Development of Semi-Autonomous RISE wheelchair with Multiple user interfaces using Robot Operating System (ROS)

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Declaration

I certify that this research work titled "*Development of Semi-Autonomous RISE wheelchair with Multiple user interfaces using Robot Operating System (ROS)*" is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources it has been properly acknowledged / referred.

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Abstract

This project is aimed to provide mobility to such patients which suffers from different physical disabilities such as Amyotrophic Lateral Sclerosis (ALS) in which body is neck down fully paralyzed like in the case of 'Stephen Hawking', also for patients with different type of deformities in the body to control the electric wheelchair using mobile phone or hand gesture control in case they are not able to reach the joystick mounted on the wheelchair or command the wheelchair remotely from their beds or easy chairs to provide them complete freedom and independency from any other human/attendee, some sensors are interfaced with the wheelchair to provide safety to the wheelchair user by eliminating the wrong commands which may cause collision with any object/human in the dynamic environment. In recent development wheelchair is equipped with such sensors which not only localize the wheelchair in outdoor environment using GPS but also in indoor environments by using simultaneously localization and mapping algorithms and Laser sensors. Stereo vision camera is mounted at front of wheelchair to provide the depth information which is used to compute the odometry of the wheelchair which is further used by mapping algorithm to map the surrounding environment. Also, the camera feed can be enabled on mobile app to remotely drive the wheelchair from anywhere.

Key Words: *Wheelchair, Electric wheelchair, Semi-Autonomous wheelchairs, RISE wheelchair, Localization, Mapping, ALS, LIDAR, Odometry, Stereo vision camera, Robot operating system, ROS, SLAM, Multiple user interfaces, mobile robotics.*

Table of Contents

List of Figures

CHAPTER 1: INTRODUCTION

Around 15 % of the total population consist of disable person, where disabilities can be of any type which limits the mobility of the persons. Some diseases are this much severe that they can even causes the whole body paralyzed, such as ALS or Amyotrophic Lateral Sclerosis which effects motors commands from the brain to the body parts, in later stages patient even losses its speaking, eating and breathing abilities.

To provide mobility to such patient's researches are proposing lot of techniques which can make their life better and can return their self-esteem and dignity, smart wheelchairs are part of these developments which can't recover the diseases but at least provide them some sort of mobility so that they can perform their daily tasks on their own, RISE wheelchair and prosthetics developed in the RISE Lab are similar type of product which provide assistance to such patients.

In this thesis a technique is developed which can help different type of patients by providing them customized features of RISE wheelchair according to their needs, brain-controlled system for patients with severe diseases i.e. ALS (malfunction of motor neurons) or para-plegia (spinal cord damaged), Mobile app/hand gesture controlled system for patients with some sort of deformities of hand/arm which causes them difficulty to reach the joystick of the conventional electric wheelchairs, semi-autonomous feature increases the safety of the wheelchair user by by-passing the commands which can cause collision with the nearby objects.

Figure 1: RISE Wheelchair

1.1 Objectives

In under developed countries like Pakistan mostly wheelchair users are still using manually operated wheelchairs in indoor and outdoor environments which is very difficult for aged people and patients with weak muscles, in developed countries people can afford electric wheelchairs so are switched to battery powered joystick controlled wheelchairs but still lot of patients with severe diseases like paralysis , mental disorders, blindness etc. still depends on attendee for sake of mobility and daily tasks.

In this work an effort is made to convert conventional wheelchairs into electric wheelchairs and modifying current electric wheelchairs into smart wheelchairs which can take their decisions on their own by observing the environment using different sensors to localize and navigate through the environment without colliding with the obstacles. Also taking goal commands from user through different user input depends on the state of the user.

The long term goal is to develop electric wheelchairs which can be affordable by the users of under developed countries and customizing the smart wheelchair to have different options for different category of patients, If patient is suffering from ALS then brain controlled wheelchairs will be provided, if patient only have the amputated limbs then muscles movements will be used to steer the wheelchairs and to provide easiness and long range control to the users mobile app is included using which user can operate the wheelchair remotely from their beds to drive the wheelchair from charging stations to appropriate position near their beds from where they can easily be shifted to the wheelchair and move around in the world.

1.2 Thesis outline

This thesis compromises of five chapters including introduction, RISE smart wheelchair, implementation, results, conclusion.

- **Introduction:** This chapter includes motivation behind selecting this topic and purpose of developing wheelchair. A brief introduction to related algorithms such as Mapping, Localization, and Navigation is given, to familiarize the reader with our research goals.

- **Literature Review:** This chapter includes information about the different modules of the state-of-the-art smart wheelchairs developed at different labs. It also compares different semi-autonomous wheelchairs and challenges behind commercializing the smart wheelchairs.
- **Implementation:** This chapter explains our brain controlled and hand-gesture / Mobile-app controlled methods. This includes interfacing EEG headset with MATLAB, using Myo-SDK to interface EMG sensors with laptop, and ROS nodes responsible for collecting the data and sending velocity commands to the base controller of the wheelchair.
- **Results:** This chapter discusses the results of interfacing different user interfaces with the RISE wheelchair.
- **Conclusion:** In this chapter, the work carried out in this research project is summed up.

1.3 Wheelchairs for Disables

There is a considerable human population with disabilities all over the world. A World Health Organization (WHO) report [1] suggests that more than a billion of population is suffering from some form of disability. A significant proportion of this disabled population is crippled, due to various reasons like leg amputation, Spinal Cord Injury or diseases like Alzheimer, Cerebral Palsy, etc. Net effect of these handicaps is that the person becomes immobile and becomes dependent on others. Recently, high tech prosthetics limbs have been developed [2], that are useful for disabilities like leg amputation, but patients whose impairments are due to other diseases, must have to use wheelchairs for mobility. According to reports 10% of individuals affected with tetraplegia (65 million) require a wheelchair for locomotion [3].

1.4 Electric Wheelchairs

For handicapped people, a wheelchair becomes a necessity and daily part of their lives. Before the advent of electric wheelchairs, a wheelchair user was required to use raw muscle strength of upper limbs to move his/her wheelchair. For patients, that lacked the required upper body strength, an attendee was required to assist them in moving their wheelchair [4]. In short, their handicap become a hindrance that limited their interaction into the society. After the invention of powered wheelchair, it became possible for them to move without assistance, requiring no physical strength.

Most of the powered wheelchair in common use today, are batter powered devices, that use electric motors to drive the wheels of wheelchair. These class of wheelchairs helped millions of disabled people in their everyday daily life routine tasks [5],[6]. With the advancements in control theory, robotics and computational capacity, it has now become possible to introduce new novel concepts and technology in assistive technologies, so that the effect of their handicap is mitigated to allow for their easier integration into society.

1.5 Semi-Autonomous Wheelchairs

Powered wheelchairs have eased the strain on wheelchair users. But there are still certain types of disabilities, like Ataxia and Dystonia, whose patients have difficulty operating wheelchair with mounted joystick. A solution proposed for such patients, is to come up with smart wheelchairs that requires a minimum set of commands from a wheelchair user, and its communication interface is customizable for each patient.

Rather than designing a smart wheelchair from scratch, it was decided to develop joystick controlled powered wheelchairs into a smart wheelchair. The goal of that transformation was to minimize the steering input required continuously to drive electric wheelchair, into higher level commands that are required occasionally. This task requires converting the wheelchair into a mobile robot. A positive side effect of this transformation for normal users of powered wheelchair is that they become free to perform other tasks while operating their wheelchair.

CHAPTER 2: Literature Review

Handicapped people rely heavily on wheelchairs to move around. In order to move independently, existing electric wheelchairs fulfills the needs of most of these individuals. Researchers have been working in several ways to help such severely disabled people, one such way is the development of smart wheelchairs, which is still area of interest among robotics researcher community. In this chapter, development of RISE smart wheelchair is discussed along with description of the important elements and features that put electric wheelchair in the category of smart wheelchairs.

2.1 Modules of Smart Wheelchair

Smart wheelchairs are typically electric wheelchairs having an on-board computer and sensors continuously giving a feedback of the surrounding [7]. Smart wheelchairs are generally equipped with several features to improve navigation including collision avoidance, obstacle avoidance, finding a way towards the goal and human machine interface tailored for specific individual needs. In following subsections these modules will be discussed which makes an ordinary wheelchair into a smart one.

2.1.1 Sensor and Electronics

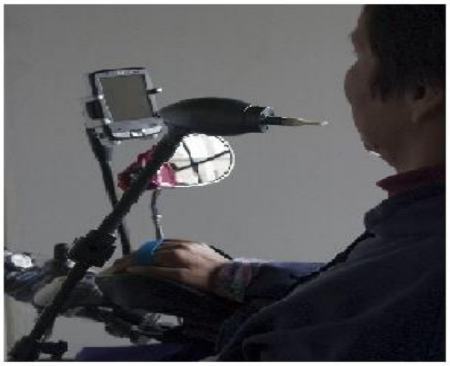
The major difference between smart wheelchair and electric wheelchair is its ability to intervene. On board sensors mounted on a smart wheelchair provide valuable feedback making it capable of perceiving its surroundings. Selecting suitable sensors for smart wheelchair is a challenging task as it needs to be reliable, cheap, accurate and robust to stand up to environment conditions. Drawbacks of each type of sensor is different, like on sound absorbent surfaces, ultrasonic range finders fail, and IR range finders fails to work in environment with light absorbent surfaces. Cameras are relatively low cost, but they need complex algorithms to accomplish the simple tasks, so it comes with computational cost. To solve this problem sensor data from multiple sensors is fused together to get a reliable result, during early era of smart wheelchair development, to perceive the environment infrared and ultrasonic sensors were used to collect the data of the surrounding around the wheelchair because of their small size and ease od data extraction. But with the advancement of sensor technology; sensors including cameras became smaller and more accurate. Today, with a wide range of cameras became smaller and more accurate. Today, with a wide range of cameras available around us working up to 60fps and having a wide information. Beside all these sensors the most important feature of any smart wheelchair is its on board PC as it is responsible of processing the sensor data and user inputs to efficiently control the wheelchair.

2.1.2 User Input Method

Commonly, Joystick is used to control the wheelchair. Although there are other options, but usually the electric wheelchairs are not configured to be used for other input options. One of the key features of smart wheelchair is to provide options for multiple interface for controlling the wheelchair as desired. In following sections, several common input methods are discussed which are used for controlling electric or an intelligent wheelchair. Though the most common interface is joystick but there are also other available interfaces such as Touch, flex sensors, Sip-n-Puff, Chin-controlled, head-controlled, speech controlled, tongue controlled etc. as shown in figure 2.1

(a) Chin Controlled

(b) Tongue Controlled



(c) Sip and Puff interface

Figure 2: Different user interfaces

Recently researchers also have started working on number of interfaces such as Eye-movement, EEG, EMG, EOG, Visual Gesture based as discussed in section 2.2

2.1.3 Environment Perception and Localization

Beside input methodologies, smart wheelchairs have some extra features. These features are deeply inherited into the fundamentals of mobile robotics, such as environment perception, ego-motion and navigation. In following sections, the idea of environment perception, ego motion and navigation are briefly discussed.

2.1.3.1 SLAM

Simultaneously localization and mapping (SLAM) is considered a key component of today's truly autonomous robots making them aware of their surrounding and capable of navigating through it. It involves a robot or subject vehicle to move through the unknown environment and mapping its surrounding while continuously updating its pose i.e. its position and orientation, relative to the continuously updated map.

SLAM is defined as a problem of creating a map and estimating the pose of the robot from the data collected using the in-board sensors. The data of nearby landmarks and the motion of robot are compiled into a probabilistic map according to the momentary pose. In the real world; there are uncertainties in both the motion of the robot and the data acquired by the robot. As the robot keeps moving; the uncertainty in its motion keeps accumulating. Similarly, the estimate of the nearby landmark becomes more uncertain due to the uncertainty in the data, resulting in the accumulation of uncertainty in the robot's pose and the created map. Since the motion of a robot in real world is always accompanied with errors creating uncertainties in the map of the environment and its relative position. Minimizing these errors is crucial for implementation of SLAM in real world. The idea of combining multiple sources of data in order to reduce the errors and improve the overall result is present around us in every domain. Taking a closer look at nature, we find out that even the human body performing different tasks is possible only because of conscious or sub-conscious use of multiple natural sensors including sense of sight, hearing, touch, taste and smell. In addition to these well-known five senses, human body is also equipped with a sense of orientation and rotation. These orientation sensors also known as semicircular canals are in the inner part of the ear. The human body navigates through the real world and maintains its pose because of the two of the above-mentioned natural senses i.e. the sense of sight provided by eyes and the sense of orientation provided by the semicircular canals located in the inner ear. While navigating through the real world, human body receives the highest amount of data through its sense of sight but without the sense of orientation it is unable to perceive if the visual data is up right or at a certain angle. Thus, we can establish that we can only obtain the correct pose of the body in real world by subconsciously using multiple senses and fusing their output in our mind.

2.1.3.2 Path Planning and Navigation

We humans usually take navigation problem as granted because in order to move towards a desired location, we do not have to intentionally plan in order to avoid the obstacles on way or to optimize the route to be followed or to infer the path of dynamic objects moving around us and to act accordingly in real time. It becomes a natural thing for us, and we do it without much efforts. An intelligent wheelchair having such capabilities can assist the user to perform activities of daily living in a much efficient way. Motion planning for navigation is an active research area and is a challenging problem to solve in real world scenarios. A basic problem is finding a way from initial point to goal point by avoiding the obstacles. The navigation subsystem is responsible for the wheelchair to maneuver smoothly and safely in its environment. The robustness of the navigation sub-system is extremely important for the user’s safety. The wheelchair should be able to navigate around without hitting obstacles and should pass through narrow passages such as doorways. For navigation the wheelchair also needs a motion a motion planner, mapping and localization tool.

2.2 Smart Wheelchair Projects

In this section a review has been done about the state of research in the field of smart wheelchair technology. The selection of parameters, which are used to evaluate different wheelchair projects is based on the type of sensors used and distinguished feature of the project. Researchers in USA developed a modular Smart Wheelchair Component System (SWCS), which modifies commercial electric wheelchair into semi-autonomous one it has sonar and IR sensors [8]. CPWNS [9] is based on camera and inertial measurement unit sensors, working on the principles of dead reckoning. It can automatically follow the saved path which are manually taught and reaches from start point to goal point. The intelligent Wheelchair [10] is furnished with infrared, vision and sonar sensors. It detects landmark using visual information and navigate autonomously to explore the environment. In intelligent Wheelchair System, combination of gesture recognition, vision and sonar is used to control the wheelchair using the facial expressions interpreted by computer vision algorithms [11].

INRO [12] is capable of autonomous navigation and forming and maintaining convoy of wheelchairs using Sonar and GPS sensors. Luoson III [13] with help of sonar, vision, and inertial measurement sensors to assist in navigation and can also track a moving target. Maid [14] has some advanced features, it can autonomously go to a goal and user can also share the autonomy in semi-autonomous mode. It uses IR, sonar and Laser Range Finder (LRF) sensors to achieve the specific tasks. Similarly, sonar, IR and bumper sensors are used in OMNI [15] and RoboChair [16] to achieve obstacle avoidance behavior.

In Roland machine learning techniques are used for learning the map during navigation in order to plan a path afterwards through real environment. It can also learn to avoid the obstacles around it with help of vision, sonar, IR and bum sensors [9]. SIRIUS [17] is also another wheelchair project which can save routes and follow the recorded routes when desired. It can also avoid obstacles by using Sonar sensors. Wheelesely [18], has vision, IR and sonar-based navigation assistance. The researchers at MIT have developed a wheelchair which can learn about the locations in the buildings and then take patient to the goal point with voice command [19].

Although the research has been state-of-the-art in developing smart wheelchair, but there is no significant breakthrough in terms of commercial perspective. The reasons mainly are the cost of the sensors and robustness of solutions in different environmental conditions. One way to cater the need of large number of populations is to develop smart wheelchairs in modular form, so the users can buy a basic form of smart electric wheelchair and later get module of their choice and configure it accordingly. For example, if someone wants to control wheelchair with eyeball movement, he only needs to get eyeball tracking module and plug it into the system. Similarly, from autonomy point of view user should have option to control amount of autonomy he wanted to share with smart wheelchair.

CHAPTER 3: Implementation

This project was divided into two parts: Hardware Design, Software Implementation.

- **Hardware Design:**
  - Developing of conventional electric wheelchair into a smart wheelchair which consists of installing sensors to get the data from the environment and controlling module to communicate with the base the base controller. Which was done by replacing the joystick module with the computer module to generate analog voltages, LASER Range Finder and a Stereo camera was installed to perceive the environment.
- **Software Implementation:**
  - ROS based control of powered wheelchair, with data receiving from sensors.
  - ROS node for sending data received from different modules to wheelchair.

3.1 Wheelchair Hardware Architecture

Our algorithms were implemented on an electric wheelchair (Suzuki MC 2000). This wheelchair comes with a joystick as an input method for navigation which is replaced by a computer (Cobra EBX-12). The motor drive of the wheelchair was connected to our ROS based computer to control its motion. This ROS based system gave us the flexibility to control the wheelchair via different HCI (Human Computer Interaction) input devices. Different user inputs brain controlled, hand gesture controlled and mobile controlled are used. The overall hardware design of the wheelchair is shown in figure 3.

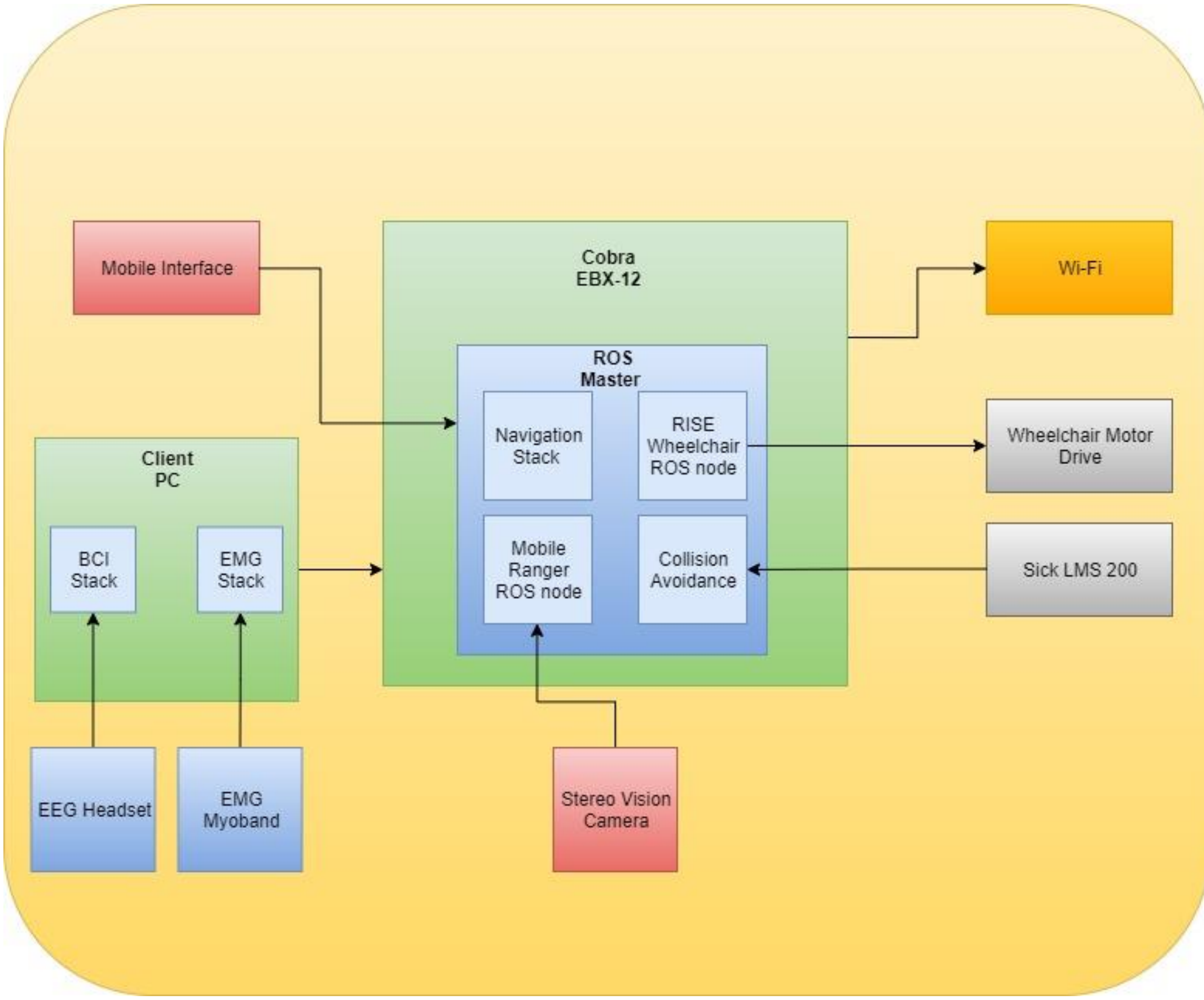


Figure 3 RISE Wheelchair Architecture

The wheelchair consisted of two electric motors, connected with the rear wheels, which were connected to a main controller powered by batteries. The main controller or the wheelchair motors drive was used to translate the command signal given by the master computer and control the speed and direction of motors. The main controller of the wheelchair was connected to a master computer which is a Cobra EBX-12 onboard computer. A Wi-Fi module was mounted on master computer for communication with other systems. A LIDAR (LMS 200) connected to the master computer via serial port was mounted on the front end of wheelchair.

The command protocol between the main motor controller and wheelchair computer was reverse engineered by logging the data from wheelchair joystick into a computer.

The on-board computer runs on Linux (Ubuntu 12.04) operating system and Robot Operating System (ROS) was installed on it. This computer was set as the master ROS server. Brain computer interfaced module , EMG based hand gesture interface and mobile app interface communicated with ROS master via Wi-Fi and sent input in the form command velocity (cmd_vel) This command velocity was then translated by ROS master to a form that is understood by the main controller of wheelchair which in turn converts it to the speed and direction of motors.

3.2 Hardware Interfacing

The most fundamental element of any smart wheelchair is hardware which includes computer, sensors and actuators if needed. RISE wheelchair is equipped with all the necessary hardware required for converting ordinary wheelchair into a smart one. In this section we will discuss everything related to RISE wheelchair's hardware, the overall hardware system block-diagram is explained in figure 4.

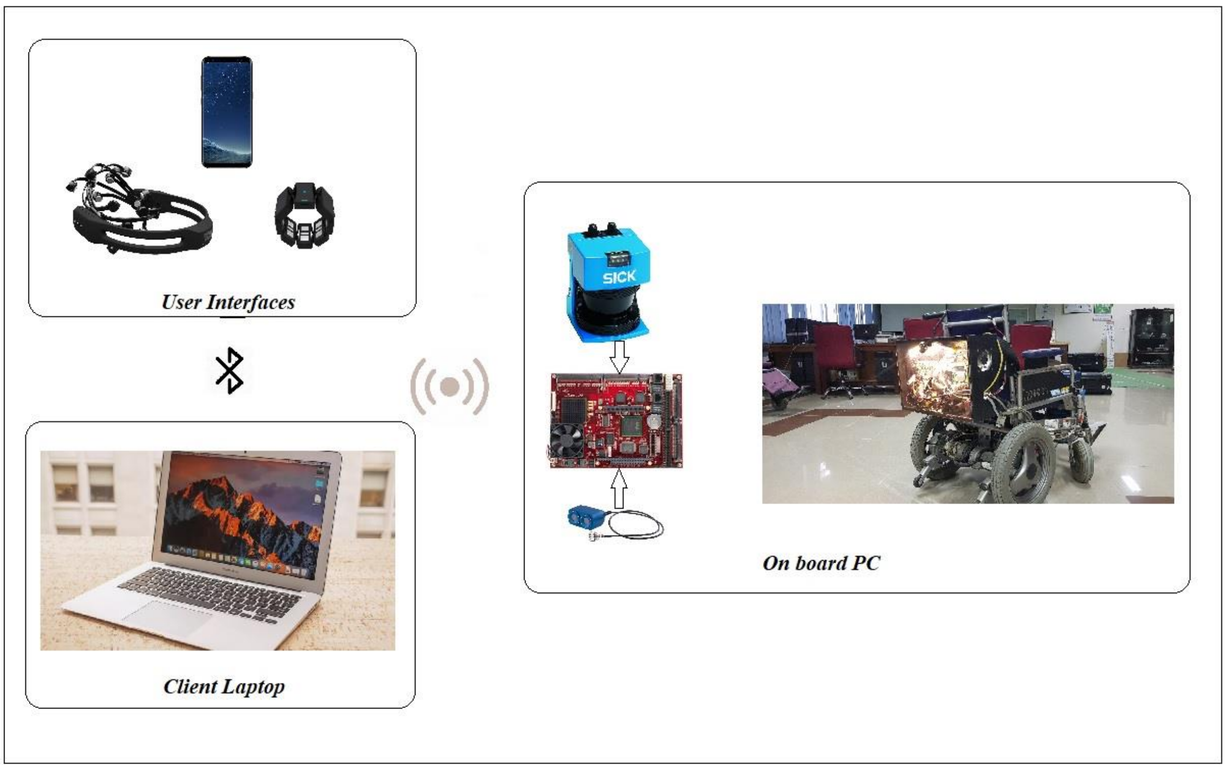


Figure 4 Hardware Interfacing

3.2.1 Hardware modules

Hardware part of the wheelchair requires adding all the required sensors to meet the requirement of environment perception, localization, and navigation. RISE wheelchair is equipped with all the necessary sensors in order to meet the mentioned requirements. Each of the module is discussed one by one in the following sections.

3.2.1.1 Stereo Vision Camera

Stereo camera is a type of camera which can measure depth because it has more than one lens, which brings capability to record images from the two cameras simultaneously. The data from images are then used to perceive the depth of the environment using camera's intrinsic model and image matching techniques. This information is further used for visual localization of the wheelchair.

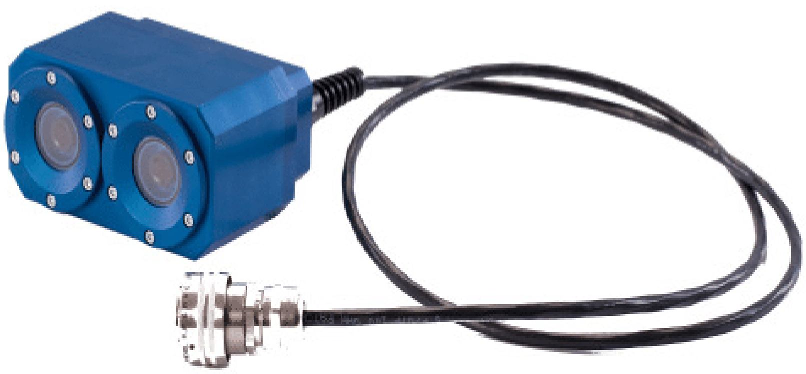


Figure 5: MobileRanger C3D Stereo Camera

3.2.1.2 LIDAR Sensor

The LIDAR emits laser beams and these beams struck with the objects in the path and return to the source. The high-speed clock then gives the complete journey time to calculate distance from the object.

In wheelchair project we have used SICK 200 laser range finder which covers 180^{o} field of view as shown in Figure 6. The LMS200 is interfaced with the on-board computer via RS 232 serial interface. It sends data in binary format after scanning the environment.

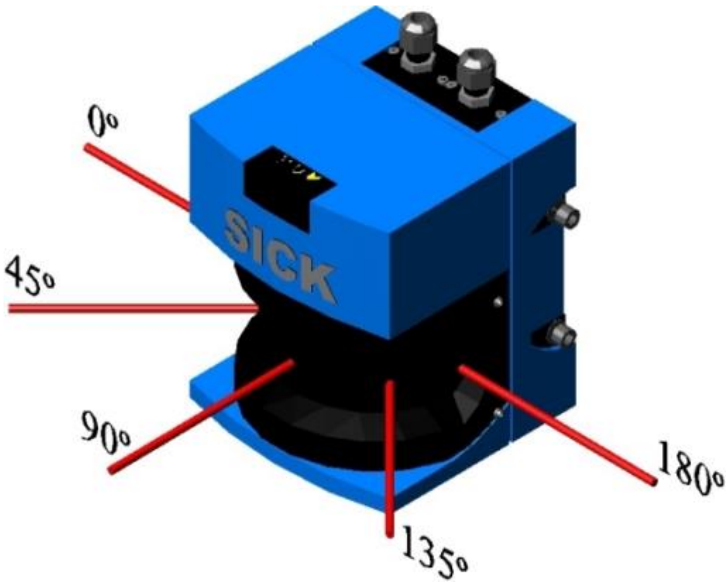


Figure 6: LIDAR SICK LMS 200

3.2.2 On board Computer

A single board computer is used for the purpose of sensor interfacing, controlling wheelchair and for running software for mobile robotic functions. In our system we have used Versalogic Cobra SBC shown in Figure 7. The Cobra has been used in Pioneer3-AT robots.

Figure 7: Versalogic Cobra Computer

3.2.3 Electronics Circuits

The base controller of the wheelchair is connected via RS 232 to the onboard computer and power is distributed through PCB board. Wheelchair has connection with its joystick via 8 pin connectors, a simple board was designed which converts 8 pin connectors to DB 9 serial connector in order to serially interface wheelchair lower drive controller with on board computer. Similarly, a board is also designed for power distribution to computer and providing an electrical ground to complete system. Two 12 volts dry cell batteries are used for power supply to all electronic except laser range finder, which is connected to wheelchair's main motors power source.

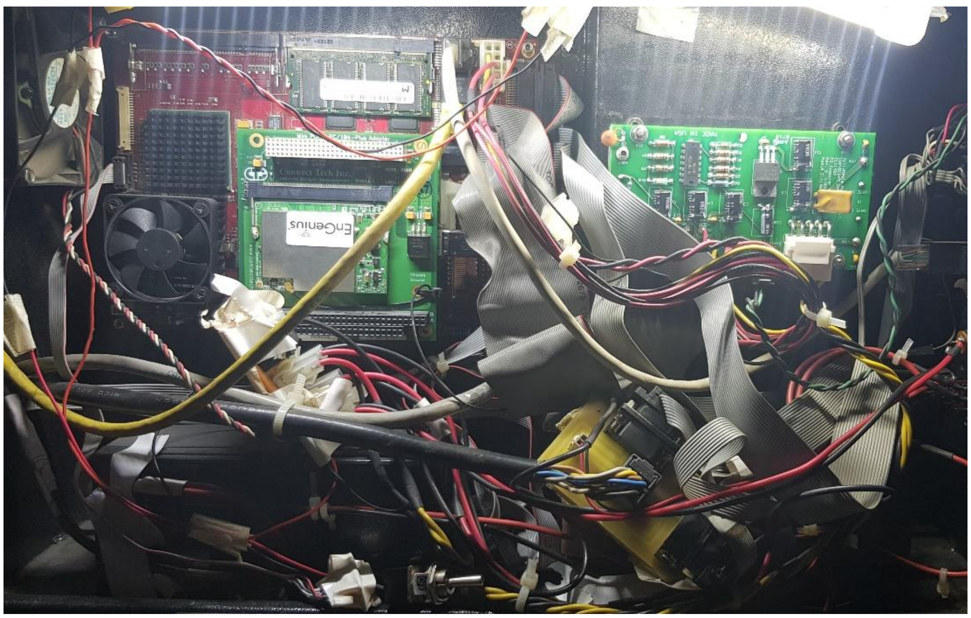


Figure 8 Wheelchair On board Circuitry

3.3 Implementation of ROS on wheelchair

Robot Operating System or its short form ROS is a structured framework which provides a layer of a communication layer, which operates upon the host operating system of a heterogenous computing cluster. The purpose of designing this framework is to simplify the task of creating complex software's and integrating them in real robots. In our case we have developed a base velocity controller by writing a C++ ROS program to translate velocity commands into joystick signals.

3.4 Structure of ROS

The fundamental building blocks of ROS implementation are explained below:

- **ROS Core**

  This is the main program that manages information of all the running nodes and message topics and binds them together at runtime. ROS core maintains a table of running nodes, storing their machine hostnames, list of their subscribed and published topic names and services, all nodes communicate with the running single instances od core to retrieve information of topics and services when subscribing and publishing new topics.

- **ROS Nodes**

  All programs running in ROS framework are called nodes. Nodes perform different tasks and have different behaviors which are used by other nodes in the ROS run time environment. The nodes provide functionalities to the robot that are required by the robot. Some nodes are sensor hardware specific, like drivers for a camera or laser range finder, while there are other nodes which are independent of a specific hardware, and work with different hardware of same type.

  One such example is the node for GMapping, API bindings in several languages is possible with ROS, such as C++, Python and LISP which gives user the flexibility to write a ROS node in a programming language of his/her choice.

- **ROS Messages**

  ROS messages are used by nodes to share information between each other. A message uses standard types of data structure or data structure developed by the user. A command line tool rosmsg can be used to get information about the message. [20]

- **ROS Topics**

  Topics are mediums used by nodes to transmit data. A topic can have various subscribers that's why data can be transmitted between nodes without a direction connection. These messages can be simple such as single number or text string, or they can be a complex data, such as map of environment. This communication is unidirectional. These topics are used to correctly bind messages from publisher and subscribers, so that the message reaches its intended nodes. The binding happens only once at time of registering, thus reducing communication overhead [20].

- **ROS Services**

  Since topics are unidirectional, if a need arises to reply to a message, it can't be done using topics. This can be done using service. Services are developed by the users and standard services do not exist for nodes [20].

- **ROS Packages**

  The Nodes and messages are combined to form a package, for easy distribution. The purpose of these packages is to benefit ROS community by sharing these packages is to benefit ROS community by sharing these packages with different research groups which gives it the ability to be easily reused. New algorithms for different robot related tasks are shared between researchers through packages, which gives these packages and ROS collectively a continuously improving capability [20].

- **Parameter Server**

  Though logically separate, ROS core provides a parameter server functionality, that is visible to all nodes. Parameter server stores a lookup table of variables that is used by running nodes to retrieve optional parameters. These optional parameters are node specific and provides a platform independent mechanism to alter the behavior running nodes [20].

3.5 Simultaneous Localization and Mapping

For any mobile robot it is mandatory to generate a map of the environment and localize itself into it. In RISE wheelchair we have this functionality by using visual odometry information calculated by using stereo camera images. In figure 9 RISE wheelchair is generating Map and localizing itself into this map. For SLAM built in ROS GMapping package is used.

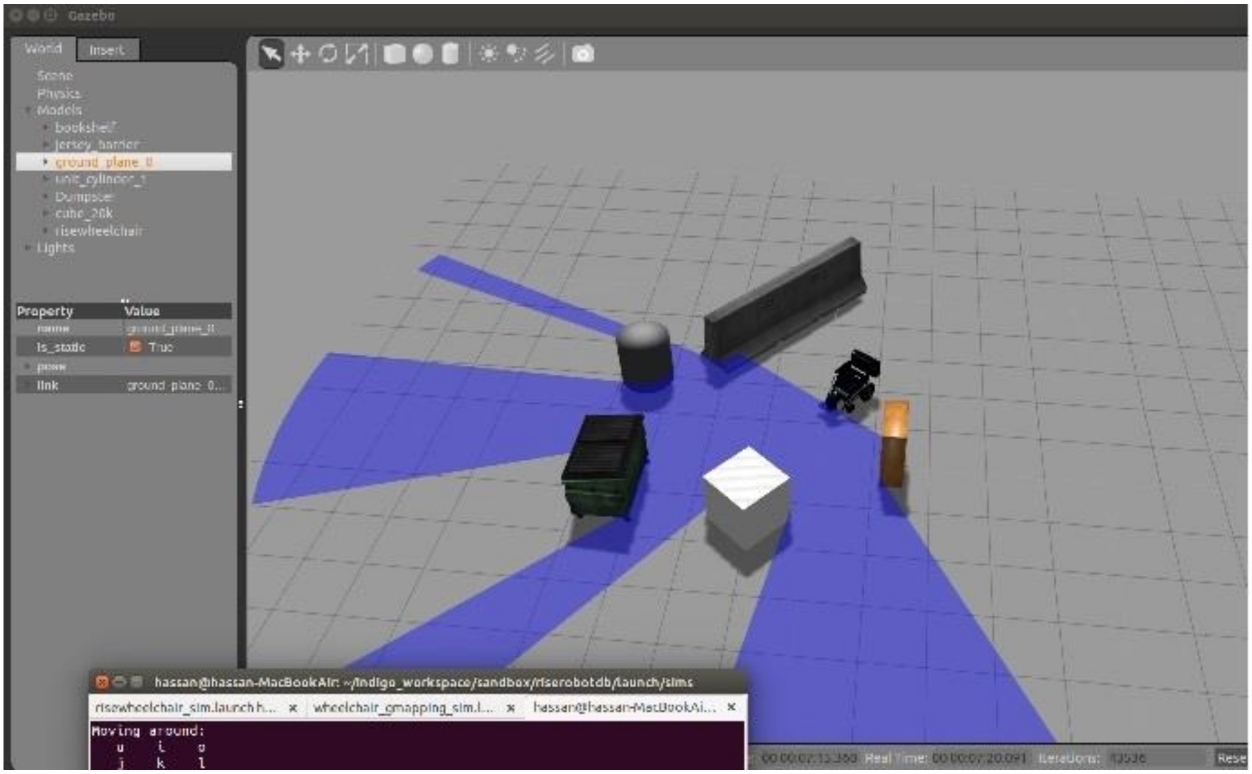


Figure 9 Replica of Real World in Gazebo

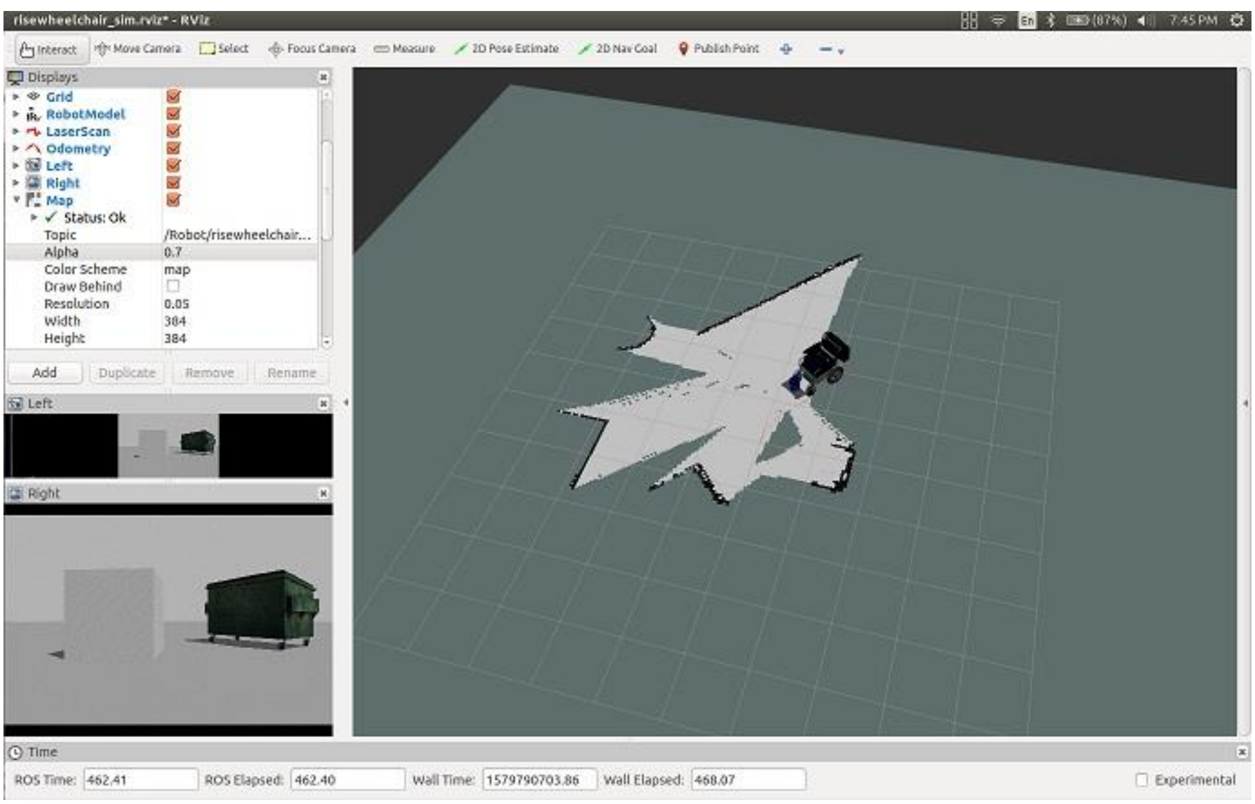


Figure 10 Mapping and localization

3.6 Navigation

Navigation in the environment is also one of the key aspects of any mobile robot. In RISE wheelchair ROS move base package is used to achieve the task. User can select the navigation goal point on the map and the move base package plans and then move the wheelchair towards the goal point.

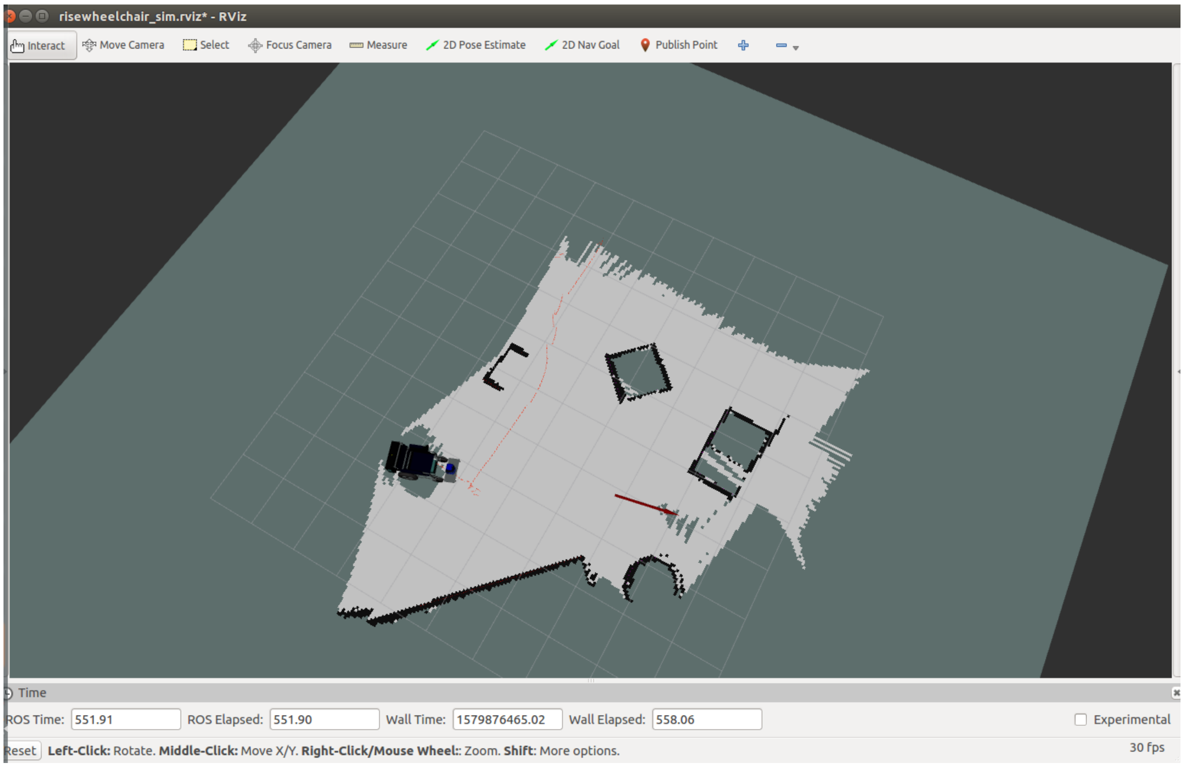


Figure 11 Navigation towards Goal

3.7 Safety module

3.7.1 Collision avoidance

In order to avoid the collision in dynamic environment. A safety module has been designed to ensure that wheelchair will not collide with anything nearby. The algorithm is based on Laser data which covers the front 180^0 field of view and laser data is divided into three angular regions as shown in the Figure 12.

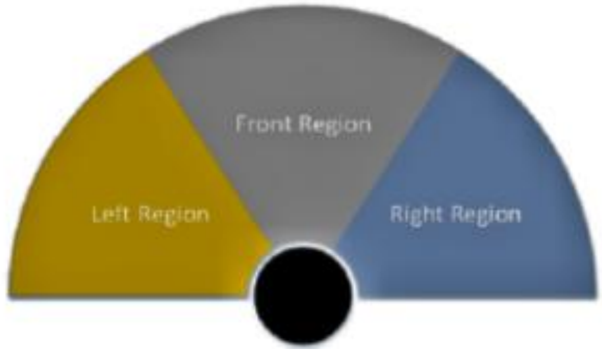


Figure 12 Three Regions of Laser

The idea is that if an object is near the wheelchair front, it will not move in that direction. In figure 13 flow diagram of algorithm is drawn. The node subscribes to Laser data and input command velocities. If obstacle is within range of any of the above regions, the command velocity towards that side will be discarded to avoid the collision, only way to drive the wheelchair is towards safer regions left behind.

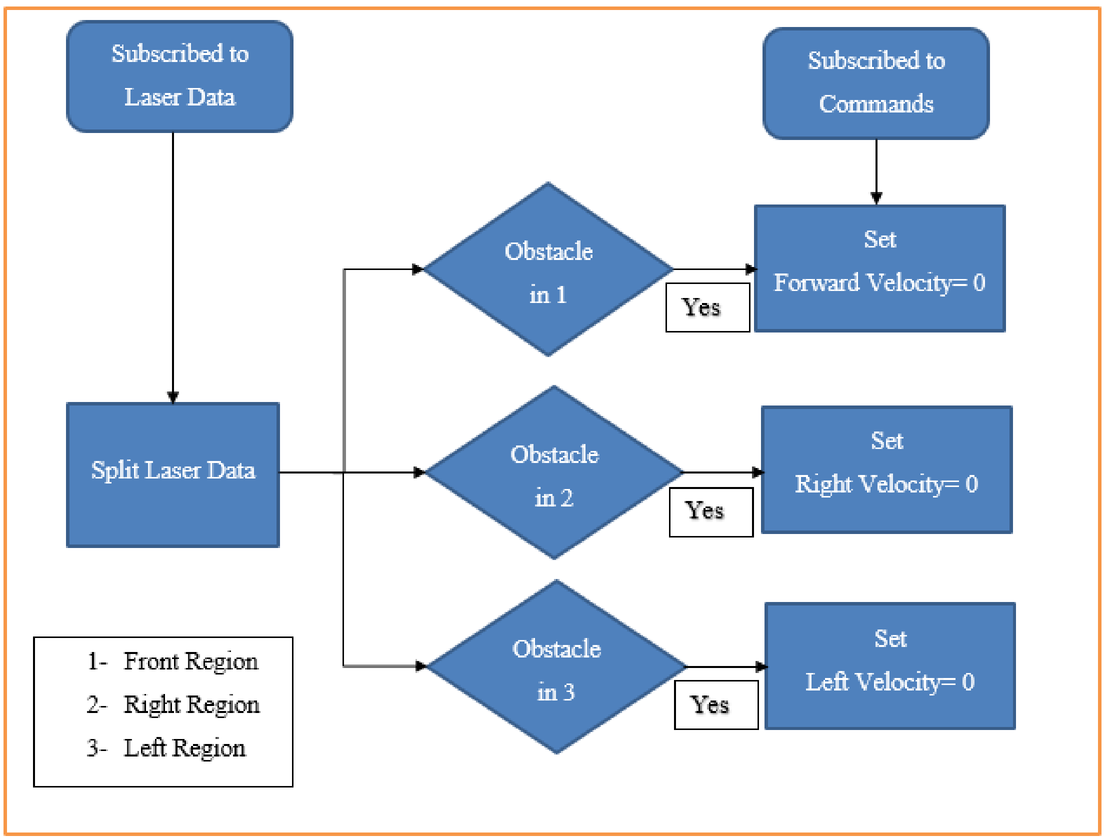


Figure 13 Collison Avoidance Flow diagram

To unable this functionality protected mode of the wheelchair must be enabled, so that it can read the data from Laser Range finder.

Chapter 4: Multiple User Interfaces

There are different kind of patients with different kind of diseases/deformities, so multiple user interfaces are designed for RISE wheelchair to provide customized functionalities to each user depends on their need. The interfaces include Brain Computer interface, EMG interface, Mobile App interface or any other source of detectable signals while keeping in view of user's comfortability. It is developed on the idea of reconfiguration of input method without doing any alteration to the base architecture of the smart wheelchair. Our system also has ability to communicate over cross OS platforms, for example mobile app interface is implemented using Android OS, while EEG and EMG interfaces are based on Windows OS, While ROS master is running on on-board computer using Linux OS.

In the following section I will discuss the interfacing of EEG headset for steering of the wheelchair , interfacing of EMG myo-band for steering the wheelchair using hand gestures, mobile app interface and different techniques which are developed to select goal position for autonomous navigation in a given map while avoiding obstacles.

4.1 Brain Computer Interfacing

The recent research and development in the field of assistive technology indicates that the use of EEG based Brain Computer Interface (BCI) has the potential of becoming a promising technology for improving the functional mobility of disabled persons. Emotiv EEG headset is developed mainly for entertainment purposes targeting gaming market. For this application we have used emotiv headset to get processed EEG data for steering the wheelchair as well as selecting navigation goal point. The headset comes with algorithms to train and detect cognitive actions as well as universal expressions such as smirking blinking and smiling.

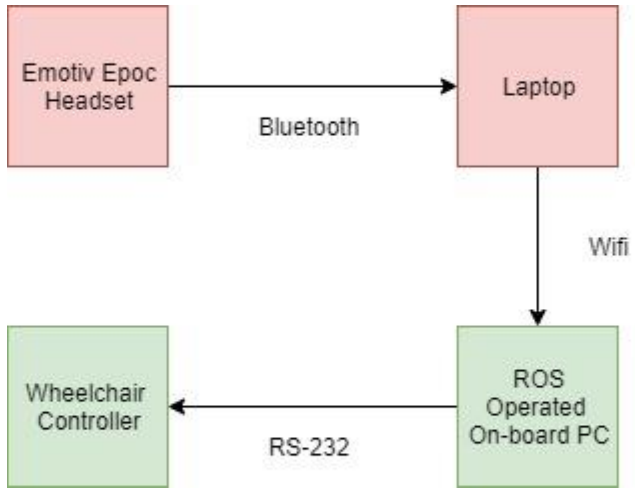


Figure 14 EEG headset interfacing

For brain computer interfacing MATLAB is used to access data from EEG and using 'Robotics toolbox' to transmit command velocities to the ROS Master running on the RISE Wheelchair. Figure 14.

4.2 EEG Based Steering

Emotiv headset is used to detect frequency on which user is focusing, the greater the number of frequencies used the greater is the chances of interference. So, in designing the algorithm for steering I have used only four distinctive frequencies, to move the wheelchair in forward, backward, right or left direction. As with any EEG based brain computer interface, the performance depends upon user's fatigue level, so better the focusing on one frequency results in better steering. The complete algorithmic flow chart is shown in figure 15.

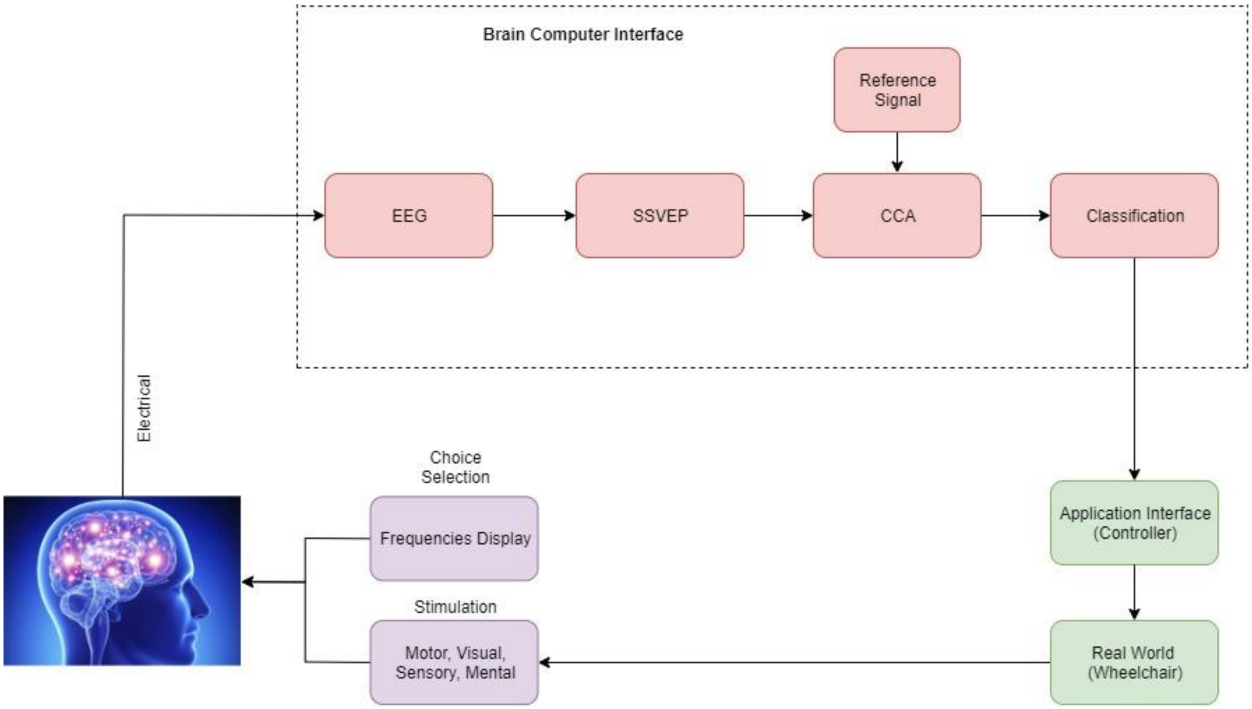


Figure 15 Brain Computer Interface

4.3 Hand gesture base Remote Control

The first desired action was to control the wheelchair using hand gesture remotely. It has a benefit for people who want to park the wheelchair, once they are off to bed, to a specific location and bring it back when needed. The benefit of using ROS as base architecture is that once we have implemented the ROS based architecture, user has option of using different applications available for controlling ROS operated mobile robots. In this application I have used Myo armband to read electrical activity in the muscles to wirelessly control the wheelchair, user only need to wear the armband and give gesture to operate the wheelchair, remaining things are done on the Clients Laptop. The demonstration of hand gesture-based control of wheelchair is shown in figure 17.

Figure 16 Different Hand gestures to Steer Wheelchair

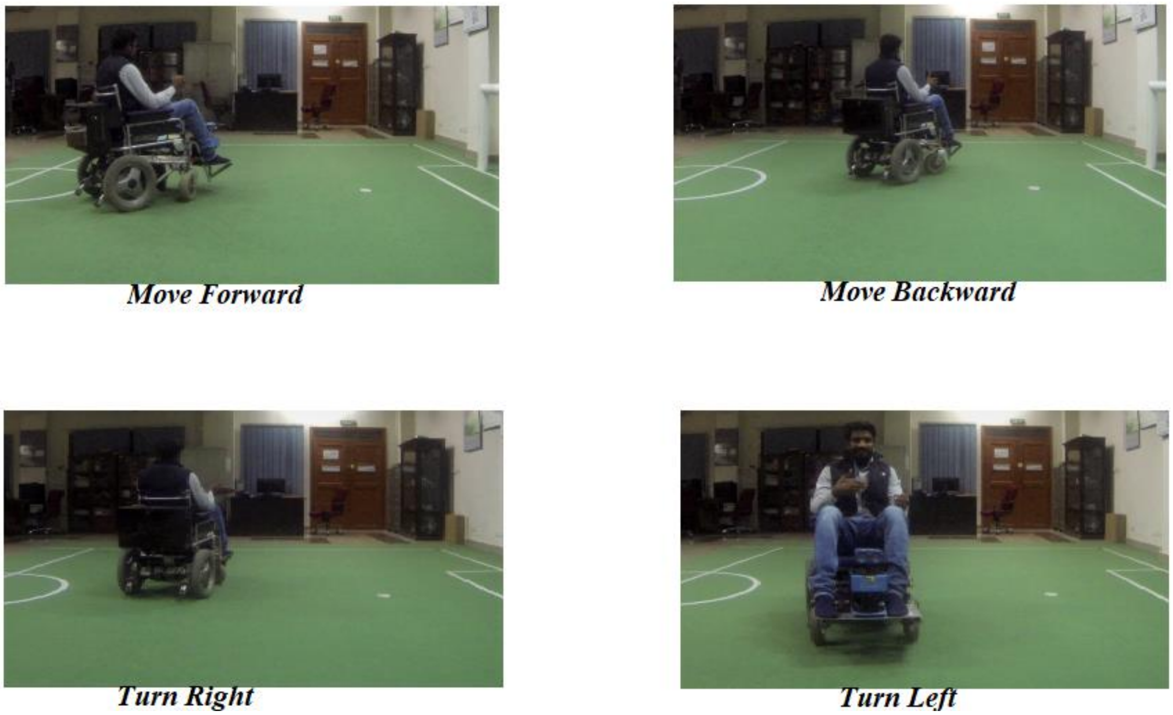


Figure 17 Steering of RISE Wheelchair using hand gestures

4.4 Smart Phone base Remote Control

The RISE wheelchair can be controlled using smart phone remotely. It has a benefit for family member to drive the powered wheelchair from some distance while patient is sitting on the wheelchair instead of using their own muscle power. The benefit of using ROS as base architecture is that once we have implemented the ROS based architecture, user has option of using different application available on Play Stores for controlling ros operated mobile robots. In this application I have used ROS Teleop ControllerAuTURBO (Kinetic), user only need to connect over the same network and connect the wheelchair's master using the IP address. The demonstration of smart phone-based control of wheelchair is shown in figure 18.

Figure 18 Operating RISE wheelchair using mobile app

4.5 Eye based Control

In order to show the modular and re-configurable nature of proposed architecture, I am showing the results of Eye based control of the wheelchair developed by a RISE lab member, Affan Zia. The camera gets the sequence of images of user's eye and algorithm is written to transform the detected eyeball movement into wheelchair actuation commands as shown in figure 19.

(a) Mode 1 (b) Mode 2

Figure 19 Eye based control

Chapter 5: Conclusion

This project was aimed to find a method to facilitate such patients who can't use their arm muscles or are amputated and can't even use a motorized wheelchair, in moving and controlling a wheelchair by some other means. Different techniques developed to drive the were discussed in this thesis. These techniques are broadly classified as, EEG based, hand gesture based, mobile app based, EOG based and SLAM techniques.

In this research and development work a complete architectural framework has been proposed and successfully designed for converting electric wheelchair into a smart one. RISE wheelchair has all the important components of a mobile robot and a reconfigurable human machine interface. The architecture has been designed considering the recent trends in robotics research community, so ROS is used as the base for RISE wheelchair. The designed system is plug and play type, meaning it has been designed without altering anything on wheelchair and can be used for a different wheelchair with similar electronics and control system. For wheelchair with different electronics, a different way of integrating the computer will be needed.

In terms of human machine interface, a brain computer interface and muscle movement detection interface has been developed. Different methods are proposed and tested for using EEG Emotiv headset for steering the wheelchair considering the needs of different users. A user can select a goal point on a map in autonomous mode using EEG headset. Still system can be reconfigured without much effort for interfacing a different sensor detecting user's intent.

The RISE wheelchair has become platform for further research and development work in the field of Assistive and Rehabilitation Robotics at RISE Lab. The project has also relied much upon feedback of experts (Figure 20) in order to develop a useful technology for disabled individuals.

Figure 20 Demonstration of RISE Wheelchair

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