Market Evaluation for Colchester Catalyst on the use of Robotic Wheelchairs

TECHNICAL REPORT: CES-514

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26th of August 2011

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Chapter 1

Executive Summary

This chapter presents a brief summary of the remaining parts of this report for those readers wanting an overview of the rest of the report in order to make a decision. This market research was conducted between 15^{th} July and 26^{th} August 2011.

1.1 Reason for Market Research

This market research was conducted at the request of Colchester Catalyst. Colchester Catalyst is a charity organisation established in the 1990s. Its main aim is making life easy for disabled people and providing support to their carers. This includes short term loan of disability equipment such as wheelchairs to those that have lower or upper body impairments [1]. Due to various user needs and advancement in technology, robotics research into wheelchairs has been increasing steadily, especially in the past decade. This involves applying mobile robotics techniques unto standard electric powered wheelchairs to aid wheelchair users during their everyday living activities. Such technology refines their joystick control commands so that they are less likely to collide with objects and people in the environment. As a result, this report was requested in order to access the possibility and feasibility of acquiring such novel wheelchairs into the existing wheelchair fleet of Colchester Catalyst.

1.2 What is a Robotic Wheelchair?

The wheel chair is a tool that has been in existence since the 6th Century. It is a tool that has helped carers of critically ill people take care of their sick loved ones by providing mobility. As a result of this tool, carers have been able to socially reintegrate their loved ones into their community to an extent thereby reducing levels of social isolation. However, the carers were sometimes hindered by the problem of weight of the user and also by their own lack of independence. This was partly solved by the introduction of electric motors to the wheelchair and a joystick. Through use of the joystick, the user is able to navigate an environment. However, for disabled or old people with muscle spasms, getting the right balance of control when navigating in an area with clutter or crowds is often very difficult.

In order to solve this problem, sensors such as sonar and laser for acquiring information from the environment including detecting obstacles and a computer to process the information are added to an existing electric wheelchair. This enables the computer know what is going on in the environment and then refine the user's input to deal accordingly with the situation. Computer intervention includes automatically stopping the wheelchair once an edge is detected, navigating around a detected obstacle, refining the user's input when going through a narrow passage or when going through a door having very little clearance on both sides.

However, most the robotic wheelchairs are still confined to the laboratories and it is only of recent that they started emerging into the commercial market. Presently, from our present knowledge, only one company is commercially producing robotic wheelchairs and this product targets the children market. However, there are bound to be other manufacturers in the near future. This report tries to answer the question of which part of the world the manufacturers will be from, whom the potential manufacturers will be and where the products are bound to appear. Recommendations are also made as to which sponsors might be interested in investing in robotic wheelchair technology towards commercial production.

1.3 Type of Marketing Research used and sources of data

We used desk research during the development of this market research on robotic wheelchairs using secondary sources of data. A desk research was used because conducting a proper market survey would cost more money and time. A secondary source of data is data that is not obtained directly but is obtained instead from an already existing source of data such as from the UK annual of statistics. The sources of information used in this report are free but are also deemed to be very reliable sources of information. Data was obtained from the UK annual of statistics and other data sources such as United States Disability Statistics Centre, United States Census Bureau, Japan Robot Association, United Nations reports, Global Industry Analysts, United Nations Economic Commission report for Europe, European Robotics Research Network among others. Information on robotic wheelchair research was obtained from survey of academic papers.

Robotic wheelchair falls under the service personal robot niche and the International Federation of Robotics (IFR) is the most up to date information source on this. However, we could not obtain information from IFR because each document could cost up to about 4000 dollars. However, we were able to get data regarding robotic wheelchair from the United Nations Economic Commission reports for Europe and for the service personal robot niche from the Global Industry Analysts. In some cases, where we were lacking data for specifically the robotic wheelchair in terms of sales or prediction for a particular year, we use data from the service personal robot information to make predictions. We also used the correlation between robotic niches to make a judgement as to whom the key players are most likely to be in this field.

1.4 Robotic Wheelchair Market Drivers

Due to the continuous advancement in medicine, people are bound to live longer all over the world. However, as people grow older, their agility and mobility reduces resulting in the need for mobility devices. Japan has one of the best national health service in the world resulting in an increase in the ageing population. Due to this ageing problem, the Japanese government is spending money on different types of robotic devices to either aid mobility or entertain the ageing population. In Europe however, the market driver is mainly the amount of young people in the 20-30 age gap that have been involved in accidents, born disable or are war veterans. Whereas in the United States, it is a combination of both factors that is an ageing population and an increase in disabled young people.

1.5 Robotic Wheelchair Market Barriers

The main barrier to the deployment of robotic wheelchairs is the feasibility in terms of manufacturing costs. This is because of the cost of materials required to build a robotic wheelchair with a laser sensor and input device such as the EEG cap (for reading brain signals) being the most expensive. As a result, developing a viable business plan is very difficult. The lack of a viable profit generating business plan stopped the development of the iBot that was very popular among disable war veterans in the United States.

1.6 Robotic Wheelchair Market Opportunities and Forecast

From the above sections, the areas with the greatest opportunities of market growth are Japan, Europe and the USA. There seems to be a strong correlation between the ageing population in Japan and them being the largest researchers in service robotics and hence robotic wheelchairs. Most of the media coverage concerned with robotics or mobility has been from Japan in terms of famous robots such as Asimo by Honda, the robotic unicycle by Honda, the i-Real by Toyota and the bed that ”morphs” into a wheelchair by Panasonic among other products. However, none of these companies have been able to commercially produce these products mostly because of the lack of a viable business plan. In Europe and the USA, the main drivers is as a result of increasing injured young people either because of accidents or wars in addition to an ageing population. As a result, these three market regions could have the greatest market opportunities in the future with the global sales in service robotics excepted to reach 8.42 billion dollars by 2015.

The robotic wheelchair market is still very young and almost non existent with practically no commercialisation of the robotic wheelchair. An exception however is the UK company- Simile Rehab Uk. However, the market landscape is bound to change as an increasing number of wheelchair companies are investigating the possibility of using robotic technology on their wheelchairs. For example, IMASEN, a Japanese company, bought a robotic technology from GeckoSystems in March 2011. GeckoSystems is a leading developer of mobile service robot technology research company based in the Altanta, USA. With their technology, robots are equipped with the capability to perform collision free navigation in a cluttered room. As a result, of this collaboration, it is possible that in the next few years, we see an adult sized electric wheelchairs with robotic technology being mass produced. This would also introduce competition into this market niche encouraging the reduction in prices from their currently expensive price tags.

1.7 Robotic Wheelchair sponsors and market strategy

As can be seen in the previous section, there is a collaboration between wheelchair company IMASEN and a mobile service robotic technology company GeckoSystems. As most novel research into mobile robotics is carried out in academia, wheelchair companies would be the most likely sponsors of continuous research into robotic wheelchairs. This collaboration between academia and industry would bring out the best of both sides and could make the production of robotic wheelchairs possible and also viable. In addition, as most research into robotic wheelchairs make use of existing electric wheelchairs, an upgrade should be relatively possible for the manufacturer with little or no cost provided the sensors and input devices used are cost effective.

1.8 Report Layout

The rest of this report is arranged as follows: in Chapter 2, we present a brief history of the electric wheelchair and a technology overview of the robotic wheelchair. We also discuss the possibility of its commercial realisation. In Chapter 3, we present a market forecast and the regions of the world that would be the major players in robotic wheelchair technology. Potential key market players in the form of companies and potential sponsors are considered in Chapter 4 while we conclude with recommendations in Chapter 5.

Chapter 2

Technology Overview and Commercial Realisation

In this chapter, we shall present a brief history of the electric wheelchair from its humble beginnings as a chair with added on wheels to its present form incorporating electric motors for providing the drive force and various electronic addons to solve various problems that users of standard wheelchairs experience daily. These electronic modifications would be discussed in section 2.2 which would set the scene for the robotic wheelchair that we shall discuss in section 2.4. In section 2.5, we shall discuss what the state of art should be in the design of the robotic wheelchair and finally in section 2.6 discuss if research into the robotic wheelchair is matured enough for commercial realisation.

2.1 Brief History of the Electric Wheelchair

The wheelchair is a tool that has been in existence since the 6th Century. It is a tool that has helped carers of critically ill people take care of their sick loved ones by providing easy mobility. The modern day format of the wheelchair is basically a chair on wheels as shown in Figures 2.1 and 2.2. Handles are often placed behind the seat for a carer to push the disabled person around. However, in some cases when the user is able, it is possible for the disabled person themselves to propeller themselves about through the manual rotation of the wheelchair's wheels.

Wheelchairs were first commercially mass manufactured by the company Everest and Jennings in 1933 [2][3]. Everest and Jenning's wheelchairs were the first to be lightweight, made of steel and collapsible. The design was patented under the US Patent 2095411, 1937. This design of the wheelchair made it easier for carers of disabled people to move them around because of a reduction in weight whilst enabling the easy storage of the wheelchair when not in use. The lightweight wheelchair also enabled users to complete tasks faster, increased comfort, and were cost-effective.

However, despite the usefulness of the wheelchair, in the most serious case of paralysis,

Figure 2.1: Attendant propelled 1920s wheelchair [4].

Figure 2.2: more modern wheelchair [2].

its use does not promote a feeling of self-reliance on the part of the disable person as he or she needs to have a capable dependable person around before he or she can go shopping, go to the commode or perform any daily living activity at all [5]. This often makes the disable or old person feeling helpless, have less self-esteem and a reduction in development for children as a result of the lack of environmental stimuli [6][7]. In addition to these effects, disabled people are more prone to depression and anxiety as a result of social isolation [8].

The above problems partly resulted in the invention of the electric wheelchair in 1960s by Dr Klein. Dr Klein's invention was as a result of the need to give world war II veterans suffering spinal cord injuries a close resemblance to normal daily life [9] [10]. The electric powered wheelchair was first mass produced by Everest and Jennings [3]. In the electric powered wheelchair, the occupant is propelled by electric motors attached to each of the main wheels of the wheelchair. The occupant steers the electric wheelchair through the use of a joystick [11]. Electric powered wheelchairs come in mainly three different wheel drive types including a *front wheel drive* in which the main electric drive motors are in front driving large wheels with castors at the rear. *Mid wheel drive* electric wheelchairs have the electric drive motors on the rear of the wheelchair driving the main large wheels with casters on the front while on the *rear wheel drive* wheelchairs the large wheels are placed so that they are under the centre of mass of the user.

Ever since the invention of the electric powered wheelchair, the number of users have been increasing. In the United states alone, 18 million people have mobility problems with 2.2 million of them using wheelchairs [4][12]. Of the 2.2 million, about 200,000 people now use electric wheelchairs in their daily living activities. Furthermore, with about 12.5% of the United states population about the age of 65 and older, this number is going to grow as a result of reduced mobility with age [8].

In the United Kingdom, about 1.5% of the total population use wheelchairs with about 20000 new users every year. 28% of those users are under 60 whilst 72% are above 60. A survey conducted in 2005 among ordinary wheelchair, electric wheelchairs and electric scooter users showed that users would want to keep informed about progress in the electric wheelchair field and especially electric scooters. Due to this growing importance of the electric wheelchair the American National Standards Institute/Rehabilitation Engineering and Assistive Technology Society of North America (ANSI/RESNA) has developed a series of standards that electric wheelchairs could be judged by based upon braking distances, obstacle climbing ability and so on [13]. However, the standard electric wheelchair is not without its problems or needs for improvement.

2.2 Problems and improvements to the Standard Electric WheelChair

There has been improvements made to the basic electric wheelchair as a result of various needs and problems that users encounter. We shall now discuss some of the needs and problems and how various wheelchair manufacturers have aimed to solve them.

2.2.1 Lack of exercise for users

It has been argued that the use of electric wheelchairs do not enable users who are still able to propel themselves about with standard wheelchairs get enough exercise. As a result, electric wheelchairs must be “prescribed” by a clinician according to the user’s ability. However, it has also been discovered that the use of standard wheelchairs can lead to injuries related to the shoulders, elbow, wrist and hand due to constant usage. This often leads to significant upper limb pain and sometimes cessation in the use of the wheelchair [14][4].

Additionally, users of wheelchair experience difficulties when going up a slope due to insufficient strength or the steepness of the slope. In order to solve these problems, Ulrich-Alber GmbH developed the E-motion electric wheelchair. It works in two modes- as standard wheelchair in which the users are able to wheel themselves about and an wheel power assist mode as shown in Figure 2.3 in which the electric drive assists the user and reduces manual effort by up to 80%. This assist drive also stops the wheelchair from rolling backwards when on a slope and aids the user when going up a steep hill. In addition, this wheelchair can be stowed away in the boot of a car and has a range of 15 miles[15].

Figure 2.3: The e-motion dual mode wheelchair.[15]

2.2.2 Using stairs

Another problem that users of electric wheel chair have is the ability to reach various ground levels that are normally accessible by able bodied persons through the use of stairs. In most areas in the United Kingdom especially in academic institutions, this has been dealt with the provision of ramps and elevators whilst in the United States, the disability act mandates that all wheelchair users should have easy access to all public services and communities as their legal rights[4]. However, in areas without such disable access, reaching those ground levels could present a problem to the users of the wheel chair.

In order to solve this problem, a French company called Topchair [16], [17] equipped the electric wheel chair with two tracks made of rubber underneath the wheelchair as shown in Figure 2.4. This made it possible for the wheelchair to climb over stairs curbs and any obstacles in a manner similar an army tank. It has four wheels with the two rear wheels powered for movement over flat terrain. Whenever stairs or a curb is encountered, switching between flat terrain operation and steps climbing is done by the press of a button. It has the capability of going over stairs up to 20cm in height and can go over 300 steps in a single battery charge. During stairs operation, the embedded system controls the tilt of the chair so that it is maintained at an horizontal level. It incorporates an infra red sensor that checks the angle of the wheelchair relative to the axis of the stairway and stops if too steep.

Figure 2.4: Showing the topchair electric wheelchair beginning to climb stairs.[17]

2.2.3 Coping with Multi Surface Terrain

The X-8 Extreme as shown in Figure 2.5 is manufactured by Magic Mobility in Australia. It solves the problem of using the electric wheelchair on various outdoor terrains by giving users the ability to drive on different kinds of extreme surfaces such as sand, soft ground, wet ground and even steep hill sides [18]. It uses a four wheel drive system with low pressure tyres in order to accomplish this. The setup makes it possible for users to experience the outdoors to a greater extent whilst reducing the vibrations caused by rough surfaces.

2.2.4 Falls during Transfers

In the case of extreme paralysis or extreme upper body weakness, transferring a patient from the bed to the wheelchair and vice versa is often a problem especially when the patient is much heavier than the carer. It has been observed that 41% of the tips and falls accidents involving the use of wheelchair occur during transfers. In order to solve

Figure 2.5: The multi-surface X-8 extreme wheelchair[18].

this problem, Panasonic developed a bed that could “morph” into a wheelchair and vice versa. The user can interact with the wheelchair using voice commands and whilst in the bed mode, a suite of multimedia services such as the TV, the Internet, access to home security cameras and video calls are available. The concept is extremely useful especially for old disabled people who spend most of their time resting [19].

Bed Mode

Shown with the back rest up

The wheelchair separated from the bed

Figure 2.6: The Panasonic ”morph” bed [20].

2.2.5 Reaching Objects

33 % of tip and fall accidents occur as a result of trying to reach an object on a shelf for example. This sometimes could result in emergency visits to the hospital. In order to solve this problem, the standard electric wheelchair has been redesigned so that users could be alleviated to different heights in order to retrieve objects from heights not normally possible if using a standard electric wheelchair. This capability makes it possible for the users to be able to converse with someone at a face level. Such a product called the iBot as shown in Figure 2.7 was sponsored by Johnson and Johnson. It uses a combination of gyroscopes, sensors and multiple computers to balance the user on two wheels. In addition

to these functions, it can climb stairs and travel over uneven terrains[21]. However, the iBot would stop production in 2012 as result of the lack of a viable business plan.

Figure 2.7: Showing the segway IBot.[22]

Figure 2.8: Showing the standing up wheelchair.

A standing wheelchair was also developed by Zhangjiagang Thriving Import & Export co called THR-FSP 129. This wheelchair as shown in Figure 2.8 also allows users to rise up to a standing position as able people. It uses two 12V 38Ah batteries with a maximum range of 20km and maximum speed of 7km/h [23].

2.2.6 Cost of a new wheelchair

From the above, it can be gleaned that users of traditional wheelchairs would have to get rid of their existing wheelchairs in order to buy an electric one. This might cause distress to some patients who have sentimental value to the wheelchair after using it over a period of time and have accepted the wheelchair as an extension or expression of themselves[4]. In addition, the wheelchair might have been adapted specially for the patient at a high cost and it might not be cost effective to buy an electric powered wheelchair to be adapted again. In such a case, an electric add on was suggested by Ju Hyun Lee [24] as shown in Figure 2.9. This structure attaches to the normal wheelchair enabling electric motorised motion.

Figure 2.9: An add on component for converting standard wheelchairs[24].

2.2.7 Other novel electric wheelchairs

Other developments that have taken place on the electric wheel chair to cater for various disable users include the electric Unicycle as shown in Figure 2.10. This device is manufactured by Honda based upon the technology that was used to create the Asimo Robot. The unicycle works by moving continuously in order to balance the weight of the user. The user controls the direction of motion by leaning in the direction he/she desire to move in.This platform is intended to be used for disabled people in crowded areas and would be useful for those that have lost control of their legs. Its portable and light weight nature makes it possible to be stowed away in a car or transported easily from one location to another in a public transport. However, it is not known whether older people have the agility to use the product.

Figure 2.10: The Honda Unicycle.[25]

2.3 The case for the Robotic Wheelchair

Despite all the advances made on the electric wheel chair as discussed in the previous section, manufacturers often fail to address some fundamental problems that come with the use of powered wheel chair in confined, dynamic areas. The home is an environment that can change very rapidly especially when pets and kids are present. In addition, such an environment is often rearranged to new layouts in order to bring newness to the environment and bring a sense of satisfaction, pleasure and comfort to the occupants. In such dynamic environments, controlling an electric wheel chair with the joystick could be very difficult especially when the user has muscle spasms. This problem was reflected in a survey carried out by users of electric wheelchairs in which 40% of the participants said that they found it difficult to carry out steering and manoeuvres during their everyday living [5].

Furthermore, it has been discovered that over a period of 18 years, 52.4% of accidents were electric scooter related, 24.6% electric wheelchair related and the other 22.6% standard wheelchair related. This seems to suggest that giving a wheelchair more power results in more incidence of accidents occurring . Another problem that needs addressing is the issue of tips and falls. Tips and falls accounted for 77.4 % of wheelchair related deaths between the year 1973 and 1987. Tips could be caused by the user detecting a drop off too late, resulting in falling out of the chair when one of the wheels go over the edge. 60.5 % of these accidents are often caused by engineering problems of the product, 25.4% by environmental factors, 9.6 % by the occupant whilst 4.6 % was caused by the system. In order to solve these problems or at least reduce their magnitude, a new niche of electric wheelchairs was born called the smart wheelchair [5].

The smart wheelchair is basically an electric wheelchair but with sensor add ons and an advanced artificial control system that arguments, refines or replaces the users commands. By using sensors, it is possible to prevent falls by detecting stair edges or sudden drop offs. Most smart wheelchairs are being developed using technology that have been developed and tested for mobile robot navigation in the environment. As a result, a smart wheelchair could be viewed either as a mobile robot with a chair added on to carry a human[26] or standard electric wheelchair with sensors, computers and novel input devices [5]. The field of mobile robots is neither in its infancy nor is it mature. For example, mobile robots can now map their environment using laser range finders and use the information to navigate from one location to another. Such advances made in the field of mobile robots make it an ideal ground to borrow some technology for use on the smart wheelchair.

2.4 Milestones in the development of the Robotic Wheelchair

As gleaned from the previous section, the biggest issues facing users of wheelchairs is ease of use in navigating the environment. This need is reflected in the research carried out on robotic wheelchairs. Even though there are many types of research in the niche of robotic wheel chair and many set of requirements that each research is trying to meet, the two basic requirements are that [27]:

- a wheel chair must be able to navigate safely and in the event of failure, do so gracefully.
- Furthermore, the wheelchair must have an effective and yet user friendly interface with the aim of reducing cognitive load of the user. Additionally, the wheelchair should be adaptable to different users needs and different environments both indoors and outdoors.

In order to meet these requirements, researchers into robotic wheelchairs have integrated various areas of research in the computer field together in order to provide solutions. These areas include computer vision, robot navigation in the form of using embedded or newly built maps and using a behaviour based approach to the development of control systems. However, based on the level of control given to the user, they can be divided into three main sections of shared control, semi-autonomous and autonomous modes of operation. We shall now discuss each category and give some examples of each by focusing on the most promising robotic wheelchairs making academia headlines. In compiling this list, our main focus is that the robotic wheel chair must be easily integrated into the existing environment with little or no need to rebuild the environment or install additional materials to make the wheelchair work. In other words, it should not only be technologically feasible but also cost effective and socially feasible. As a result, robotic wheelchairs that involve the need for RFID sensors to be embedded into the environment such as in [28] are not considered. The examples of robots in each section is not exhaustive but give a flavor of what to expect under each mode of user control.

2.4.1 Shared Control:

In shared control, the user controls the robotic wheelchair directly through the use of mostly a joystick. On some wheelchairs though such as in [29], the face is used as the mode of wheelchair control. In shared control, sensors such as sonar or laser are used to prevent the wheelchair from bumping into objects or people. The Wheelesley robotic wheelchair as shown in Figure 2.11 is an example of shared control in which sonar sensors are used to avoid obstacles and used to keep the wheelchair in the centre of a hallway. A Graphical User Interface is used to receive commands from the user by using a eye tracking method they called "Eagle eyes". If desired, a single switch that enables navigation between buttons of the Graphical User Interface can be used to control the wheelchair. However, this approach would be slow. In tests carried out, the user spent 25% less time in navigating an obstacle course with 71% less orders when using the eye tracking method [30] [31].

Figure 2.11: Showing the Wheelesley robotic wheelchair [31].

Another example is the NavChair [32] in Figure 2.12 which receives input from the user in the form of a joystick but is also able to perform automatically perform wall following, obstacle detection and avoidance, and passage through a door. In [33], an adaptive scheme is used for the shared control so that whenever the user is having difficulty navigating in the environment, more help from the computer is given to the user.

The system receives commands of left, right, forward and back from the user through an electroencephalogram (EEG) sensor cap in addition to commands from a standard joystick. Furthermore, the system is also able to perform obstacle avoidance, collision avoidance in the form of an emergency stop and orientation recovery to correct the wheelchair's

Figure 2.12: Showing the navChair robotic wheelchair with sonar sensors[32].

orientation if it is not aligned to the goal direction. The shared mode of control would be more suited to people who have lost control of their lower limbs but can still use their hands to provide continuous input to an input device such as a joystick.

2.4.2 Semi Autonomous Control:

In semi autonomous control, the user gives a short term goal to the robotic wheelchair and the wheelchair takes complete control in getting the user from the present location to the desired destination whilst avoiding obstacles and collisions. The Tin Man project as in [34] is an example of such a control system. It was built on a commercially available wheelchair from the company Vector Wheelchair Corporation. It uses sensors to observe its environment and receives input from the user through a joystick and button type interface. The Tin man enables users to spend less time interacting with the wheelchair by for example maintaining a constant heading without user input. This makes it usable for users with muscle spasms. It also enables a user to specify a particular set of coordinates to move the wheelchair too and in future will include the facility to use a home or office map for navigation. Another example is in [35] , where input from the user is received via an EEG sensor cap as shown in Figure 2.13.

The system uses laser scanners to develop a map of the environment shown in Figure 2.14 and displays it visually for the user as shown in Figure 2.15. The user then looks at the location he or she wants to go to on the map and after a visual stimulation process, commands are sent to the wheelchair to be carried out[35]. Another example of a semi-autonomous control is in [36] where the wheelchair is able to follow someone. In this case, a camera in addition to sonar sensors is used to track a selected person. This wheelchair is shown in Figure 2.16. The semi autonomous mode of control would be more suited for quadriplegias who have totally or partially lost control of their limbs and as a result cannot control the wheelchair through continuous input devices.

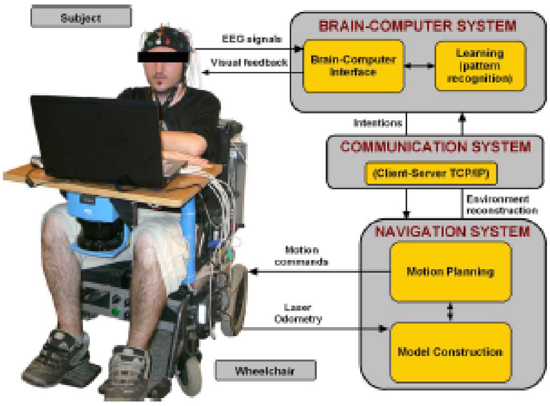


Figure 2.13: Showing non-invasive use of EEG sensor cap with wheelchair[35].

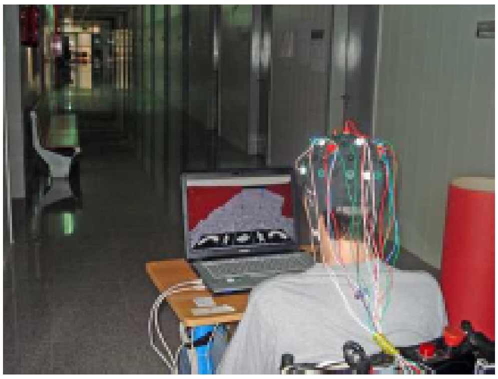


Figure 2.14: Showing the real world around wheelchair[35].

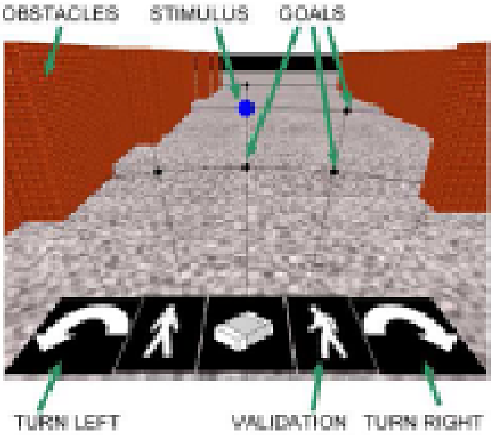


Figure 2.15: Showing the constructed virtual world around the wheelchair[35].

2.4.3 Autonomous Control:

The autonomous mode of control would also be suited for quadriplegias for outdoor travels. In autonomous control, the map of the area is needed, and the robotic wheelchair

Figure 2.16: Showing a semi autonomous wheelchair with camera[36].

takes complete control of the entire operation of conveying the user from present location to goal entirely without any input from the user. In order to do this, the wheelchair must be equipped with the capability to know its present location. This can be done through the use of magnetic strips, GPS or wifi as in [37].

An example of a robotic wheelchair that uses autonomous control is MAid (Mobility Aid for Elderly and Disabled People) as shown in Figure 2.17. The wheelchair was designed to help the elderly and those that have been affected by paraplegia, multiple sclerosis, poliomyelitis and so on [38]. The robotic system was built upon a commercial wheelchair chassis. The biggest use of MAid is in providing aid to users in a crowded environment such as a shopping mall or a rail way station. Human navigation of an ordinary wheelchair in such environments is very difficult as the user needs to keep making constant adjustments to avoid colliding into moving people. The MAid robotic system uses a laser scanner and ultrasonics to detect an ever changing environment and uses the information to find the safest and less crowded route in the environment. When confronted with lots of people at once, the wheelchair automatically stops similarly to what a human will do in that situation. Input is received from the user in the form of a goal destination in the environment. This system has been successfully tested in the central station of Ulmm during rush-hour amongst other areas [38].

The Bremen Autonomous Wheelchair shown in Figure 2.18 is another example of an autonomous wheelchair based on the commercially available Meyra wheelchair. The wheelchair was equipped with 27 polaroid sonar sensors mounted around the system and a industrial PC behind the seat. In addition to providing autonomous navigation

Figure 2.17: Showing the MAid robotic wheelchair with sensors.[38]

over pre-taught paths, it also has hallway centering capability, wall following, obstacle avoidance and door way navigation. Its modular software architecture also enables users to be able to configure it depending on their level of ability [30][39].

Figure 2.18: Showing the Bremen autonomous robotic wheelchair with sensors[30].

2.5 Suggested state of the art in design

As would be seen from above, robotic wheelchairs need to be designed based on the users need and the disability level. This makes it difficult to design a universal wheelchair that would address all users needs. In order to address this, we shall consider two important areas that are necessary for a robotic wheelchair to be effective, firstly, Sensor and User Input devices and secondly control of the wheelchair.

2.5.1 Sensors and User Input devices:

It is suggested that robotic wheelchairs should be built with a generic interface to which any input device and sensor could be connected to. This is possible nowadays with the USB protocol on personal computers. This enable touch screens, joysticks, sip and puff devices, Electroencephalography devices and various types of sensors to be added to the robotic wheel chair easily.

In addition, sensors such as sonar, GPS, Laser and so on, should be easily added to the robotic wheelchair. In presenting this approach, we are assuming from the study of robotic wheelchairs above that processing or the "brain" of the robotic wheelchair would be on a standard personal computer running an operating system like Linux or windows. By following this approach, customers of wheelchair only need to tell a manufacturer what their condition and needs are and the manufacturer can then custom build their wheelchair for them in regards to the sensory requirements and input needed.

2.5.2 Control:

As discussed in section 2.4, control of wheelchair can be done as shared control, semi-autonomous or autonomous. Each mode of control is needed depending on the circumstances in the environment and also the condition of the user. It is suggested that all modes of control are implemented on the robotic wheelchair and then the user can decide what mode to use at any given time depending on the circumstances in the environment and their needs. For example, the autonomous scheme of control could be used in a crowded environment as such in a rail station or shopping mail, in order to reduce continuous control burden on the user. The user decides where he or she wants to go and the wheelchair navigates to the location whilst avoiding obstacles.

In order to do this however, a map of the railway station or mall is needed. It might be possible to have the government install novel wifi based location map interrogating schemes so that once a wheelchair or anybody at all wants a map of a public area, it can be downloaded to a mobile device or in our case, the robotic wheelchair. This would enable the user to then choose a shop or platform to go to and enjoy the ride of going through the shopping mall instead of concentrating on avoiding people. It would also enable the user to carry bought items. Depending on the distance from home, a wheelchair could also be equipped with GPS in order to enable users plot a course to a desired location. This could be done with Google maps by extracting the pedestrian path information from it.

Semiautonomous scheme of control could be more necessary in the home where the environment is not big and short term goals are more appropriate. This enables the user to go to various places in the immediate environment (e.g Kitchen to dinning room) whilst avoiding obstacles. Shared control will be necessary when fine adjustments such as getting as close as possible to the bed is necessary. In this case, the obstacle detection might need to be turned off to allow this.

If the above were followed, then it opens room for flexibility for the users of the wheelchair to decide what they need in regards to building the wheelchair and what level of assistance is needed when performing daily activities. In other words, following the above suggestion gives them more self-dependence and control over developing circumstances in the environment, having a say in where they want to go resulting in improved self-image and esteem. This changes the wheelchair from a device of occasional frustration to a device that enhances freedom.

Of course, hurdles still need to be crossed to develop an universal wheelchair of the sort described above in terms of cost, however, using the open source community of software developers could reduce these costs.

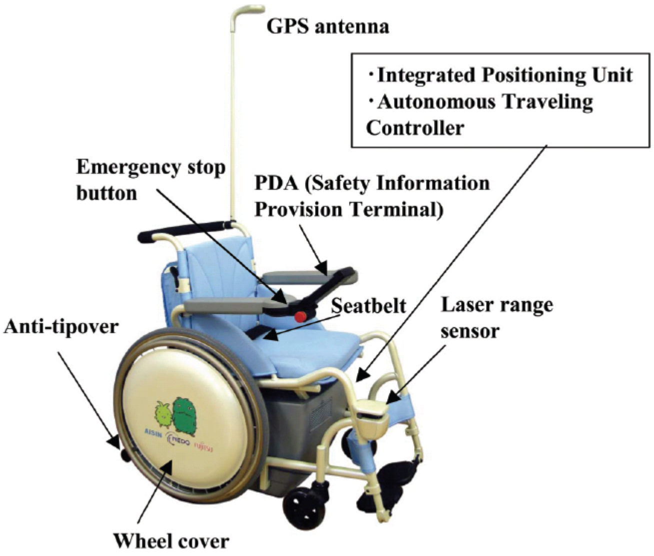


Figure 2.19: TAO Aicle

A wheelchair that might have the capabilities described above is the TAO Aicle shown in Figure 2.19. This wheelchair is a prototype of the Japanese company Aisin Seiki Co. Ltd and uses GPS and RFID tags in the environment to get a user of the system from point to point whilst avoiding obstacles. By communicating with base servers and other infrastructures as shown in Figure 2.20. This wheelchair transmits position information, battery status and route data to a base station. This makes it possible to track and display the position of each wheelchair. However, the dependence of this wheelchair on constructing the environment exactly to fit it through the use of RFID tags and servers that relay exact position information based on the detected RFID tags make it prone to failure in the event of a communication break down.

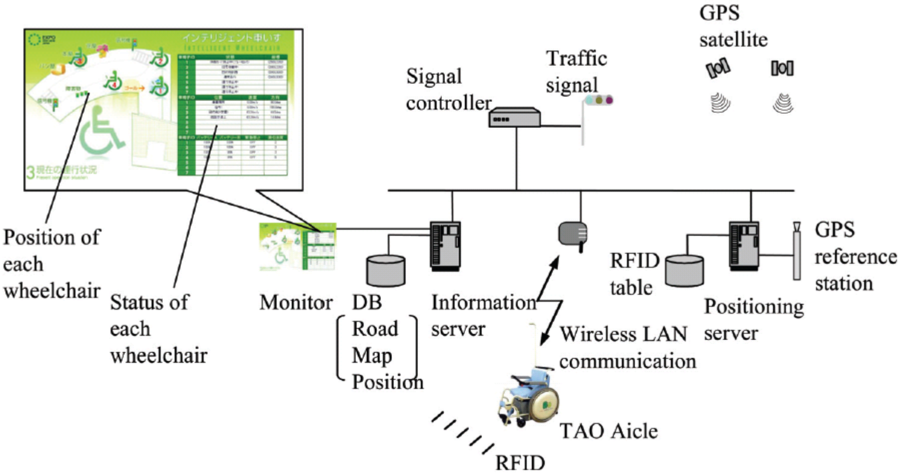


Figure 2.20: Support infrastructure of the TAO Aicle

2.6 Commercial Realisation

Most robotic wheelchairs are still confined to research and academic institutions. However, as the graph in Figure 2.21 predicted, there has been some commercial realisation of the robotic wheelchair in some parts of the world. The major problem in developing robotic wheelchair is the cost of materials required to manufacture them. This was the major issue when the iBot's manufacturing was stopped.

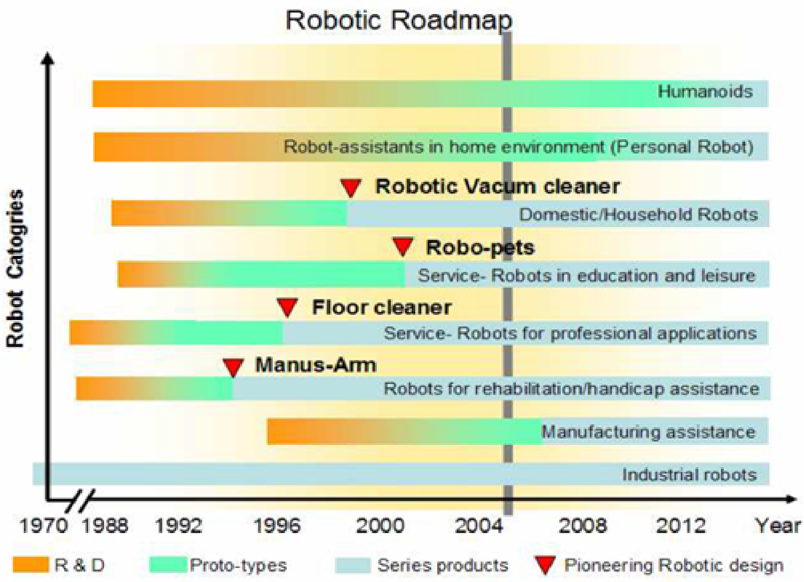


Figure 2.21: Showing the time line for the availability of robotic wheelchairs.

Present companies manufacturing robotic wheelchair include the United Kingdom company called *Simile Rehab.* They manufacture robotic wheelchairs called “smart wheelchairs”. This company’s robotic wheelchairs targeted for Children have sonar, bump and line detection sensors. Operating modes include bump and stop, bump and backup, line following and lastly bump and turn. Another company called *Nurion Industries* manufacture the “wheelchair pathfinder” kit. These kit includes sensors to be used on any wheelchair and include sonar and a laser range finder. Vibration alerts are produced when an obstacle or drop-off is detected but the system does not have active control of the wheelchair.

Chapter 3

Market Forecast and Region Major Players

In this chapter, we shall discuss how improvements in medicine is causing an increase in demand for robotic wheelchair. We shall also discuss how this raises in Market demand is going to increase the world production of service robots in the next few years in section3.1 and which countries would be the most likely key players in section 3.2.

3.1 Market demand and Forecast

According to a 2007 United Nations report, 15% of the world's population would be above 60 in 2020. This will rise to 22% by the year 2050 compared to just 11% in 2007. In Japan, 35% of the population would be above 60 in 2050 while in the United States, by 2020, over 8 million people would be above 85. These increases in life expectancy are caused by improvements in medicine and increase in the need for mobility devices for this age group. This trend has caused most governments especially Japan to invest heavily in catering for this age group. This includes investment in assistive or welfare robotics and this market is expected to increase as predicted by the Japan Robot Association in Figure 3.1.

According to the World Technology Evaluation Center (WTEC) report, when compared to other robotic niches in Figure 3.2,it can be seen that the service robot niche is predicted to dominate the robotics market[40]. This prediction is also supported by the statistics company Global Industry Analysts who claim that this niche would be worth 38.42 billion dollars by 2015 as a result of advancing technological development, application possibilities caused by this development demographic shifts and the rise of the new service economy [41].

In addition, to the above 60 age group, the number of younger people that disabled increases the number of people that would be needing service robots considerably. Their disability could be from birth, as a result of accidents or war injuries. For example,

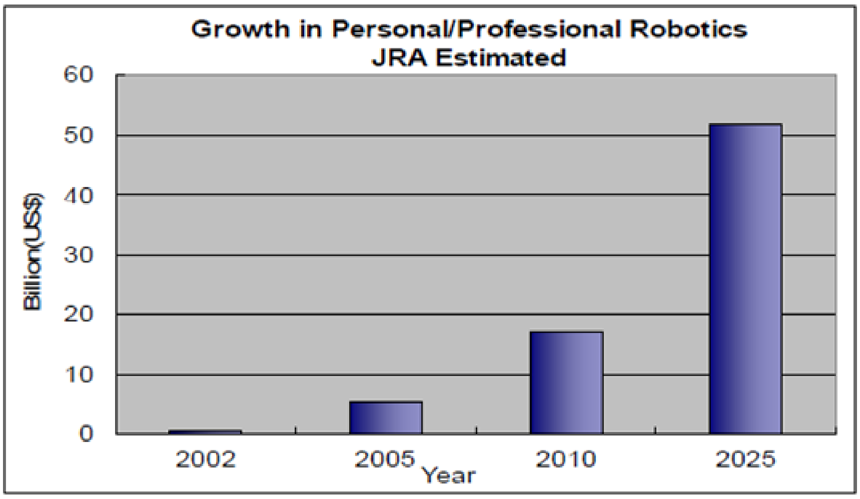


Figure 3.1: Showing growth of welfare robots in the next 14 years (JAR).

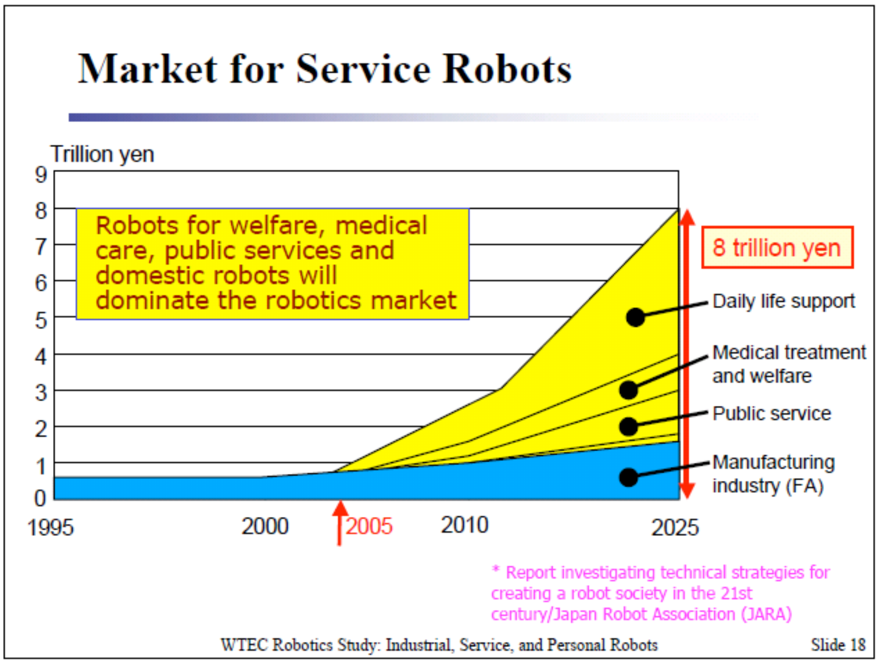


Figure 3.2: Showing predicted market growth in welfare robots in comparison to other niches[48].

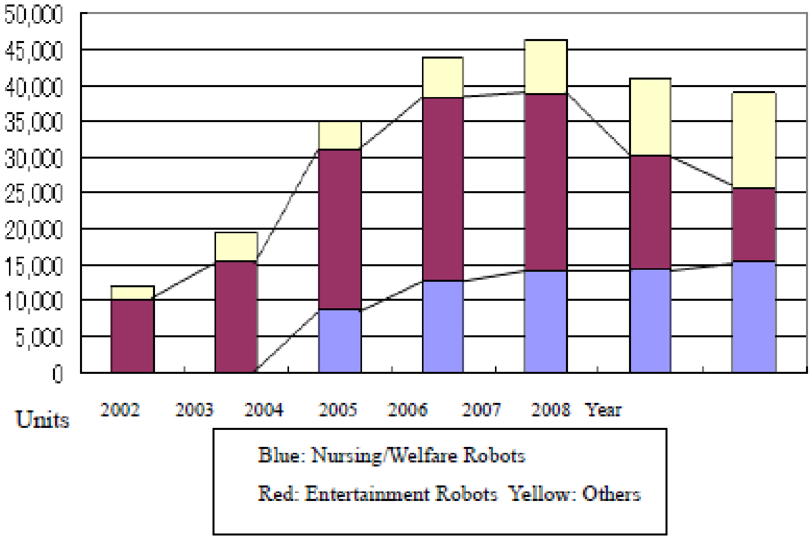


Figure 3.3: Showing predicted investment growth in welfare robots [45].

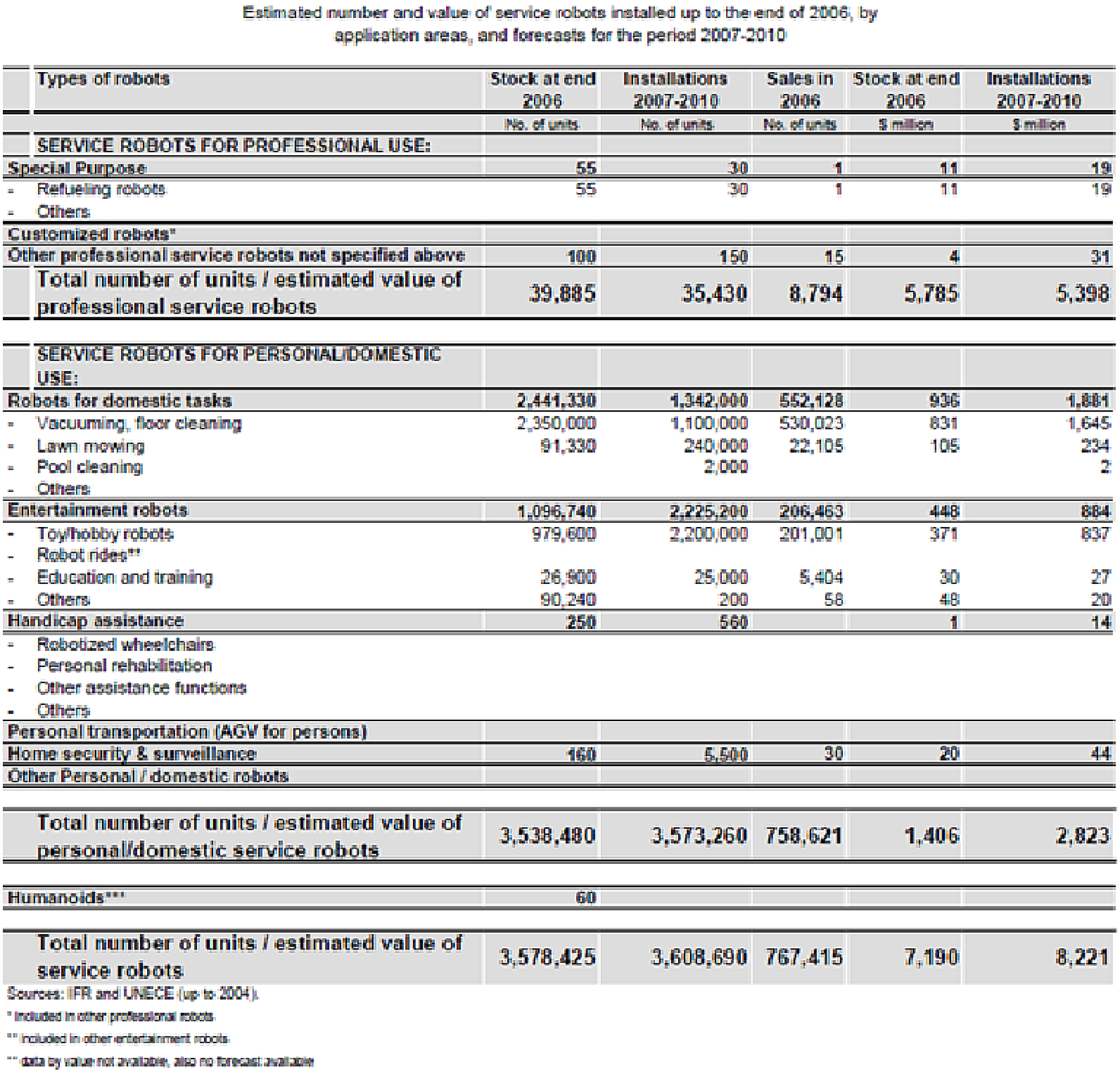
the U.S. Census Bureau facts and statistics relating to United States Veterans states that about 5.5 million war veterans are disabled [42]. In the United Kingdom, according to the Online Uk National statistics there were 233 veterans from both the Iraq and Afghanistan war that were classified as disabled [43]. In addition, about 50% of people in the age group of 20 - 30 are affected by one form of mobility difficulty or another in the United Kingdom which is about 3.5 million people using the Annual abstract of statistics [44].

This increase in the number of disable and older people has caused a progressive increase in the number of assistive robots sold each year. For example, in Japan the number of service robots sold each year has steadily increased as shown in Figure 3.3[45]. This trend also follows into the Europe as well as can be seen in Figure 3.5 obtained from the United Nations Economic Commission report for Europe [46] and in Figure 3.4 obtained from the European Robotics Research Network report under the sections handicap assistance and wheelchair robots [47].

In the former report, in 2002 there were only 160 of assistive robots with 40 predicted in the year range of 2002-2005. However, in the latter report, there was actually an increase nearly double with the number of units expected to be sold to double in the year range 2007-2010 and the amount of sales to increase from 1 to 14 million.

3.2 Key Region Market Players

The countries that would contain key market players in the service robotics market would be Europe, Japan and the United States. This could be observed by looking at the data displayed in Figure 3.6 obtained from the WTEC [40]. As can be seen, there is continuous



Estimated number and value of service robots installed up to the end of 2006, by application areas, and forecasts for the period 2007-2010

Types of robots	Stock at end 2006	Installations 2007-2010	Sales in 2006	Stock at end 2006	Installations 2007-2010
	No. of units	No. of units	No. of units	$ million	$ million
SERVICE ROBOTS FOR PROFESSIONAL USE:					
Special Purpose	**55**	**30**	**1**	**11**	**19**
- Refueling robots	55	30	1	11	19
- Others					
Customized robots*					
Other professional service robots not specified above	**100**	**150**	**15**	**4**	**31**
Total number of units / estimated value of professional service robots	**39,885**	**35,430**	**8,794**	**5,785**	**5,398**
SERVICE ROBOTS FOR PERSONAL/DOMESTIC USE:					
Robots for domestic tasks	**2,441,330**	**1,342,000**	**552,128**	**936**	**1,881**
- Vacuuming, floor cleaning	2,350,000	1,100,000	530,023	831	1,645
- Lawn mowing	91,330	240,000	22,105	105	234
- Pool cleaning		2,000			2
- Others					
Entertainment robots	**1,096,740**	**2,225,200**	**206,463**	**448**	**884**
- Toy/hobby robots	979,600	2,200,000	201,001	371	837
- Robot rides**					
- Education and training	26,900	25,000	5,404	30	27
- Others	90,240	200	58	48	20
Handicap assistance	**250**	**560**		**1**	**14**
- Robotized wheelchairs					
- Personal rehabilitation					
- Other assistance functions					
- Others					
Personal transportation (AGV for persons)					
Home security & surveillance	**160**	**5,500**	**30**	**20**	**44**
Other Personal / domestic robots					
Total number of units / estimated value of personal/domestic service robots	**3,538,480**	**3,573,260**	**758,621**	**1,406**	**2,823**
Humanoids***	**60**				
Total number of units / estimated value of service robots	**3,578,425**	**3,608,690**	**767,415**	**7,190**	**8,221**

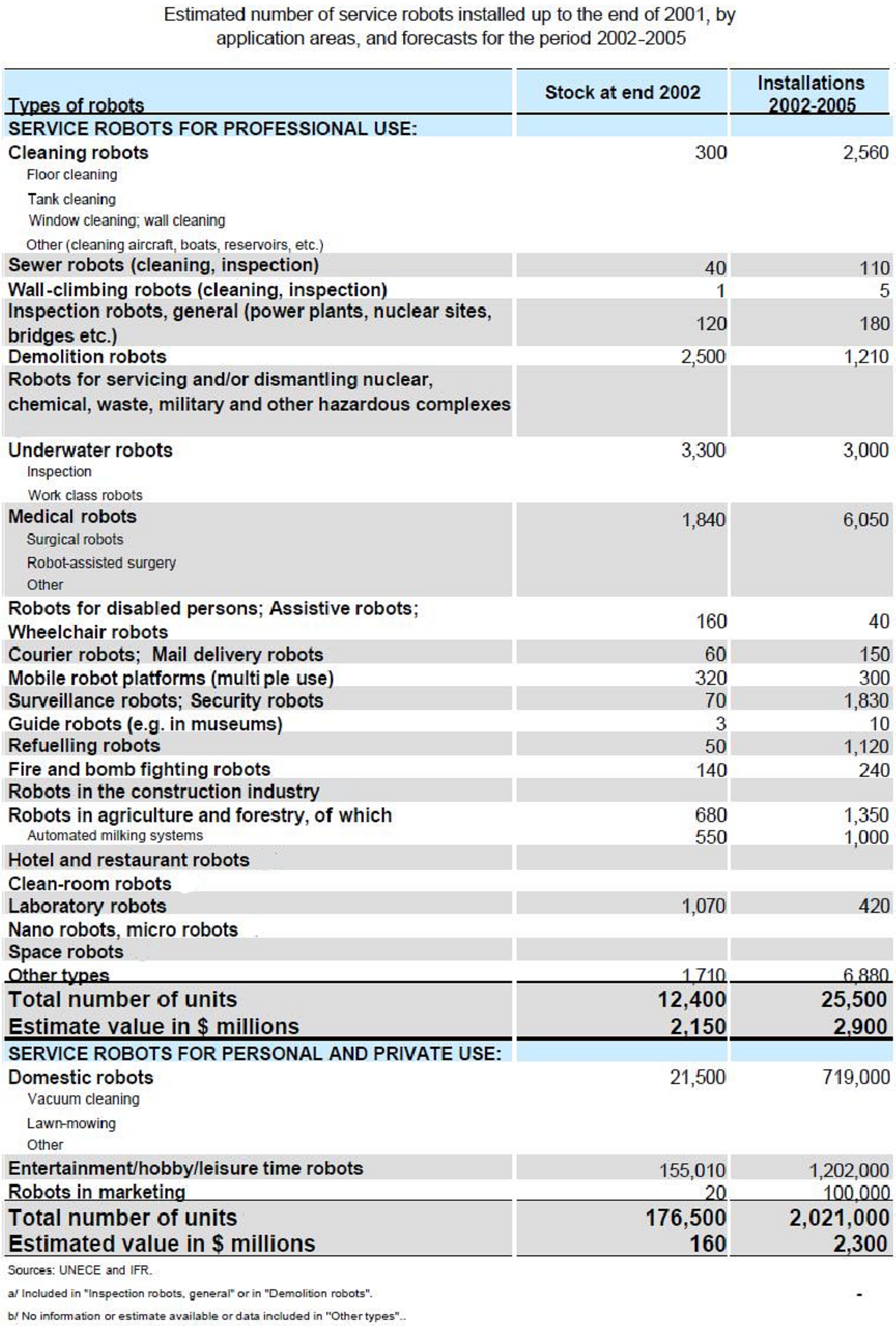
Sources: IFR and UNECE (up to 2004).

* Included in other professional robots.

** Included in other entertainment robots.

*** data by value not available, also no forecast available

Figure 3.4: Robot estimate at the end of 2006 and forecast for 2007 - 2010[47].



Estimated number of service robots installed up to the end of 2001, by application areas, and forecasts for the period 2002-2005

Types of robots	Stock at end 2002	Installations 2002-2005
SERVICE ROBOTS FOR PROFESSIONAL USE:		
Cleaning robots	300	2,560
Floor cleaning		
Tank cleaning		
Window cleaning; wall cleaning		
Other (cleaning aircraft, boats, reservoirs, etc.)		
Sewer robots (cleaning, inspection)	40	110
Wall-climbing robots (cleaning, inspection)	1	5
Inspection robots, general (power plants, nuclear sites, bridges etc.)	120	180
Demolition robots	2,500	1,210
Robots for servicing and/or dismantling nuclear, chemical, waste, military and other hazardous complexes		
Underwater robots	3,300	3,000
Inspection		
Work class robots		
Medical robots	1,840	6,050
Surgical robots		
Robot-assisted surgery		
Other		
Robots for disabled persons; Assistive robots; Wheelchair robots	160	40
Courier robots; Mail delivery robots	60	150
Mobile robot platforms (multiple use)	320	300
Surveillance robots; Security robots	70	1,830
Guide robots (e.g. in museums)	3	10
Refuelling robots	50	1,120
Fire and bomb fighting robots	140	240
Robots in the construction industry		
Robots in agriculture and forestry, of which	680	1,350
Automated milking systems	550	1,000
Hotel and restaurant robots		
Clean-room robots		
Laboratory robots	1,070	420
Nano robots, micro robots		
Space robots		
Other types	1,710	6,880
Total number of units	**12,400**	**25,500**
Estimate value in $ millions	**2,150**	**2,900**
SERVICE ROBOTS FOR PERSONAL AND PRIVATE USE:		
Domestic robots	21,500	719,000
Vacuum cleaning		
Lawn-mowing		
Other		
Entertainment/hobby/leisure time robots	155,010	1,202,000
Robots in marketing	20	100,000
Total number of units	**176,500**	**2,021,000**
Estimated value in $ millions	**160**	**2,300**

Sources: UNECE and IFR.

a/ Included in "Inspection robots, general" or in "Demolition robots".

b/ No information or estimate available or data included in "Other types"..

Figure 3.5: Robot estimate at the end of 2001 and forecast for 2002 - 2005[46].

growth in Europe with the growth eroding the market share that Japan had.

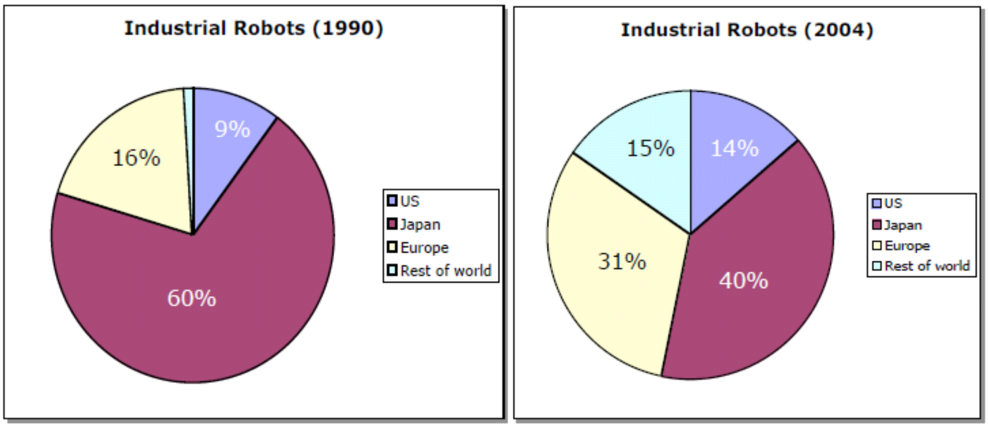


Figure 3.6: International Robot market comparison [40].

Chapter 4

Key Market Players and Potential Sponsors

In this chapter, we shall discuss the present key market players in the area of robotic wheelchairs and those that might become one in the next 5 years in section 4.1. We also discuss which companies could have a market share of the robotic wheelchair market if presented with the right opportunities in section 4.2. A market strategy that could help these companies is also presented. We conclude in section 4.3 with a brief discussion about robotic wheelchair research carried out at the University of Essex.

4.1 Key Market Players

4.1.1 Smart Rehab (UK):

This United Kingdom based company has been manufacturing robotic wheelchairs for over 6 years and has targeted the children population market. Its "smart wheelchair" range has discussed in Chapter 2 have sonar, bump and line detection sensors that enable the use of novel robotic technology. Their setup would be useful in investigating even more advanced control for the wheelchair. With their expertise in making the wheelchair commercially viable, range of products, experience, it is possible that this company would be the leading producer of novel commercial robotic wheelchairs for some years to come.

4.1.2 TopChair (France):

This company produced a wheelchair capable of climbing stairs as discussed in chapter 2. This company was created in September 2002 and has sold wheelchairs to many countries except the USA. The exception in the USA could be because of the sale of the iBot wheelchair which also has the capability of climbing up and down stairs albeit without tracks. The use of tracks might make for a smoother ride when going up the stairs compared to the iBot. Their wheelchairs are manufactured in Montrabe and they claim that their wheelchair could be modified according to different users needs. Due to the commercial nature of the wheelchair, a lot has gone into making sure that it is safe for use by ordinary users however, for the past 9 years, not much has changed in the design of the product.

4.1.3 Deka Research(USA):

Deka Research is a Research and development company in the USA that researches into various medical devices including the Segway Human Transporter and an advanced prosthetic arm for DARPA (Defense Advanced Research Projects Agency) [49]. The company also researched into the self balancing iBot shown in Figure 2.7. The company sold manufacturing rights to Johnson and Johnson for production with US war veterans as its target market. The production of the iBot was partly funded by the US government. However due to the recent US Federal Government cuts, funding to this project was stopped as its balance and stair climbing capability were not deemed important [50] when compared to standard wheelchairs. This stopped the production of the iBot as it was not financially viable after the cuts. Nevertheless, the company is still in the process of creating a viable market plan and might re-launch the product or come up with a new one in the near future.

4.1.4 Gecko Systems (USA):

Gecko Systems is a USA company that has over fourteen years experience in the development of mobile service robots. They have developed a “collision free” system that was deployed on a robot called Carebot. This was done by using a combination of optical range finding and vision systems, Microsoft Kinetic, advanced robot controller boards and sensor fusion [51]. Their technology was sold to the Japanese company IMASEN engineering corporation that specialises in manufacturing electric wheelchairs [52] in March 2011 and as a result, it is possible that the first commercially produced robotic wheelchairs from Japan would be produced soon.

4.1.5 Independence Technology (USA):

This company is part of the Johnson and Johnson group of companies specialising in the production of pharmaceutical, diagnostic, therapeutic, surgical, and biotechnology products. They also produced the iBot wheelchair but stopped production after the US Federal government stopped supporting them due to a lack of viable business plan. However, the experience obtained from the development of the iBot wheelchair might enable them to develop robotic wheelchairs if they can collaborate with a research institution established in mobile robot technology or buy the technology from them. At present, all production of the iBot wheelchair has ceased with no immediate plan to resume manufacturing [53].

4.1.6 IMASEN Engineering Corporation (Japan):

This Japanese company was established in 1971 making it one of the oldest wheelchair manufacturing companies. It has experienced in the development of mechatronics and electric wheelchairs. With its recent purchase from GeckoSystems US, this company with its human-electronic-machine interface expertise might become a major market competitor in the production of adult size robotic wheelchair in the next few years [54].

4.1.7 Panasonic (Japan):

Panasonic Japan has been investigating the development of robotic wheelchair that can morph into a bed and vice versa. The company is the second largest electronics company in the world and has plans to increase its robot sales to 1.1 billion dollars by 2015/16. It has decided to focus on assistance bots such as motorized lifter/mover,a kitchen arm and the robotic bed. These bots would enable users to direct and personalize their own care from day to day increasing their independence. However, it is unlikely that the currently developed robotic wheelchair/bed would be suitable for outdoor environments. Nevertheless, with the companies revenue, electronics experience and modifications, it is possible that it can be converted for use outdoors very soon [55].

4.1.8 Honda (Japan):

Honda was made famous through the unveiling of the Asimo robot from its research in robotics and assistive technology. Using technology from the robot, it has recently developed the first robotic unicycle called the U3-X that help people with disabilities to move around. However, it is not clear if this product would be feasible to mass produce yet. This company is in competition with Toyota and as not yet unveiled any innovative wheelchair like projects.

4.1.9 Toyota(Japan):

Toyota Japan recently demonstrated a brain controlled electric wheelchair using an EEG sensor cap as shown in Figure 4.1. The system processes thought patterns for move left, right or forward commands and does not need training. The system even adapts itself to the behaviour of the driver which means its accuracy improves over time. Toyota also unveiled the i-Real electric wheelchair in Figure 4.2 that has two large front wheels and a small rear one. It works like the segway and offers a upright seating position. It has sensors all round it that alerts the user and people around to obstacles through vibrations, sound and light signals [56]. It was to enter commercial production in mid

Figure 4.1: The toyota BCI robotic wheelchair [23].

Figure 4.2: The Toyota's i-Real robotic wheelchair [23].

2008 but till now has not. The reason could be because of cost factors also. Nevertheless, with Toyota's large revenue base and Japanese government support, it is possible that this company also becomes a world leader in robotic wheelchairs given time [23] and if production is made viable.

4.1.10 Permobil(USA):

This company has branches in over 30 countries world wide. They have experience in manufacturing electric wheelchairs (both indoors and outdoors), seat systems, electronics and drive systems. Using their novel advanced control system in combination with intelligent control system, they claim that driving performance and safety of their electric wheelchair is improved and makes driving it simpler and more natural with higher precision. They also use a product called co-pilot on some of their wheelchairs to provide power steering to a pushchair and make it highly intuitive to control for an attendant.

The company has a future aim of developing a thinking wheelchair and with their world wide coverage and electronics expertise, they could be readily placed to become a world leader [57].

4.1.11 Zhangjiagang Thriving Import & Export co (Japan):

This company was established in 2000 and specialise in manufacturing medical beds, hospital furniture, stretchers and other medical products. It recently showed cased the standing wheelchair showed in Figure 2.8 as a research product. However, this company does not have a firm footing in wheelchair manufacturing yet.

4.1.12 Aisin Seiki Co. Ltd (Japan)

Aisin Seiki was founded in 1949 and produces components and systems for the automotive industry. This company also manufactures the commercially available TAO light II electric wheelchair. Currently, it unveiled a research prototype of an intelligent wheelchair called TAO Aicle as discussed in chapter 2. However, there is currently no mention about commercially making TAO Aicle available. Nevertheless, the company is in a very good position when compared to other wheelchair companies in terms of having wheelchair manufacturing expertise in addition to having a robotic technology expertise [58].

4.2 Market Strategy and Potential Sponsors

As can be seen in the previous section, there is a collaboration between wheelchair company IMASEN Engineering Corporation and a mobile service robotic technology company GeckoSystems. As most novel research into mobile robotics is carried out in Universities across the world, wheelchair companies would be the most likely sponsors of continuous research into robotic wheelchairs. This collaboration between academia and industry would bring out the best of both sides and could make the production of robotic wheelchairs possible and also viable.

In addition, as most research into robotic wheelchairs make use of existing electric wheelchairs, an upgrade should be relatively possible for the manufacturer with little or no cost provided the sensors and input devices used are cost effective. Most wheelchair companies in the UK do not have or are not considering applying robotic wheelchair technology to their present electric wheelchairs. This could be because of lack of knowledge of such technology, lack of market demand due to public ignorance of such technology or the fact that there is no immediate competition as a result of the technology among them. However, whatever the cause, this is bound to change as more companies around the world embrace the mass production of robotic wheelchairs.

It might be the case that if the manufacturers of electric wheelchair in the United Kingdom were presented with this eventuality, they might consider sponsoring and adopting this technology. Below are some of the wheelchair companies in the United Kingdom and Europe that might be interested in such undertaking.

4.2.1 Roma Medical (UK):

Roma Medical was founded in 1978 and manufactures mobility and rehabilitation products. They have sold their wheelchairs to over 25 countries world wide. They started manufacturing electric scooters in 2002 when a scooter manufacturer approached them with their shoprider range of scooters and power chairs. With good marketing strategy, their scooter sales soared and the shoprider brand became the leading brand in the UK with annual sales of more than 25000 units. This company judging from its profile is willing to take risks and keep expanding its product range. As a result, it might be willing to invest into developing robotic wheelchairs [59].

4.2.2 Sunrise Medical (UK):

Sunrise Medical was founded in 1983 and currently operates in the United Kingdom, Mexico, United States, Germany and Spain with distributors in over 90 countries worldwide. They have a range of wheelchair products including the Quickie powerchair range. However, they are still yet to incorporate robotic technology into their products and could be approached as a potential sponsor [60].

4.2.3 Pride Medical (USA and UK):

Pride Medical is based in the USA with a subsidiary in the UK, Netherlands, Italy, Canada and Australia. They manufacture a range of mobility products including power chairs, scooters and lift chairs. They do not have any plans for incorporating robotic technology into their range of products judging from their future range of product plans [61].

4.2.4 Invacare (UK):

Invacare was founded in 1856 and has selected and merged with various companies over the years. This included the purchase of a wheelchair company called Easi-Glide in 1976. They manufacture a variety of products to help with assisted living including hoists, slings and lifters. They also manufacture powered wheelchairs and scooters [62].

4.2.5 Exact Dynamics (Netherlands):

Exact Dynamics is a Netherlands based company that has been in existence since 1991. They developed and manufactured the robotic manipulators Manus and ARM. Both robotic manipulators are attached to wheelchairs so that users that lack control of their

Figure 4.3: Showing the iArm in use.

arms could be fed using the manipulators as shown in Figure 4.3. Both manipulators are very popular and it is unlikely that this company would switch to the research into robotic wheelchairs any time soon.

4.2.6 Bluebotics(Switzerland):

Bluebotics is a Switzerland based company that was a spin off from the Autonomous System lab of the Ecole Polytechnique Federale de Lausanne. It was found in 2001 and specialises in providing entertainment, automation and service robots. They have a large experience with autonomous navigation technology and if combined with a wheelchair based company, might be possible to develop a robotic wheelchair.

4.2.7 Meyra-Ortopedia(Germany):

This company based in Germany has manufactured both standard wheelchairs and electric wheelchairs including rehabilitation aids. They have been able to convert the CAN bus signalling system from the automotive industry into use on their electric wheelchairs One of their innovative products include the ability to control a standard personal computer from their manufactured wheelchair using Bluetooth. This company has a lot of technology know how but does not seem to have developed or have any plans to develop robotic wheelchairs.

4.3 Robotic Wheelchair research at the University of Essex

University of Essex as a huge expertise in the area of robotics including mobile robots, unmanned aerial vehicles, brain computer interface, multiple distributed agents systems and so on. Using this combination of expertise, it has been possible to develop algorithms that enable ordinary electric wheelchairs become robotic wheelchairs as shown in Figure

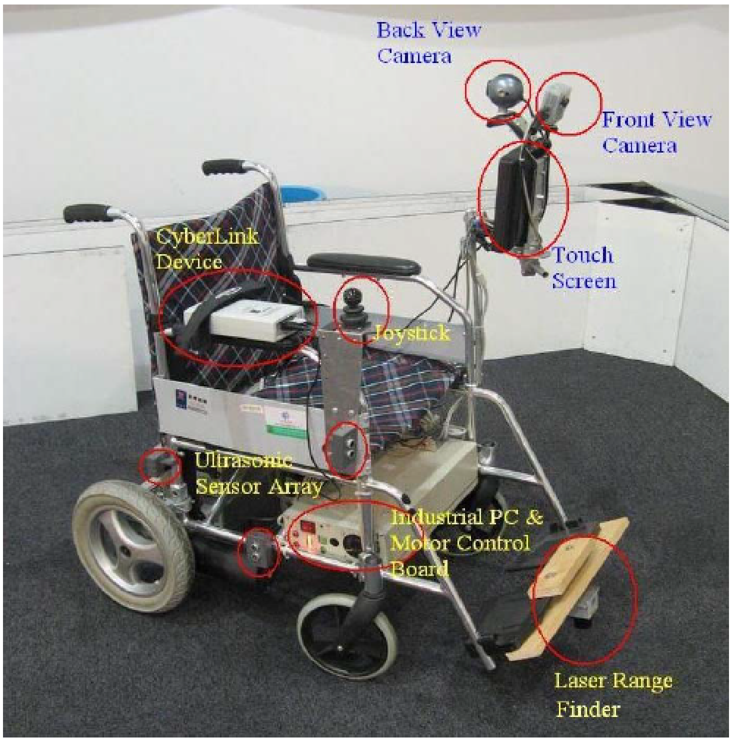


Figure 4.4: Showing the University of Essex Robotic Wheelchair.

4.4. As seen in Figure 4.4, we use a variety of sensors in combination with an Industrial PC (Personal Computer). However, we have been able to replace this with a standard Personal Computer that can be bought off the shelf. Up to date, the control of robotic wheelchairs using brain waves, facial gestures, and jaw gestures has been achieved.

Recently, an algorithm that enables sound control of wheelchairs in addition to using low power lasers to provide obstacle detection and avoidance capabilities to the wheelchair has been developed. Furthermore, development of algorithms that would enable an individual robot know its position in an underwater environment using GPS is currently being carried out. Operating in this environment is particularly challenging because GPS signals cannot penetrate water.

Most researchers have proposed the use of cameras to replace costly sensory devices such as the laser and sonar. This is because the camera can detect obstacles and various objects in the environment through the use of object detection and classification algorithms. Nevertheless, they have a limitation especially in low light conditions, and when the sun is at a low angle especially in autumn and winter months. In order to mitigate against these problems, the use of Microsoft Kinetic is currently being considered as it has a infra red camera in combination with a normal camera that could be used to detect objects even when the light conditions do not permit. This sensor is most likely going to make the robotic wheelchair cost effective to manufacture because of its cheap price and possible range of applications. Using these range of expertise at the University of Essex, it is possible to provide algorithms that would enable a standard wheelchair become a robotic wheelchair when equipped with sensors.

Chapter 5

Conclusion and Recommendations

The standard wheelchair would still be around for some years to come especially in developing countries. However, as time progresses, robotic wheelchairs would take over the market share that once belonged to the standard wheelchair. This can be seen from the data collected and presented in chapter 3 that the number of robots for disable people, assistive robots and wheelchair robots sold every year has been increasing steadily. However, when compared with industrial robotics, the market share of this niche is small. This could be as a result of the lack of information on the part of potential users of the technology or it could be because of high cost associated with such devices. It is believed that the latter could be the case considering the type and amount of research that high profile companies such as Toyota, Honda and Panasonic have put into robotic wheelchair research.

In other words, the cost barrier of producing cost effective and affordable robotic wheelchair need to be broken through before these products could make it more readily into users homes. As technology improves and cost of sensors reduces, this could be the case in the next 10 years. Nevertheless, there are still some companies such as Simile Rehab UK that have been able to commercially develop what we like to call first generation commercial robotic wheelchairs. However, the reason why they remain the only commercially producing robotic wheelchair company could be because of their children target population thereby making manufacture of parts cheaper. A robotic wheelchair from this company costs about 8627.92 pounds. This fits into the price range of electric powered wheelchairs with the cheapest costing 1000 pounds and the most expensive costing 16000 pounds in the form of the iBot electric wheelchair. As can be seen in Chapter 2, most research into robotic wheelchair has embedded sensors and computers. This trend enables an electric wheelchair manufacturer to collaborate with an academic institution researching, i.e. the incorporation of robotic technology onto wheelchair for a better market share in the near future.

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