Path Planning Automated Guided Robot

Mohd Azlan Shah Abd Rahim and Illani Mohd Nawi

Abstract— **This project concerns the design and fabrication of the Automated Guided Robot (AGR) prototype, utilizing genetic algorithm (GA) as a mainframe in helping the robot to generate a self-understanding of the area of work and mobilization to a destination desired by the user. The main objective of this project is to create and develop a Path Planning Mobile Robot able to avoid obstacles in its path and reach a target designated position from its starting point utilizing 4 wheel-based rover body, sensors, linear motors and microcontrollers. The paper describes the design process of the AGR development, from the initiation of idea to development of algorithms, to virtual prototype development of AGR mechanisms and controller board, to fabrication, to mobility, obstacle avoidance and path planning test. Two methods of path planning are presented, using compass bearing in undetermined space and predetermined path. Obstacle avoidance and path planning algorithms has been tested using the completed design of AGR body.**

Index Terms— **feedback, genetic algorithms, magnetic compass, obstacle avoidance, path planning, robotics control system**.

I. Introduction

Robotics is known as a new revolution to the entity of beings that varies according to its uses. In modern day environments, robotics and automation are involved in almost every industrial activity and conveniently improve the efficiency, productivity and reliability of a system. Robotics is also implemented in medical practice, construction, outer-space exploration, household assistance, mobile transportation and quite recently, underwater exploration [1]-[6].

Currently there has been study of automated guided robots which is used in transportation and exploration that can be configured for different terrain. These designs are on locomotion, Hopfield Neural Network, Genetic Algorithm and etc [7]-[9]. For example, JPL (Jet Propulsion Laboratory, NASA) in U.S.A have developed many rovers. Sojourner which were landed in Mars in 1997 adopted rocker-bogie locomotion, Blue Rover uses three-segment locomotion, the mini Mars rover Go-For has a active wheel-legged locomotion, Nano Rover utilize posable-truct chassis, and Elastic Loop Mobility System was also designed as new type of locomotion for planetary exploration [10].

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Mohd Azlan Shah Abdul Rahim works with PETRONAS Control Engineering Group, Malacca, Malaysia. Illani Mohd Nawi is working with Electrical and Electronics Engineering Department, University of Technology PETRONAS, Tronoh, Perak, Malaysia.. (E-mail:azlanshah_rahim@petronas.com.my,alan2204@gmail.com, illaninawi@petronas.com.my, illani_mn@yahoo.com).

Robot Path Planning or robot Motion Planning is one of the important areas of interest in robot's offline decision making algorithms. In this problem, the aim is to find a collision free path, which the robot can follow to reach the target from its start position. Analysis and research on autonomous path planning has included innovative advancements in the use of artificial intelligence (AI). With advancement in the study of this subject, technology with uncontrollable situations such as outer space exploration and deep sea excavation can be further improved. New technology such as autonomous vehicle systems may also be able to utilize such algorithms which are fail-safe.

The main objective of this project is to create and develop a Path Planning Mobile Robot able to avoid obstacles in its path and reach a target designated position from its starting point utilizing 4-wheel based rover body, sensors, linear motors and microcontrollers. A study on obstacle avoidance using ultrasonic sonar sensing, path planning [11], and global positioning using genetic algorithm, GA, has been performed, prior to project initiation. The following stages in Fig. 1 were identified and followed to produce this AGR.

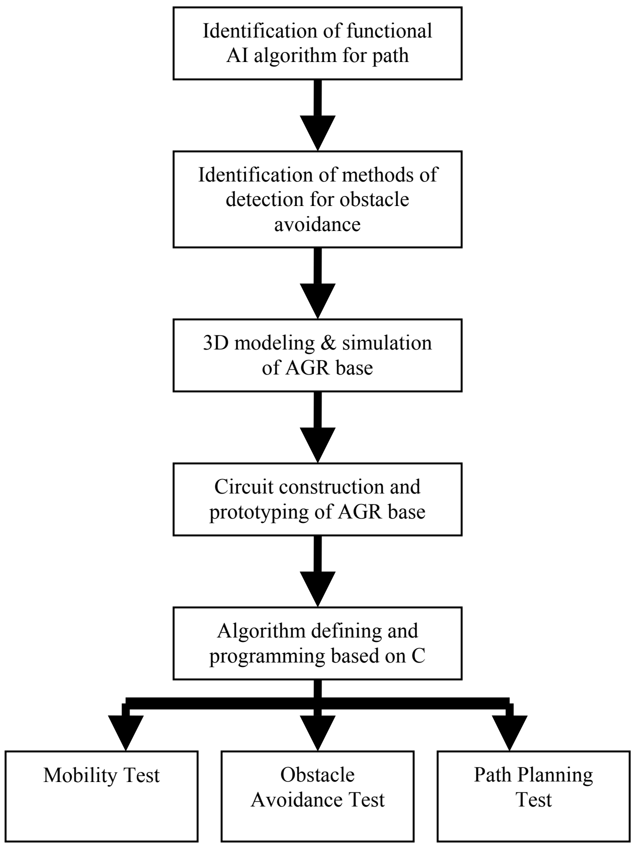

Fig. 1: Procedure identification and workflow diagram

II. METHODS OF DETECTION AND SENSOR SYSTEMS AS FEEDBACK ANALYSIS

With sensors, robots are said to be able to obtain vision, sense of touch, balance, and even hearing. According to their tasks and application, robots are given the appropriate sensors that function as the feedback systems in a controller. Autonomous Guided Robot (AGR) systems are classified as rover based robotics that require vision-type and touch sensors. The AGR should be able to maneuver and counteract with the environment using sensors to detect the obstacles around, remember its current position and calculate a new path to take [12].

The sensors identified for the construction of the AGR in this project are ultrasonic proximity detectors, and electronic magnetic compass. The function of the proximity detectors is to detect any objects surrounding the robot within a range specified. The proximity detectors are placed on the front, left and right face of the robot to ensure wider sonar-like detection. An electronic magnetic compass detects the strongest magnetic flux generation and generates that as the North Pole. Using this compass, the AGR can generate sense of direction and will not lose its path once avoiding an obstacle. 3 ultrasonic sensors have been installed for obstacle detecting and 1 magnetic compass for bearing change detection.

III. DIFFERENTIAL DRIVE AND STEERING

Automobiles are manufactured with 4 wheels, with two at each sides of the mobile. This gives the automobile much more balance and stability than having only a single wheel at the front. The two wheels on the front help create grip when the car is driven forward by the back wheels connected to the engine. Maneuverability is done by steering the two wheels on the front, where the car is able to turn in a curve which cancels the requirement for it to stop to take a 90^0 turn. This not only increases the speed of movement, but also reduces power consumption. This exact design is used on the robot rover intended in this project.

This possible design was sketched, as in Fig. 2 and a brief idea on steering was developed in the progress. Instead of using a stepper motor which is ultimately heavier, two servo motors are used to steer individually the two front tires. But this individual steering is actually done in synchronization such as in cars, where both tires turn the same amount and degree. The standard servo motors would be able to turn 180^0, which can be set to even 90^0 to the left and right. The DC motor drivers are still maintained to drive the rover and control the speed of the rover. A relay controlled power MOSFET H-bridge motor driver controls each DC motor.

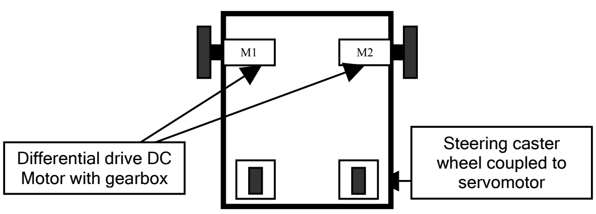

Fig. 2: Differential drive with servo steering

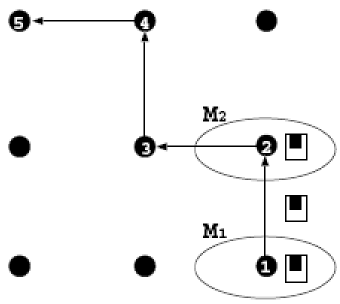

Fig. 3: Node-wise 2D positioning

IV. PATH PLANNING AND OBSTACLE AVOIDANCE

In the development of global positioning for a mobile robot, the frequent use of 2D arrays commonly arise as the most basic and effective method. Logically in mapping a certain area, the normal axis that would be noticed is the X-axis and the Y-axis which will give suitable amount of information for the robot to perform a node-wise recognition and carry out global positioning. The Fig. 3 shows a node-wise 2D movement of a simulated robot from node 1 to 5 which uses sensor networks [13].

The effectiveness of such networks have been proven to be 80% efficient and are reliable in a fast-response and rugged situation. In this project, a slightly more complex 3D form of array has been applied for the grid-based global positioning. The axis would consist of the normal X and Y-axis, and an additional radius (ϴ) axis, as in Fig. 4. This ϴ-axis is possible with the use of the CMPS03 magnetic compass which would feedback the bearing value of the robot. This bearing value is converted to degrees which would be used in determining the radius of perception for the AGR. With the use of this axis, certain error in 2D arrays could be dealt with which would have resulted from the robot having a slight bearing change which would ultimately change the accumulated X or Y value. Correction can be done using the ϴ-axis value. This concept is used to in algorithm building for robot navigation.

To apply such arrays, a probabilistic approach and mathematical function must be developed to enhance the array. In a journal written by Maxim A. Batalin and Gaurav S. Sukhatme [13], the theoretical iteration of probabilities would be applied according to the number of actions and nodes that could and would be developed by the artificial intelligence. This would of course be a finite number, which could be bounded by the wanted map of the area in discussion. The probabilistic function is capable to predict the next movement from the list of possible actions and nodes.

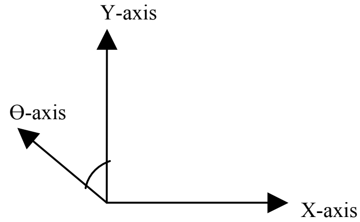

Fig. 4: 3D axis

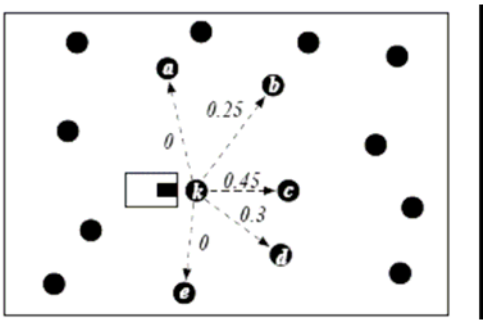

Fig. 5: An example of a discrete probability distribution of vertex (sensor node) k for direction (action)

Fig. 5 shows an example given by [13] of a typical discrete probability distribution for a vertex (sensor node) per action (direction). Mass distribution of probability is a sum of 1, and nodes with obstacles will be stated as zero.

The mathematical model that has been developed here as in (1) is based upon the understanding that the 3rd axis is used as an error correction for X and Y, thus the system is the sum of changes of the bearing towards the probability matrix of XY:

$$U(t+1) = \sum \left[P(t) * U(t)\right] \pm \arg \theta(t) \quad (1)$$

Where,
U(t) = array iteration for actions possible
P(t) = Probability matrix of XY
Θ(t) = Bearing change of compass (range)

V. Body Structure and Mechanism

Utilizing simulation programs such as MATLAB SIMULINK and SolidWorks, the basic criterion and the capacity of the AGR could be analyzed and predicted before the actual model was made. Once tests were carried out in the simulation which included stress test, weight to torque ratio, etc, the components such as the DC motor and materials were purchased. These simulations actually help in reducing the cost and duration of the project as less or no modification needs to be done to the structure once a perfectly precise 3D model has been created.

A. *Generation of 3D design*

The software used for this purpose is Solidworks® 2006 3D modeling software. Before carrying out the design, a sketch was made with design constraints which include minimal dimension of 40mm^2 for the base; based on the simulations performed using SolidWorks, and components required and placement. The design also includes the dimensions for the material used which is rectangular hollow aluminum 2” x 1”, rectangular hollow 3” x 1”, L shaped aluminum 1” x 1” and tube hollow aluminum 2” diameter. The components selected for the AGR are the RS stepper motor for steering control of the 2 front castor wheels, 2 DC brushed planetary geared motors for driving, the magnetic compass for direction feedback, and 3 ultrasonic proximity sensors for obstacle detection. Fig. 6 shows the dimension constraint for the robot base:

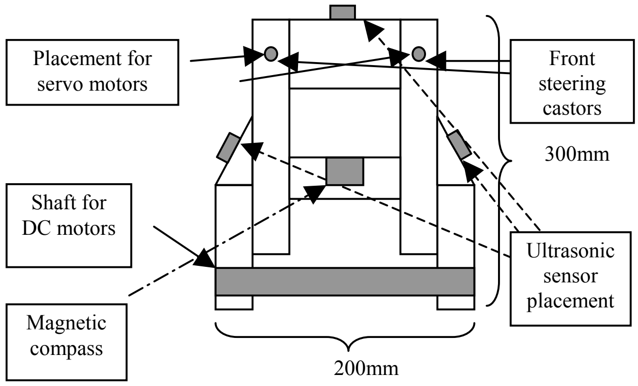

Fig. 6: Top view of AGR base 2D sketch

The 3D model created is the base of the AGR. Fig. 7 below shows the 3D model created in Solidworks 2006.

B. *Simulation using Simulink MATLab*

This simulation is to calculate the appropriate loading and the balance of the robot with the use of rated brushed DC motors and the wheel radius. The ratings are calculated and entered into the blockset and a system is built using these blocksets to generate a differential driven robot for simulation purposes. The ‘Animation block’ generates the animation of the differentially driven vehicle robot.

The ratings and values of gain for PID controller derived from the transfer function of the Brushed Direct Current Motor (BDCM) are entered in the blockset and the simulation is done. The transfer function is as follows [14]:

$$\frac{\omega(s)}{V_a(s)} = \frac{K}{(Js+b)(Ls+R)+K^2} \quad (2)$$

Where,
Ls = Armature Inductance (H)
R = Armature winding Resistance (Ohm)
Kb = Km = K = Motor torque constant (N-m/A)
Js = Moment of inertia (kg-m^2)
b = viscous friction coefficient (N-msec/rad)

The simulation consists of variable values V1, V2, L1 and L2. V1 and V2 are the variable speed drive of each corresponding motor and L1 and L2 are the loading capacity of the corresponding wheels. The simulation is also able to produce results for the angular arc movement described before for obstacle avoidance which can be used directly.

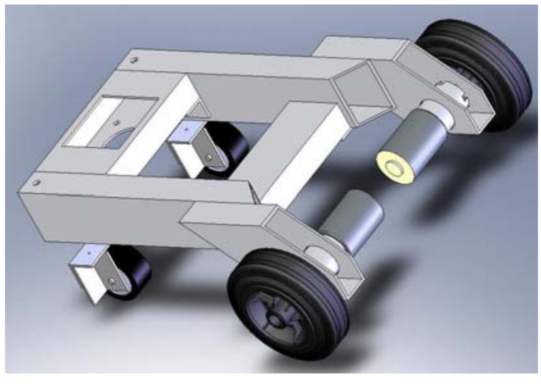

Fig. 7: Full Solidworks 3D model of AGR

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Fig. 8: Fabricated AGR isometric view

C. Actual fabrication of AGR prototype structure

Using aluminum hollow and L bars, the AGR prototype was constructed and fabricated according to the obtained design criteria and size. The fabricated prototype is shown in Fig. 8.

VI. Circuit Construction

The circuitry is designed and fabricated through a few phases which are:

A. Circuit design and simulation in PSPICE-AD

B. Acquiring components and wires from EE store

C. Circuit testing and troubleshooting on breadboard

D. Veroboard finalized working circuit design.

Appendix 1 and 2 show the designed schematics for the control system and motor driver respectively.

VII. Obstacle Avoidance and Path Planning Test

The AGR is able to sense two condition changes when moving which are the obstacles surrounding it and the North Pole bearing change. Using the 3 ultrasonic sensors; S1, S2 and S3, the AGR basically has an 180^0 view of its area in front and will be able to avoid any obstacles facing it. The algorithm developed for obstacle avoidance, is presented in Fig. 9.

There are two ways in planning its next movement to a proposed end waypoint, which is either by using the compass bearing of the waypoint or using a predetermined path scheduled by exactly informing the AGR of the obstacles it will face. As in Fig. 10, the distance from its end point to starting point could be determined as a bearing of the North. It is possible to move from the start point using the North bearing as a calibrating feedback to the controlled movement of the AGR. The AGR moves according to this bearing until it reaches the end point whilst avoiding any obstacles using the ultrasonic sensors as a secondary movement. When the AGR turns to avoid an obstacle, it will return to the North bearing after avoiding the obstacle. It is unnecessary to give a predetermined path to the controller and this reduces the amount of error in movement in the case there are more obstacles present.

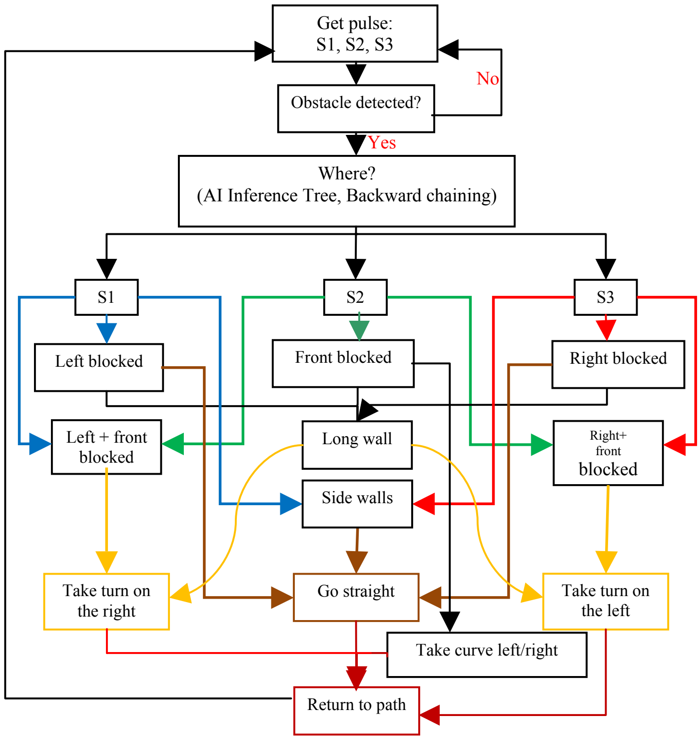

Fig. 9: Obstacle avoidance algorithm

The downside of this method is that the North bearing can be changed if there is a magnetic presence anywhere surrounding the AGR. The electronic compass will detect the strongest magnetic frequency present as the North Pole. This result in error reading, thus the AGR may not be able to reach its end point.

As an alternative, random approaches are possible using the obstacle avoidance algorithm. As the AGR moves forward, it is constantly detecting any obstacles in front of it. An algorithm is developed to actually allow the AGR to move according to the arrows shown in Figure 11 towards the end waypoint. The movement actually follows the limitation of space of the predetermined area, and it will follow the wall of which may lead to the end waypoint. When obstacles are detected, the AGR will avoid accordingly. Any amount of obstacles are possible, thus random obstacles can be placed in this situation. The AGR will continue moving until it reaches the end waypoint, which achieves the objective of this project. The downside is that the amount of time taken for each trial may vary, and may also be very long periods.

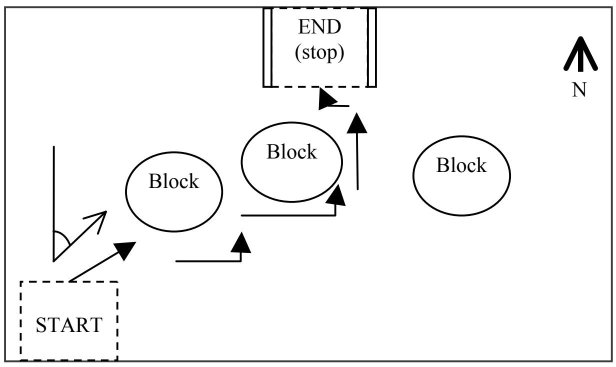

Fig. 10: Possible path taken by the AGR in an undetermined space

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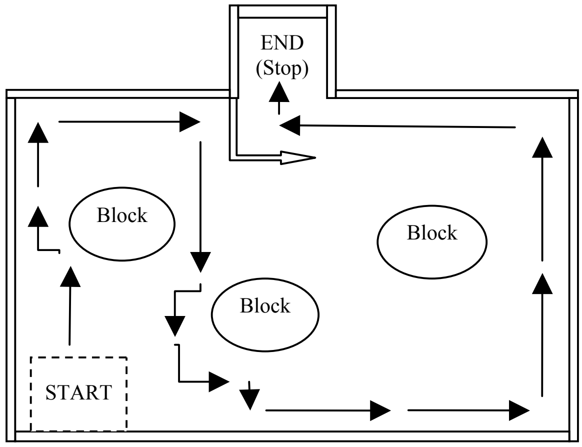

Fig. 11: Possible path taken by the AGR in a predetermined space

The conclusive approach after testing has been made is using the North bearing as the primary feedback for path planning. Consecutive test results show that less error is made using this method and movement from the START point to the END point takes a shorter period of time. Some of the future works to be performed are improvising the obstacle avoidance algorithms and global positioning sytem, and lay out several methods to avoid any other stronger magnetic frequency presence, which will initiate error to the system.

VIII. Conclusions

The author has achieved the objectives of the project with the completion of a fully working prototype by the end of the project period. The author has developed 3D and MATLab simulations to predict the movement of the robot in certain conditions. Through these simulations and 3D models, the AGR was constructed and configured to carry out tasks according to the objectives of this project.

The prototype is structurally ready and troubleshooting process was carried out to fulfill the desired condition. The AI of the AGR dependant on the coding of the controller has been tested and verified to be able to carry out the tasks of obstacle avoidance and path planning. The AGR is able to move in a random behavior from one point and end at a final designated point using limited sensors without colliding with randomized objects within the path. The AGR's controller algorithm can be modified and updated to further improve the speed, accuracy and also precision of the robot mechanism. This AGR is to be further used for testing the various path planning and obstacle avoidance algorithms in RoboCon team projects.

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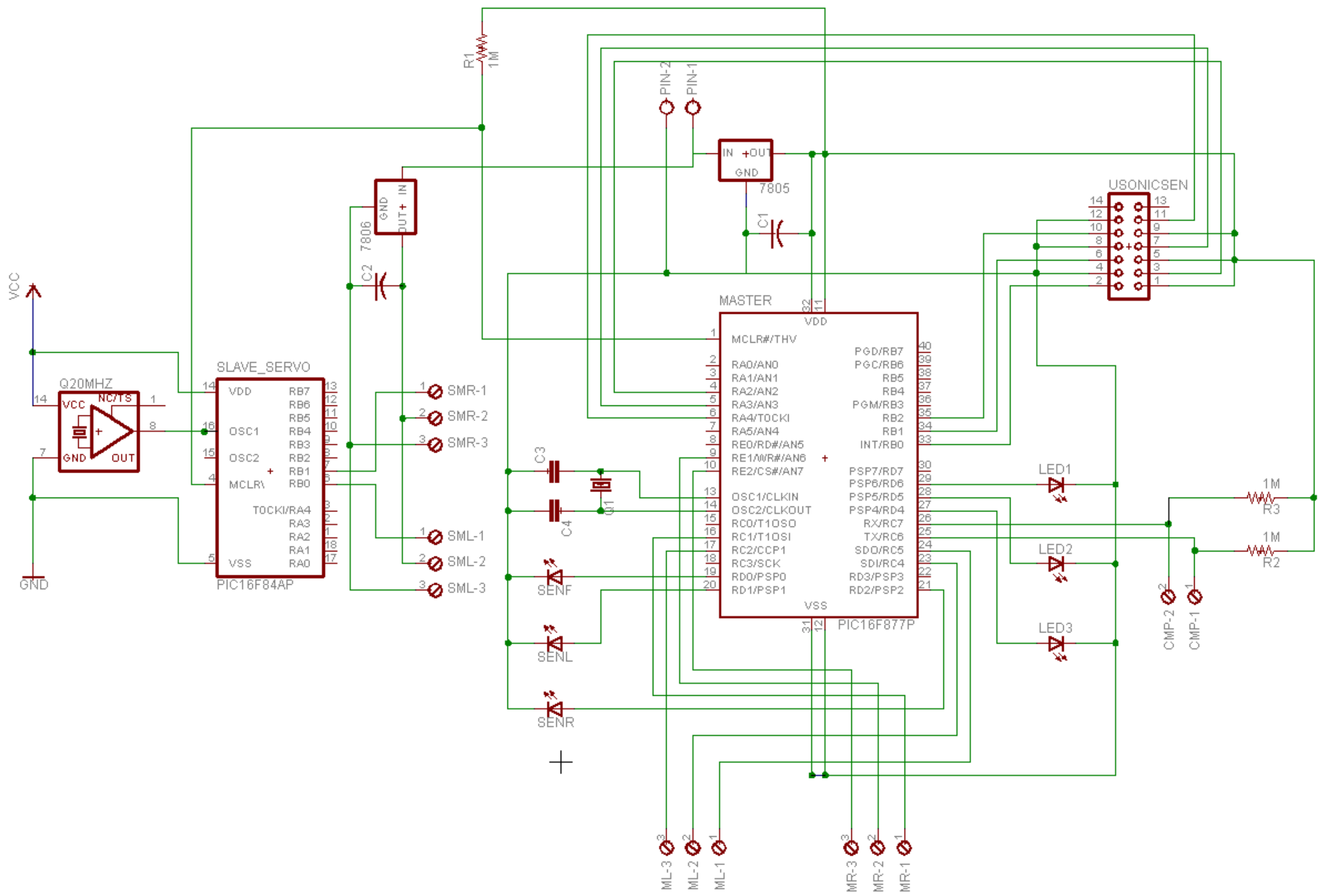
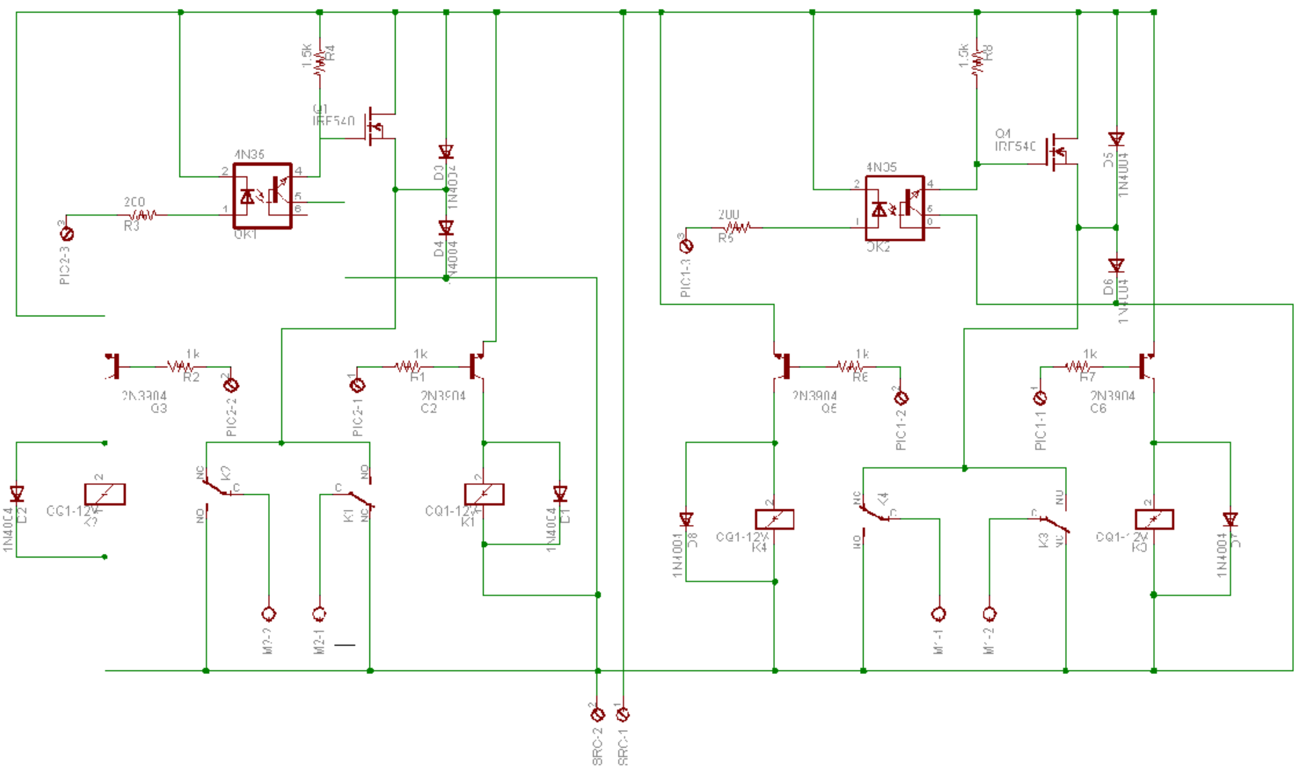
APPENDIX



Appendix 1: EAGLE Schematic for AGR target board



Appendix 2: EAGLE Schematic for MOSFET motor driver