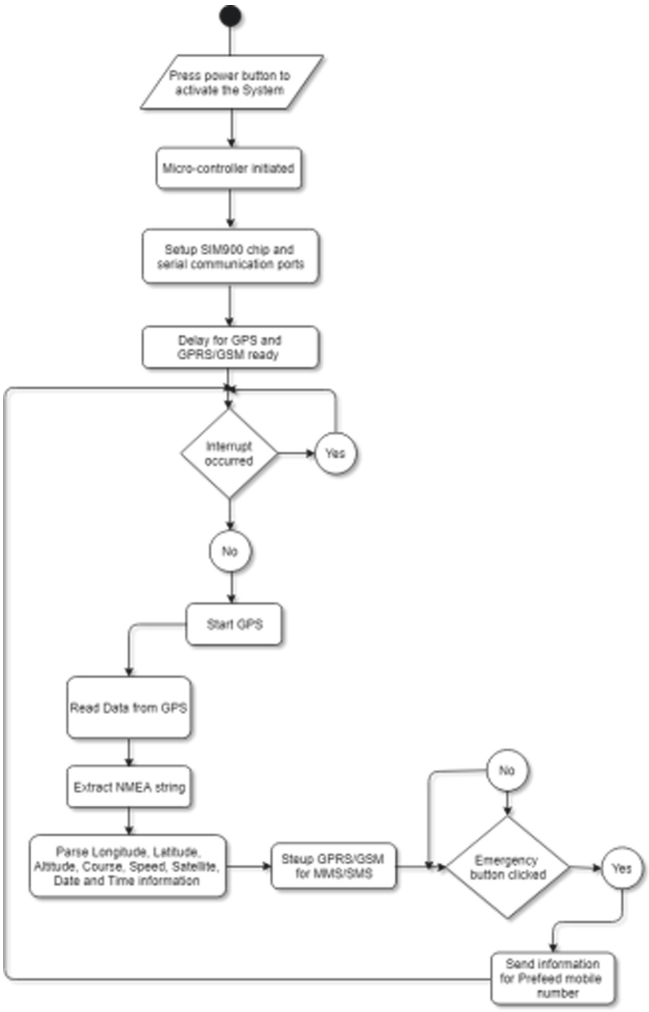

Fig. 5. Location information convoyed methodology

(NMEA) format text here we take latitude, longitude, altitude, degree, speed date, time, and visible satellite using Arduino Tiny GPS library. If the VIP becomes unaware of his/her location, face any difficulties upon pressing the emergency button he/she can send an SMS/MMS to the preferred mobile number [19, 20] as shown in Fig. 5.

3.1 Modeling and Assembly of Foldable Smart Stick

As stated in the above under literature review canes were divide based on purpose into six, foldability into two, and cane tips into four. However, when we came to this designed stick it consists of the most important futures of the canes so it makes it very generic to other canes which were designed. Its length measured 120 cm, the foldability joint found in each 40 cm, the system case which used to hold the system was 40 × 20 cm wider which was found at the center of the stick that means 50 cm was left from the bottom and upper of the system case, it had hand grips that give the VIP comfort and support when it holds the stick, also it had a wheel at the bottom of the stick so it will not get stuck on the cracks in the sidewalk and reduce the error which occurred by the ultrasonic sensor due to cane movement because of this the VIP was not miss-lead and made a decision by corrupted information. The foldability of the stick was helping those VIP to keep the stick easily and we use steel not PVC hence it was enough to support the VIP.

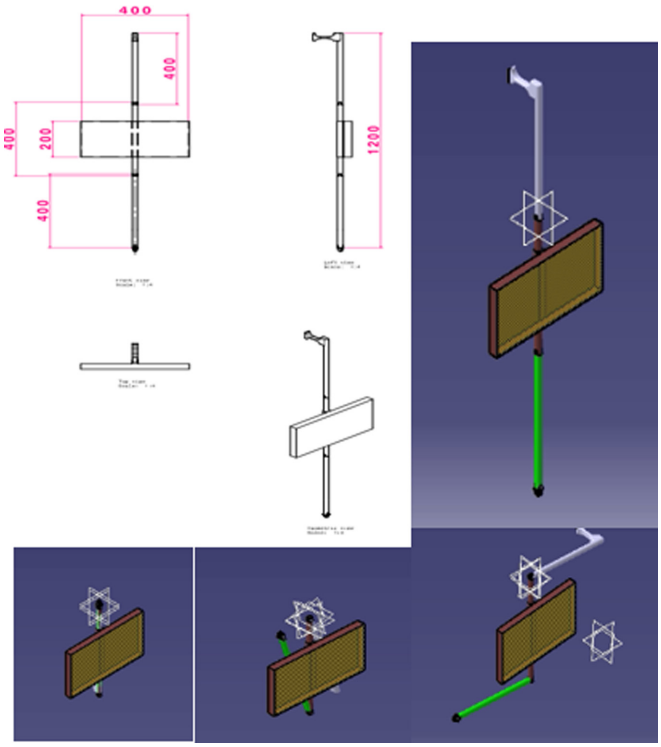

Fig. 6. Modeling and assembling of smart stick framework

4 Autonomous Smart Stick Framework Design

The proposed framework has an Arduino Uno microcontroller which used to control the signals which came from the sensor unit, recognition subsystem, communication unit, control buttons, and also interprets and possessed actions based on the coming signal hence notification sent to the preferred phone number to give information about the current location of the VIP to his/her relatives or caregivers when he/she pressed the emergency button.

The inclusive functions of the system were powered by the rechargeable battery with the solar panel it helps the system to run the integrated circuit properly and works day and night without the failure of power. In order not to spend power the power button used to start when the VIP in need of the Stick else switch off the system it helps to save the power of the rechargeable battery. Via speaker, the system gives the VIP alerts and notifications to warn them not to face obstacles, to take the right path, and to create awareness about his/her environments.

We chose to display time and date from the internet rather than Arduino because the time and date will be incorrect once the Arduino is reset. The date and time have to be compelled to be set once the sketch starts, this may be through a synchronization message from an external time supply like a laptop connected through an interface. While navigation depending on 3G or Wi-Fi to access the intermate and retrieves the map and other information to geographically present your location with the designated route. The general framework is shown in Fig. 7.

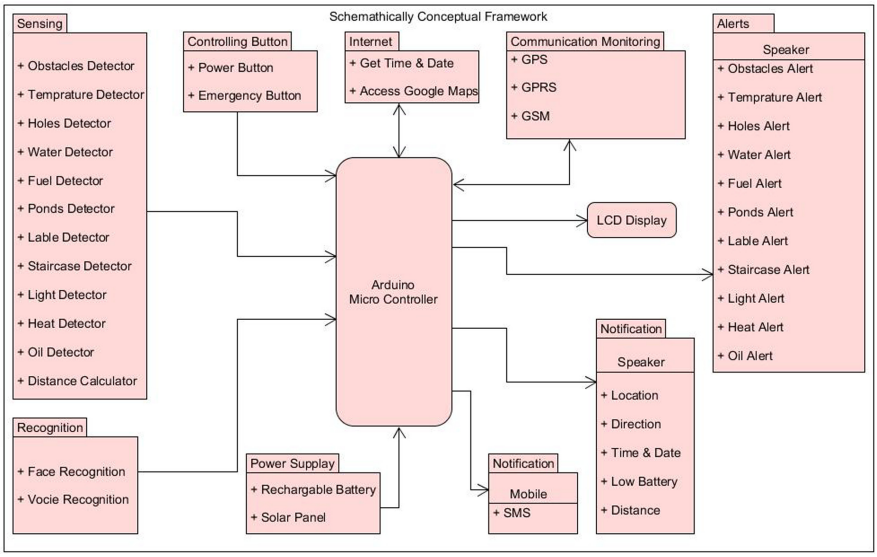

Fig. 7. Schematically representation of an autonomous smart stick

5 Results and Discussions

The experiments had been carried out to evaluate the deliberate Framework. The maximum goal of this looks at turned into to assist VIP to safely-pass amongst obstacles, holes, ponds, and specific hurdles visaged via way of means of them of their existence. The solution evolved is an easy guidance resource for them. The benefit of the gadget lies inside the plain reality that it's going to inspire be a surely inexpensive solution to variation VIP worldwide. The aimed aggregate of many working sub-structures makes a time-disturbing gadget that video display units the environmental state of affairs of static and dynamic items and gives vital remarks forming navigation a number of precise, safe, and secure [15].

The model of the proposed framework consists of an Arduino Uno board interfaced with sensors which used to sense an obstacle's found in the way of the VIP and that creates a challenge to them also interrupt not to achieve their goal, hence to overcome those problems that VIP faced this system included a lot of sensors which used to detect temperature, holes, water, fuel, ponds, label, staircase, light, heat, oil and distance calculator also GPS, GPRS/GSM was part of the framework mainly which used to outdoor navigation and helps the VIP to aware where he/she existed, hotels, schools, square, religious organizations, universities, bus station, etc. He/She can also send SMS and MMS to their relative or caregiver whose phone number was recorded on the system ample or commensurate information was delivered which include longitude, latitude, altitude, speed, degree and time and date which expressed or used to check when the message was received or sent to those who were responsible for the intended VIP.

The stick was designed in such a way that was used to indoor and outdoor navigations it detects obstacle within 0 cm–50 cm (very near), 50 cm–200 cm (near), 200 cm–400 cm–600 cm (moderate), 600 cm–1000 cm (far) and the rest was put under very fare range. The system was simulated successfully. The system also considers if the VIP walks faster than the standard ranges i.e., despite the fact that walking speed can vary considerably depending on numerous components such as height, weight, age, territory, area, load, culture, exertion and well-being, the normal human walking speed is around 5.0 kilometers per hour (km^2/h) or about 1.4 meters per second (m/s) or about 3.1 miles per hour (mph) [21, 22] the output results show that the system can provide the required output notification (warning) to the user as sound and vibration while detecting the obstacles within the range of 0 cm to 1000 cm and also buzzer frequency increases as the obstacle approaches closely.

The simulation shows that the interfacing of the GPS and GPRS/GSM modules was successfully done using Proteus and finding the finest path and showing the route from source to the destination was successfully done using SWI-Prolong applied by the Dijkstra algorithm. Generally, the system was simulated by using Proteus software and SWI-Prolog. The program code was written by using Arduino programing language, Prolog and Phyton (i.e., which applied in face recognition system which was worked by applying morphological segmentation) furthermore the stick included different buttons like the power button, emergency button, etc. and voice recognizer module which used to control overall function of the system with a stable power supply that

helps to run these integrated systems like rechargeable battery integrated with 12 V power supply solar panel.

5.1 Evaluation and Experimentation

The framework was evaluated based on the following criteria which stated below and this framework was excel when we compared with other related works which were done early in terms of obstacle detection range, the information conveyed, sensor alert notification, power supply & foldability, recognition system & foldability, system component connection.

5.1.1 Obstacle Detection Range

Under this section we presented the comparison between this study and other related works based on obstacle detection range as stated in Fig. 8 most of the related works detect obstacles in the maximum range of 4 m; however, this study obstacle detection range exceeds other related works more than twice in detecting obstacles and alerted or gave a notification for those VIP who use the system.

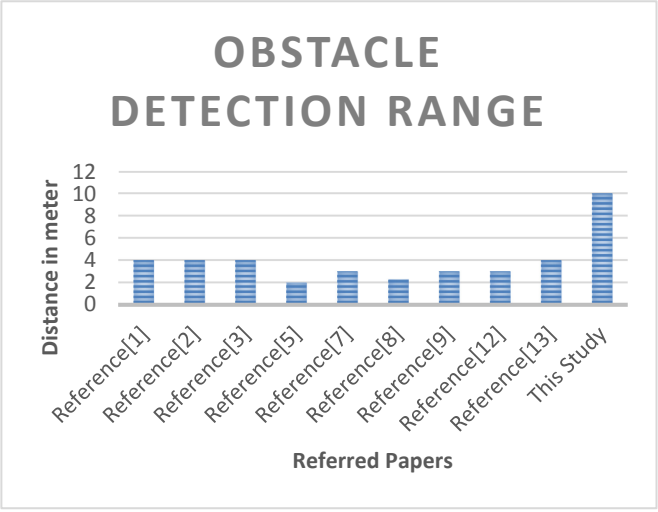

Fig. 8. Obstacle detection range

5.1.2 GPS, GPRS/GSM Information Conveyed

Here in Fig. 9, we were presented with the information conveyed when an accident was occurred the information includes the area of the VIP according to longitude, latitude, and altitude; speed if it was in the moment, date, and time of the message sent to the relative caregiver. Based on this we achieved all these evaluation criteria in comparing other related works which focused or give information only the longitude and latitude and some papers not consider or integrated such modules that helps to conveyed information during an accident and outdoor moment of the VIP.

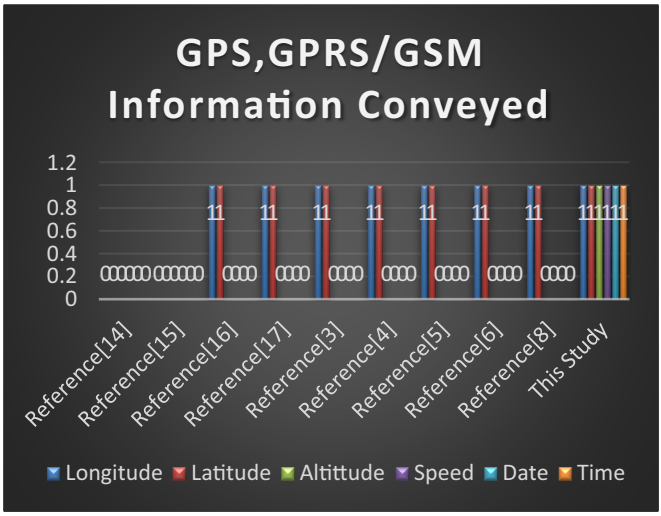

Fig. 9. GPS, GPRS/GSM information conveyed

5.1.3 Sensor Alert Notification

Over here we intended to how this study outshine other studies in case of alerting VIP during their indoor and outdoor moment and navigation as you see in Fig. 10, we took seven evaluation criteria water, fuel, staircase, motion, light, temperature, and hole based on this some related works has not given notification and the rest achieve at max four criteria.

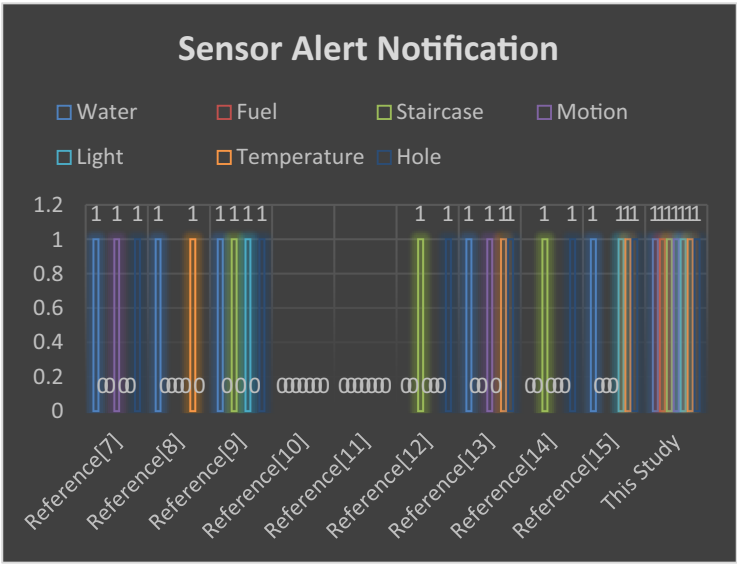

Fig. 10. Sensor alert notifications

5.1.4 Power Supply and Foldability

Under this evaluation criteria we took a look at the backbone of the system which is the power supply and how the stick is smart in accordance with keeping easily this study and other related studies as one can see from Fig. 11 all are not include a solar panel which indicates that they haven't sufficient power supply to run the integrated circuit properly throughout day and night whether in the urban or rural area and aren't foldable so the VIP didn't feel safe when they keep their smart stick; however, in this study, we consider all these things and make the stick more generic following power supply and keeping the stick gives the VIP more comfort than the other smart stick which was made previously.

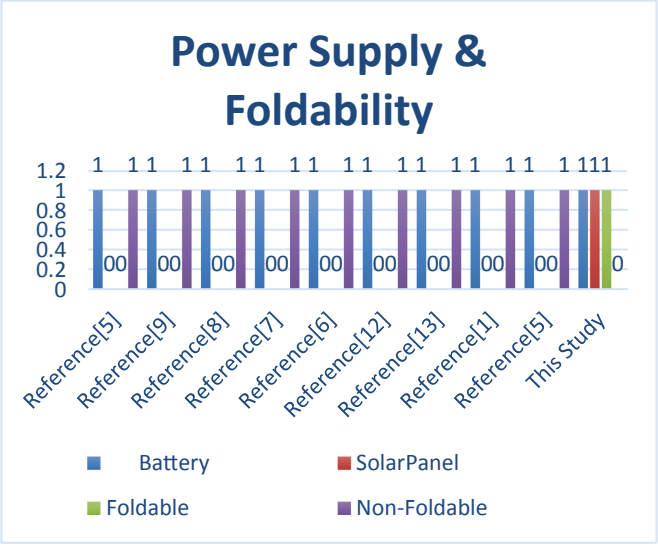

Fig. 11. Power supply and foldability

5.1.5 Recognition System and Messaging

Under Fig. 12, we figured out how the system interacted with VIP through messaging and voice command in addition to recognizing peoples who stand Infront of the VIP and identify who is either known by the VIP or not. Based on this when we evaluated as you see from Fig. 12 some of the related works didn't encompass both of the evaluation criteria that means messaging and recognition system, but some related works include SMS and voice recognition. However, in this study, we include both the messaging and recognition that means voice and face recognition with SMS and MMS hence we use GPRS over GSM which helps to achieve MMS.

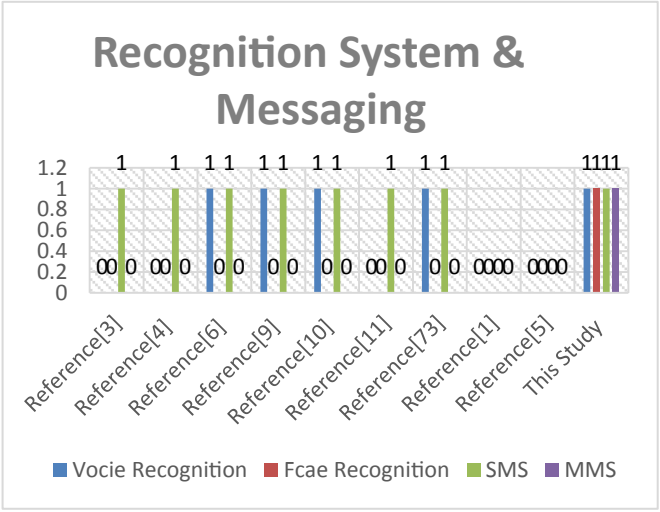

Fig. 12. Recognition system and messaging

5.1.6 System Component Connection

In Fig. 13 evaluated related works and this study based on their component connection did it encompass both wired and wireless connection or not as you see this study possessed both connection types but not the other so using this smart stick is better than the rest which mad previously in different aspects when we connect devices in wirelessly their detection, communication rang also increases and easy to maintain, add or remove components and when we think about foldability using wireless connection became preferred because it didn't oppose in which edge did we bent the stick.

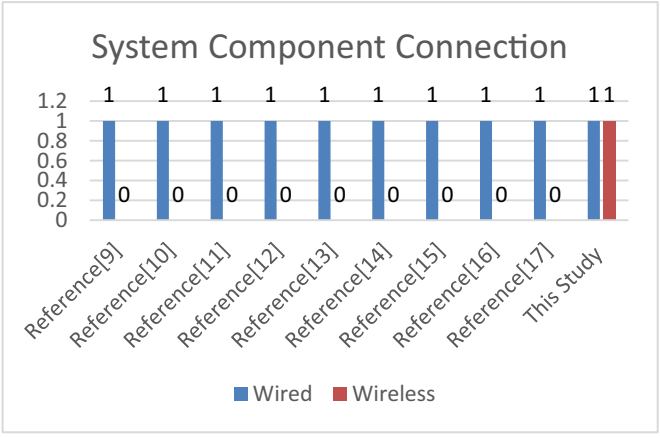

Fig. 13. System component connection

6 Conclusions

Vision is the maximum essential a part of human body structure as 83% of statistics man or women receives from the surroundings is through sight. So, this research work has been done to assist VIP to safely-move among obstacles and hurdles faced by them in their daily life and navigate indoor and outdoor environments without any interface with sighted people. The solution developed is a user-friendly navigational aid for them. The advantage of the system lies in the fact that it can prove to be a very low-cost solution to VIP. The proposed device that monitors the environmental state of affairs of static and dynamic gadgets and presents vital comments forming navigation greater precise, safe, and secure. This could also be considered a crude way of giving the VIP a sense of vision.

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