Chapter 2 Related Works

2.1 Plight of People with Mobility Issues

Today’s world comprises of a large variety of people. Many are healthy and many suffer from various ailments. Some of them depend on others for their living. All are busy and there are less people to care for the increasing number of elderly and the physically challenged people. Recent studies show that people with mobility issues are isolated from the society. Whether their condition is physical, emotional or mental, all met the same attitudes. They were kept off from social gatherings because they needed special attention or people to take care of them. Assistive aids are often required for them to facilitate mobility, communication, self-care or domestic activities. Also these people find it tough to even navigate inside the home without external aids. It requires a dedicated person to take care of such people. This makes the physically challenged often think that they are burden to others. Due to industrialization, especially in developing nations, elders and physically challenged are left alone at home. In a typical Indian family both the parents go to work and the children go to school. The elders are alone at home taking care of the house. The situation is same even if they are very old or even if they require medical attention as it is very expensive to hire a personal nurse or to admit them in private old age homes. In developed nations like US it is common that the adult children and the parents live separately even if the parents are very old and need external aid.

In a study conducted by Michael K. Gusmano [16], Assistant Professor of Health Policy and Management, Columbia University, for NYC’s population 75+, 56% are living with at least one disability. But there are roughly 200 census tracts in which 88% of these age cohort are living with one or more disability. As per the WHO, 2011 report on disability, more than billion people live with some form of disability which is about 15% of world’s population. It also says that 18.6% adults over the age of 18 are having moderate to severe difficulty in moving around [31]. Another report in Mont, 2007, supports this by stating that one out of five people has at least some walking and one in twenty has severe difficulty [32]. According to the study by ISPO/USAID/WHO, 2006, the number of people with disabilities in developing countries who require a wheelchair is approximately 1% of the population [33]. This means that in India alone, more than ten million wheelchairs are required.
2.2 Four Giants of Geriatrics

There is a rapid growth of the oldest groups among the older population in the world. In most parts of the world, the 80-and-over age group is growing faster than any other, and is expected to continue as the fastest growing segment of the population for at least the next 50 years as shown in [19]. Increased age normally leads to various issues. For example, health conditions typically decline with advancing age, and this suggests an escalation in the demand for long-term care. At the global level, the average annual growth rate of persons aged 80 years or over (3.8 per cent) is currently twice as high as the growth rate of the population over 60 years of age (1.9 per cent). In 1950, there were 205 million persons aged 60 or over throughout the world. Fifty years later, the number of persons aged 60 or over increased about three times to 606 million as shown in [19]. It is becoming increasingly tougher in the diagnosis and management of the so called "four giants" of geriatrics (memory loss, urinary incontinence, depression and falls/immobility) as well as the chronic diseases that are common in later life and that can often be prevented or delayed as discussed in [20]. The elderly people find automated wheelchairs as an easy way for locomotion as shown in [2].

2.3 Mobility Issues with Stroke Patients and SCI Patients

According to WHO every year, between 250,000 and 500,000 people suffer a spinal cord injury (SCI) all over the world. As per WHO, physical barriers to basic mobility is one of the three factors that result in the exclusion of many people with SCI from full participation in society. For improving care and overcoming health, social and economic barriers of people with SCI, WHO suggests using appropriate assistive devices that would help people to perform everyday activities. It also states that only 5-15% of the people with SCI in low and middle income countries have access to assistive devices that they need. There are about 400,000 SCI patients in USA alone, with about 15,000 new injuries every year[1].

Each year, about 15 million people worldwide are affected by stroke and 80% of the people affected by stroke are having mobility issues [48]. The assistive devices in the market are very generic in nature and very few of them available are too costly for the people of developing and underdeveloped nations. Nuclear families which enveloped the western nations have found its
way into many developing nations and the need for such assistive devices have increased manifold in these low income countries.

2.4 Mobility Aids in Rehabilitation Process

Many people in developing nations or poor countries cannot afford to have an electrical wheelchair robot. Even the companies which make electric wheelchairs in such countries, import parts like joysticks, motor controllers etc. from developed countries which is one of the reasons for the high cost of electric wheelchairs in these countries. For example, the Callidai Motor Works in Chennai, India and the Ostrich Mobility, Bangalore, India buy the parts of the electric wheelchair including the joystick controllers, motor controllers, electric motors etc. and assemble them at their companies to make electric wheelchairs. Not all the users of such wheelchairs are comfortable with the wheelchair controllers like joysticks or keypad. At Ostrich Mobility, users who found it very difficult to use the joystick controller navigation returned some of these electric wheelchairs.

The M A MATH, which is an NGO in Kerala, India and which is famous for its support in humanitarian cause, has around three thousand inmates of whom elders and physically challenged are about 20%. Most elders cannot afford such electric wheelchairs. The very few who use such wheelchairs are not comfortable with the design. A German inmate at this NGO who is handicapped and who uses an electric wheelchair bought from Germany said that it was neither user friendly nor cost effective. She expressed that a gesture-based wheelchair would be an ideal choice for her use

2.5 Existing Solutions

The most common among the control methods for wheelchair navigation are mouth-stick based control, keypad-based control, joystick-based control and brain actuated wheelchair controls as explained in papers (Paulo Coelho et al., 2005, Luis Montesano et al., 2010, Brice Rebsamen et al., 2010, Tuan Nghia Nguyen et al. 2011). Other methods such as neural network control (Xueliang Huo et al. 2009), pupil-tracking control (Zhou Ren et al., 2013), head-movement-based control (Yoshinori Kuno et al., 2000) and tongue-based control (Chern-Sheng Lin et al., 2006) are sometimes used in severe cases of paralysis. In paper (Cheryl D. Metcalf et al., 2013), (Eshed Ohn-Bar et al., 2014) and (Cristina Manresa et al., 2000) the authors discuss
about a gesture based and vision driven wheelchair for the physically challenged and automotive interfaces. HMMs based and FSM based hand gesture recognition were also used (J. Yamato et al. 1992) and (M. Yeasin and S. Chaudhuri, 2000). There are other control methods as in (Seiichiro Katsura et al., 2006), in which Kalman based active observer controller for wheeled mobile robots and as in (Sakiko Tashiro et al., 2008), in which the motion control is based on quarry of environmental information.

Gesture recognition methods and systems are vast in number which are based on MEMS based accelerometers (Ahmad Akl et al., 2011, Zhiyuan Lu et al., 2014), Kinect sensors (Zhou Ren et al., 2013), Ultrasonic sensors (Kaustubh Kalgaonkar et al., 2009), Vision sensors (Shengli Zhou et al., 2014), laser based (Perrin, S. et al., 2004) etc. Several different algorithms and techniques including pattern matching (Karthik, T.N. et al., 2013, Hasanuzzaman, M. et al., 2004, Raheja, J.L. et al., 2010), histograms (Igorevich, R.R. et al., 2010, Hanning Zhou et al., 2004), graph matching (Ben W. Miners et al., 2005), fuzzy based (Mu-Chun Su et al., 2000, Songmin Jia et al., 2012, Lekova A.K et al., 2013), neural networks (Ghosh, D.K et al., 2011, Tuan Nghia Nguyen et al., 2011, Wang Xinyu et al., 2010), HMM based (T. Starner et al., 1995, H. S. Yoon et al., 2001), FSM based (M. Yeasin et al., 2000, P. Hong et al., 2000) etc. are used for gesture identification. Glove based gesture device (Wang Xinyu et al., 2010) uses sensors that are attached to the glove for the users to wear and use. There are camera and Kinect based gesture devices where a user might still be expected to wear a glove with markers. Most of the Gesture based recognition and identification finds wide use in robot control, video gaming, text editing, vehicle system control, HCI, multimedia interfaces etc. Some of the navigation control methods are discussed below.

2.6 Joystick Based Navigation Control

This method uses joystick as the primary interface between the user and the wheelchair. Using joystick, one can manually control the wheelchair. Here the user has to press and hold the buttons provided on the joystick to move to the desired direction. The movement is achieved by controlling the electric motors attached to the wheel according to the button pressed on the joystick. This technique makes the user more autonomous than wheelchair which uses physical power to move. To be able to use this, the user must have some motor skills to operate the joystick. So this wheelchair can be of great benefit for a paraplegic person i.e., a person with
disability only in hind limbs or region lower to hip. This can be implemented as an additional feature like in [7]. One of the disadvantages of this method is that the extensive or prolonged use of joystick may cause numbness or soreness in the hands and can make it uncomfortable for the user to use.

**2.7 Touch Screen Based Navigation Control**

Use of touch screen is very much user friendly and requires very less muscle movement form the user. Touch screen is used as input device and LCD displays the user’s gesture correctly when recognized as in [9]. An IR obstacle detection unit can be used which is fixed to the wheelchair to avoid possible collision. A resistive touch screen will be best suited for this application as it is low cost and has greater lifespan compared to other types of touch screens available. From the screen, user can either select a predefined path or can create their path in real-time.

**2.8 Human Eye Controlled Navigation Control**

In this technique, webcams are used to read the human eye, to detect its movements and to control the wheelchair as in [8]. This can be either designed in the form of a wearable device or can be attached to the wheelchair, where the user has to adjust him while sitting so that the device can detect the eye movement properly. Another webcam can be fixed to the same structure facing away from the user towards the forward direction for obstacle detection. One of the major disadvantages of this system is that it cannot be used by a person with squinted eyes. Another disadvantage would be that the user must continuously look into the unit and cannot concentrate on other works which can make the user feel uncomfortable.

**2.9 Non-invasive Brain Signal Interface Control (I)**

In this technique, two electrodes are placed non-invasively on the scalp and signals are collected as in [4]. A P300 signal and a reference signal is detected and processed for navigation. P300 is an event related potential signal which is any measured brain response that has direct relation with the thought processing part of the brain. This technique has great practical application, at the same time, it is quiet risky as the user has to continuously sit and monitor the wheelchair for its navigation and can be considered as a disadvantage. Here, the brain signals are
used to select the pre-defined destination point in the menu and then the wheelchair moves in the selected path. One of the major advantages is that no beforehand training is needed for using this system.

2.10 Non-invasive Brain Signal Interface Control (II)

In this method, the user faces a screen and concentrates on the area of the space to reach. A visual stimulation process elicits the neurological phenomenon and the EEG signal processing detects the target areas as in [5]. This target area represents a location that is given to the autonomous navigation system, which drives the wheelchair to the desired place while avoiding collisions with the obstacles detected by the laser scanner. This technique allows the user to navigate the wheelchair without serious training for a long term. This method gives great accuracy in the interaction and flexibility to the user, since the wheelchair can autonomously navigate in unknown and evolving scenarios using the on-board sensors. Shortcoming of this system is that with the synchronous operation, the user has to continuously concentrate on the task. BMI is still in the stage of development as the number of symbols decoded by it is very less. Thus, the control of a wheelchair must rely on a navigation system that receives sparse commands from the user. This method requires complex processing of EEG signals and requires one or more microprocessors dedicated for controlling the chair. The cost of this method is high as a result.

2.11 Survey at Rehabilitation Center, AIMS, Kochi

An initial survey was conducted at the Physical Medicine and Rehabilitation Department of Amrita Institute of Medical Sciences, Amrita Vishwa Vidyapeetham University, Cochin, Kerala, India about the hand gesture based wheelchair. The following questionnaire was given to the doctors at the department.

1. How many patients visit your clinic/hospital in a day to whom the wheelchair is suggested?

2. While prescribing a wheelchair what all factors do you consider in mind?

3. Do people ask for the type of wheelchair or do you suggest based on their physical condition?
4. Has wheelchair got any role in skin breakdown?

5. How many people switch on to manual wheelchair even when they are suggested to use automated wheelchairs?

6. On what criteria do you suggest a wheelchair to your patient?

7. What do you suggest your patient to buy or rent a wheelchair?

8. How often do you suggest them to change the wheelchair?

9. What type of wheelchair do you suggest to your patients at present?

The summary of the answers to the questionnaire is provided here. The wheelchair is suggested to at least three patients daily who visit this department which puts total number of patients for whom wheelchair is suggested, at 1095 every year. While prescribing the wheelchair the doctors consider primary diagnosis, co-morbidities, functional status, goal, socio-economic status and potential for return to work as the primary factors. The doctors suggest the patients what type of wheelchair is best for them. The prevailing wheelchairs (joystick based) are unsatisfactory for the population (stroke patients and SCI patients) that the doctors treat. For patients with severe quadriplegia it takes time to recover some motor control in their hands. Hand gesture based wheelchair can be used only by those patients who are able to move their hands back and forth to a certain extent without external help. There might be heat produced because of the battery underneath the seat which might cause damage to the skin of the user who are seated. As the existing powered wheelchairs with joystick control are not suitable for the patients whom the doctors treat, they suggest buying only a manual wheelchair. They rarely suggest changing the wheelchairs. The answers only point to the fact that the existing joystick based control mechanism is not suitable for stroke patients and SCI patients and that which is suitable for them is not available in India.