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Automation of Battery Powered Mobility For Physically Challenged

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ABSTRACT
Wheelchairs are an essential assistive device for many individuals with injury or disability. Manual wheelchairs provide a relatively low-cost solution to the mobility needs of such individuals. Furthermore, they provide an effective means of improving the user's cardiopulmonary function and upper-limb muscle strength. However, manual wheelchairs have a gross loss of mechanical efficiency, and thus the risk of user fatigue and upper-limb injury is increased.

I. INTRODUCTION

1.1 Background of Study

A battery powered mobility for physically challenged is a wheel chair that is propelled by means of a direct current motor rather than manual power. Automatic 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. Automatic wheelchair also may be used not just by people with conventional mobility impairments, but also by people with cardiovascular and fatigue based conditions.

Manual wheelchair and Automatic/Electric power wheelchair are available in current situation for assisting handicapped people. Manual wheelchairs can be operated by persons who have the use of their upper body or someone available to assist. But it only can move in limited surface only. In order to propel a manual wheelchair, a user not only has to move their weight, but they have to move the weight of the wheelchair as well. Some disabilities problems do not permit to move wheelchair manually. Most automatic wheelchairs are implemented by modifying existing Powered Wheelchair systems. These approaches arrange sensors and computing hardware around an existing infrastructure. The approach take advantage of pre-built control and motor systems. Complex control problems was presented but can yield impressive results. User uses the traditional wheelchairs need help from others or their own body power. Moreover physically weak users also face problems to grip joystick for moving the automated wheelchairs. In this circumstance, this project aims to design an automatic prototype wheelchair with button control which is fabricated from locally available resources and cheaper technologies that would be viable for disable person in the developing country like Nigeria.

This project is distinguished from most other similar projects in its attempts to produce practical results using a minimum of equipment and computing power. The idea of this project can be further defined through several distinct criteria;

This wheelchair will benefit the most individuals if the cost is not prohibitive. This factor is currently controlled by using locally available material and technology also it must use practical components they should seek to maximize on-board battery life through power efficiency and minimize maintenance concerns through simplicity and durability, it also guarantees easy and comfortable driving, facilitates learning to handle the chair and obtaining maximum efficiency, provides the ultimate easy movement & effortless independent operation without assistance by handicapped.

1.2 Statement of the problem

Manual wheelchairs can be operated by persons who can use their upper body or someone available to assist but can only move in limited surface. In order to propel a manual wheelchair, a user not only has to move their weight, but they have to move the weight of the wheelchair as well. Some disabilities problems do not permit to move wheelchair manually, and this has caused many of them to be static in a position and restricted in moving from one place to another at their free will or even dependent on someone that is available to assist. However ,this project will develop an

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automatic wheelchair based on button control for the physically challenged.

1.3 Aim and Objectives

The aim of this project is to design and implementautomatic battery powered mobility for physically challenged. The objectives are as follows;

i. To investigate the existing mobility means of physically challenged people
ii. To design automatic wheelchair using control button for physically challenged people
iii. To implement the design in (ii) above
iv. To evaluate the performance of the developed automatic wheelchair using the speedometer

1.4 Scope of study

Power wheelchairs are used predominantly by people with both lower and upper extremity impairment resulting from cerebral palsy, high-level spinal cord injury, or muscular dystrophy. The propulsion system of powered wheelchairs typically consists of a DC motor, most wheelchairs uses the permanent magnet DC motors (PM motors), with one 12V lead acid batteries providing a 24V supply. Permanent magnet motor have a linear torque-speed characteristic making them easy to control. This project will be limited to just having it been controlled with button that will enable it to move to and fro and the use of a speedometer to calculate the speed of the distance covered with a display screen that will inform when the battery is low, when the system is on and when is system is switched off.In other not to be limited in usage,two battery level notification will be infused which are led monitoring unit, and a buzzer to alert at a low level which will be able to create a restriction for movement of the user so as not to be stranded when the battery goes off, also we will infuse the system with a night lamp that automatically switches on at night to aid movement.

II. LITERATURE REVIEW

2.1 Mobility for physically challenged person

The wheelchair is one of the most commonly used assistive devices to promote mobility and enhance quality of life for people who have difficulties in walking (e.g. a person with spinal cord injuries resulting in quadriplegia or paraplegia, muscular dystrophy,etc.). Wheelchair mobility opens up opportunities for wheelchair users to study, work, and engage in social activities and access services such as healthcare. In addition to providing mobility, an appropriate wheelchair benefits the physical health and quality of life of the users by helping in reducing common problems such as pressure sores, progression of deformities and improves respiration and digestion.

To ensure effective mobility, wheelchair users need a wheelchair which fits them correctly and meets their specific needs. However statistics show that about 10% of the global population, i.e. about 650 million people, have disabilities and of these, some 10% require a wheelchair. It is thus estimated that about 1% of a total population, or 10% of a people with a disability, need a wheelchair, i.e. about 65 million people worldwide

In addition, it was estimated that in 2003, 20 million of those requiring a wheelchair for mobility did not have one. There are indications that only a minority of those in need of wheelchairs has access to them, and of these very few have access to an appropriate wheelchair.

2.2 Automation

Application of machines to tasks once performed by human beings or, increasingly, to tasks that would otherwise be impossible. Although the term mechanization is often used to refer to the simple replacement of human labor by machines, automation generally implies the integration of machines into a self-governing system. Automation has revolutionized those areas in which it has been introduced, and there is scarcely an aspect of modern life that has been unaffected by it.

The term automation was coined in the automobile industry about 1946 to describe the increased use of automatic devices and controls in mechanized production lines. The origin of the word is attributed to D.S. Harder, an engineering manager at the Ford Motor Company at the time. The term is used widely in a manufacturing context, but it is also applied outside manufacturing in connection with a variety of systems in which there is a significant substitution of mechanical, electrical, or computerized action for human effort and intelligence.

2.3 Power sources

There are many sources of power available, but the most commonly used power in today's automated systems is electricity. Electrical power is the most versatile, because it can be readily generated from other sources (e.g., fossil fuel, hydroelectric, solar, and nuclear) and it can be readily converted into other types of power (e.g., mechanical, hydraulic, and pneumatic) to perform

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useful work. In addition, electrical energy can be stored in high-performance, long-life batteries.

2.4 Deep- cycle battery

A deep-cycle battery is a battery designed to be regularly deeply discharged using most of its capacity. The term is traditionally used for lead–acid batteries in the same form factor as automotive batteries; and contrasted with starter or 'cranking' automotive batteries designed to deliver only a small part of their capacity in a short, high-current burst for cranking the engine.

For lead-acid deep-cycle batteries there is an inverse correlation between the depth of discharge (DOD) of the battery and the number of charge and discharge cycles it can perform; with an average "depth of discharge" of around 50% suggested as the best for storage vs cost.

Newer technologies than the traditional lead-acid (such as lithium-ion batteries) are becoming commonplace in smaller sizes in uses such as smart phones and laptops. The new technologies are also beginning to become common in the same form factor as the automotive lead-acid batteries, although at a large price premium.

2.5 Microcontrollers

A microcontroller is a type of microprocessor furnished in a single integrated circuit and needing a minimum of support chips as shown in figure 2.1. Its principal nature is self-sufficiency and low cost. It is not intended to be used as a computing device in the conventional sense; that is, a microcontroller is not designed to be a data processing machine, but rather an intelligent core for a specialized dedicated system.Microcontrollers are embedded in many control, monitoring, and processing systems. Some are general-purpose devices but most microcontrollers are used in specialized systems such as washing machines, telephones, microwave ovens, automobiles, and weapons of many kinds. A microcontroller usually includes a central processor, input and output ports, memory for program and data storage, an internal clock, and one or more peripheral devices such as timers, counters, analog-to-digital converters, serial communication facilities, and watchdog circuits. (Gaikwad; et al., 2013)

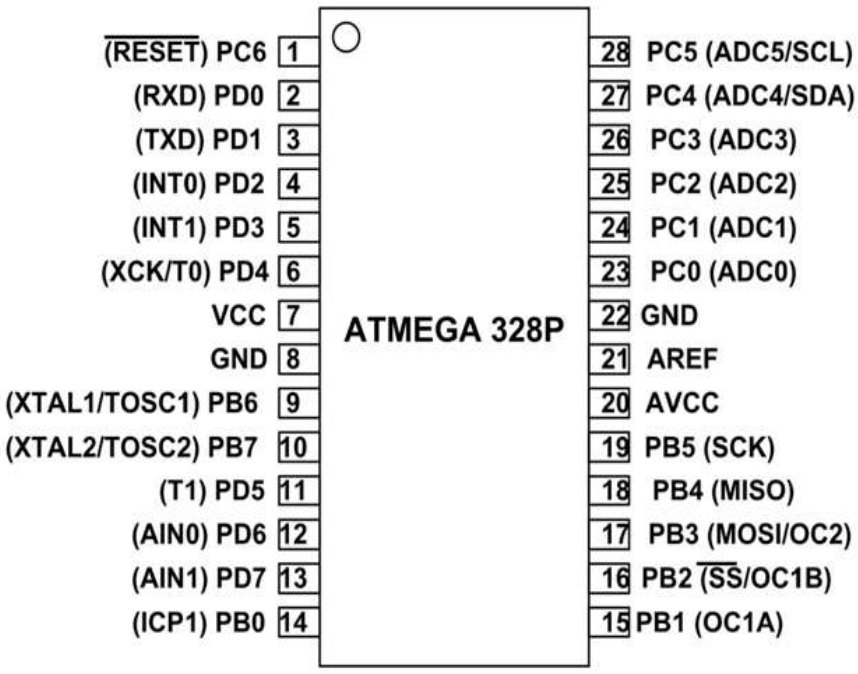

Figure 2.1: Pin configuration of Atmega 328p

2.6 Speedometer

The speedometer was originally patented by JosipBelušić (Giuseppe Bellussich) in 1888. He presented his invention at the 1889 Exposition Universal in Paris. His invention had a pointer and a magnet, using electricity to work. German

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inventor Otto Schultze patented his version (which, like Belušić's, ran on eddy currents) on 7 October 1902.

The speedometer uses a rotating flexible cable usually driven by gearing linked to the output of the vehicle's transmission. The early Volkswagen Beetle and many motorcycles, however, use a cable driven from a front wheel (Getornet al.,2008).

When the vehicle is in motion, a speedometer gear assembly turns a speedometer cable, which then turns the speedometer mechanism itself. A small permanent magnet affixed to the speedometer cable interacts with a small aluminum cup (called a speedup) attached to the shaft of the pointer on the analog speedometer instrument. As the magnet rotates near the cup, the changing magnetic field produces eddy current in the cup, which themselves produce another magnetic field. The effect is that the magnet exerts a torque on the cup, "dragging" it, and thus the speedometer pointer, in the direction of its rotation with no mechanical connection between them.

The pointer shaft is held toward zero by a fine torsion spring. The torque on the cup increases with the speed of rotation of the magnet. Thus an increase in the speed of the car will twist the cup and speedometer pointer against the spring. The cup and pointer will turn until the torque of the eddy currents on the cup are balanced by the opposing torque of the spring, and then stop. Given the torque on the cup is proportional to the car's speed, and the spring's deflection is proportional to the torque, the angle of the pointer is also proportional to the speed, so that equally spaced markers on the dial can be used for gaps in speed. At a given speed, the pointer will remain motionless and pointing to the appropriate number on the speedometer's dial.

The return spring is calibrated such that a given revolution speed of the cable corresponds to a specific speed indication on the speedometer. This calibration must take into account several factors, including ratios of the tail shaft gears that drive the flexible cable, the final drive ratio in the differential, and the diameter of the driven tires.

One of the key disadvantages of the eddy current speedometer is that it cannot show the vehicle speed when running in reverse gear since the cup would turn in the opposite direction – in this scenario the needle would be driven against its mechanical stop pin on the zero position.

2.9 Related works

Electric wheelchairs have been researched since the early 1980s and have been developed on four continents .Some Electric wheelchairs operate similarly to autonomous robots: the user specifies a final destination and supervises as the smart wheelchair plans and executes a path to the target location. To reach the destination, the systems typically require either a complete map of the area through which they navigate or modifications to their environment (e.g., tape tracks placed on the floor or markers placed on the walls). They are usually unable to compensate for unplanned obstacles or travel in unknown areas. Smart wheelchairs in this group are most appropriate for users who

(1) Lack the ability to plan and/or execute a path to a destination and

(2) Spend most of their time within the same controlled environment. Another group of smart wheelchairs assists only with collision avoidance, and the user has all the duties of planning and navigating. These systems do not normally require an internal map of an area or any specific alterations to the environment. However, they do require more planning and continuous user assistance and are only appropriate for users who can effectively plan and execute a path to a destination. A final group of smart wheelchairs offers both autonomous and semiautonomous navigation. Smart wheelchairs have also been used to explore a variety of alternatives to the more “traditional” input methods associated with powered wheelchairs (e.g., joystick, pneumatic switches). Automatic speech recognition has often been used for smart wheelchairs, because of the low cost and wide availability of commercial speech recognition hardware and software. More exotic input methods that have been implemented include using electrooculographic activity that detects where the wheelchair user is looking or using machine vision for calculating the position and orientation of the head. Estimates for prevalence and incidence are provided, along with estimates for the proportion of individuals within each diagnosis who need a wheelchair. In addition, symptoms associated with each diagnosis that might interfere with wheelchair use are discussed. Before making the final decision regarding the choice of the minor project.(Pranayet al., 2017)from department of mechanical engineering dit university, Dehradun project report page 10.

Around many researches done in the field of speech recognition.Due to sophisticated signal processing algorithms and powerful computers available, computer based speech processing system nowadays have reached complex structure with high accuracy. The challenge is to maintain standard performance while using limited computation and memory resources. Researches in

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the area of wheelchair control system are still going on. Many people with disabilities do not have the skill essential to control a joystick on an electrical wheelchair. This can be a great drawback for the user who is permanently unable to move any of the arms or legs. They can use their wheelchair easier only using voice commands. In the proposed design, the main idea of using voice activated technology for controlling the motion of the wheelchair is to prove that it can be an exclusive solution for severely disabled. The approach implemented is based on interfacing a microcontroller with a speech recognition IC from a dependent speaker. For future technology wheelchair would be fully autonomous that will move automatic based on the user expression and behavior. That should be fully automatic and wireless. In this project firstly we are working on the voice based automaticwheelchair and after that we will combine software based that will be controlled by computer and GSM mobile phones. A lot of efforts have been made to develop robotic wheelchairs that operate in the same way to an autonomous robot so that the user gives a final target and directs as the smart wheelchair moves to the goal. Other smart wheelchairs limit their assist level to collision avoidance, these systems do not normally require prior knowledge of an area. A voice controlled wheelchair can assist by giving input as a voice commands like right, left, back, forward, etc. here we can also controlled our wheelchair by some angle where user wants to rotate its wheelchair by like 30˚,45˚, 60˚ etc. This implementation is new from the other prototype developed and it is very useful for turning the wheelchair left and right with some angle. And this method can be achieved by using servo or stepper motor of high torques and less RPM (Krantiet al., 2013).

Voice controlled mechanism can also be used to operate power wheelchair by the individual who can produce consistent and distinguishable voice. This technology makes use of speech recognition system for taking voice of the user as the input signal. Before this speech recognition system is used for actual control of the wheelchair it has to be trained. The set of command spoken by the user will be saved by this system. During operation the user speaks a command into the microphone; the speech recognition system will compare the spoken command with the saved command and will transmit the computer code associated with it. In this way we can operate the wheelchair. The advantage of this technology is that, users don't have to physically operate the wheelchair and it is also easy to learn. Out of all these assistive technologies which were developed, very few assistive technologies has been proved successful in outer environment rather than in research laboratories. There are various technical and psychophysical factors which affect the acceptance rate of an assistive technology which are as follows:

• It should be easy and convenient to operate
• Device should require less time to learn
• It should be cosmetically suitable (Deepabalaet al., 2018).

DulariSahu proposed an eye control wheelchair for disabled person. This eliminates the personal assistant required for those persons. The whole system is controlled by Raspberry PI .ReonaCerejo issued proposed on Arduino circuit. The whole system is controlled by the Arduino. Arduino is a simple microcontroller board and open source development environment that allows to make functional and creative projects by using arduino microcontroller and software. And make the system affordable. And this paper also more concentrate on find the direction in which eye look using MATLAB frame. Depending upon the location of pupil in these blocks action is performed. GundaGautam proposed on image capturing module and image analysis module. Image Capture Module: - Image Capturing is to capture a sequence of iris images from the subject using a camera. In iris recognition image capturing is a very necessary step. Since iris is small in size and dark in color, it is challenging to achieve good image. The image is then changed from RGB to gray level for further processing. It is to capture a sequence of iris images from the subject using a camera. Image Analysis Module:- Image analysis is done by segmentation. Segmentation is to remove non useful information namely the pupil segment and part outside the iris. Segmentation is done by daugman algorithm. Daugman algorithm proposes an Integra-differential operator to find both the pupil and iris contour. This process works even if image taken in little dark environment .AnkurThakur in 2008 proposed on Matlab component and script. Mat lab component includes the topics are as follows

1. Initialization of variables and setting communication.
2. Image capture and eye detection.
3. Image processing.
4. Movement detection. Using the idea listed in survey we developed a wheelchair for paralyzed person

III. RESULTS AND DISCUSSION

3.1 Results

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Before using any component, it is advisable to test them before soldering and also to test each stage of the project during construction. This approach provides us with an easy way to trace fault and easily correct them.The physical realization of the project is very vital. Here the paper work is transformed into a finished hardware. After carrying out all the paper design and analysis, the project was implemented, constructed and tested to ensure its working ability. The construction of this project was done in stages.

1. The implementation of the whole project on a solder-less experiment board.
2. The soldering of the circuits on Vero boards.
3. The mechanization of the wheelchair.
4. The implementation of the power management unit of the chair.
5. Monitoring the speed sensor on it ability to send speed signal to the speedometer.

3.2 Implementation

The implementation of this project was done on the Vero board, this is where the needed basic components where fixed such as integrated circuit socket, transistor, capacitor, resistor and etc. To confirm the workability of the circuits before the power supply stage was soldered. The implementation of the project on Vero board was successful and it met the desired design aims with each stage functioning as designed.

The speed sensor, the led, the liquid crystal display, and the integrated circuits were rightly tested before implementing them on the main component of the project work. The Atmega328p ICs were programmed to work efficiently and synchronically, accurate sensing of speed by the speed sensor was also implemented and accurately monitored.

3.3 Soldering

The various circuits and stages of this project were soldered in tandem to meet desired workability of the project. The microcontroller stage was first soldered before the setting up the power management unit, which will manage the battery level and recharging of the battery for proper efficiency of the battery to power the wheelchair. The soldering of the project was done on a Vero board.

3.4 Mechanization of the wheel chair

The wheel-chair was mechanized in other for it to be propelled by the dc motor by interconnecting the gear with the shaft connecting the back tires together, and this was done by a local blacksmith in Ogbomosho.

3.5 Power management set up

The power management was set up, by allowing a recharge of the battery by an A/.C,and also monitoring the battery level with an indicator done by using led having the color red ,yellow and green to indicate it strength to notify the next charge time.

3.6 Speed Management unit

The speed sensor was attached to the tire edge where it will sense the speed through the magnet attached there and sending signal to the speedometer.

3.7.1 Discussion of the result

3.7.1 Problem encountered

Like every research and practical engineering work, diverse kinds of problems are often encountered. The problems encountered in this project and how they were solved and maneuveredare listed below.

1. During the testing of the Vero after soldering the components on it,we needed to test the connection accuracy by preloading a code into it using a loading cable, and it popped up an error message which we had to trace back to the soldering one after the other and this actually caused a problem before detecting what was wrong.
2. During the implementation of the battery level monitoring unit, we were faced with challenges on trying to allow it read an external battery level.
3. Getting a DC motor also became a challenge because those that were gotten were not compatible with the chair, as a result of this the project was slowed down a bit.
4. Getting the accurate reading from the speed sensor to the speedometer was a bit of a challenge that caused us to check for errors

CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The project which is the automation of mobility for the physically challenged designed considering some factors such as economic application, design economy, availability of components and research materials, efficiency, compatibility, and also durability. The performance of the project after test met design specifications. However, the general operation of the project and performance is dependent on the user who is prone to human error such as wrong use of the battery system.

Also the operation is dependent on how well the soldering is done, and the positioning of the components on the Vero board. If poor soldering lead is used the circuit might form dry joint early and in that case the project might fail.

Also if logic elements are soldered near components that radiate heat, overheating might occur and affect the performance of the entire system. Other factors that might affect performance include transportation, packaging, ventilation, quality of components, handling and usage.

The construction was done in such a way that it makes maintenance and repairs an easy task and affordable for the user should there be any system breakdown. The project really gave a good exposure toelectronic vehicle and practical electronics generally which is one of the major challenges in this field now and in future. The project was quite challenging and tedious but eventually it was a success.

However, like every aspect of engineering there is still a room for improvement and further research on the project as suggested in the recommendations written out in the section that follows in the paragraph below

4.2 Recommendations.

By future research, the project work can be improved upon. The following areas were highlighted for this purpose.

1. The whole circuitry can be reduced by making use of integrated circuit with higher scale of integration.
2. The department can make this a project on themselves by supporting the project so that there can be more improvement in terms of the functions on which the wheelchair can perform.
3. Moreover, it is recommended that students should be enlightened on new areas of technology that are yet to be addressed in order to bring solution to the various problems faced by man in his day to day activities.

REFERENCE

[1]. "A History of the World –Object : Bath Chair". BBC. 2012-09-02. Retrieved 2012-11-19.

[2]. "Battery Recycling".Batterycouncil.org. 2012.Retrieved 2014-10-02.

[3]. "Belušić, Josip". Hrvatskatehničkaenciklopedija [Croatian Technical Encyclopedia].Retrieved 19 August 2020.

[4]. "Commission Directive 97/39/EC of 24 June 1997 adapting to technical progress Council Directive 75/443/EEC of 26 June 1975 relating to the reverse and speedometer equipment of motor vehicles". European Commission.Retrieved 7 January 2007.

[5]. "Regulation No 39 of the Economic Commission for Europe of the United Nations (UN/ECE) — Uniform provisions concerning the approval of vehicles with regard to the speedometer equipment including its installation". European Commission.Retrieved 8 April 2017.

[6]. "Relay". EtymOnline.com.

[7]. "Speedometer".Siemens. 26 April 2005. Retrieved 30 January 2015.

[8]. "The electromechanical relay of Joseph Henry". GeorgiDalakov. Archived from the original on 2012-06-18.Retrieved 2012-06-21.

[9]. "Udini → Flow". proquest.com. Retrieved 30 January 2015.

[10]. "Understanding Relays & Wiring Diagrams". Swe-Check.Swe-Check.Retrieved 16 December 2020.

[11]. "UNECE Transport Division – Vehicle Regulations – Addenda to 1958 agreement – Regulations 21–40".UN Economic Commission for Europe.Retrieved 30 January 2015.

[12]. "US442849Ang use United States". Google Patents.Retrieved 21 September 2020.

[13]. "X-brace construction for collapsible invalids' wheel chairs".

[14]. ^ "Accessibility Beach Going Wheelchairs".Retrieved 14 September 2018.

[15]. 423–36. doi:10.1682/jrrd.2004.08.0101. ISSN 0748-7711. PMID 16320139.

[16]. Allen S, Resnik L, Roy J. Promoting Independence for Wheelchair Users: The Role of Home Accommodations. Gerontologist, 2006;46(1):115–123.

[17]. David Linden, Thomas B. Reddy (ed). Handbook Of Batteries 3rd Edition. McGraw-Hill, New York, 2002 ISBN 0-07-135978-8, pages 25-44 to 23-53

[18]. Everest, Herbert A., Jennings, Harry C., Sr., "Folding wheel chair", US Patent 2095411, 1937

[19]. Flemmer, Claire L.; Flemmer, Rory C. (2015-11-07). "A review of manual wheelchairs". Disability and Rehabilitation: Assistive Technology. **11** (3): 177–187. doi:10.3109/17483107.2015.1099747. ISSN 1748-3107. PMID 26549405. S2CID 900682.

[20]. Gibberd, William (1966). "Edward Davy". Australian Dictionary of Biography.Melbourne University Press. ISSN 1833-7538.Retrieved 7 June 2012 – via National Centre of Biography, Australian National University.

[21]. Harris, William (10 July 2007). "How Speedometers Work". How stuff works. Retrieved 30 January 2015.
[22]. Howitt J. Patronage or Partnership? Lessons Learned from Wheelchair Provision in Nicaragua [Thesis]. Georgetown University, Washington DC, 2005.
[23]. https://mysite.du.edu/~jcalvert/tel/morse/morse.htm#H1
[24]. Icons of Invention: The Makers of the Modern World from Gutenberg to Gates. ABC-CLIO. 2009. p. 153. ISBN 9780313347436.
[25]. Johnson, Nelson (2012-02-01). Boardwalk Empire: The Birth, High Times, and Corruption of Atlantic City (Kindle ed.). Independent Publishers Group. p. 28.
[26]. Joseph Flaherty (24 May 2012). "Putting the 'Whee!'Back in 'Wheelchair'".Wired.Retrieved 25 May 2012.
[27]. Jump up to:[a b] Bellis, Mary. "History of the Wheelchair". thoughtco.com. Retrieved April 14, 2017.
[28]. Jump up to:[a b c] "History of Wheelchairs". wheelchair-information.com. Retrieved April 14, 2017.
[29]. Jump up to:[a b c d e f] Lange, M. L. (June 2000). Tilt in space versus recline – New trends in an old debate. Technology Special Interest Section Quarterly, **10**:1-3.
[30]. Jump up to:[a b] Koerth-Baker, Maggie (2 February 2009). "Who Invented the Wheelchair?". mentalfloss.com. Retrieved April 14, 2017.
[31]. Jump up to:[a b] Maggie Koerth-Baker. "Who Invented the Wheelchair?". Mental Floss Inc. Retrieved 25 May 2012.
[32]. Jump up to:[a b] US 1647, Morse, Samuel E.B., "Improvement in the Mode of Communicating Information by Signals by the Application of Electromagnetism", published June 20, 1840 Archived May 24, 2012, at the Wayback Machine
[33]. Krizack, M. It's Not About Wheelchairs. Whirlwind Wheelchair International, San Francisco, Ca, 2003 (http://www.whirlwindwheelchair.org/articles/current/article_c02.htm, accessed 8 march 2008).
[34]. Langbein, W Edwin; Fehr, Linda (1993). "Research Device to Preproduction Prot
[35]. Lester, I.E. "Charles Babbage and the Difference Engine". NewMyths.com. Retrieved 20 November 2020.
[36]. Lithium RV Battery System Cost Analysis". Technomadia.com. 16 November 2011. Retrieved 7 January 2019.
[37]. Livingstone, Roslyn; Field, Debra (24 April 2014). "Systematic review of power mobility outcomes for infants, children and adolescents with mobility limitations". Clinical Rehabilitation. **28** (10): 954–964. doi:10.1177/0269215514531262. PMID 24764156. S2CID 44311983.
[38]. Marshall Batteries. "Are "Deep Cycle" batteries constructed differently?".Retrieved 2016-06-07.
[39]. Mason, C. R. "Art & Science of Protective Relaying, Chapter 2, GE Consumer & Electrical".Retrieved October 9, 2011.
[40]. Richard C. Simpson, (2005) "Smart Wheelchairs: A Literature Review" J. Rehabilitation Res. & Dev. 42 (4), pp. 423-438.
[41]. Richard W. Bulliet (2020). The Wheel: Inventions and Reinventions. New York, NY: Columbia University Press. p. 129. ISBN 9780231540612.
[42]. Sarah Frost, Kylie Mines, Jamie Noon, ElsjeScheffler, and Rebecca Jackson Stoeckle.Wheelchair Service Training Package - Reference Manual for Participants - Basic Level. Section A. Core Knowledge.World Health Organization, Geneva. 2012
[43]. Sarah Frost, Kylie Mines, Jamie Noon, ElsjeScheffler, and Rebecca Jackson Stoeckle.Wheelchair Service Training Package - Reference Manual for Participants - Basic Level. Section A. Core Knowledge.World Health Organization, Geneva. 2012
[44]. Scientific American Inventions and Discoveries: All the Milestones in Ingenuity--From the Discovery of Fire to the Invention of the Microwave Oven. John Wiley & Sons.2005-01-28. p. 311. ISBN 9780471660248.
[45]. Simpson, Richard C. (2005). "Smart wheelchairs: A literature review". The Journal of Rehabilitation Research and Development. **42** (4)
[46]. Sobey, Ed (2009). A Field Guide to Automotive Technology. Chicago Review Press. p. 78. ISBN 9781556528125.Retrieved 30 January 2015.
[47]. Susan Allen, Linda Resnik and Jason Roy; Promoting Independence for

Wheelchair User's : The Role of Home Accomodations, The Gerontological Society of America, 46: 115-123, 2006.
[48]. Thomas Coulson (1950). Joseph Henry: His Life and Work. Princeton: Princeton University Press.
[49]. Tolerico ML, Ding D, Cooper RA, Spaeth DM. Assessing mobility characteristics and activity levels of manual wheelchair users. Journal of rehabilitation research and development. 2007 May 20;44(4):561.
[50]. William Armstrong, Johan Borg, Marc Krizack, AlidaLindsley, Kylie Mines, Jon Pearlman, Kim Reisinger, Sarah Sheldon. Guidelines on the Provision of Manual Wheelchairs in Less Resourced Settings. World Health Organization; Geneva: 2008.
[51]. William Armstrong, Johan Borg, Marc Krizack, AlidaLindsley, Kylie Mines, Jon Pearlman, Kim Reisinger, Sarah Sheldon. Guidelines on the Provision of Manual Wheelchairs in Less Resourced Settings. World Health Organization; Geneva: 2008.
[52]. World Health Organization,World Bank World Report on Disability. Geneva:World Health Organization; 2011 (http://www.who.int/disabilities/world_repo