

A Review Paper on Wheelchair Evolution

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Abstract— wheelchair is the important part of physically challenged people and not even provides mobility but also plays vital role in their daily life to do physical activity and social participation. In India, according to survey of 2019, number of physically challenged people using wheelchairs were 2.2 percent. This paper aims to provide a complete overview of development of wheelchair from its invention to the most recent stage of the advancement according to various researchers. We expect that the information gathered in this study will enhance awareness regarding the research done in field of wheelchairs, and helps to increase the functional mobility of wheelchair users by understanding conventional wheelchairs, PW, SW followed by its features and advantages.

Keywords: Conventional Wheelchair, PW, SW

I. INTRODUCTION

The wheelchair has been in existence for many years, in early 90s it were conventional and only limited to provide mobility on flat surface operated either by user or by help of caretaker. As the further research took place, the more advancement were done in this field. Since then, wheelchairs have become lighter, stronger, and better suited for everyday use. Now a days wheelchairs are either manual or electrically propelled by motor and battery [16].

As first wheel chair was invented, it had three wheels [14] which afterwards converted into four wheels wheelchair for more stability and was conventionally operated by user or caretaker. Further advancement done which results the PW, operated by joystick or remote control as mobility provides by motors. But some users like paralysed patients, visually impaired patients, mentally challenged patients were not able to operate PW by its own. To overcome this issue, the Smart wheelchairs were invented which are able to provide Navigation using co-robot system.

To understand more information about wheelchair, we have explained the methodology in three parts as conventional, PW and SW.

II. CONVENTIONAL WHEELCHAIR

The first known dedicated wheelchair called an invalid's chair invented by an unknown inventor in 1595 and was made for Phillip II of Spain. Afterwards in 1783, John Dawson of Bath, England, designed a chair with two large wheels and one small one [37] [48]. But as it was not that comfortable, hence many improvements were made and in 1869 patent for a wheelchair showed the first model with two rear push wheels and two small front casters like today's conventional wheelchairs [15]. Latterly design of foldable frames, eliminates the difficulty in transportation of wheelchairs for a long distance travelling and allow to transport it within occupying less space while long distance

travelling via car or bus etc. First folding wheelchair where invented in 1932 by engineer, Harry Jennings [15]. After this number of mechanisms were introduced by many researchers and engineers for ease to folding and stretching the conventional wheelchairs, which makes it more flexible.

A. Folding Wheelchair

A simple design for folding wheelchair by using a frame from a commercially available wheelchair and adapting it to house an ergonomic drive system which decreases weight and increased accessibility [1]. Rigid frame wheelchairs are generally welded and lighter than foldable frames. Whereas the folding frames have more power loss during the mobility because of bolted parts and mechanism.

B. Tricycle

It is very helpful for those patients whose legs are not functional. Tricycles are three wheeled wheelchairs and driven by hand peddles instead of legs where one hand is used to rotate the peddle and the other hand is used to steer the tricycle [34]. As one research, shock absorber designed and mounted on a manually operated tricycle to reduce the effect of traveling over rough ground, leading to improved ride quality, and increase in comfort due to substantially reduced amplitude of disturbances [33]. To make it more reliable a retrofitted tricycle design, in such a way that wheelchair user can access the motorized tricycle with wheelchair by ramp arrangement. And capable of driven by engine of old two wheeler [49].

C. Sports Wheelchair

Wheelchair sports first began in the 1940s, Since Many advances have since taken place to improve both the increasingly specialised sports wheelchairs and other associated equipment that have evolved to meet the needs of the people that use them [27]. There are a number of adjustable multi-sport chairs available that allow individuals to participate in various sports while investigating different settings utilizing only one piece of equipment [28]. Sport wheelchairs motivates and encourages disabled people to participation in various Sports like basketball, Rugby, wheelchair racing, Hand cycling etc. [50].



Fig. 1: Sport wheelchair in Wheelchair Racing [50] and Retrofitted Tricycle [49]

As conventional wheelchairs are economical and affordable for every user, to make it more reliable and comfortable there are many modifications have done on it by providing various accessories within minimum cost, such as, safety belts, adjustable backrest, back seat tilting features, support for neck, health kit box etc.

III. POWER WHEELCHAIR

Electric powered wheelchairs are designed for indoor use, outdoor use, or even both. They are generally prescribed for persons who have difficulty in using a manual chair due to arm, hand, shoulder or more general disabling conditions [4].

The concept of the power chair comes in 1953, when Canadian researcher George Klein makes first PW for WWII veterans. By 1954, Klein had a reliable system that used a controller, batteries, a hand control and two motors, the concept that runs power chairs today [15].

The basic components used for construct power wheelchairs are listed below

- 1) Frame or chassis: It is the main body of wheelchair which holds wheels, driving mechanisms, electronic devices and supports the seats. Frame is available as conventional or rigid, foldable, stretchable etc.
- 2) Motors: It provides the motion to wheels by means of driving system. DC Geared motors used due to on loading conditions, it provides constant speed.
- 3) Power supply: 12V to 24V DC Dry cell batteries used to provide power to the motors. Generally lead acid batteries preferred which are rechargeable, harmless, and weightless compared to others available [4] [36].
- 4) Mechanisms: It makes wheelchair more flexible to operate in adverse conditions like stair climbing, tilting or stretching, for comfortable sitting etc.
- 5) Controllers: Mainly PW operated by means of Joystick. But now a days many advancement in PW occurred which there are a growing number of alternative options that are becoming available, includes light touch mini joysticks, switches, touchpads and sip and puff controls [17].

P. Swapna et al. designed Joystick controller based mobility wheelchair for the all possible direction of movements like left, right, and straight and back by using the DC geared motors, utilizes the power from the lead acid batteries [4]. As PWs operated on batteries, it need to recharge frequently which cause electricity consumption. To reduce dependency on nonrenewable Energy a design of doubly powered wheelchair were introduced, which runs on solar as well electric batteries to operate DC motors for mobility [3].

A. Stair Climbing

Many buildings have not adapted disabled friendly structures like ramps, lifts etc. Therefore many times wheelchair users face difficulties in those infrastructures to reach at top floors. By considering those issue, many engineers and researchers have designed stair climbing mechanism for wheelchair that can be easily climb stairs in non-disabled friendly infrastructures.

The mechanism gripped by conveyor belt and pulleys on new steel frame attached below main frame to allow it to climb stairs using DC Geared motor [5]. In order to pass over obstacles like curbs and stairs, ramp and sliding mechanism that makes the normal wheelchair to climb the curbs on the streets and accessing the buildings without ramp facility [12].

B. Stretchable Wheelchair

Wheelchair users need to take too much efforts for lie down on bed as they need to take rest. Also it's very tough task to transfer paralyzed patient from wheelchair to stretcher for care taker and more than one caretakers required in some situations [48]. Understanding those various issues, wheelchair cum stretcher has most valuable role, which is capable of shifting various positions like Semi-Chair and Stretcher either by electrically or Pneumatic and hydraulic actuator.

In order to reduce this issue Thomas Paul et al. designed a Mechanism that can be stretching into bed by a lead screw connected with a hinge joint which translates turning motion into linear motion. The height of the stretcher can be adjusted using a manually operated Hydraulic jack [2]. As well as simple parallelogram mechanism which lift the chair up along with the patient and the slider crank mechanism used to stretch the chair [35].

Power wheelchairs provide many advantages for users like Increases the mobility, increases Manoeuvrability, improve Physical Supportability and decreases dependency on others. [31]. this are mainly for users who have not enough strength in hand muscles to operate conventional wheelchairs. Day by Day many advantages are taken place PW to make it more efficient and economical. PW plays important role to improve user's quality of life.[52]



Fig. 2: Frame based Stretchable wheelchair [54] and stairs climbing wheelchair [12]

IV. SMART WHEELCHAIR

PWs are not able to fulfil requirements of users like visually impaired person, persons with a highest level of Spinal Cord Injury [51], where they are only able to control a muscle movement from neck and above. In such conditions normal joystick is not viable anymore [23]. In this situations Smart wheelchairs plays main role as SWs are one steps forward to PW, which operates on robotic system. Various Sensors and Processing units make it intelligent that can make self-decision to Navigation.

Now a day's robot becomes an essential thing in industrial as well as in human life. These robots can provide

a support to disable people in their day today life [21]. Use of robots and AI provide better solution for advancement of Wheelchair like eye tracking [21], vision based, and gesture controlled, Brain controlled wheelchairs. According to the disabilities as well as requirements, wheelchairs available are explained.

A. Gesture Controlled SW

Mobility of wheelchair done by the hand gesture movement which based on the principle that finger movement and hand gestures can be effectively translated into computer interpreted signals using Accelerometers [8] [11]. On other hand Myoelectric signals acquired from four forearm muscles activity which processed to calculate the RMS envelope for each channel to motion command of the wheelchair. [10]

B. Voice Controlled SW

It has made mobility convenient using speech recognition technology in which people can control the wheelchairs with their speech, without typing on the board or operating buttons for the system [18]. With the use of mobile app, user voice command is transmitted with the use of Bluetooth or Wi-Fi module and fed to the Microcontroller where predefined command are already stored in the detection system. And accordingly motor performs the task interested by the person. [7] [45]. The wheelchair having combination of touch mode, voice mode and accelerometer based to control navigation is useful to all type of users [32] [42].

C. SW Using MEMS Technology

The MEMS (Micro-Electro-Mechanical) technology for quadriplegics patients interprets the situation of the user's head into speed and directional control of the wheelchair [13]. For making it more better and easier, development of a Hand-glove controlled wheel chair based on MEMS technology provides mobility according hand movements translates using the flex sensors [44].

D. SW Using Computer Vision Technology

Approach that employs computer vision techniques which facilitate space perception and navigation, greatly enhances the mobility of the elderly and disabled without requiring them to exercise motor control [29]. The on-board computer on the wheelchair runs vision software that processes the stereo video system into distance range information and provide the navigation to wheelchair [30]. Ergonomic vision based co-robot, access 360 degrees of motion direction as well as a continuous range of speed and is collaborates with the robotic wheelchair as head motions via the egocentric computer vision based control [9].

E. Brain Controlled

The Defitech Foundation Chair in Non-Invasive Brain-Machine Interface (CNBI) performs research on the use of human brain signals to control devices and software in order to interact with the world [20] [19]. Basically BCI taken under two types first is Invasive BCI methods in which electrodes placed directly on or inside the cortex. And second is Non-invasive BCIs, can use a variety of brain signals input, such as electroencephalograms (EEG) generally used [22]. EEG based wheelchair driving system

that allows an individual with mobility impairments to perform daily living activities independently. The electrical activity of the brain can be monitored in real-time using an array of electrodes, which are placed on the scalp in a process known as EEG [39] [40].

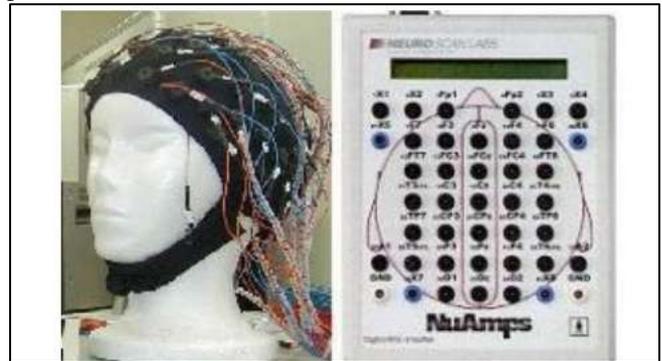


Fig. 3: Acquisition devices (Scalp and signal amplifier) [26]

By capturing brainwaves produced by synchronized electrical pulses using sensors placed on the scalp, it translates into movement commands by the Arduino microcontroller which in turn move the wheelchair [6] [38]. The Mind controlled wheelchair controls the direction and motion of wheelchair based on the decision taken by the user. The mind wave headset is used in the mind controlled wheelchair to pick up EEG signals from the brain [25]. EEG signs to control wheelchair has been viewed the improvement of an eye blink which offers climb to trademark signals, these exercises can be used to control an external structure [24].

Benefits of brain controlled SW includes : easy to handle, Suitable for all kind people, Less power consumption, Wireless control, Less interference due to encoding techniques, Less deviation and high sensitivity, Flexible hardware changes etc. [6].

F. Features equipped SW

As the SW are very known for self-navigation and operated on user command, sometimes user cannot notice the obstacles in pathway and collision may takes place. To avoid such situations the obstacles avoiding sensors mainly used, which not only detects the obstacles but also stops the WC. Now a days many SW are equipped with obstacles avoiding sensors, GPS and GSM system to locate on Google maps [4]. SW are autonomous and helps the patient to be independent. Assistive can improve the quality of life as well as the mobility and safety for disabled people [41] [43]. Co-robot control system used in wheelchair provides a more natural human robot interface and enhance the mobility of SW without hand usage [10]. There are many new concepts have available in wheelchairs according to users need. To make it more comfortable and safe research have done like two seat Wheelchair, size shifting wheelchair, illuminated wheelchair, career wheelchair, etc. [53].

V. CONCLUSION

After studying the literature we have reviewed that there are wide range of changes taken place in wheelchair from conventional to PW and SW. Wheelchairs are available for all kind of users according to demands and functionality. As sensors and controlling units are getting smaller and

cheaper, wheelchairs are available in less cost as well as for many applications like indoor or outdoor mobility, sports etc. Also robotics and artificial intelligence applied for developing SW. Journey of Wheelchair has begun from conventional to SW followed by the PW, and still research is taking place to make it more comfortable and economical.

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