Components that could build up a ideal Power-wheelchair

Samarjeet P Chavan[#1], Vivek P Deodeshmukh[*2]
[#]*M.E EXT,C Electronics and Telecommunication Department, D.J.Sanghvi College of Engineering, Mumbai-400056, India.*
**Assistant Professor, Biomedical Department, D.J. Sanghvi College of Engineering, Mumbai-400056, India.*

Abstract

A robotic wheelchair system should be a general purpose navigational assistant in environments that are accessible for the disabled (e.g., ramps and doorways of sufficient width to allow a wheelchair to pass). A reactive system is one that does not use maps for navigation. One of the advantages of reactive systems is that the users are not limited to one particular location by the need for maps or environment modifications. The target community for robotic system consists of people who are unable to drive a manual wheelchair. The users vary in ability and access methods. Some people can move a joystick, but are unable to make fine corrections to movement using the joystick. Other people are able to click one or more switches using their head or other body part. Some potential users are unable to control a powered wheelchair with any of the available access devices. The wide variety of user abilities in our target community requires that the system be adaptable for many types of access devices. While members of the target community have different abilities, we assume that all users will have some common qualities. We expect that any potential user can give high-level commands to the wheelchair through some access method and a customized user interface. We assume that the user of the wheelchair is able to see, although later versions of the system may be developed for the visually impaired. We also assume that a potential user has the cognitive ability to learn to how to operate the system and to continue to successfully operate the system once out of a training environment.

Keywords — *Power wheelchair, Motor's, Battery set, Access methods in a wheelchair.*

I. INTRODUCTION

A motorized wheelchair or electric-powered wheelchair is a wheelchair that is propelled by means of an electric motor rather than manual power. Motorized wheelchairs are useful for those who are not able to impel a manual wheelchair or who may need to employ a wheelchair for distances or over terrain which would be strenuous in a manual wheelchair. They may also be used not just by people with conventional mobility impairments, but also by people with cardiovascular and fatigue based conditions. Electric wheelchairs have enhanced the quality of life for many people with physical disabilities through the mobility they afford. The selection of power chair will rely on many factors; including the kind of surface setting the chair will be driven over, the need to settle thresholds and curbs, and clearance widths in accustomed environment. The most fundamental job of the chair is to take input from the user, usually in the form of a small joystick, and decipher that motion into power to the wheels to move the person in the preferred direction. The last few years have seen abundant improvements and models that give the user unmatched control of the wheelchair in terms of both user effort and vehicle aptitude.

A robotic wheelchair is usually a semi-autonomous system, which means that a full solution to Artificial Intelligence problems do not need to be found before a useful system can be built. A robotic wheelchair can take advantage of the intelligence of the chair's user by asking for help when the system has difficulty navigating. The use of powered wheelchairs with high manoeuvrability and navigational intelligence is one of the great steps towards the integration of severely physically disabled and mentally handicapped people. Driving a wheelchair in domestic environments is a difficult task even for a normal person and becomes even more difficult for people with arms or hands impairments. Tetraplegic people are completely unable to operate a joystick unless they use the tongue, which is obviously a very tedious task. Simultaneously blind and paraplegic people deal with a very uneasy situation which couples two problems: locomotion and localization [1].

Development of new systems for disabled and elderly people's assistance requires a multidisciplinary approach based on new technologies according to the users‟ needs. Researches in medical, paramedical and advanced technologies fields can collaborate directly to develop new strategies ranging from simple assistance to various access services such as websites, Smart phone and so on. As a kind of rehabilitation systems, intelligent wheelchairs can play an important role in helping the handicapped and the elderly people to live more independently and autonomously [2-3]. One of the main trends in smart wheelchairs development is

how to ensure a reliable remote tele-operation task with obstacle avoidance in a constrained environment taking into account system's interactive behaviour. Various methods have been investigated in this context such as edge detection [4], potential field [5] and impedance control [6]. In edge detection methods, the objective is to determine the vertical edges of the obstacle and consequently attempts to steer the mobile system around an edge. The main drawback is the proximity between the mobile system and the obstacles which is not suitable for the real time computation. Potential field methods allow a collision avoidance motion planning by generating a virtual force against obstacles and toward the goal. An attractive force between the mobile system and the target, and a repulsive force against obstacles are generated.

In response to the demands of wheelchair users for equal access, hand-propelled wheelchairs, electrically controlled wheelchairs, and automated-guided wheelchairs(AGW) have been developed. However, because upper body strength is required, a hand-propelled wheelchair does not permit an older or severely disabled person an extensive range of travel. An electrically-controlled wheelchair can be controlled by a manually-operated joystick-but because this type of wheelchair sometimes zigzags, and a slight movement of a joystick can cause a quick turn, driving an electrically-controlled wheelchair requires the operator to be skilled both in turning, and in direction-change operations-especially on narrow or curved roads. Therefore, it is difficult for many severely disabled and or elderly persons to operate them skillfully. Assistive robotics is improving the lifestyle of the physically challenged people to a great extent. In recent times there have been a wide range of assistive and guidance systems available in robotics to make their life less complicated and motile. These robots in are very efficient and enable the user to move around with ease. In recent times there have been various control systems developing specialized for people with various disorders and disabilities. The systems that are developed are highly competitive in replacing the old traditional systems. There are many assistive systems using visual aids like video-oculography systems, infrared-oculography, eyeball sensing using electro-oculography and much more. There are even systems based on voice recognition too. The basic assisting using voice control is to detect basic commands using joystick or tactile screen. These applications are quite popular among people with limited upper body motility. There are certain drawbacks in these systems. They cannot be used by people of higher disability because they require fine and accurate control which is most of the time not possible. There are two basic requirements for any robotic wheelchair system. First and foremost, a robotic wheelchair must navigate safely for long periods of time. Any failures must be graceful to prevent harm from coming to the user. Second, in order for such a system to be useful, it must interact effectively with the user. Outside of these two requirements, desirable features may include outdoor as well as indoor navigation, automatic mode selection based upon the current environment and task to reduce the cognitive overhead of the user, and easily adaptable user interfaces. Robotic technologies have the potential to improve the lifestyles of people suffering from one or more disabilities. Related developments are often grouped under the terms Rehabilitation Technologies or Assistive Technologies. They attempt to restore human abilities that have been reduced or lost by disease, accident, or old age. Mobility is one such function.

WHAT CUSTOMER'S LOOK FOR IN A POWER WHEELCHAIR?

a. A stable seating base:

The convention says the seat should have a level base and be wide enough to house outdoor clothing if required. However it must not be so wide that the user is obligated to sit asymmetrically for support. Narrow seats cause discomfort and risk causing pressure sores. Poor sitting balance causes postural asymmetry or disparity in muscle tone, requiring a supportive seat unit with trunk and pelvic supports.

b. A vehicle that is easy to maneuver:

A few wheelchairs are designed primarily for indoor use and have a tendency to be smaller and more maneuverable. We have to make sure that the wheelchair can

- Go through doorways and over thresholds;
- Maneuver on floor planes;
- Make constricted turns from hallways into living rooms;
- Move backwards on requirement, e.g. Reversing out of the toilet;
- Go down shop aisles.

The powered wheelchair does not adjust instantly to a variation in direction because the castors need a split second to twirl round. Vehicles intended virtuously for outdoor use typically have very wide turning circles and wide/deep plodded tires for easier movement over uneven as well as lenient ground.

c. A stable vehicle:

All power-driven vehicles are stable on even ground. A user with a lower limb confiscation, particularly a high level or double amputation, should be cautious while choosing a wheelchair because the

deficiency of weight at the front may distress the centre of gravity and could root the vehicle to tip backwards mainly when climbing kerbs. Stability can also reduce if the backrest of the wheelchair is reclined or is tilted backwards (tilt-in-space).

d. Freedom of travel:

Motorized vehicles permit the user to navigate long distances without too much individual effort. Even though many wheelchairs have a decent distance per battery ratio, to travel these distances more time is essential. It might take a minimum of four hours to cover 25km (16 miles) in a pavement-only vehicle.

e. A vehicle that is easy to transport:

Transport of a wheelchair requires flexibility (to reach catches and, plugs, for example); strength (to lift the component parts); and standing/walking stability. Majority of motorized wheelchairs have a collapsible frame that can be pleated once the batteries have been detached. A few wheelchairs also contain separable motors. The frame might not fold down as efficiently as the frame of a manual wheelchair and will be bulkier to lift. If the backrest of the wheelchair folds down, they can be carried into the back of a car through ramps.

f. A vehicle that meets the Assistant's needs:

For easy handling by the assistant, controls are positioned on the right or left pushing handle of the wheelchair. Dual controls not only empower users to be autonomous when required, but also enable someone else to help when the need ascends. The comfort and mobility prerequisites of the wheelchair inhabitant are of paramount significance. In order for the assistant to undertake routine upkeep, such as pumping up tires and putting the wheelchair on charge, and dismantling and assembling the wheelchair then he/she must be convoluted in the choice of the vehicle to ensure that the essential tasks are manageable.

II. COMPONENTS THAT COULD BUILD UP A IDEAL POWERED WHEELCHAIR.

A. Chassis

A chassis consists of an internal framework that supports a wheelchair in its construction and use. In case of wheelchairs, a light weight, foldable chassis is desirable for construction. Provision has to be made for mounting motors, battery set, sensor's and other components. Such a chassis should be designed that it remains highly productive, efficient and portable all at a time.

Light Weight chassis like the ones made from titanium or carbon material should be used. The main advantage of using such material's is that the decrease in weight of the material makes the wheelchair more portable and easy to handle. Though titanium and carbon material are light in weight, they are very hard and thus can carry large amount of weights.

Ti-Lite which specializes in wheelchair manufacturing and customization uses titanium for the frames of several lines of its high performance wheelchairs[7]. Titanium has the highest strength-to-weight ratio of any metal, it is highly durable, and it absorbs vibrations better than other common frame materials such as aluminium. These unique properties make it desirable, but because titanium is difficult to refine and requires expertise and precision in welding and bending, it is a more costly material. Ti-Lite makes wheelchairs in both titanium and aluminium[8]. The design and manufacturing process uses parametric modelling[9],computer aided design and finite element analysis technologies to optimize design and material choices[10].

- Strength-to-Weight: Titanium has the highest strength-to-weight ratio of any metal on Earth. This means that one can use less titanium while still building a stronger frame. Using less material leads to a lighter frame and reduces the cost difference between titanium and other materials.
- Smooth Ride: Titanium dampens vibration, decreasing the amount of vibration transmitted to the user. The result is a smoother ride that has significant benefits whenever and wherever you roll: Fewer and less noticeable bumps and jolts, reduced fatigue, and increased comfort.
- Durability: Titanium's durability is unmatched. It does not rust or corrode in any atmospheric environment and its strength, toughness, and fatigue resistance means that the frame structure will take a pounding without failing. While other metals start to fatigue with repetitive use, titanium does not show signs of wear even after years of use.

Seat and Backrest

As stated earlier, customer considers the seat of a wheelchair as a major constraint before buying a wheelchair. Thus, seat is expected to be comfortable, and wide enough to occupy the user. Timeline of seats on a wheelchair are from previous wooden seats to current cushion comfort seats. Latest wheelchair seats also comprise various features like alternating pressure cushions etc, which are advantageous for users who need to use a chair for long times.

End users feel that comfort and quality of life can be significantly and positively impacted by available seating and positioning systems. A huge advancement has already done in this field. Still, many aspects of seating and positioning can be improved. Among the highest priority unmet needs were adjustability and customization of seating systems. There is a need to prescribe appropriate seating systems for children so that they are not given a large wheelchair that they will eventually grow into. Precision fitting for wheelchair users of all ages will enhance an individual‘s comfort, stability and function. Additionally, end users should be able to adjust their seating and positioning throughout the day. Improved selection and fitting of seating and positioning systems is imperative as injuries can be caused by or exacerbated by inappropriate or poorly fitted seating and positioning systems. Proper and well fit seating systems are also critical to the preservation of an end user‘s remaining functional abilities [11].

B. Motor's

Here in power wheelchairs, motors are used to move the wheels. There are many types of electric motors plus more if gasoline and other fueled engines are considered, but one amongst following are usually chosen for electronic vehicles:

- In a continuous DC motor, application of power causes the shaft to rotate continually. The shaft stops only when the power is removed, or if the motor is stalled because it can no longer drive the load attached to it.
- In a stepping motor, applying power causes the shaft to rotate a few degrees, then stop. Continuous rotation of the shaft requires that the power be pulsed to the motor. As with continuous DC motors, there are sub-types of stepping motors. Permanent magnet steppers are the ones you'll likely encounter, and they are also the easiest to use.
- A special “subset” of continuous motors is the servo motor, which in typical cases combines a continuous DC motor with a “feedback loop” to ensure accurate positioning. There are many types of servo motors; a common form is the kind used in model and hobby radio-controlled cars and planes.

Each of this above type have equal advantages and disadvantages as follows:

Table. 1: Various Types of Motors.

Motor Type	Pros	Cons
Continuous DC	Wide variety available, Easy to control via computer with relays or electronic switches.	Requires gear reduction to provide torques needed for most robotic applications.
	With gearbox, larger DC motors can power around 100Kgs.	Poor standards in sizing and mounting arrangements.
Stepper	Does not require gear reduction to power at low speeds.	Poor performance under varying loads. Not great for robot locomotion over uneven surfaces.
	Low cost when purchased on the surplus market.	Consumes high current.
	Dynamic braking effect achieved by leaving coils of stepper motor energized	Needs special driving circuit to provide stepping rotation.
R/C servo	Least expensive non-surplus source for gear motors.	Requires modification for continuous rotation.
	Can be used for precise angular control, or for continuous rotation.	Requires special driving circuit.
	Available in several standard sizes, with standard mounting holes.	Though more powerful servos are available, practical weight limit is very low.

C. Type of Drive

The foremost electric wheelchair was invented by George Klein with the purpose to help the wounded soldiers of the World War II. With time, it has evolved into many designs and forms. The electric wheelchair is characteristically categorized into three categories

- The front wheel powered chair: This design is incorporated in power chair for indoor

purposes. This is a four wheel driven chair and is most flexible.

- Mid wheel powered chair: This electric wheelchair design is apposite for indoors but it has sturdy steering functions.
- The rear wheel powered chair: It is a power chair facilitated for outdoors. Being rear wheeled, they are appropriate for rugged roads.

D. Electronic Components

1) Motor Driver

A motor driver IC is an integrated circuit chip which is usually used to control motors in autonomous robots. Motor driver ICs act as an interface between microprocessors in robots and the motors in the robot. A motor driver circuit is designed to drive an electromagnetic load, such as a brushed or brushless motor, stepper motor or a solenoid or relay. Motors typically require voltages and/or currents that exceed what can be provided by the analog or digital signal processing circuitry that controls them. A motor driver is a small current amplifier; the function of motor drivers is to take a low-current control signal and then turn it into a higher-current signal that can drive a motor.

2) Sensors

Various sensors can be utilized in various applications of this technology. Addition of sensor's like Line Trackers, Bump Sensors, Vision Dead Reckoning, Laser Range Finder, Dead Reckoning etc will definitely help in making system more reliable and increase its functionalities. The only problem regarding sensors will be dealing with calibration. As the size of the system itself is very small, precision calibration is required. Installation of multiple sensors on the system will require huge precision. Thus, the need of the sensors should be identified before their installation. Addition of more sensors also increases the cost directly.

3) Processing and Control Unit

A dedicated decision system should be designed for efficient execution of the system. Decision unit being the most important unit, care should be taken while design. Designer should first chalk out all the desired functionalities and only then start adding required components to the design. Effective design would mean efficient system and reduce the cost. One can also use various processors already available in the market. But, using a readymade chip means limited functionality.

4) Battery Set

A set of lithium polymer batteries is highly preferred these days. A lithium polymer battery, or more correctly lithium-ion polymer battery (abbreviated variously as LiPo, LIP, Li-poly and others), is a rechargeable battery of lithium-ion technology in a pouch format. Unlike cylindrical and prismatic cells, LiPo's come in a soft package or pouch, this makes them lighter but also less rigid. Lithium-polymer differs from other battery systems in the type of electrolyte used. The original polymer design dating back to the 1970s used a solid (dry) polymer electrolyte that resembles a plastic-like film. This insulator allows the exchange of ions (electrically charged atoms) and replaces the traditional porous separator that is soaked with electrolyte. A solid polymer has poor conductivity at room temperature and the battery must be heated to 60°C (140°F) and higher to enable current flow. Large polymer batteries for stationary applications were available that needed heating but these have since disappeared. The much anticipated hype of the "true plastic battery" promised in the early 2000s did not materialize as conductivity could not be attained at ambient temperature. To make the modern Li-polymer battery conductive at room temperature, gelled electrolyte has been added. All Li-ion polymer cells today incorporate a micro porous separator with some moisture. Li-polymer can be built on many systems, such as Li-cobalt, NMC, Li-phosphate and Li-manganese; it is not considered unique battery chemistry. Most so-called Li-polymer packs are for the consumer market and are based on Li-cobalt. With gelled electrolyte added, what is the difference between a normal Li ion and Li ion polymer? As far as the user is concerned, lithium polymer is essentially the same as lithium-ion. Both systems use identical cathode and anode material and contain a similar amount of electrolyte. Li-polymer is unique in that a micro porous electrolyte replaces the traditional porous separator. Li-polymer offers slightly higher specific energy and can be made thinner than conventional Li-ion, but the manufacturing cost is said to be higher than cylindrical design. For purpose of discussion, pouch cells are often identified as being Li-polymer.

5) Access Method

In the rehabilitation community, access methods are devices used to enable people to drive wheelchairs or control computers. Many different access methods for powered wheelchairs are currently used. The default access method is a joystick. If a user has sufficient control with a joystick, no additional assistance is necessary. These users would not be candidates for a robotic wheelchair since they are able to drive without the system. If a person has some control of a joystick, but not very fine control, joystick movement can be limited through the addition of a plate which restricts the joystick to primary directions. Users in this group might be aided by a robotic system. If they push the joystick forward, the fine control could be taken over by the robotic system. If a user is unable to use a joystick, there are other access devices which can be employed. A switch or group of switches can be used to control the

wheelchair. If a user has the ability to use multiple switches, different switches can be linked to each navigation command. The multiple switches can be on the wheelchair tray, mounted around the user's head or placed anywhere that the user will be able to reliably hit them. Another access method for wheelchairs is a sip and puff system. With this method, the user controls the wheelchair with blowing or sucking on a tube. If the user can control the air well enough, soft and hard sips or puffs can be linked to control commands. This is analogous to the multiple switch system above. If the user has only one switch site, the wheelchair must be controlled using single switch scanning. In this mode, a panel of lights scans through four directional commands (forward, left,

Right and back). The user clicks the switch when the desired command is lit. If the user is travelling forward and drifts left, he must stop, turn the chair to the right and then select forward again. This mode of driving is very slow and difficult; it is the method of last resort. Obviously, a robotic wheelchair system could help this group of users. Most research on robotic wheelchairs has not focused on the issue of access methods. Most of the current systems are driven using a joystick (e.g., [12], [11], and [5]). A few researchers have used voice control for driving a robotic wheelchair (e.g., [5]). Voice control can be problematic because a failure to recognize a voice command could cause the user to be unable to travel safely. Additionally, some members of our target community are non-verbal.

III. CONCLUSION

Different mechanisms had been studied and researched upon, depending on different power drives and transmission mechanisms, such as mid-wheel powered, front wheel powered, track mechanism, clustered wheel concept and caterpillar wheel concept. Following set of requirements in a ideal and desirable wheelchair are made,

- The chair is required to be a rear wheel powered chair. As, it is facilitated for outdoors. Being rear wheeled, they are appropriate for rugged roads. Additionally, being a rear wheel powered, the design becomes impressive as the weight of the user is appropriately distributed on the design. Practically, the motors are carrying the user instead of pulling tediously as in case of front wheel powered chairs.
- The chair should have easy access methods. Easy access method may only attract a large set of users. Complex access methods might increase the features involved but won't fit into users mind-set. Easy access methods would also prove to be helpful for helpers. There can be cases where multiple helpers are needed or the helper is unaware how to drive a chair. Thus, if the access method are easy enough, new user or helper may find it very easy to handle and use, even on their first use. A easy access method will also mean a wheelchair which is easy to maneuver. Thus, it can go through doorways and over thresholds, maneuver on floor planes, make constricted turns from hallways into living rooms, move backwards on requirement, e.g. Reversing out of the toilet.
- The chair should be portable. One may expect that his/her wheelchair may not lead his/her family, friends in a problematic situation in case of transportation. The wheelchair must be easy to go as handy, as possible. Thus, it must incorporate various features like its folding ability, detachable, low on weight etc.
- The chair must have enough power to last for a day. Now, this is a tricky statement as large amount of power directly means large power sources i.e. Large batteries. But, incorporating large batteries means increasing weight of the wheelchair simultaneously decreasing the portability. Thus, design should be able to run the chair for a large amount of time, but it must remain portable as stated before. To attain this requirement, design can include rechargeable set of batteries, which then mean that if charger is present, it also should be portable and safe enough.

REFERENCES

[1] G. Pires, N. Honório, C. Lopes, U. Nunes, A. T Almeida, "Autonomous Wheelchair for Disabled People", Institute of Systems and Robotics University of Coimbra, Polo II,3030 Coimbra, Portugal.

[2] Tao Lu, Kui Yuan, Haibing Zhu and Huosheng Hu, "An embedded control system for intelligent wheelchair", in Proceedings of 27th Annual International Conference of the IEEE Engineering in Medicine & Biology Society, Shanghai, China, 2005.

[3] T. Rofer and A. Lankenau, , "Ensuring safe obstacle avoidance in a shared-control system", in Proceedings of 7th IEEE International Conference on Emerging Technologies and Factory Automation, vol.2, pp.1405-1414, July 1999.

[4] J. Borenstein and Y. Koren, "Obstacle avoidance with ultrasonic sensors", IEEE Journal of Robotics and Automation, vol.RA-4, no.2, pp.213-218, 1988.

[5] J. Borenstein and Y. Koren, "Real-time obstacle avoidance for fact mobile robots", IEEE Transaction on System, Man and Cybernetics, vol.19, no.5, pp.1179-1187, 1989.

[6] N. Hogan, "Impedance control: An approach to manipulation", Part I, Part II, Part III, ASME J. Dynamic Systems, Measurements and Control, vol.107, no.1, pp.1-24, 1985.

[7] The Frame Game".PN/Paraplegia News (Pvamag.com) (June 2011). Retrieved 2013-06-08.

[8] "The Titanium Revolution Revisited". New Mobility. Retrieved 2013-06-08.

[9] Sorby, Dennis K. Lieu, Sheryl (2009). Visualization, modeling, and graphics for engineering design (1st ed.). Clifton Park, NY: Delmar Cengage Learning. pp. A2 – A4. ISBN 9781401842499.

[10] Stackpole, Beth (2011-05-04). "Features - TiLite Races Ahead with Custom Wheelchair Design". Design News. Retrieved 2013-06-08

[11] The Industry Profile on Wheeled Mobility Editors: Stephen Bauer and Mary Ellen Buning