ROBOT GUIDANCE WITH HEAD MOVEMENTS

by

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A Graduation Project Report

Electrical Electronics Engineering Department

JUNE 2021

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A Report Presented in Partial Fulfilment of the Requirements for the Degree Bachelor of Science in Electrical Electronics Engineering

ESKISEHIR OSMANGAZI UNIVERSITY

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ABSTRACT

Today, there are many diseases that restrict many of the mobility of people due to a physiological disorder. The most common of these diseases is MS, also known as Multiple Sclerosis. This disease is a disease that occurs as a result of physical damage to the protective sheath around the nerve wires carrying messages between the brain and spinal cord. As a result of these and other physiological disorders such as ALS (Amyotrophic lateral sclerosis) or paralysis, people become dependent on wheelchairs. Wheelchairs are tools used to meet the special needs of users in situations that restrict their physical movements. With the development of technology, there is a change in wheelchairs. There are many types, usage areas and usage types such as manual wheelchairs, electric wheelchairs, powerchair football and power football wheelchairs. Some of the people who use these chairs have much less mobility than others. Therefore, serious studies have been carried out on the development of smart and robotic wheelchairs in order to ensure the independence of these people in their daily lives, to facilitate the lives of disabled individuals and to enable them to continue their daily lives comfortably. In this study, it was designed to enable individuals who have had spinal cord injury, who are paralyzed from the neck down due to congenital or illness and who cannot use their hands and are dependent on a bed or a wheelchair, in order to facilitate their lives with minimum head movement.

In order to control the wheelchair more comfortably, it is necessary to first determine the user's face area in order to detect the head movements of the users with the help of a camera. 68 important points are determined on the perceived face and head movement is detected through these determined points. If the perceived head movement complies with one of the previously determined movements, the movement direction of the wheelchair is decided. The wheelchair will perform the appropriate movement in the direction of the decision. Thus, the user can comfortably use the wheelchair in semi-autonomous mode. Within the scope of this study, in addition to moving their wheelchairs by orthopedically disabled people with head movements, it is of great value in terms of people's ability to control robots with head movements.

Keywords: *Wheelchair, autonomous and semi-autonomous systems, mobile robot*

ÖZET

Günümüzde fizyolojik bir rahatsızlık nedeniyle insanların hareket yeteneklerinin birçoğunu kısıtlayan birçok hastalık mevcuttur. Bu hastalıklardan en çok karşılaşılanı MS diğer adıyla Multiple Skleroz hastalığıdır. Bu hastalık beyinde ve omurilik arasında mesajları taşıyan sinir telleri etrafındaki koruyucu kılıfın fiziksel tahribin oluşması sonucu ortaya çıkan bir hastalıktır. Bu ve buna benzer sonuçları olan ALS (Amyotrofik Lateral Skleroz) veya felç gibi fizyolojik rahatsızlıklar sonucunda insanlar tekerlekli sandalyelere bağımlı hale gelmektedir. Tekerlekli sandalyeler, fiziksel hareketlerini kısıtlayan durumlarda kullanıcıların özel ihtiyaçlarını karşılamak için kullanılan araçlardır. Teknolojinin gelişmesiyle birlikte tekerlekli sandalyelerde de bir değişim söz konusudur. Manuel olarak kullanılan tekerlekli sandalye, elektrikli tekerlekli sandalye, powerchair futbol ve güç futbol tekerlekli sandalyeleri gibi birçok çeşidi, kullanım alanı ve kullanım çeşidi vardır. Bu sandalyeleri kullanan insanların bazılarının hareket edebilme yetenekleri diğerlerine göre çok daha azdır. Bu yüzden bu insanlara günlük yaşamlarında bağımsızlıklarını sağlamak, engelli bireylerin yaşamlarını kolaylaştırabilmek ve günlük yaşantılarına rahatlıkla devam etmelerini sağlayabilmek amacıyla akıllı ve robotik tekerlekli sandalyelerin geliştirilmesi üzerine ciddi çalışmalar yapılmıştır. Bu çalışmada omurilik zedelenmesi geçiren, doğuştan veya bir hastalıktan kaynaklanan sebeplerle boyundan aşağısı felç olup elini kullanamayan yatağa veya tekerlekli sandalyeye bağımlı olan bireylerin hayatını kolaylaştırmak için minimum kafa hareketi ile tekerlekli sandalyelerini kontrol edebilmeleri amacıyla tasarlanmıştır. Tekerlekli sandalyeyi daha rahat kontrol edebilmeleri için bir kamera yardımıyla kullanıcıların kafa hareketlerini tespit etmek için öncelikle kullanıcının yüz bölgesinin tespit edilmesi gerekmektedir. Algılanan yüz üzerinde önemli 68 nokta belirlenir ve bu belirlenen noktalar vasıtasıyla baş hareketi algılanmaktadır. Algılanan baş hareketi daha önceden belirlenen hareketlerden birine uyuyorsa tekerlekli sandalyenin gideceği hareket yönüne karar verilmiştir. Tekerlekli sandalye karar verilen yön doğrultusunda uygun hareketi gerçekleştirecektir. Böylece kullanıcı yarı otonom mod ile tekerlekli sandalyeyi rahatça kullanabilir. Bu çalışma kapsamında ortopedik engelli kişilerin baş hareketleriyle kendi tekerlekli sandalyelerini hareket ettirmeye ek olarak baş hareketleriyle robotları kontrol edebilmeleri açısından önemli bir değer taşımaktadır.

Anahtar Kelimeler: *Tekerlekli sandalye, otonom ve yarı otonom sistemler*

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LIST OF SYMBOLS AND ABBREVIATIONS

Symbol	**Explanation**
k:	Distance constant

Abbreviation	**Explanation**
HOG	Histogram of Oriented Gradient
AI	Artificial Intelligent
SVM	Support Vector Machines
ROS	Robot Operating System
iBUG	Intelligent Behaviour Understanding Group
ROS	Robot Operating System

1. INTRODUCTION

Every year, around the world, millions of people struggle with spinal cord injury (SCI). The SCI is the loss of muscle function, sensation, motor skills due to the damage to the nervous system as a result of the spinal cord injury. As a result of this damage, paraplegia or quadriplegia may occur in the body. Patients with paraplegia often remain paralysed from the waist down. Quadriplegia, which occurs as a result of damage to a part of the spinal cord in the neck, is paralysis that causes loss of sensation and movement in the arms, legs and trunk. Patients with paraplegia or quadriplegia are wheelchair-dependent. Paraplegic people can use the wheelchair with their hands without any help; however, quadriplegic people have difficulty in using a wheelchair manually (even with a joystick) because they cannot use any part of their body except the head. Also, they need someone's help to use the wheelchair, which negatively affects patients psychologically. Therefore, a control mechanism above the neck should be developed. This system should be safe and easy to use for patients. Moreover, the mechanism should have many sensors that can help detect obstacles. This perception should help the patient to drive in a wheelchair in autonomous mode and semi-autonomous mode.

Today, with the advancement of technology, improvements in the field of smart wheelchairs have also increased. Many studies have been completed in the field of smart wheelchair. Many techniques have been developed to increase the mobility of people with disabilities and offer them more freedom. Some of the techniques developed are studied here.

For quadriplegic people, the control command can be taken from the tongue. X. Huo, J. Wang and M. Ghovanloo [1] developed the Tongue Drive System (TDS). It detects tongue movement using a magnet and magnetic sensors to move the wheelchair. The recommended navigation device requires drilling of the tongue. People should avoid putting ferromagnetic devices in their mouths, and the magnetic tracer should be eliminated if the consumer has an MRI process. It's quite uncomfortable to talk to individuals with magnetic tracers in the mouth.

Morten Enemark Lund [28] et al., proposed intelligent wheelchair controlled by inductive tongue. To take after the standard joystick, 8 sensors with fuzzy logic-based control of the flexible wheelchair were designed. It has 18 in-mouth sensors worked by tongue boring, and all establishments are built into the mouth framework. The yield values of the sensors were transmitted wirelessly to the outside microcontroller, which forms the data to control the wheelchair utilizing an analog joystick.

Rafael Barea, Luciano Boquete, Manuel Mazo[2] designed an eye-controlled wheelchair based on electrooculography (EOG) to assist disabled people. In this study, an electrooculography eye model that can detect eye movements using electrooculography and obtain the direction of gaze is designed. For accurate navigation, the environment should not be dim and the size of the person's eye should be appropriate. Itching and irritation may occur with prolonged use.

In control systems, the signal can be received by many methods. Among them, one of the effective ones is audio signals. M. B. Kumaran and a. P. Renold [3] developed a robotic wheelchair that is controlled and driven using voice recognition. But the proposed system is not very useful, as it is not effective in loud environments.

They designed a robotic wheelchair controlled by N.Shinde and K.George[4] with brain waves and winks. Brain signals differ from person to person and need to be adjusted for proper movement.

Aleksandar Pajkanovic, Branko Dokic [5] designed a wheelchair that can be controlled by head movements by use of an accelerometer, a microcontroller and mechanical actuator. By using the accelerometer sensor, head movement information is determined in the designed system. The obtained data is transferred to the microprocessor, and the device can be directed by various algorithms.

Preeti Srivastava, Dr. S. Chatterjee, Ritula Thakur designed a wheelchair that controlled the face movements recognition acknowledgement with the assistance of an accelerometer. The proposed Navigation System [6] utilizes an accelerometer and a pre-Met threshold voltage to control developments that give the ideal route yield continuously.

Unlike other proposed methods, in this mechanism, head movements can be determined by extracting attributes from 68 different points of the face, and with this method, the control of the wheelchair with a minimum level of head movement can be achieved. Head movements detected by a web camera can ensure that the control of the wheelchair is both low-cost and without the need for complicated wearable equipment. With this method, people who have lost their mobility will be able to control the wheelchair without the need for physical strength, and at the same time, it is possible that the head movement detected with only a web camera will positively affect the psychology of the patients.

2. REQUIREMENTS SPECIFICATION

When the robot is completed, it is expected that the patient will be successfully guided to the desired coordinate, the patient will be able to control the robot with head movement, the patient will be able to communicate successfully with the robot with voice commands, and the necessary actions will be taken from the robot.

- **Physical Requirements**

  The total weight of the system is 20 kg.

  The maximum payload is 100 kg.

  The system will be manufactured in a volume of approximately 204 cm^3.

- **Performance and Functionality Requirements**

  80% chance of understanding the patient's speech correctly when communicated via voice commands.

  90% of the desired position can be achieved successfully.

  The robot successfully chooses the head movements.

- **Economic Requirements**

  The total parts and manufacturing cost cannot exceed 1000₺ per unit except the robot.

- **Health and Safety Requirements**

OSHA refers to ANSI/RIA R15.06-2012 from the Robotic Industrial Association. Robots perform unsafe, hazardous, highly repetitive, or unpleasant tasks. According to studies conducted by OSHA, many robot accidents occur during non-routine operating conditions. These operating conditions include programming, maintenance, testing, setup, and adjustments. If a worker is introduced into the robot's work envelope, unintended operations could result in an injury. The standards set in place by the RIA help minimize the dangers that can occur during these operations.

- **Manufacturability and Maintainability Requirements**

The system will be designed for the people working on the robot will provide easy readability.

3. STANDARDS

- **1873-2015 IEEE** (Standard for Robot Map Data Representation for Navigation): In the two-dimensional (2D) map created in our design, 1873-2015 IEEE standard was taken into account.

- **1872-2015 IEEE** (Standard Ontologies for Robotics and Automation): 1872-2015 IEEE standard was taken as an example in the interaction phase of the study between humans and robots.

- **ISO 18646-2:2019** (Robotics — Performance criteria and related test methods for service robots): In the study, ISO 18646-2: 2019 standard was taken into consideration for criteria such as navigation performance, exposure accuracy and detecting obstacles.

- **ISO/DIS 22166-1** (Robotics — Modularity for service robots — Part 1: General requirements): Since the robot developed in the study can be evaluated as a service robot, ISO / DIS 22166-1 standard was taken into consideration in this study.

4. PATENTS

- Low-cost, high-reliability controller for remotely operated robots, U.S. patent application Ser. No. 14/185,548
- Monitoring, diagnostic and tracking tool for autonomous mobile robots, U.S. patent application Ser. No. 13/624,373
- Autonomous mobile robot for handling job assignments in a physical environment inhabited by stationary and non-stationary obstacles, Patent No: EP2807526B1
- Autonomous mobile robot system, Patent No: JP4920645B2

5. THEORETICAL BACKGROUND

5.1 Gmapping Algorithm

Gmapping algorithm using LiDAR, IMU and odometry data create a 2D grid map. The robot acquires the knowledge of the environment with the LiDAR sensor, the attitude information with the IMU, and the location information with the odometry. In this way it adjusts the map for the next moment. RBPF uses this information to predict the position and attitude of the particle at the next moment.

The screen matching algorithm compares the robot position and attitude obtained with the position and attitude predicted by the RBPF. In this way, it achieves the optimal position and attitude for each particle. The particle filter takes samples around optimal positions and attitudes, generating the mean, variance, and gaussian distribution. The weight of each particle is adjusted, and it is calculated whether to sample again according to the threshold value [7]. The flowchart of the described algorithm is shown in Figure 1**.**

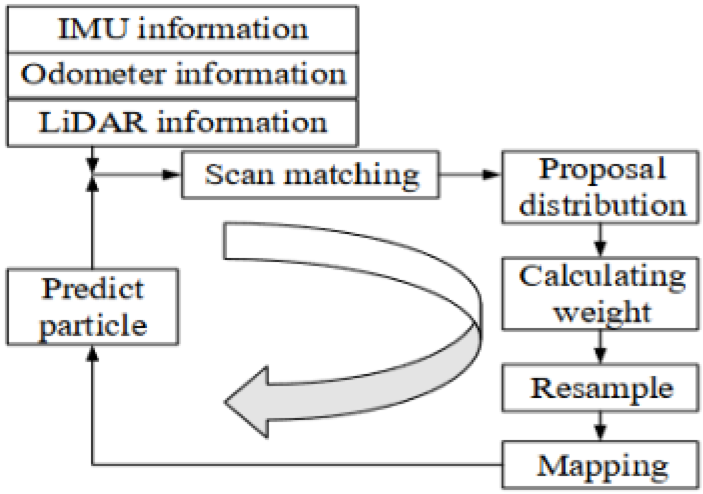

Figure 1. *Flowchart of the Gmapping Algorithm*

The Gmapping algorithm is based on scan-matched method and grid-map for pose estimation and map generation. As a SLAM approach Gmapping algorithm was used in this study [8,9]. SLAM algorithms are based on Bayes Filter in Equation (1) generally.

$$P(k) = \sum_{i=t}^{N} w_i \delta_s(x) \tag{1}$$

Map is generated by using the Gmapping algorithm is presented as grid maps. It is based on Rao-Blackwellized particle filter (RBPF) to learn grid maps from laser range data. In Equation (2), RBPF the joint posterior between map data pt and the state $x_{1:t}$ = $x_1 \ldots$, x_t of the robot is been estimated by using measurement data from laser scan $z_{1:t}$ = z_1, …, z_t [10].

$$P(x_{1:t}, P|z_{1:t}, u_{1:t-1}) \tag{2}$$

EKF or other Kalman Filter based algorithms are efficient for linearized distributions. RBPF is more efficient than the Kalman Filters for non-gaussian distribution [11]. Basic principle of RBPF is to set state of hypotheses. Each particle keeps a state with the measurements obtained by the laser scanner. Each landmark is associated with the corresponding particle. The strongest hypotheses are kept with given weights and the weak one is omitted after resampling [9,12,13]. Each particle represents as potential poses of the robot and each state represent posterior.

$$P(z_{1:t}, u_{0:t-1}) = P(z_{1:t}, u_{0:t-1}) * P(x_{1:t}, z_{1:t}) \tag{3}$$

Probability proportional in Equation (3) selects the most probable particle where each particle filter carries a map by comparing the particles with the observations and its own map.

The steps of the algorithm are as follows:

5.1.1. Sampling

New particles are first drawn utilizing the odometer, giving the main gauge of the robot position. It is then contrasted with the map acquired so far by including the 8 most recent perceptions to the new particles. If the scan matcher says it is fruitful, another proposition is inspected around the position returned by it [14].

5.1.2. Importance Weighting

A proportion of the ${w_t}^{(i)}$ of how well a particle I drawn from the improved offer distribution speaks to the objective distribution is allocated. The formula is given in Equation (4) [20].

$$w_t^{(i)} = \frac{(z_{1:t}, u_{1:t-1})}{\pi(z_{1:t}, u_{1:t-1}} \tag{4}$$

5.1.3. Adaptive Resampling

Contingent upon the result of N_{eff}, which depicts how well the objective distribution is represented by the particles set got from the inspecting step, a resampling step may be performed. The formula is given in Equation (5) [14].

$$N_{eff} = \frac{1}{\sum_{i=1}^{N}(w^{(i)})^{z}} \tag{5}$$

5.1.4. Map Estimation

Lastly, the map conveyed by every particle is refreshed by considering the historical backdrop of robot poses and the perceptions acquired up until now [14].

5.2 Voice Detection

Speech recognition is a system used to recognize human voice commands and convert it into data that can be processed by a computer. Sound is audible and has certain signal characteristics, whereas speech is a word-structured sound. Speech recognition and speech are one of the efforts needed to be able to recognize and identify sounds. Speech recognition can be divided into acoustic-speech future methods, artificial intelligence future methods, and pattern recognition methods. A pattern recognition approach for speech recognition can be illustrated on the block diagram and is shown in Figure 2 [15].

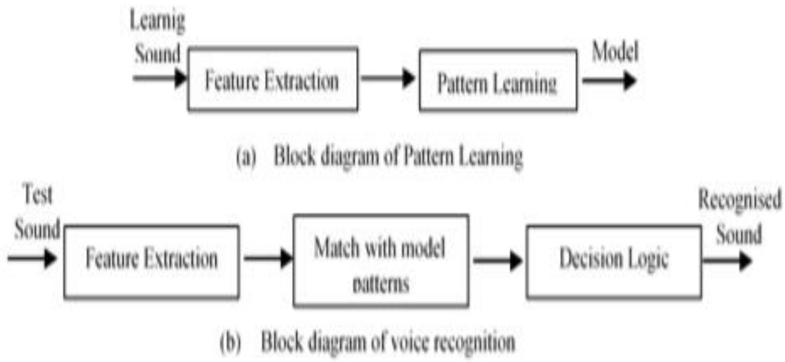

Figure 2. *Speech recognition block diagram*

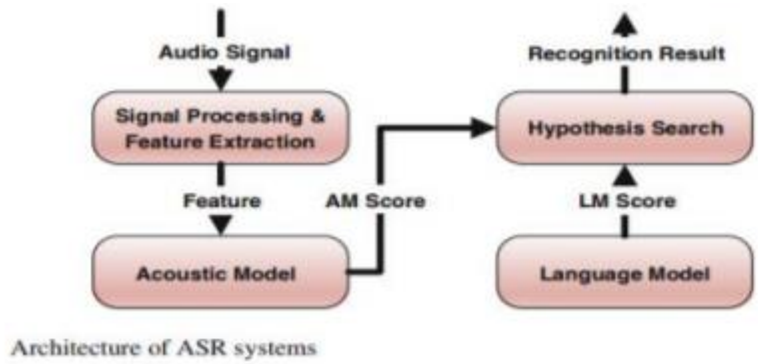

Figure 3. *Architecture of an ASR System*

Figure 3 shows the architecture of an automatic speech recognition (ASR) system. It is used in many applications and consists of four components: [16,17], signal processing and feature extraction, acoustic model (AM), language model (LM) and virtual search. The feature processing and extraction component takes an audio signal as an input, removes noise and channel distortion, improves audio, converts the signal into the frequency domain in the time domain, extracts visible vector features, [18].

Machine learning is part of the Google Cloud Platform that listens, sees, understands the world around you and builds applications. For pre-trained machine learning models, the Google

Translate API and Cloud Vision API are integrated into the Google Cloud Speech API. These complete APIs allow developers to develop display, speech, and translation applications [19]. The Google Cloud Speech API allows developers to easily apply neural network models using the API to convert speech to text. The API recognizes more than 110 languages and variants and supports a global user base. You can also use the application's microphone to create the user's text via dictation and enable voice commands and controls to recognize the uploaded audio on request, create an audio file, and create an audio store. Can be integrated with. Google's cloud storage [20].

5.3 Map of Environment and Ensuring Autonomous Movement of Robot

It is necessary to control the robot with the help of some head movements, to define a series of actions and to perform functions according to the defined actions. The designed robot has two operating modes, fully autonomous and semi-autonomous.

The user, who chooses one of the predefined points with the robot's head movements, tries to reach the targeted point thanks to the route planners in the ROS. Environment mapping was also carried out in fully autonomous mode. In order for the wheelchair to work in fully autonomous mode, it must first recognize the environment, so the robot must first map the environment and position itself on this map. Then the user selects a target point via the interface. By using the synchronous positioning and mapping (SLAM) algorithm with the help of a 360 degree laser sensor (Leonard and Durrant-Whyte (1991)), the robot was enabled to obtain environmental map information. The extracted environment map is given in Figure 4.

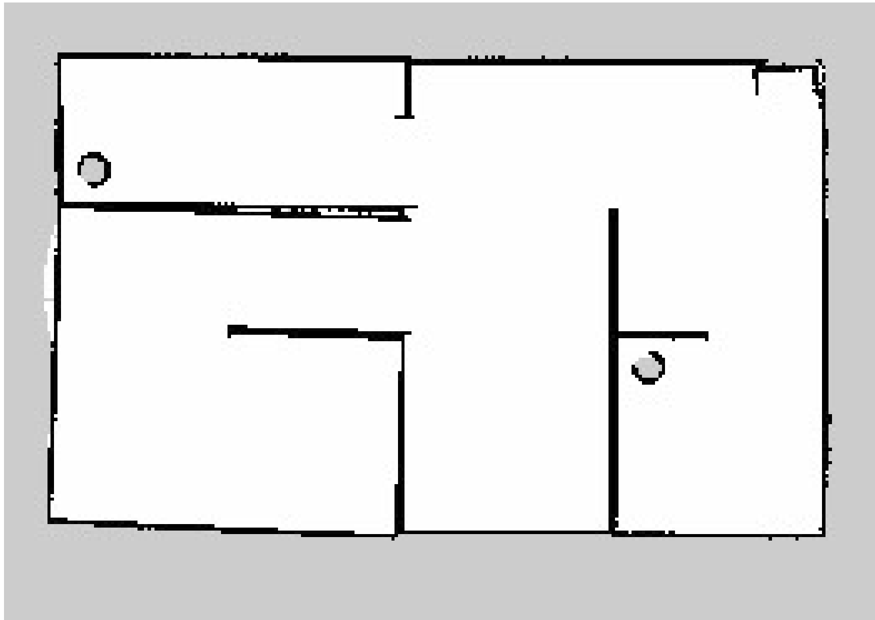

Figure 4. *Environment Map Extracted with Simultaneous Geolocation and Mapping Algorithm*

6. METHODOLOGY

It is aimed to develop a method that will enable people with very limited mobility to use wheelchairs that require physical strength and control their wheelchairs in order to make their lives more sustainable and provide low-cost and minimal head movement without the need for any wearable equipment. The increase in the rate of use in wheelchairs has brought about studies that can be beneficial to people in this area and the developments in wheelchairs. The methodology is explained step by step below.

6.1 Robot Control with Feature Extraction and Head Movement

Face detection is an artificial intelligence (AI)-based computer technology used to find and identify human faces in digital images. Face detection technology; It is a technology that is frequently used in the fields of health, military and security. Face recognition has advanced from basic computer vision techniques to advances in machine learning to increasingly complex artificial neural networks and related technologies. Our face has various features that can be defined, the DLib library is used to detect these features.

The dlib library was developed with the C++ programming language and has been under development since 2002. It is an open source library that contains machine learning, deep learning and computer vision algorithms. Main algorithms and methods included in the Dlib library: Machine learning algorithms such as SVM, RLS, K-Means, CNN, DNN, ANN, SMO, image processing algorithms and methods such as SURF, HOG, FHOG, Color Space Transformations, Thread functions, numerical It includes calculation functions as well as network and gui functions.

Within the scope of this project, first of all, the dlib library's get_frontal_face_detector function is used to detect faces on images. This function gives a pre-trained object detector. The Directed Gradient Histogram (HOG) image descriptor and a Linear Support Vector Machine (SVM) are highly accurate object classifiers. With the detector provided by this function, the faces on the photo are detected.

Then, 68 points on the face must be determined. The study by Kazemi and Sullivan (2014) presents an algorithm for computationally accurate estimation of the location of 68 landmarks. This is a new algorithm that provides accuracy superior to or comparable to the latest technological methods on standard datasets. With the algorithm created in this study by Kazemi and Sullivan (2014), Sagonas et al. (2018) provides fast face detection and 68 landmarks are determined on a face. 68 points to be detected on the face are as shown in Figure 5.

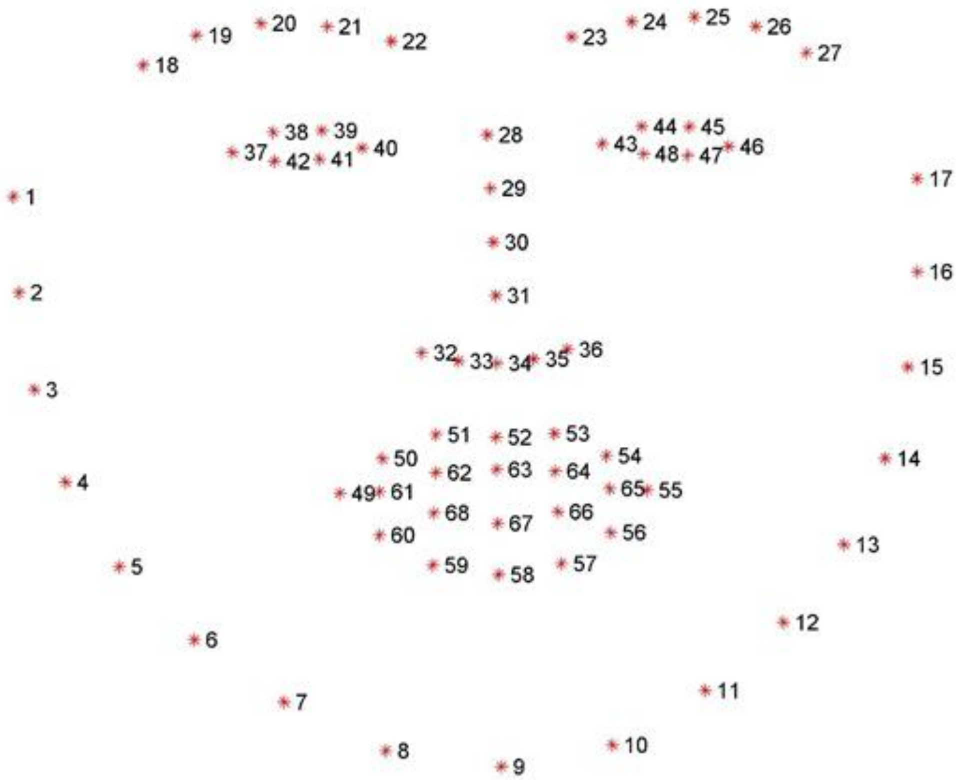

Figure 5. *Visualizing The 68 Facial Landmark Coordinates From The iBUG 300-W Dataset [31]*

For the correct perception of head movements, the 46th point of the right eye, the 37th point of the left eye and the 28th point of the nose between the eyes are used. The expressions used to decide the head movement by looking at the size and angle of the blue and red lines.

The eye points found for head movements are considered fixed and the direction of head movement is determined by considering the changes in these points. Expressions for finding the direction of motion, including left eye - LP (x_1,y_1), right eye - RP (x_2, y_2), nose point - NP (x_N, y_N), and distance constant c, are given in the Table 1.

$$right: ||RP - NP|| < ||LP - NP|| + k \tag{6}$$

$$left: \left|\left|LP - NP\right|\right| < \left|\left|RP - NP\right|\right| + k \tag{7}$$

$$up: \frac{(y_2 - y_N) + (y_1 - y_N)}{2} > c \tag{8}$$

$$down: \frac{(y_2 - y_N) + (y_1 - y_N)}{2} < c \tag{9}$$

Table 1 gives an explanation of the information sent to the robot based on head movements.

Table 1. *Head Movements*

ID	Movement	Description
0	No Movement	The angular and linear velocity is sent to the robot as zero.
1	Turn Right	The angular velocity is sent to the robot as (0.2).
2	Go Forward	The linear speed is sent to the robot as (0.1).
3	Turn Right	The angular velocity is sent to the robot as (-0.2).
4	Go Backward	The linear speed is sent to the robot as (-0.1).

6.2 Preparation of Simulation Environment

The studies in the simulation environment for the tests were carried out on the computer containing Ubuntu 18.04 and ROS Melodic. Studies have been carried out in the GAZEBO environment. Tests will be carried out so that the robot will be started in different locations in the home environment. The environment created for the tests is as in Figure 6. There is a need for an environment where the wheelchair to be used in the Gazebo simulation environment can be tested. Therefore, modeling of a ready-made home environment will be used. Figure 6 shows the home environment where the wheelchair will be tested.

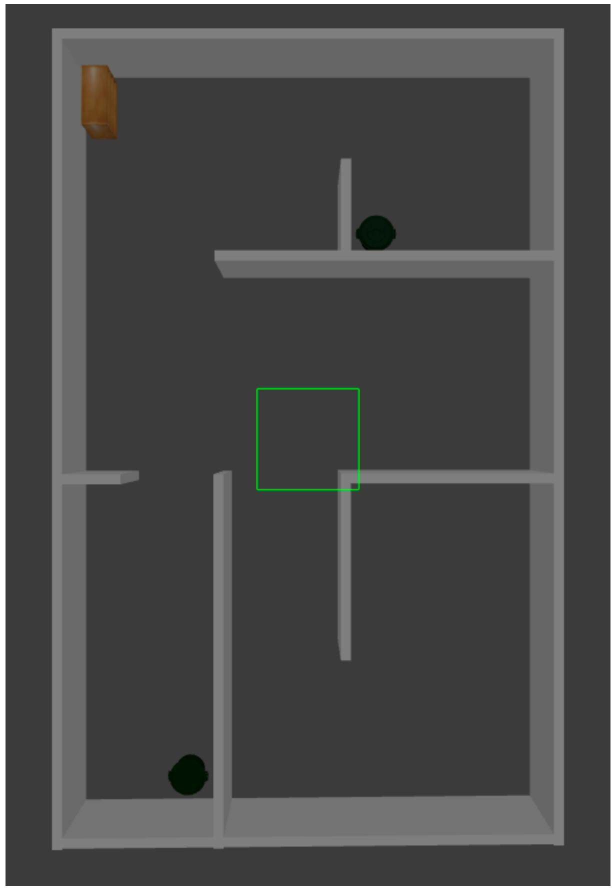

Figure 6. *Home Environment Model*

6.3 SLAM Algorithm

SLAM are algorithms developed as a solution to the problem of robots moving autonomously in unknown environments. SLAM allows the robot to determine its own location within the map by mapping an uncharted area. This process can be used in many 14 different environments. For example, environments with variable terrains, environments with limited landmarks and weather environments can be a solution for navigation. SLAM algorithms use geometric marks as bookmarks and the sensors (scanners) on the robot are observed and matched with the locations in their maps. In this case, the robot can detect its location in the environment where the landmarks are used.

SLAM algorithms are based on certain approaches. Examples of these are filter-based approach and optimization approach. Filter-based approaches follow steps that repeat predictions and updates. It contains information about the environment and the status of the robot with the probability density function. These approaches include the particle filter and the Kalman filter family. The optimization approach uses package adjustment to predict movement, based on recording some keyframes [21].

In general, SLAM algorithms manage many sensor data such as distance sensors, laser sensors and RF sensors as related map components called landmarks [22]. These algorithms are probability-based because of their ability to filter noise and deal with obstacles in the environment [23]. There are laser-based SLAM algorithms that can be used in ROS. These algorithms include RBPF based Gmapping, EKF based Hector SLAM, and Karto SLAM using graph-based mapping. Gmapping and Hector SLAM give better results than other algorithms [22,24]. Gmapping algorithm was preferred for use in this study.

6.4. Software

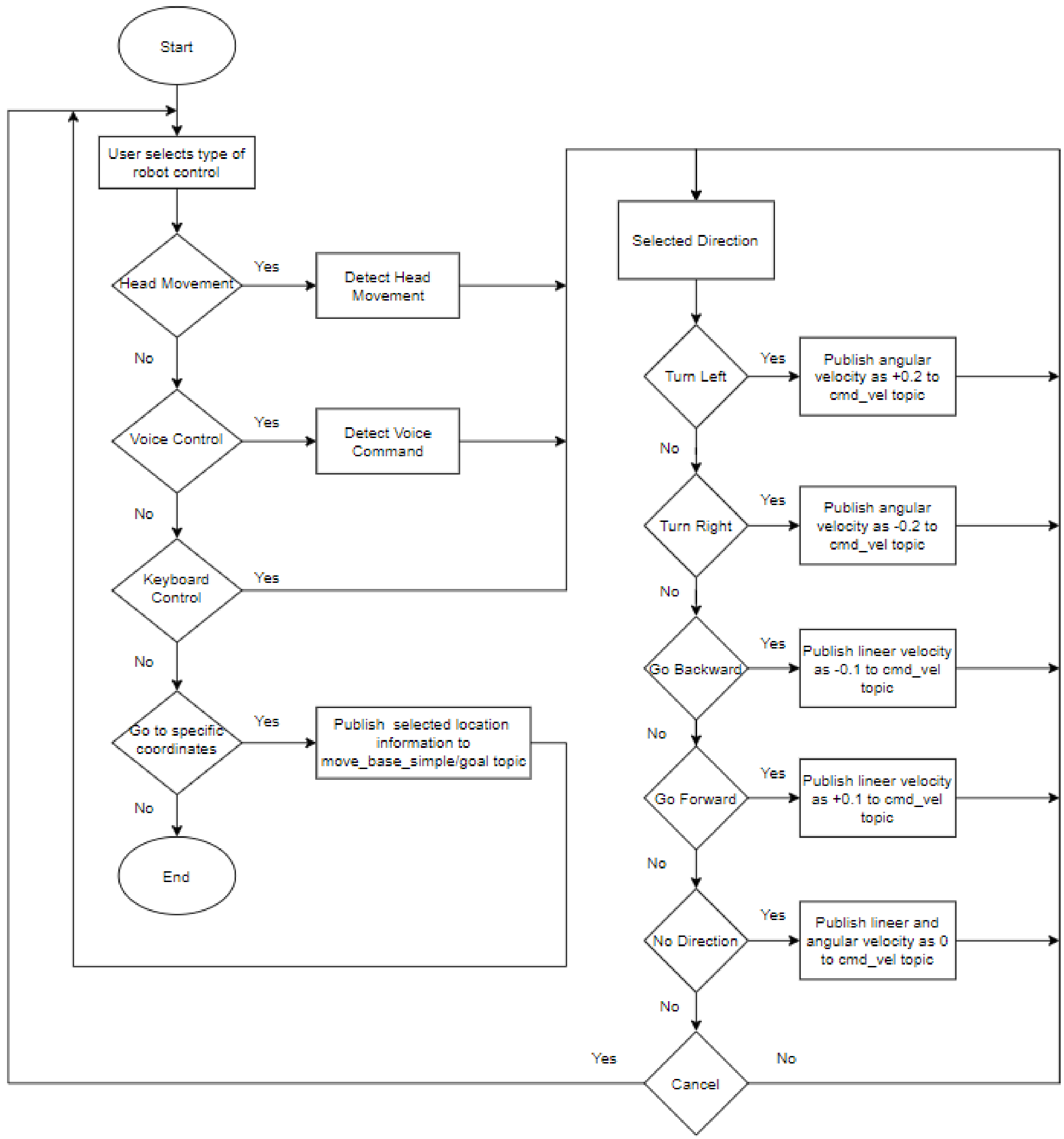

Figure 7. *Flowchart of Robot Control*

Within the scope of the project, ROS will be used to control hardware components. ROS is an operating system that allows robots to be controlled. So it actually runs software that controls hardware components. By using this platform, the equipment that will enable the robot to move, camera, microphone and distance sensor are controlled. An interface is used so that the user can control the robot. The program that enables the robot to act appropriately according to the data coming from the interface is a program that runs on the operating system. The flow chart of the program is shown in Figure 7.

6.5 System Hardware

The wheelchair robot model shown Figure 8 comprises three parts.

Part 1: This section, which is a wheelchair model, has a total of 4 wheels, 2 small and 2 large. This section is the basic platform of the robot. If desired, only this section can be used.

Part 2: It is the part where the head movements and facial expressions of the human model sitting in a wheelchair are detected from the camera.Part 3: This part, where the lidar sensor is located, is the top part of the model.

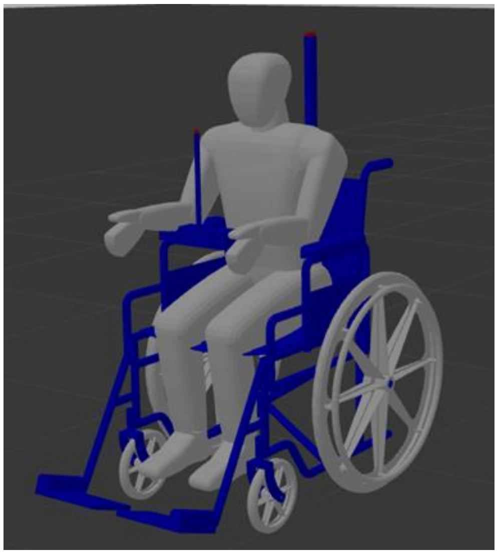

Figure 8. *Wheelchair Robot Model*

6.6 Voice Detection

A voice recognition system was integrated with a mapping algorithm using ROS firmware. Gazebo and Rviz were used to visualize the system controlling the Robot's actionsfirst, voice recognition was performed. The speech recognition package was used for this process. The Speech Recognition Package is a package that works with Python3. This package converts audio from the user's microphone into text using the Google API. It does this by dividing the sound of a speech recording into individual sounds, analyzing each sound, using algorithms to find the word that best suits that language, and copying those sounds into text.

Its code, written in Python, was integrated into the ROS package and used to control the robot. For this, three nodes were created. The first node publishes the recognized text in the std_msgs/string format. The second node interprets the output message (forward, backward ,right ,left,kitchen) and publishes it as a topic at the CMD level, the message format is Twist (). If the last node is a cmd_vel, the robot moves in the desired direction.into text.

6.7 Tools

- **ROS**

  ROS is a free and open source middleware for robot applications. Although ROS is not an operating system, it offers services designed for a heterogeneous set of computers such as hardware abstraction, low-level device control, message transmission between processes, and package management. It is the interface that allows the robot to process the data it receives through sensors from the outside world and send it back to the robot as a command [25].

- **GAZEBO**

  Gazebo is a robot simulator. It enables the user to create the environments that the robot wants to be found and to simulate the robot in these environments. In Gazebo, the user can design model of the robot and include sensors in the robot in a 3D environment. In order to make the robot's tests in the environment, obstacles can be placed in the environment. Figure 6 example for Gazebo simulation environment can be shown [25].

- **RViz**

  RViz is a simulation environment that allows sensor data to be observed visually. Data in 3D environments can be used, for example, for mapping the environment with a laser 19 sensors and for automated navigation. It can be used for data such as point cloud or depth view with data from sensors [25].

- **Qt5 Designer**

Qt Designer program was preferred in the design of the interface. Since the interface designed in Qt Designer can be changed dynamically with code, head, voice and keyboard control of the robot can be provided by integrating ROS using Python. Qt Designer is a Qt tool that provides you design and build graphical user interfaces (GUIs) using Qwidgets. windows or dialogs can be created and customized in what-you-see-is-what-you-get (WYSIWYG) style and can be tested using different styles and resolutions [26].

- **SolidWorks**

Solidworks was preferred for the design of the wheelchair model in the project. Solidworks, which is used to develop mechatronic systems, is powered by 3DEXPERIENCE and is a software that offers computer-aided 3D solid modeling and design (3D CAD) where designers can create their own prototypes [27]. The model designed in solidworks can be viewed from Figure 9.

Figure 9. *Wheelchair Model*

7. EXPERIMENTS

7.1 Robot Controller Interface

Qt Designer program was used for interface design. In the program used, help was obtained from 'drag-and-drop' and coding techniques. The interface was created using tools such as buttons, textbox and labels, as seen in Figure 10.

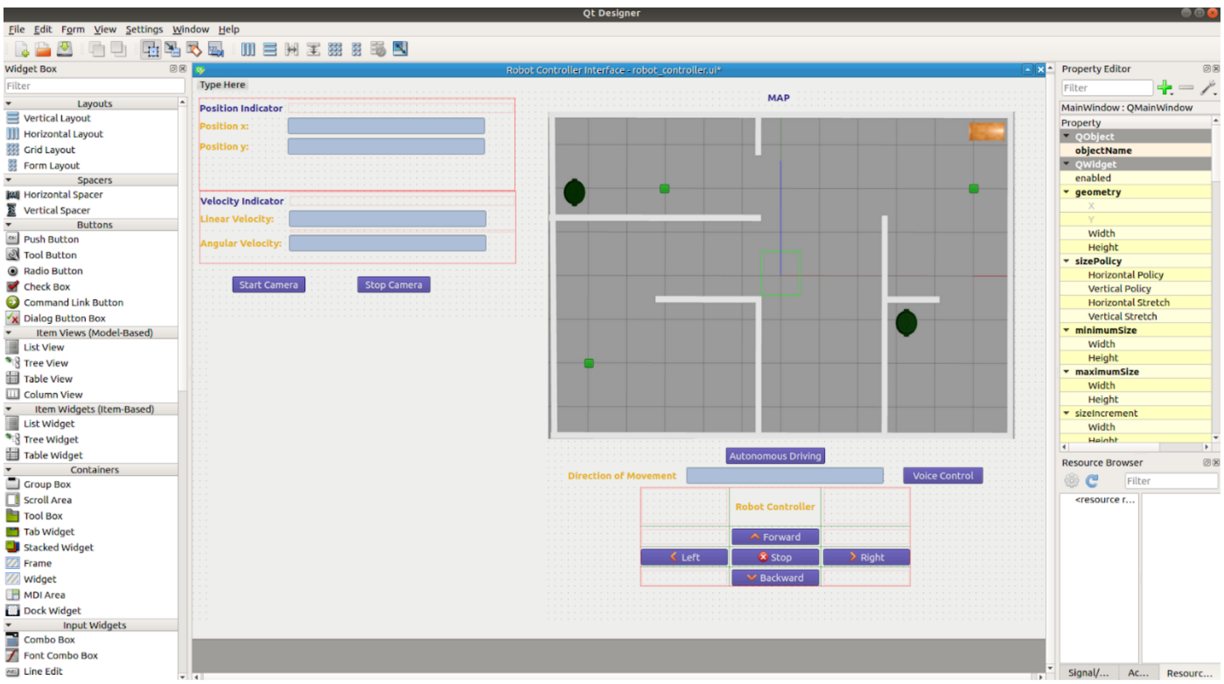

Figure 10. *Interface Design*

The width of the interface is set to 1300 and its height to 850. Line edits have been added to instantly see the robot's position and speed information. A start button has been added to display the face detection from the web camera with facial landmarks and at the same time, a stop button has been added to turn off the camera, as seen in Figure 11.

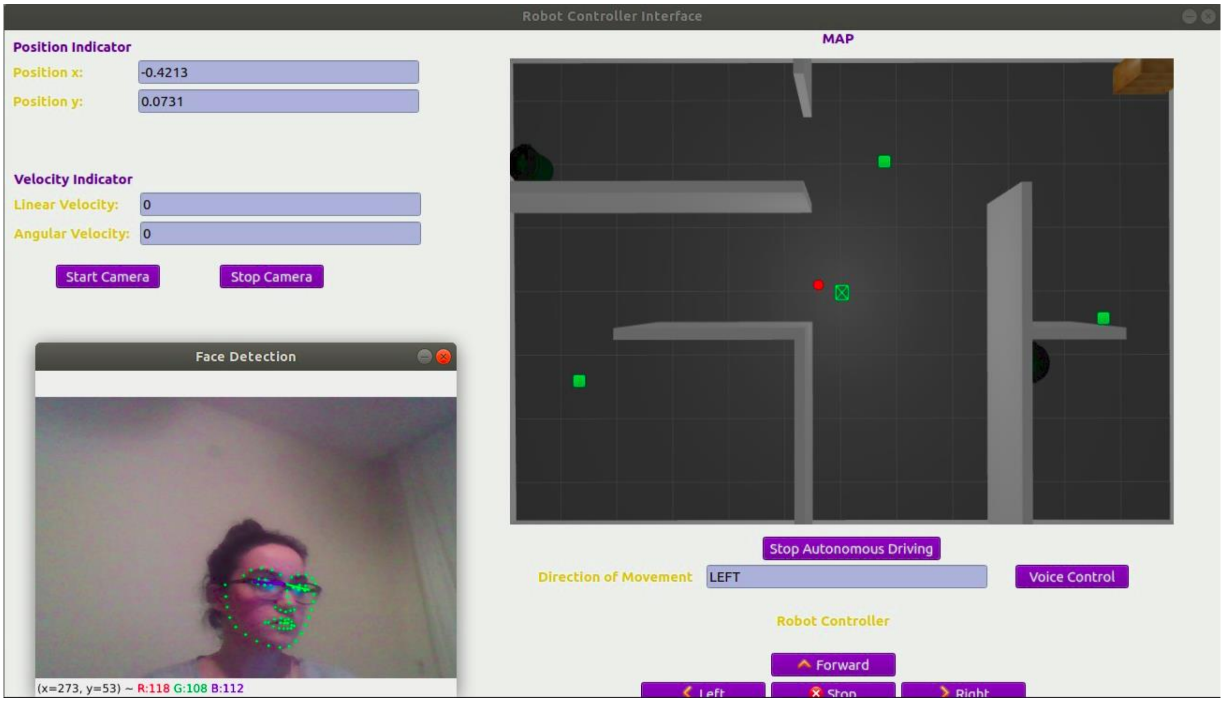

Figure 11. *Camera on the Interface*

It was visualized by adding a map label in order to see in which environment the robot was traveling and the current location of the robot. In addition, autonomous targets can be given to the robot on this map and the robot can be made to go to these targets, as seen in the Figure 12.

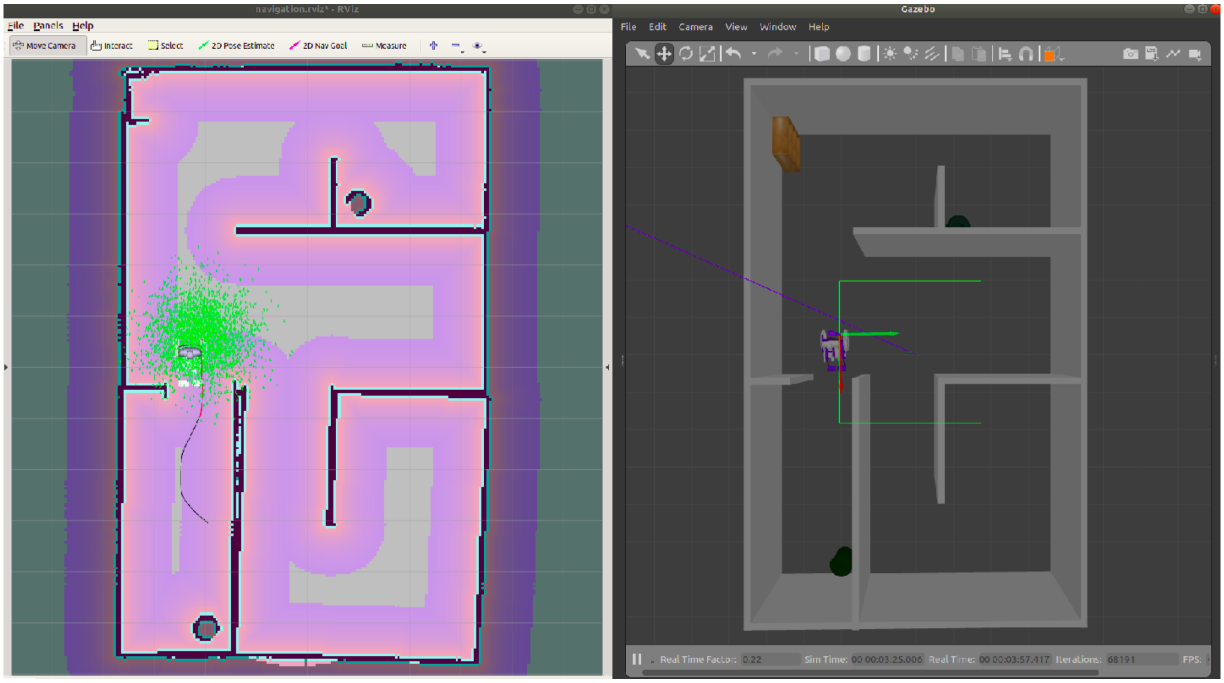

Figure 12. *Autonomous Movement*

The robot needs to follow the created path for autonomous driving to the given target and reach this target. The successful completion of autonomous driving by the robot can be examined in Figure 13.

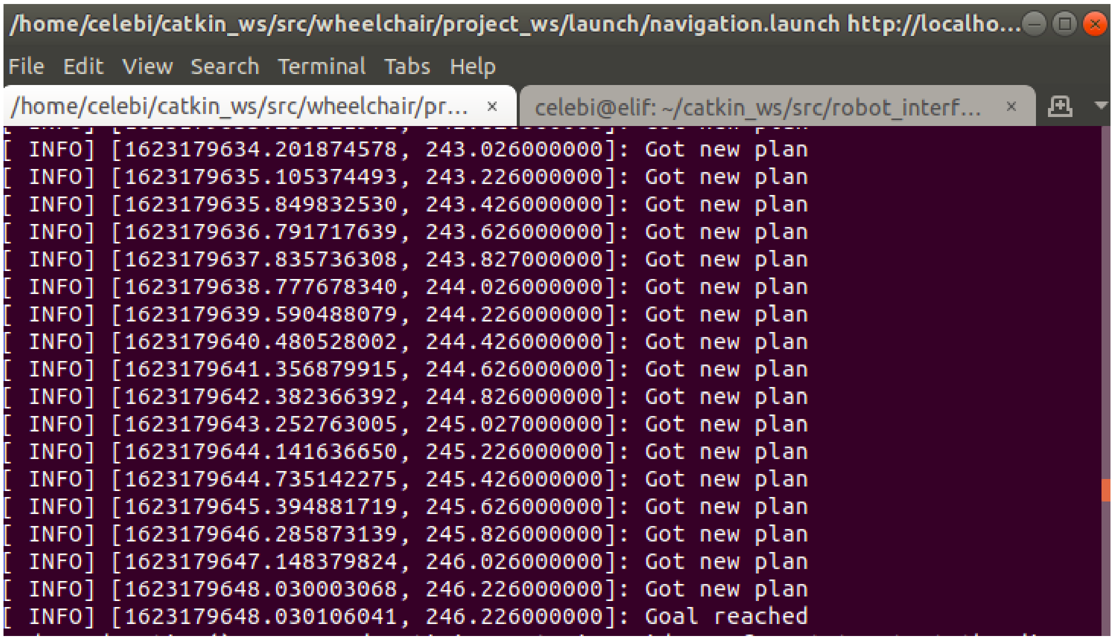

Figure 13. *Autonomous Motion Terminal Output*

In addition, when the robot is controlled by voice, it can drive autonomously and reach these targets. For this, the voice control button must be activated. In addition, the robot was controlled by using shortcuts from the keyboard and controlled with the mouse. The purpose of this is to offer different options to the user.

When the robot is moved with the head, voice or keyboard, the direction of the detected movement can be seen on the interface, as seen in Figure 14.

Figure 14. *Voice Control in Interface*

7.2 Autonomously Navigation

In order to conclude the project, the robot must be tested in the Gazebo simulation environment. For this reason, an environment design was made for the robot in Gazebo. This design is observed in Figure 15.

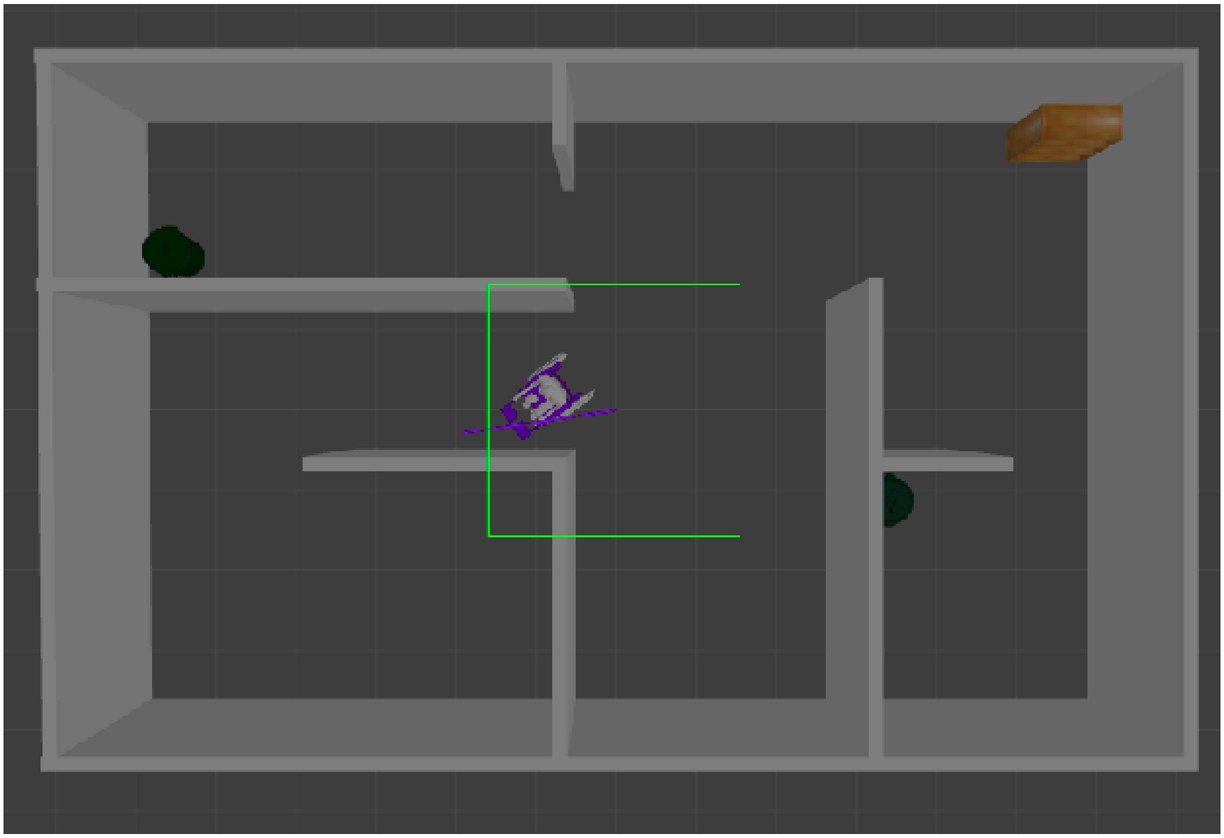

Figure 15. *Test environment for the project*

The robot needs to know the map of the environment for its autonomous movement. For this, the gmapping algorithm in ROS was used to create the environment map. The mapping process of the environment can be seen in the Figure 16.

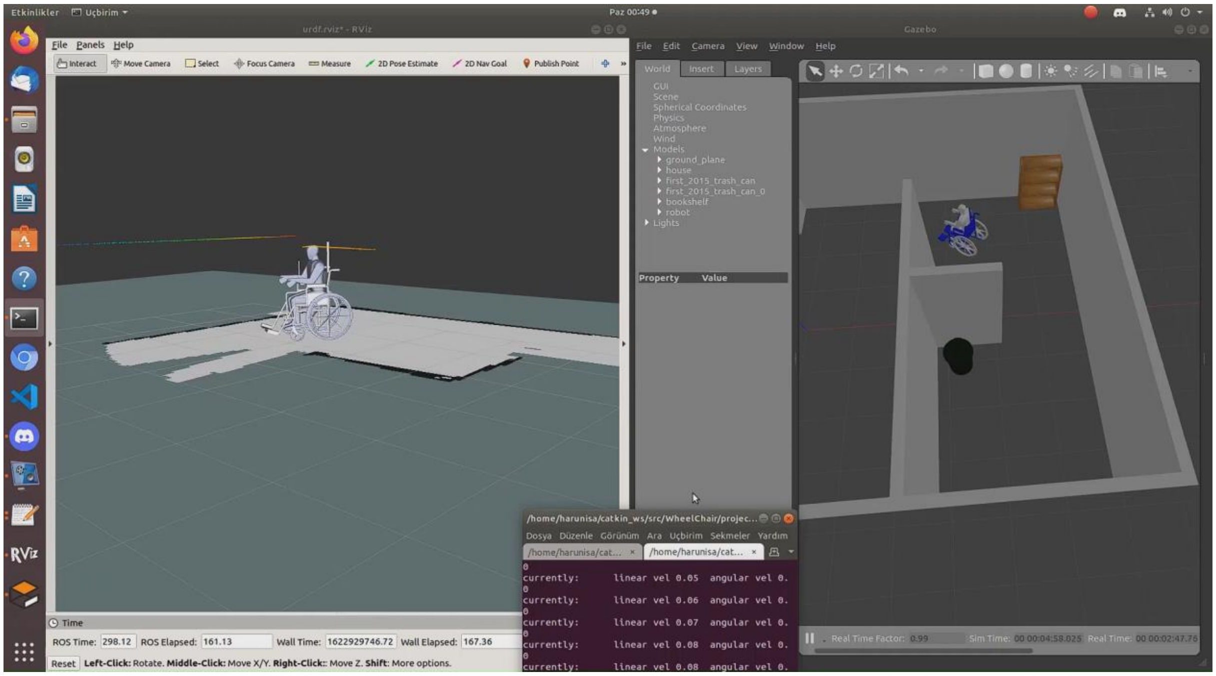

__Figure 16.__ Examples of the Map revealing with Gmapping

It was aimed for the wheelchair to reach the desired position autonomously in the prepared environment. The sample environment designed for this purpose was mapped using the Gmapping algorithm.

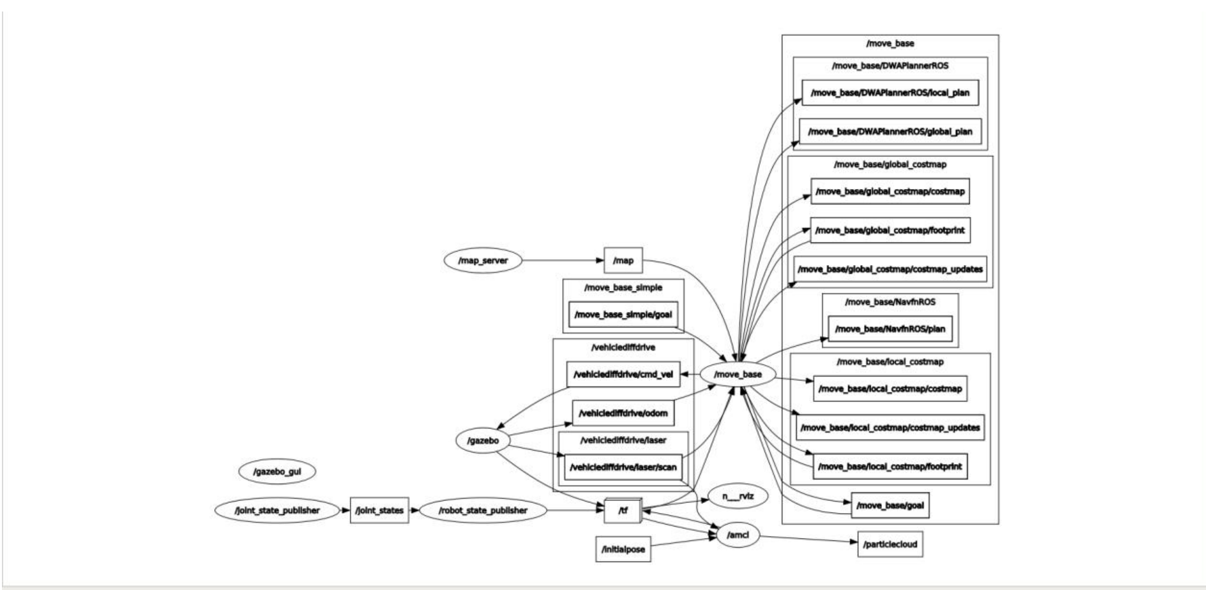

__Figure 17.__ ROS node and topics rqt_graph for autonomous navigation

The diagram given Figure 17 shows the connection diagram of the ROS nodes and topics. This scheme contains nodes and topics that provide the robot's autonomous movement. Firstly, it is the topic called move_base_simple / goal, which takes the desired position of the robot to go. This topic gets the coordinate and orientation information that should be visited for the robot. It transmits this information to the node named move_base. This node takes map odometer and laserscan data from topics such as map, odom, lidar to make the appropriate plan. The created path is shared with the topic / move_base / DWAPlannerROS / global_plan. Also, with the local_planner, the speed is adjusted according to the location of the robot. This information is shared with the topic named vehiclediffdrive/cmd_vel, and it changes the speed of the robot in the gazebo environment. AMCL node tries to match the laser scans with the map, thereby detecting any deviations in the exposure estimation based on the odometer. This deviation is then compensated by posting a transformation between the map frame and the vehiclediffdrive/odom frame, so the transformation map-> base_frame corresponds to the robot's actual exposure in the world.

In this study, it enables the robot to go right, left, forward and backward with head movements perceived from facial landmarks, but by assigning autonomous targets to certain points in this face extraction, the robot can be made to go to these targets.

8. PROJECT PLAN

- **Work Package 1 – Creating Gazebo Model of Robot:** Basic engineering and scientific principles, related technologies and existing solutions are searched.
- **Work Package 2 – Preparation of Simulation Environment for Tests:** The house model determined in the GAZEBO environment was designed.
- **Work Package 3 – Map of Environment and Ensuring Autonomous Movement of Robot:** The robot was enabled to move autonomously in the created gazebo environment.
- **Work Package 4 – Robot Control with Head Movement:** Head movements of the robot were controlled with feature extraction algorithm.

- **Work Package 4 – Robot Control with Voice:** Voice of the robot was controlled with Speech Recognition algorithm.
- **Work Package 4 – Robot Control with Keyboard:** Control of the robot was provided from keyboard with using shortcuts.
- **Work Package 5 – Integration of Simulation Environment Tests:** The desired data was obtained with the used algorithms. It was integrated into the robot to provide head movements.
- **Work Package 6 – Preparation of Robot Hardware and Integration of Sensors:** Based on the test results, the robot was created and the sensors were integrated.
- **Work Package 7 – Environment Mapping and Positioning Using UWB Positioning System:** The robot was guided on the map and reached the target.
- **Work Package 8 – Graphical User Interface:** An interface has been designed to observe the robot's movement, speed and position. In addition, autonomous or semi-autonomous movements of the robot can be decided using this interface.

Table 2. *Resource Assignments For Work Packages*

Work Package	Resource	Duration(Weeks)
1	Metin Pekdemir, Elif Çelebi	2
2	Metin Pekdemir, Elif Genç, Harun Akgül, Elif Çelebi	2
3	Elif Genç, Harun Akgül	3
4	Metin Pekdemir, Elif Çelebi	3
5	Metin Pekdemir, Elif Genç, Harun Akgül, Elif Çelebi	2
6	Elif Genç, Harun Akgül	3
7	Elif Genç, Harun Akgül	3
8	Metin Pekdemir, Elif Genç, Harun Akgül, Elif Çelebi	2
PROJECT COMPLETION TIME		**20**

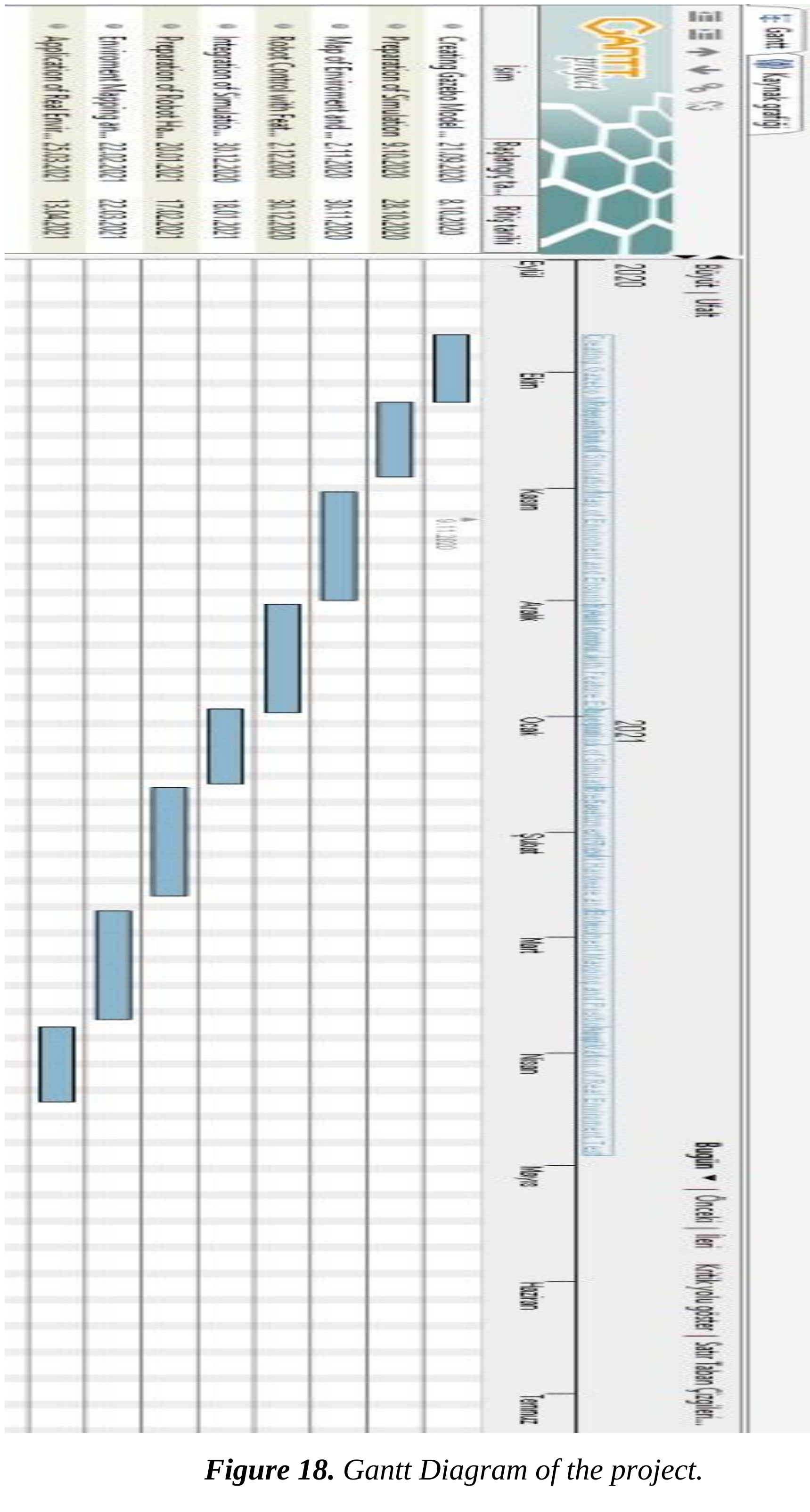

Figure 18. *Gantt Diagram of the project.*

9. CONCLUSION

In this study, a smart wheelchair was developed for individuals with limited mobility and unable to use joysticks to move comfortably and be independent. Facial features were extracted with the help of a web camera, and thanks to these, head movements were easily detected. The robot, which has two different operating modes, goes to the target location specified by the user through ROS planners in fully autonomous mode, creates the environment map and positions itself on the map. In semi-autonomous mode, the user is able to direct the robot with head movements. As a result of this study, it has been shown that the robot can be easily controlled by head movements. It is aimed to increase the sensitivity of the head movements created in future studies and to control the robot in an easier way.

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