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EVOLUTION OF INTELLIGENT WHEELCHAIRS AND THEIR ROBOTIC INSPIRED ENHANCEMENTS–A SURVEY

Daniel Raja Sundaram. S[1]
[1,] Chief Physiotherapist,
Mayopathy Institute of Muscular Dystrophy & Research Center,
Tirunelveli- 627426,
Tamil Nadu, India

Shanthi Devi. M[2]
[2] Chief Physiotherapist,
Mayopathy Institute of Muscular Dystrophy & Research Center,
Tirunelveli- 627426,
Tamil Nadu, India

ABSTRACT

This study presents the evolution of the wheelchair system which the most needed assistive device for the physically challenged and old age people. Substantial literature is available to analyze the enhancement of conventional wheelchair equipment to meet the self- navigation requirement of the patients. Growing Sensor Technologies and automation processes changed the existing wheelchair system desperately to meet the independent mobility of the needy. Robotic Arm Manipulation Technique eventually reached the height to accommodate the need of the disable individual. Such intelligent wheelchairs not only fulfill the need of the patients but also improve their confident level and psychological independency. Hence this survey aims in collecting information about the available intelligent wheel chair systems. This paper briefs about the conventional wheelchair system followed by an elaborate survey about the Smart Chairs and commercially available Smart chair models and their advantage and disadvantages. Finally the Robotic based modification of wheelchair literature is studied. A study which highlights the beneficial part of Smart Wheelchairs for self-assistive movement of the needy is also presented.

KEY WORDS: *Smart Chair, Intelligence, Sensors, Robotic manipulation, Self-Navigation*

I. INTRODUCTION

Wheelchair is a necessary Assistive Equipment for the aged people and children who are affected by the diseases like Duchenne Muscular Dystrophy, Quadriplegia etc. To operate such wheelchairs and for movement control; nursing and manpower is required. Various types of Manual Operation based armchairs with wheels are readily available in the market. Patient management using wheelchairs are widely discussed right from early 80's. Gibson *et. al.* (1975) studied the role of wheelchairs in the management of the Muscular Dystrophy patients and reported the improved attitude of the patients [1]. Tefft *et. al.*(1999) and Trefler et.al. (2004) reported the uses of various types of wheelchairs such as power wheelchairs, manual wheelchairs, scooters, and walkers and their benefits to both children and adult [2-3]. Also they added their inferences about incremental vocational and educational of the patients. They observed self-reliant feelings of patients who are using such wheelchairs. Voice controlled wheelchairs are widely used and commercially simple ones. Miller et.al. (1985) presented the use of voice controller for making intelligent wheelchairs [4].

McGuire (1999) presented about the Voice operated wheelchair technique as an Assistive Technology for People with Disabilities [5]. Clark and Roemer (1977) & Amori (1992) & Simpson and Levine (2002) designed a voice controlled wheelchairs for the disabled. In all these cases Voice control has long been pursued as a control mechanism for wheelchairs and voice commands are used as the navigational aid for the all above designed wheelchairs [6-8]. To further improve the accuracy and ease of self-navigation and control robotic based wheelchairs came into the picture from early 90's. Robotic armchairs are useful for the patients who have the problems like muscular weakness, cognitive problems etc. Römer et. al. (2004) and Kinova et.al. (2011) presented the benefits and economic aspects of the robotic assistive devices [9-10]

From the literature, it is evident that voice controlled devices and robotic manipulated devices make the nursing process ease and make the patients comfortable and confident. Rest of the paper elaborates about the relevant commercially available devices and proposed designs available in the literature. This paper is organized as follows. Chapter II details about various voice control systems followed by the Robotic based wheelchair survey as Chapter III. Chapter IV investigates the systems designed by various universities and industries. Chapter V gives the short patient survey on the benefit of intelligent wheelchairs followed by Conclusion as Chapter
VI.

II. VOICE CONTROL BASED WHEEL CHAIRS

Among the available smart wheelchair systems, Voice controlled wheel chairs consume a wide space. Gomi and Ide (1996) developed a voice controlled wheelchairs for physically disabled. But it was observed that the accuracy of the system is lower and the voice recognition time delay was more [11]. Wang et.al. (1996) developed an auto navigation system using voice control and reported its use for sick persons [12]. Montesano et.al. (2010) developed an intelligent wheelchair system for the patients with Cerebral Palsy problem [13]. Nipanikar et.al. (2013) reported the uses of voice controlled automatic wheelchairs for physically disabled persons [14]. Suryawanshi et.al. (2013) developed a voice operated wheelchairs and analyzed the operation of the same with various age group of people who have disability. How et.al. (2013) evaluated the need of voice controlled intelligent wheelchairs for the cognitive disabled persons [15]. Sivakumar and Sudhagar (2015) developed a voice controlled intelligent wheelchair system and were checked with hundred different persons for voice recognition control [16]. In all these developed systems, Voice commands such as Forward movement, backward movement, Left and right movements have been ensured. Mobility impairments can further treated better with robotic related techniques in which the mobility and finger operations can be supported by robotic arms. Section III details the robotic inspired wheel chairs.

III. ROBOTIC BASED WHEEL CHAIRS

This section explores about some of the smart wheelchairs which are using Robotic Techniques. Bach et.al (1990) proposed Wheelchair-mounted robot manipulators for the long term use by patients with Duchenne Muscular Dystrophy which was the good initiative in the domain of robotic based assistive devices design [17]. Harwin et.al. (1995) analyzed the factors and parameters which are dictating the design of rehabilitation robots [18]. Kim et.al. (1999) reported the role of Assistive Robots and analyzed the Autonomy Impacts, Performance and Satisfaction by a Study in which Spinal Cord Injured patients were inducted [19]. Tsui et.al. (2008) had taken the survey about the assistive robotic technology by means of the domain specific measures such as the kind of disease and the age group of the patients etc [20]. Montesano (2006) developed a robotic wheelchair for the patients who have cognitive disability and tested the same with people have different cognitive problems [13]. Table 1 shows some of the developed robotic wheelchair systems and their significant features.

Table 1. Some of the Developed Robotic Wheelchair Systems

Sl.No.	Name of the System	Designed and Developed by	Significant Features (Iosif 2015 [21])
1.	*KARES System*	Department of Electrical Engineering KAIST, Korea	6 degrees of freedom robotic arm, a gripper, a high cognitive load on the user part (Song et.al. 1998 [22])
2.	*The Weston Wheelchair*	Bath Institute of Medical Engineering, UK.	Manipulator is mounted to a wheelchair, vertical actuator, an upper arm, a wrist and a gripper (Hillman et.al. 2005 [23])
3.	*The Raptor Arm*	Applied Resources	4 degrees of freedom robotic arm and a planar gripper. control the arm with either a joystick or a 10-button controller (Iosif 2015 [21])
4.	*The Manus Arm*	Exact Dynamics	6 degrees of freedom robotic arm with servo motors, the joystick has 2 degrees of freedom, switch between the degrees in order to manipulate with the arm in 3D space (Hylke 2005 & Eftring and Boschian 1998 & Kwee 1989 & Tijsma 2005 [24-27])
5.	*The Mats*	University of Carlos III, Spain	5 degrees of freedom robotic arm, totally autonomous and needs only power supply, It can also be dismantled off the chair and take a permanent position (Iosif 2015 [21])
6.	*DORA*	University of Massachusetts, Lowell.	A single motor, three plastic finger,14 different handles (Iosif 2015 [21])
7.	*RIBA*	Institute of Physical and Chemical Research, Japan	Lifting facility, sensors, Cameras and microphones for the human-interaction (Mukai et.al. 2011 [28])
8.	*PerMMA*	University of Pittsburgh, USA.	2 Manus Arms with enhanced manipulation facility (Xu et.al. 2010)
9.	*Dee-light*	University of Rice, USA,	Game controller, Remote controller (Iosif 2015 [29])
10.	*JACO*	Kinova	The 7 degree of freedom refer to six movement in three-dimensional space, six movement of JACO's wrist and opening and closing the 3 fingers, 3 Joysticks (Iosif 2015 [21])

IV. SMART WHEEL CHAIRS DESIGNED BY UNIVERSITIES AND INSTITUTES

Apart from the above mentioned significant works in the field of smart wheelchair design, various universities and research institutes are also contributing their ideas. Table 2 gives the details of the same.

Table 2. Smart Wheel Chairs developed by Universities and Institutions

Sl.No.	Name of the System	Designed and Developed by	Significant Features
1.	The TAO Project	Applied AI Systems	For indoor navigation, Joystick based control (Yanco 1998 [30])
2.	Wheelesley	MIT AI Lab	Robotic indoor and outdoor navigational system (Yanco 1998 [30])
3.	Deictically Controlled Wheelchair	Northeastern University	Robo based commanding system for navigation (Yanco 1998 [30]))
4.	NavChair	University of Michigan	Switches based control (Yanco 1998 [30]))
5.	Rehabilitation Robot	The Middlesex University	Control based on the Gesture Recognition (Parsons et.al. 2005 [31])
6.	Tin Man II	KISS Institute for Practical Robotics	Cost effective Robotic System with reduced Sensors (Yanco 1998 [30)
7.	Voice-commendable Robotic Wheelchair	MIT Lab	Speech Recognized ordinary power Wheelchair [32]
8.	PlexWheel	Plexus and TAR University College	Gesture Recognition and reduced size and weight device [33]

V. BENEFIT ANALYSIS

Simpson et. al. (2008) created a test bed to know how many people would benefit from smart wheelchairs [34]. In this survey, they considered the patients who were affected by Alzheimer Disease, Amyotrophic Lateral Sclerosis, Cerebral Palsy, Cerebro Vascular Accident, Multiple Sclerosis, Multiple System Atrophy, Parkinson Disease, Progressive Supra Nuclear Palsy, Severe Traumatic Brain Injury and Spinal Cord Injury and analyzed the benefits of intelligent wheelchairs. Their finding includes;

i. 61 to 91 percent of individuals would benefit from a smart wheelchair at least some of the time.

ii. The number of wheelchair users has grown at an average annual rate of 5.9 percent a year.

iii. At that rate, by 2010, wheelchair users will increase to 4.3 million, with 2.6 million to 3.9 million of these users benefitting from a smart wheelchair. Their findings are tabulated in Table 3.

LaPlante (2003) was reported the same in his demographic analysis about the wheeled mobility device users [35].

Table 3. Benefit Rate Analysis Finding

Sl.No.	Diagnosis	Estimated need of Wheel Chair in (%) (Simpson et. al. 2008 [34])
1.	Alzheimer Disease	15
2.	Amyotrophic Lateral Sclerosis	80
3.	Cerebral Palsy	86
4.	Cerebro Vascular Accident (right-hemisphere)	25
5.	Cerebro Vascular Accident (left-hemisphere)	25
6.	Multiple Sclerosis	69
7.	Multiple System Atrophy	60
8.	Parkinson Disease	10
9.	Progressive Supra Nuclear Palsy	70
10.	Severe Traumatic Brain Injury	9
11.	Spinal Cord Injury	100

VI. CONCLUSION

The presented survey highlights the relevant technologies available in the field of Voice Recognition and Robotic based wheelchair development. Now-a-days, wheelchair models are being developed by using Object Recognition techniques, Body Tracking techniques, Algorithms based on Learning Patterns of Behavior, Recognizing Facial Expressions controlled techniques. Human-Machine-Interaction (HMI) models can better be established using the above mentioned methods. Health Monitoring, Assistive Lifting to stand-up using gesture recognition are also find their space in this wheelchair enhancement process. Even though this survey presents the significant developed systems, it will provide room for the researchers to explore the available systems and to identify the future scope of the systems.

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