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A low-cost assistive wheelchair for handicapped & elderly people

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ABSTRACT

In this paper, a mixed control wheelchair (MCW) is presented to overcome problem related to movement and user command for elderly and paralyzed people. The MCW comprises of five individual control blocks, which are fed at the main control unit to provide appropriate control actions. The main feature of this assistive device is that it can navigate by following the eyesight of the user. The proposed MCW can also be controlled using either joystick or voice command or finger movement or through mobile app or a combination of all. This system uses multiple sensor networks to measure the terrain condition, users command and translate it into control action. The proposed control system runs on a Raspberry Pi, which can able to take a proper turn as well as capable to control forward or backward motion. Raspberry Pi, camera module and sensors networks, etc. were all connected into the android mobile system, shortening the physical distance between the disabled person end and the supervisor end and serial communication was used. Multiple-Layer system architecture with outstanding control functions was constructed that uses android mobile interfacing to realize the automatic control and capture videos of the room remotely. It is shown that the users can carry out all essential tasks with the proposed MCW, almost as fast as with the traditional controller. The smart wheelchair can assist elderly people and also improve their quality of life.

1. Introduction

In recent years, researchers have become increasingly interested in the field of rehabilitation. Assistive technology is an emerging area in the current study where some robotic devices can be used to strengthen the ability of people with disabilities or older people to survive in their daily living activities. In general, any assistive device of these categories must be adapted to auxiliary applications in a way that can be easily managed by the user. In fact, the problem is not only with providing high tech devices to people with disabilities and seniors but also developing a system that is able to meet user needs. However, together with the economic considerations with customer satisfaction, the driven wheelchair selection process must include factors such as assessing the physical location of a person, functional capacity and user requirements and other factors. Physical considerations include posture, strength, sensation, visual acuity, perception and power efficiency. The contribution of this article is to design and apply this human-robot-interaction [1] concept to a specific assistive system that allows an individual to increase the autonomy of the entire system by participating in all levels of operation and the system can take care of the physical capabilities and abilities of people. The recent trend of supportive wheelchairs has been widely studied in both academics and industries around the world. However, very few of them have been able to handle customer requirements in real life and together have achieved market success. In 1595 an unknown manufacturer designed a wheelchair for Philips II in Spain. In imitation of this, in 1655, Stephen Farfer, a paralogous watchmaker, built a three-wheeled self-propelled chair, later it is known as wheelchair [2]. Wheelchair design has become increasingly important in the 21st century in combining emerging technologies. Several studies have suggested that assistive wheelchair can bring more easy life for lower limb disable and elderly people. A wide range of wheelchairs such as tilt-in-space [3], elevation and stair-climbing wheelchairs [4,5], are now available. With the advancement of technology, wheelchairs are currently designed to be controlled with a joystick, head gesture or pinch

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and other technologies. There are some assistive wheelchair technologies where it can be controlled through a human–machine HMI control interface. Examples include voice command control [6,7], follow-up movements of the eyes [8], or follow the movements of the tongue [9,10]. In works [11] such as the author addresses a system that controls the chair movement based on voice commands. But their control solutions presented by the authors are extremely expensive. In other research, such as [12], the author proposed a system where the user could control the wheelchair with the movement of his head, where a camera is mounted and it records the movement of the user's head. In another case, the author describes a fancy control interface [13] where the EMG wheelchair controls the electrical activity (Electrography) of the user's muscles. In the workplace [14], the authors used to control in which the user's brain was able to drive the wheelchair by measuring electrical trends produced by EEG (electroencephalography). But in this kind of system, there is plenty of limitation. After analysing the state of the art in interfaces and control systems for assistive wheelchairs, it has realized a lack in the design of control devices and raises many difficulties. This proposed work presents device hardware which capable of being connected to almost all of the wheels as well as all the peripheral on electric wheelchairs by image processing technique. This device implements a simple standard protocol that allows third-party developers to design different control interfaces that work with all the electric wheelchairs. However, with the use of these modern technology wheelchairs, there are concerns about its careful and risk-free environment. Some surveys indicate an increasing number of accidents, which is proportional to the number of devices, especially among older users [15–17]. For this, a secure operation is very important where the user is in control of the time in danger. To overcome this kind of situation we made the architecture of this wheelchair such a way so that it will be a stable condition in all environments and the user can easily control the system.

In the rest of this proposed paper, Section 2 reviews the architecture related to proposed smart wheelchair where all the necessary hardware and software configuration discussed. Method of proposed wheelchair is presented in Section 3. This section describes in detail the specification and requirement of all the required devices as well as how this proposed system is worked. Section 4 describes the Result and Discussion of some experimental work with this proposed system and Section 5 reviews the Conclusion.

2. Architecture

The goal of this proposed work is not just to avoid obstacles, but to identify the way to operate and to assist the user by identifying object decisions related to user preference. The users guided path (operated via a joystick or object detection system) and the wheelchair instantaneous environment (provided from the output of sensors) is used to determine the control signal by sending the wheelchair, and the wheelchair direction and speed are based on the smart Wheel Chair Object detection. Instead, the trick for the suggested task is to automatically pick the object. For a number of applications, the simple modification of the mouse or joystick may be sufficient to facilitate the user with special needs to use a computer or similar device, and many of these products are commonly available. There are many choices for the modified mouse, and customized joysticks also provide an alternate control. Some of the other devices that have been used are steering wheels, thumb mouse, trackball, foot-ball trackball, extra-large joysticks, and mouse with controllable friction. Although these products are very useful in helping people who are unable to use the computer mouse or keyboard, often these are not sufficient for providing the users with easy and robust control. There are a number of devices and software solutions that have been developed especially for helping people with special needs.

2.1. Overall architecture

In this proposed method we use several modules that have been implemented using Raspberry 4, a single board computer. This methodology is used to separate computing-intensive tasks (completed by Raspberry Pi) and controlling tasks (completed by Arduino). Some low-cost sensors like Arduino, ultrasonic sensor, pi noir camera, motor driver, BLDC-Hub motor, joystick controller are also used in this system. Fig. 1 shows the system architecture, where all devices are connected to the Raspberry Pi. The system flowchart is shown in Fig. 2 where if any obstacles occur in the front of the system, how it will overcome those obstacles.

2.2. Hardware Description

Some hardware component of this system is discussed in more detail below.

2.2.1. Motor driver mechanism

A motor driver circuit is used to running the motor which is like the current amplifier. The main purpose of the motor driver circuit is to take a low current signal and convert it to a high current signal so that it can rub the motors smoothly. The reason behind using a motor driver is because the motors cannot be connected to the Arduino directly as they don't get sufficient power from it. L239D IC which is 16 pin IC out of which 4 pins are input (2, 7, 10 & 15) and 4 pins are output (3, 6, 11, 14) pins are used to control the staring mechanism control by Aurdino. A circuit diagram of a motor drive mechanism is shown in Fig. 3(a) and ASMC-04 servo motor is connected in a front for steering purpose shown in Fig. 3(b). When user want to focus an object system will automatically calculate the angel of rotation of user head and based on the angel servo will rotate accordingly.

2.2.2. BLDC Hub Motor

Brushless DC motors (BLDCs) have become increasingly concentrated in the field of motor control technology for many motor manufacturers due to its increasing use in many applications. BLDC motors are much better-quality to other brushed DC motors for variable speed handling, high efficiency and superior heat dissipation capability [18]. These motors have become very effective in the development of digital controls for reliability and cheap pricing. The assembly of BLDC to this proposed system is shown in Fig. 4(a). The brushless DC motor (known as BLDC) is a permanent magnet synchronous electric motor driven by direct flow (DC) power, and by replacing it with an electronically controlled rebuilding structure, the replacement changes the phase flow and moves the motor to generate rotation torque.

2.3. Software Description

The controller of the proposed system is implemented using python. It is an interpretive, interpreter, object-centric, high-level general-purpose programming language. Its high-level data structure supports multiple programming paradigms, including object-oriented and functional programming and its interpreter is available for many operating systems. This is open-source software that makes it very effective in quick edit-test-debug cycles and reduces the cost of program maintenance.

OpenCV or Open Source Computer Vision Library is an open-source computer vision library [19]. It is sometimes called the machine learning software library. OpenCV is designed to provide

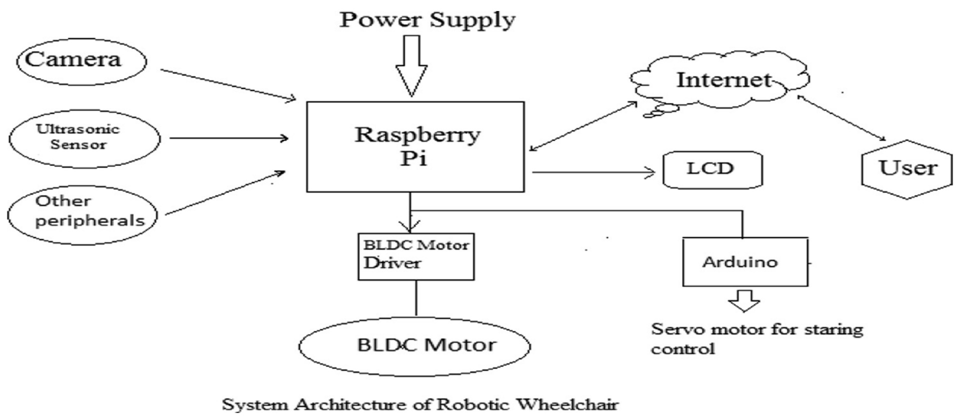


Fig. 1. System architecture of the smart wheelchair.

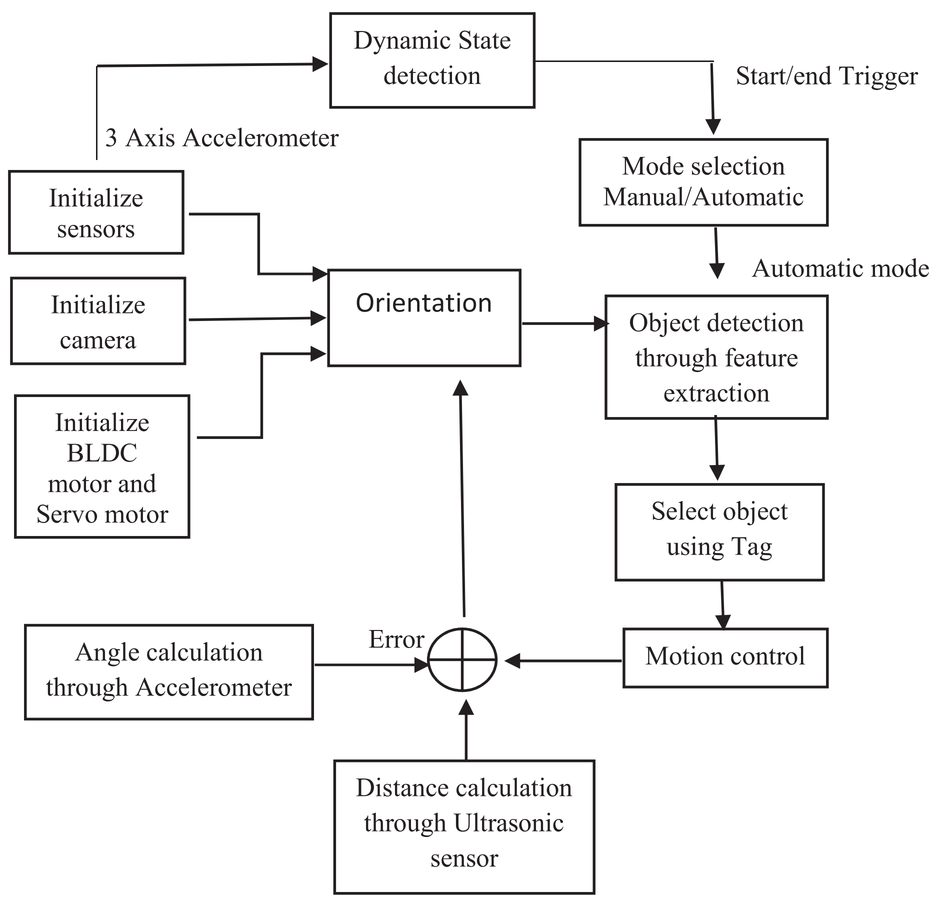


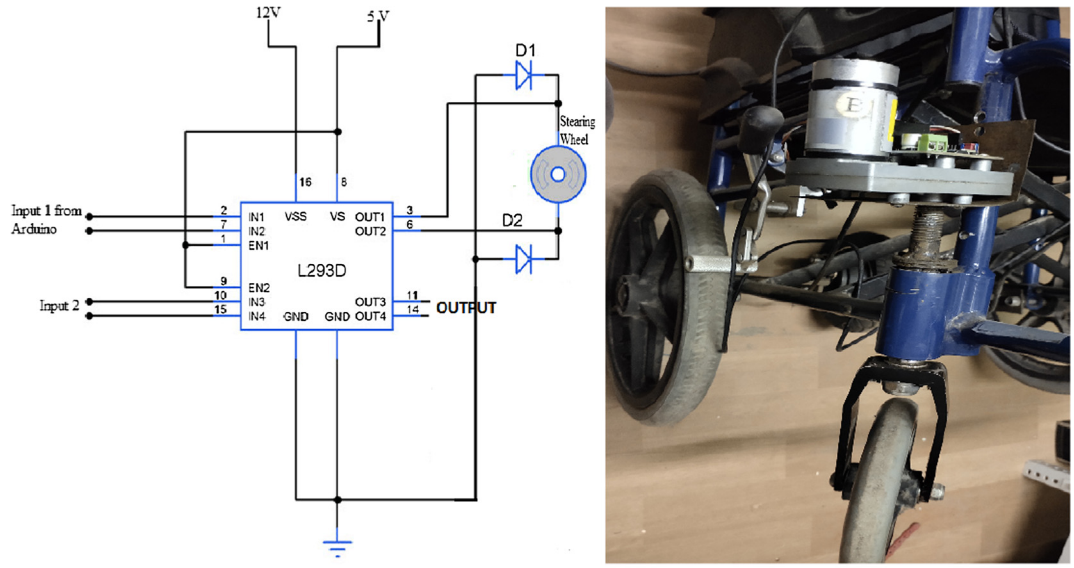
Fig. 2. Flow chart of the system.

a common framework for various computer vision applications and accelerate the use of machine perception in commercial products. Users can easily create or modify their programming to be a BSD-licensed product. At least two thousand optimized algorithms currently exist in the OpenCV library. These algorithms are used for various tasks such as identifying human faces, identifying different objects, categorizing human actions from a video, tracking a moving object, extracting a 3D model from an object, etc. This library is currently used by agencies, research teams and widely used in government agencies.

Fig. 4 shows the different parts of the proposed wheelchair where Fig. 4(a) consist of BLDC hub motor with diameter 17 cm and back wheel with 34 cm diameter. Fig. 4(b) shows the steering wheel assembly with diameter 14 cm which connected through ASMC-04 servo motor. Fig. 4(c) shows the prototype of the proposed system where Pi camera and an ultrasonic sensor is attached to the user head and Fig. 4(d) refers the overall concept mapping of the proposed system.

3. Methodology

The basic scheme of the elements presents in a chair and the modification that must be made to install the designed control



(a) (b)

Fig. 3. (a) Circuit diagram of a motor driver L239D IC (b) ASMC-04 digital servo for steering the front wheel.

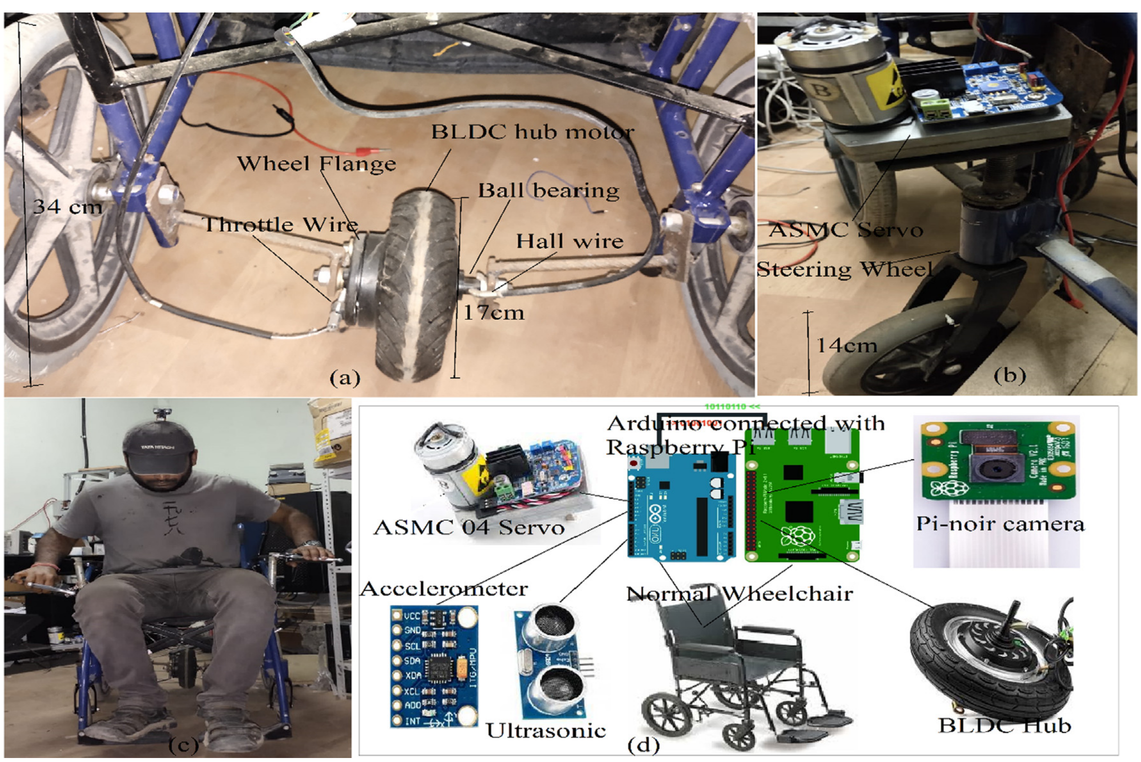
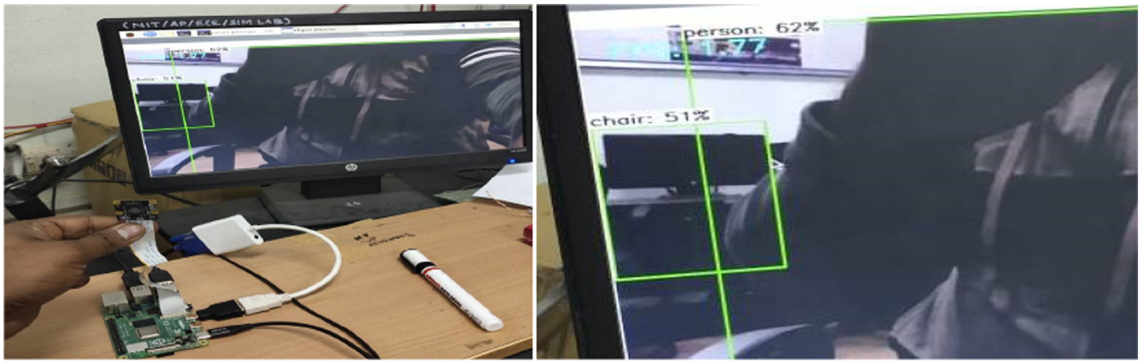


Fig. 4. Wheelchair assembly with components.

board. In our proposed designed board has a Raspberry Pi 4 Model B which is responsible for performing the tasks for all the systems. The motor control driver is used to running the motor and responsible for moving the wheelchair. Here we have approved a new approach by Raspberry Pi to our proposed system which is most cost-effective and simple in architecture than previously invented all the systems. This proposed system has an application called Open CV is installed. With this open CV, raspberry pi will record live video streaming and identify any object, or person. This allows the system to detect up to 80 different objects within an image or video frame, and each object is individually identified using a bounding box. Tensorflow [20] can detect various objects from an image or video stream and provide information about its location within the image. Interfacing of Pi-noir camera with Raspberry pi is shown in Fig. 5(a) and system is detecting a chair is shown in Fig. 5(b).

Tensorflow uses pre-trained and customized models to identify hundreds of objects with a function. A common feature of Tensorflow is to identify what an image represents. Image classification is the act of predicting what is represented by an image. An image classification model helps to recognize the original image.



(a) (b)

Fig. 5. (a) Pi camera is connected with Raspberry pi (b) System is detecting a chair.

For example, the proposed system is trained to identify only five different types of object representation photo frames. The objects are medicine strip, table, chairs, bottles and glass.

Subsequently, when a model's image is rendered as the system input, the proposed system only output the image represented by four previously trained models which are shown in table1. Subsequently, when a model's image is rendered as the system input, the proposed system only output the image represented by four previously trained models which is shown in table1.

As a result, a chair has a 51% chance of being present in the input picture. Image classification can only tell the probability that an image represents one or more classes with previously trained models. Image classification is labelled when modelling images. Each label is given a separate category name so that it has the advantage of identifying the model. An image is given as the input to a model for estimation and the system gives an array of possibilities between 0 and 1 of the model. Each image output of an image is mixed with the previously trained label and starts compressing it. The system gives the label the model most likely to be. The sum of all numbers into the array is always equal to 100. An example of this is given below in Fig. 6.

An IR camera is interfaced with the Raspberry Pi, positioned in such a way that the user's focus can follow. When the user focuses on an object, the Raspberry Pi processes live video streaming and detect the object with the object detection algorithm. Once the object is detected, the Raspberry Pi sends the instruction to the motor driver to move the object in the proper place. If there is a barrier between the wheelchair and the object, Raspberry Pi will have to be programmed such a way so that it can overcome it. Fig. 2 shows how the wheelchair will reach the user's proposed direction if the system detects an object. We used OpenCV for programming functions that target real-time computer vision. Then we installed an open-source library called TensorFlow for dataflow programming across different tasks. It is a symbolic math library and is also used for neural networks such as machine learning algorithms. TensorFlow provides a framework for object detection in OpenCV. It contains many trend models of everyday life such as TV, computer, parson, cycle, board, laptop, glass, table, chair, etc. We can also include any model we want to include in this library.

Table 1
Success rate of object detection.

Sl No	Object type	Probability
1	Medicine Strip	22%
2	Table	23%
3	**Chair**	**51%**
4	Bottle	2%
5	Glass	2%

Two different kind of objects i.e. a bottle and chair detected by proposed system shown in Fig. 7(a) and (b).

By using this method, only the objects in this library that are selected by programming will be output to the GPIO pin of the Raspberry Pi when it comes to living video streaming. The Raspberry Pi will send the instruction to the motor drive circuit using an Arduino, utilizing the output of this GPIO pin. Like that instruction, the motor driver circuit will drive the wheelchair to that object. For example, in a room, there are many objects such as TV, refrigerator, table, chair, cupboard, bed, computer, etc. Our system can detect all of these objects. If the table and chairs have been selected by the programmer then when the user looks at these two objects, our proposed system is capable of moving only those two objects. Looking at the rest of the objects, the system will not move.

Here is an Arduino connection set up with a Raspberry Pi so the two boards can communicate with one another and this whole task can be done very easily. Only with Raspberry Pi could the whole work be done, so the Arduino and motor drive circuits would not be needed. But the main problem with this is the delay time. The processing time of the Raspberry Pi processor on this proposed system is very limited. This can take a lot of processing time to complete many tasks at once. To solve this problem, all the image processing related work will be done by Raspberry Pi and the work will do by Arduino on ultrasonic sensor and motor driver.

This whole system can be run by a second person using his android mobile up. Users can control the Raspberry Pi through Android Mobile using an open-source application called VNC Viewer. To implement this, the VNC Viewer application must be installed on the android mobile. This application is available in the Play Store on Android Mobile. Raspberry Pi and Android mobile must be connected to the same network with a Wi-Fi hotspot. Then it is possible to get control of the Raspberry Pi from the mobile app by typing in the specific IP address of the Raspberry Pi from the VNC viewer app. The IP Scanner application can be used to find out the IP address of the Raspberry Pi. IP Scanner application can show IP addresses of all the devices belonging to the same network.

To say, someone living far away from home in his workplace and in time cannot take care of his elderly parents or patients. In such an environment this proposed system can be very useful. Where the caregiver can provide timely care using his mobile compromises, he can extend his help to these people by providing timely medicine or a glass of water.

For testing this system, some objects in the laboratory such as medicine, tables, chairs, computers, etc. are included in the library of the system. As a result, when the user focuses on the object, the Raspberry Pi camera detects the object from live video streaming

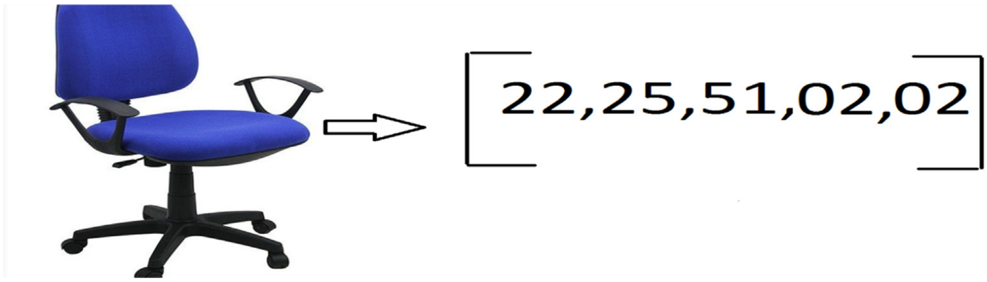


Fig. 6. System is predicting the object as a chair.

(a) (b)

Fig. 7. (a) A water bottle is detected (b) chair is detected.

Table 2
Test Attributes.

Features	Estimate
Camera speed for Frame Capture	25 fps
Highest speed achieved by wheelchair	6 km/hr
Distance required to stop (Break)	1 to 2 feet
Radius rotation	1.3 feet

and sends the instruction to the motor driver. Wheelchair automatically reaches the destination after crosses all the obstacles and it is also enabled to pick or drop items.

The following characteristics were noted down during control of this assistive wheelchair shown in Table 2.

Algorithm for TensorFlow object detection

Step 1: Install libraries including supporting files into raspberry pi.
Step 2: For object detection .xml file are created for each image.
Step 3: Images are divided into two parts, i.e. Training and testing image along with their .xml
Step 4: For test and train images .csv file are created.
Step 5: For train and test images, tf.record are created using . csv files and images folder.
Step 6: Pertained models are downloaded and configured.
Step 7: Training and custom images using a pre-trained model.
Step 8: Models are created by exporting path using the checkpoint which previously saved.
Step 9: Frozen_inference_graph.pb + new check point + saved models directory all are created inside model.
Step10: Make a prediction using this newly created model.
Step11: System is ready for predict models from live video streaming or images.

4. Result and Discussion

The system is tested in an indoor environment using a Pi NOIR camera. The camera starts capturing videos and extracts the frames. Frames are converted to many classifications. It can be illustrated in Fig. 7, that region of interest is alone taken into consideration to detect the user's focus point. Meanwhile, the image processing program has been initiated. A small rectangular box, from the frame extracted, the Tensor flow algorithm is been deployed to determine the movement of the eyes. According to the movement of the eyes, the wheelchair is controlled. It is a real fact that dependent mobility is not acceptable for any age people, In the adult group age its create a negative self-respect image, for any age group like student it creates an obstacle to achieve their education goals and about 40% of disabled community has to face the difficulties in operating a standard power type wheelchair, so for removing these difficulties we use some recant technologies of mobile robots which helps to create a very "smart wheelchair."

A smart wheelchair has two bases one is a computer based as well as collection of some sensors, and other is a mobile robot bate to which the seat has attached, here some drawbacks occur which can be remove through (MWC) that is "smart wheelchair component system", so we attached a collection of the component to a standard type of wheelchair.

A MWC should be design in such way that all traditional type of input (like analog joystick as well as sip n puff switch and some different set of electronic control system after that further improvement are possible here.

Way of performance of MWC- in 30 cm of area its obstacle clear sensor work as min average safe mode, max audible noise is approx 55 of db.

The hardware of MWC is control electronic system, navigation assist software, and sensor. The power is supplied through the batteries of the wheelchair to required components like sensor etc. and power varies from 5 V to 24 V, the MWC mainly used the infrared as well as bump sensor because they have some positive and negative feather of strength.

In the navigation of software, the python language is used to run through computer, this software can read the value of diff type of input signals as well as sensor with the rate of 10 Hz.

For control purpose the joystick signal is navigated through software by voltage regulation, for increase or decrease the speed of chair or to change the direction of the chair we have to give a bound of voltage increase or decrease, if any one wants to stop the chair then it have to bound the component above or below of neutral the voltage of given power supply and for the moment in different direction we have to command on the system software through which it moves or change its direction which we should desired for further change in speed or direction we have to depend on software as well as neutral voltage.

As if no command or (in case of no signal) will occur then the software does not move in any direction, no movement will occur in this case but if lots of signals cases at single time then also no motion will be happening so the chair will remain at same position so this case is solved by the "MWC" by introduced a special type of overdrive switch that will help the user to bypass the system software and can control the chair through the signal which comes by the joystick.

A visual display is used for a special purpose of debugging that is provided by the computer system but user interface is not directly rely the visual effect of the given feedback, the wheelchair movement in different direction will be depend on the sensor signal.

System has not to be expected that it will give any visual type of feedback but some little feedback can be explored further.

Now the performance can be evaluated by some criteria and its reliability, it has three main configurations (name as front wheel, mid wheel or center wheel and a rear wheel) that is verified MWC in the different wheelchair model, here some defined limit of maximum speed has provided to each of the wheelchair which has compared to its achievable speed, the speed of wheelchair is computational so we can sudden control the chair through any dynamic obstacle.

For testing the performance of MWC we have to take care of some simple things – try to maintain a fixed safe distance from any type of obstacle and try to detect the size of the obstacle, some different capability also tested here like travelling by narrow hall or to travel by the doorways and also test the capability of the user which can maintain the conversation without any effect of noise. In the test of reliability, we provide software to the computer that leads to move each of the wheelchairs in a given fixed enclosed area that should contain some obstacle.

5. Conclusion

This paper presents the development of a wheel wheelchair and its control using camera. This proposed wheelchair could be a good replacement for those imported commercially and become recourse for the elderly, helpless and disabled people of lower income rate. The result of the MWC is that it will provide a large area of movement though the desired direction can be also including very close obstacle in the consideration, can follow the wall and door passage. While testing in the reliability some collision occurred which can be future removed by using more number of sensors but the system cost may increase. The proposed wheel chair is safe for indoor use but for outdoor environment more number of sensor and force balancing methodology is required.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

[1] Kundu AS, Mazumder O, Lenka PK, Bhaumik S. Hand Gesture Recognition Based Omnidirectional Wheelchair Control Using IMU and EMG Sensors. J Intell Rob Syst 2018;91(3):529–1241.
[2] K. NIAS, March 2019. [Online]. Available: https://blog.sciencemuseum.org.uk/history-of-the-wheelchair/.
[3] Hischke MM, Reiser RF. Effect of rear wheel suspension on tilt-in-space wheelchair shock and vibration attenuation. PM&R 2018;10(10):1040–50.
[4] Saski K, Eguchi Y, Suzuki K. Stair-climbing wheelchair with lever propulsion control of rotary legs. Adv Rob 2020;34(12):802–13.
[5] Behera PK, Gupta A. Novel design of stair climbing wheelchair. J Mech Sci Technol 2018;32(10):4903–8.
[6] Nishimori M, Takeshi S, Ryosuke K. Voice controlled intelligent wheelchair, In: SICE annual conference 2007. IEEE, 2007; 2007.
[7] Simpson RC, Levine SP. Voice control of a powered wheelchair. IEEE Trans Neural Syst Rehabil Eng 2002;10(2):122–5.
[8] Plesnick S, Domenico R, Patrick L. Eye-controlled wheelchair. In: IEEE Canada International Humanitarian Technology Conference-(IHTC), Canada; 2014.
[9] Joshi SN. Tongue motion controlled wheel chair. Int Org Res Dev 2020;7(2):14–9.
[10] Liao L, Wu Y, Xiang Y, Yan X, Shi J, Bai J, et al. Control system of powered wheelchairs based on tongue motion detection. IEEE 15th International Conference on Cognitive Informatics & Cognitive Computing (ICCI*.CC), 2016.
[11] Abed AA. Design of voice controlled smart wheelchair. Int J Comput Appl 2015;131(1):32–8.
[12] Patil H. Design and making of head motion controlled wheel chair. Int J Res Eng Sci Manage 2020;3(6):80–4.
[13] Jang G, Kim J, Lee S, Choi Y. EMG-based continuous control scheme with simple classifier for electric power wheelchair. IEEE Trans Ind Electron 2016;63(6):3695–702.
[14] Li Z, Zhao S, Duan J, Su CY, Yang C, Xingang Z. Human cooperative wheelchair with brain–machine interaction based on shared control strategy. IEEE/ASME Trans Mechatron 2016;22(1):185–95.
[15] Parikh SP, Grassi V, Kumar V, Okamoto J. Usability study of a control framework for an intelligent wheelchair. 2005 IEEE international conference on robotics and automation, 2005.
[16] Berjón R, Mateos M, Barriuso A, Muriel I. Alternative human-machine interface system for powered wheelchairs. In: 2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH); 2011.
[17] Kucukyilmaz A, Demiris Y. Learning shared control by demonstration for personalized wheelchair assistance. IEEE Trans Haptic 2018;11(3):431–42.
[18] Yedamale P. Brushless DC (BLDC) motor fundamentals. Microchip Technology Inc; 2003. p. 3–15.
[19] Tapu R, Mocanu B, Zaharia T. DEEP-SEE: Joint object detection, tracking and recognition with application to visually impaired navigational assistance. Sensors 2017;17(11):2473.
[20] Talele A, Patil A, Barse B. Detection of real time objects using tensor flow and OpenCV. Asian J Converg Technol 2019;3(1):1–45.