AUTOMATED GUIDED VEHICLE APPLICATION FOR DISPENSER

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AUTOMATED GUIDED VEHICLE APPLICATION FOR DISPENSER

ARAVINTHAN A/L RAJAANDRA

A report submitted in partial fulfillment of the requirements
for the award of the degree of
Bachelor of Mechanical Engineering

Faculty of Mechanical Engineering
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to Humanity's quest for knowledge

to Lord Siva

to Nisha

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ABSTRACT

Automation has become a very important part of our lives. More and more human functions are being automated every day. This brings enormous benefits in terms of efficiency and technological advancement. Indeed an important criterion of any advanced society is the level of automation within it. This too is the ultimate goal of this project. The purpose of this project was to automate one of the last labour centric environments, the office. And the specific function we are seeking to automate is that of pouring a cup of water into a cup in the middle of a meeting. To achieve this, a function specific Automated Guided Vehicle (AGV) was built. This robot functions as a dispenser; hence the name Automated Guided Dispenser (AGD). The physical platform was fabricated using Poly Methyl Methacrylate Acrylic. The electronic circuit was assembled. The control function is performed by a PIC Microcontroller. The program was also written. The mechanical components were either fabricated or bought. A guidance system was also developed. Once the individual tasks were completed the AGD was assembled and tested. The AGD design and development was successful and it works as planned.

ABSTRAK

Automasi merupakan sebahagian penting hidup kita. Dengan berlalunya setiap hari, semakin banyak fungsi manusia diautomasikan. Ini memberi kelebihan dari segi efisiensi dan pembangunan teknologi. Malah, antara kriteria penting bagi suatu masyarakt maju adalah tahap pengautomasian dalam masyarakat itu. Secara asasnya, ini merupakan matlamat ulung projek ini. Tujuan projek ini adalah mengautomasikan salah satu antara tempat yang paling kurang tahap automasinya iaitu pejabat. Dan fungsi spesifik yang kita cuba mengautomasi ialah satu perkara mudah, iaitu menuang air ke dalam gelas di suatu mesyurat atau konferens. Untuk melakukan ini, satu *Automated Guided Vehicle (AGV)* fungsi spesifik telah dibina. Kerana robot ini akan berfunsi sebagai *dispenser*, ia akan dikenali sebagai *Automated Guided Dispenser (AGD)*. Badan AGD diperbuat daripada Poly Methyl Methacrylate Acrylic. Litar electronic telah dibuat. Funsi kawalan dilakukan oleh *PIC Microcontroller*. Program untuk *PIC* telah ditulis. Komponen mekanikal telah dibuat atau dibeli. Sistem panduan juga dibina. Setelah setiap elemen individu ini siap dibina, AGD telah dipasang dan diuji. Reka bentuk dan pembuatan AGD telah berjaya dan ia berfungsi seperti dirancang.

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LIST OF SYMBOLS

F	Farad, unit of capacitor
g	Gravitational Acceleration
m	Mass
N	Newton
V	Volume
Ω	Ohm, Value of resistance
μ	Micro, 1×10^{-6}
ρ	Density

LIST OF ABBREVIATIONS

AGV	Automated Guided Vehicle
AGD	Automated Guided Dispenser
CAD	Computer Aided Design
CAM	Computer Aided Manufacturing
cm	Centimeter
mm	Milimeter
PIC	Programmable Integrated Circuit
PMMA	Polymethyl Methacrylate Acrylic

CHAPTER 1

INTRODUCTION

1.1 PROJECT MOTIVATION

What in essence is a robot, in the form of an Automated Guided Vehicle (AGV), is going to fill your cup in the middle of a meeting. This takes a lot of effort to implement successfully, especially if you consider how easily it could be done by humans, such as a secretary or yourself. But in a long term scenario, automating this function will improve efficiency. Automation is the word here. Even in absolute terms, automation increases efficiency (“automation.” Encyclopædia Britannica, 2008). For example, trying to fill a glass in the middle of a meeting causes interruptions and in turn distracts attention from the meeting. By automating this function, there will be one less interruption. Besides, the ultimate goal of an industrialized society is to reduce dependency on human labor and improve efficiency. This is our ultimate motivation to try and let a robot take over this task ("industrialization." Encyclopædia Britannica, 2008).

Unlike modern industrial settings, the office remains labor-centric. When it comes to the actual work done in offices, it will be difficult to remove the human element. Artificial Intelligence simply has not reached human level competency. We cannot yet have robots interacting with humans, and listening and reacting to our complaints, for example ("artificial intelligence.” Encyclopædia Britannica, 2008). In the meantime however, we can automate the peripheral functions currently being done by humans; Hence the topic of this project.

The fundamental idea behind this project would be automation. As a nation and society, we are trying to become industrialized. And automation is a major part of this. In essence, this project is just an extension of that process. In this particular case, we are looking at a scope that until now has not been concentrated upon much, the office.

1.2 PROJECT BACKGROUND

Let us consider our conference table to be oblong shaped with curved ends, a typical shape. In designing and implementing an Automated Guided Dispenser (AGD) to fill cups on such a conference table, there are many technical problems to be considered.

Firstly, we need to consider a Guidance System. There needs to be a system to guide the AGD around the table. We could rely on sensors around the table to tell it where to turn or go in a straight line. Or we could settle for a simple rail system, which is much less sophisticated hence much more easily implemented.

Next, there is the consideration of Travel Time. The problem here would be the period of time the AGD needs to reach a person on the conference table. If we go with a system where the robot just travels around the table at a set pace, and fills cups as needed along the way, it will be considerably easier to design and implement. But if traveling unidirectional, the machine will go around the table rather than back up to fill a cup placed on the filling platform it just passed. This works, but basically wastes time. An optimum system would be a stationary vehicle, which moves into position by detecting a cup being placed, and fills it up.

Thirdly, the AGD needs to stop at the correct position. This is an obvious problem that needs addressing. As a cup is placed on any particular platform around the table, the AGD must know where exactly the cup is. So as to be certain that the water will go into the cup rather than all over the table. There are multiple solutions for this problem.

Fourth is the problem of dispensing water and a suitable amount at that. How do we get the water from our reservoir into the cup? Furthermore we can only speculate on the size of the cup any one person might put in the way of the AGD. It would seem appropriate to keep the reservoir static and have a pump send the water out a nozzle mounted on the AGD into the cup. But how do we adapt the whole mechanism onto a moving vehicle? On the issue of amount of water, one solution would be to give all the users similar cups. But there might be water left in the cup. The safest way seems to be to just dispense a moderate amount of water. Or have a stop button on the AGD to stop the dispensing process when the user feels he has enough.

Next, controlling the noise generated. The AGD's operation cannot be too noisy. If we expect to use this system on a conference table, which will be used in conferences and meetings, the noise level should not be so loud as to interrupt the meeting.

The sixth problem identified is the volume of water available. The volume of water carried by the AGD has to be considered as well. Too little and it will need constant refilling, which beats the purpose of the automation. Too big a volume and the AGD will be heavy and cumbersome and use too much power.

Lastly we have to look at the type of drink to be dispensed. Water would seem like an easy option. But in a meeting, the participants might prefer coffee. This is a purely social consideration. However if demanded so, the AGD will have to carry coffee, if it is to be a successful commercial venture. However, coffee cannot be served cold, so there is a need to integrate a heating mechanism onto the AGD.

1.3 PROJECT PROBLEM STATEMENT

There are two problems we are looking to solve in the course of this project. The main consideration is actually moving. This has to be achieved as a basic minimum. The AGD will achieve motion by employing DC motors.

Secondly a guidance system has to be developed. This is a basic component of any AGV. There has to be a guidance system to make the AGD go around the table without falling off. Opting for a sensor based system with fuzzy-logic controls such as sensor lines on the table will make it more sophisticated and neat (Gaskins and Tanchoco, 1987). But this will entail even more high level integration such as line detection sensors with stepper motors and microcontrollers to manipulate the wheels to turn and so on. So for a first level project, a guidance rail system looks more viable. This will be in the form of a simple rail attached to the top of the table. The AGD will simply go along the path defined by this restriction.

Stopping at the correct position seems to be a fair demand of an AGD. This problem too will be addressed (Maxwell, and Muckstadt, 1982). This will be done by having a sensor on the AGD body itself. This will preclude any need to consider seating arrangements. Furthermore, this will remove the need to embed multiple sensors on the table and connect these to the AGD. The on board sensor could be a simple light sensitive sensor which will be blocked by placing a cup. As the AGD passes by, the sensor will be triggered, stopping it. Then it can start dispensing.

1.4 PROJECT OBJECTIVES

In the course of completing this project, there are a few objectives to be fulfilled. These are:

a) Designing an Automated Guided Vehicle that is able to go around a conference table and stop at certain positions.
b) Building the mechanical part of the guided vehicle.
c) Building the electrical and electronic parts of the guided vehicle
d) Writeing the software for the guided vehicle.
e) Assembling and testing the automated guided vehicle to fill a cup on a conference table.

1.5 PROJECT SCOPES

Without yet considering unforeseeable problems that might crop up later, these are the exclusions and the things known but not attempted to solve:

a) The developed Automated Guided Dispenser is only a prototype and is not ready to function as a commercial product.
b) The noise levels may not yet be meeting or conference-friendly.
c) The speed at which this Automated Guided Dispenser functions might be considered as slow.

1.6 PROJECT REPORT ORGANIZATION

The rest of the report is organized as follows:

a) Chapter 2: Literature Review and Background Knowledge
   - Review the available literature on earlier attempts at building a similar machine. A historical angle on such a vehicle, regarding stages of developments, demands, successes and latest developments will be provided.
   - This will form the background knowledge needed before attempting to build one.

b) Chapter 3: Design and Methodology
   - Development of the proposed working methods of each Project Problem solution is presented.
   - System design is shown along with explanations for the choices made.
   - All elements of the proposed design are built and assembled.

c) Chapter 4: Result
   - The completed Automated Guided Dispenser is tested.
   - The result of this is presented.

d) Chapter 5: Project Conclusion
   - Conclusions on the completed project are provided, with suggestions for future study and further developments.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This chapter will look to review the previous designs, established operational controls, advances made and problems encountered in the design,development and control of automated guided vehicle applications such as automated guided dispensers. In doing this, we hope to understand problems that might be encountered and realize more fully the extent to which this project can contribute to the development of automated guided vehicles.

2.2 Definition

Before proceeding any further, it is best to establish a fundamental understanding of what an automated guided dispenser is. This can be done by deconstructing the concept of automated guided dispenser into previously researched basic concepts. The advantage in doing this is that we can then base our design and control formulations around guiding principles and ideas of which the parameters are well understood.

2.2.1 AUTOMATED GUIDED VEHICLE

An automated guided vehicle (AGV) is an unmanned vehicle used as a means of transportation. This can be of materials, people, tools, etc. AGVs first came into usage circa. 1955. (Müller, 1983). The use of AGVs has grown immensely since. They are in usage in a multitude of applications and situations such as manufacturing, distribution and transportation. They can be used in indoor or outdoor environments. It is estimated that there are more than 20,000 AGVs in use throughout the industrial range (Gotting, 2000).

2.2.2 AUTOMATED DISPENSER

A dispenser is defined as "a machine or container designed so that you can get an item or quantity of something from it in an easy and convenient way" by the Collins COBUILD Dictionary 2006 (Collins 2006). While automated is considered as using machines to do the work instead of people (Collins 2006). So the combination can be understood as a machine that does the dispensing without the need of human intervention.

2.2.3 AUTOMATED GUIDED DISPENSER

An automated guided dispenser (AGD) is in theory a machine that is able to transport and dispense without human intervention.

2.3 TYPES OF NAVIGATION SYSTEMS

AGVs can be split into two categories by virtue of their guidance systems. These are "free- ranging" and "path restricted" types.

2.3.1 FREE-RANGING

The first type may use dead reckoning and laser or infrared light equipment, whereby light reflected from mirrors in position is triangulated to determine its location. Grid patterns on the floor created using transponders or magnets or chess board patterns are scanned optically to calibrate the position (Mantel and Landeweerd, 1995).

Figure 2.1 Mirrors and Lasers Type AGVs

[Source: Bastian Material Handling]

2.3.2 PATH RESTRICTED

The second type of AGVs is the restricted type. These AGVs are confined to a set network of paths called tracks. These paths can be in the form of induction wires, magnets, paint, or tape track that is optically followed (Mantel and Landeweerd, 1995).

Figure 2.2 Magnetic-guided AGV

[Source: Murata Machinery Ltd]

Another major path restricted type of guidance system is using rails which are then followed by the AGV (Malmborg, 2003).

Figure 2.3 Rail-guided AGV

[Source: ThomasNet Industrial Newsroom® (TIN)]

2.4 FUNCTION OF AGVS

In the manufacturing sector, AGVs are used to transport all types of materials related to the manufacturing process. This will bring savings in terms of time and cost. This is especially true for environments with repeating transportation patterns. AGVs can be programmed to perform repetitive tasks efficiently and without fault.

Other examples of environments with such possibilities are distribution, trans-shipment, and transportation systems. In these environments, materials or cargo are moved continuously point-to-point.

Warehouses and cross docking centers are examples of distribution areas. For the internal transport of, for example, pallets between the various departments, such as receiving, storage, sorting and shipment, AGVs can be used optimally.

In trans-shipment systems, such as container terminals, AGVs take care of the transport of products between the various modes of transport. In a highly standardized layout such as this where every movement has been planned and organized, automating the actual moving of the products is the logical next step.

A study presents an overview of available technology for automation in container terminals (Götting, 2000). The navigation and vehicle guidance systems applicable in various indoor/outdoor environments are described and explained. Many of these elements can be successfully implemented fairly easily.

In a performance review, Haefner and Bieschke (1998) state that AGV systems can provide benefits to both the port and its customers by executing transportation requests between vessels and non-automated inland transportation terminals. Usually, this transportation process is one of the least efficient and most costly processes used in the outdoor transportation process. This is so because of the many modes of transportations involved and the time spent moving cargo between the vehicles, which is enormous. Automating this can cut costs radically.

One of the most advance modes of transportation systems in modern cities is the underground automated transportation system with AGVs travelling in tunnels called tubes between locations, companies or buildings even. Newer airports also have these types of transportations connecting them to major cities (Van der Heijden et al.,2002a,b).

It has even been studied if AGVs can be used as a communication system between work stations (Maughan and Lewis, 2000). A number of AGVs can operate to transport jobs from one location to another. These AGVs belong to an Automated Guided Vehicle System (AGV system). The AGV system itself might be part of a larger system such as an intelligent flexible manufacturing system. (Lim et al., 1989)

The most recent development in AGV Applications is the office/commercial type. These AGVs operate in office environment and large building. One of the major functions performed by this type of AGVs is delivering mail in multi-story office building.

2.5 AVAILABLE AGVS

We will look at some of the AGVs currently available in the market. This will give as an indication of the requirements of the market and the development work that will have to be done.

2.5.1 TOW TYPE

This type of AGV is used for pulling carts, trailers, dollies, etc. They typically range from 10,000 to 50,000 pounds towing capacity. Train lengths depend on capacity, space and trailer tracking performance.

Figure 2.4 Tow Type AGV

[Source: AGV Products Corp.]

2.5.2 UNIT LOAD TYPE

These are self-contained AGVs that carry products on their built-in load decks. They typically transport pallets, totes, rolls and racks, usually one or two at a time. Often incorporating automatic load transfers at pick and drop stations.

Figure 2.5 Unit Load Type AGV

[Source: Egemin Automation Global]

2.5.3 FORK TYPE

This AGV utilizes a fork/mast lift mechanism for interfacing with loads at various elevations. Often, loads that are at floor or stand level are retrieved and deposited automatically.

Figure 2.6 Fork Type AGV

[Source: Egemin Automation Global]

2.5.4 HEAVY CARRIER TYPE

This is an AGV Designed to transport large or very heavy loads. These are typically used in primary metal and paper industries. Capable of transporting dies, rolls, coils, and ingots weighing in excess of 250,000 pounds.

Figure 2.7 Heavy Carrier Type AGV
[Source: Industrial Automation]

2.5.5 COMMERCIAL/OFFICE TYPE

These are smaller units with capacities of less than 500 pounds. Designed to transport small totes or small loads in light manufacturing or clean environments. Versions are also used to distribute mail in offices.

Figure 2.8 Commercial/Office Type

[Source: Egemin Automation Global]

2.6 CONCLUSION

From the review, we can see what the essential components of an AGV system are. We need to have a clear application for which an AGV can be built and programmed. There has to be a suitable physical platform in terms of shape and weight. There needs to be a guidance system by which the AGV will recognize its intended path. Furthermore it needs elements such as sensors to recognize position and points at which it must perform the intended function. Having identified all the necessary elements, we can move on to the next step.

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

In this section we will be looking at the complete flow of the project. We will be looking at the entire process in separate sections. Each section will contain the most relevant aspects to that particular stage of development.

In the course of developing any product, there will be many distinct elements coming into play. This chapter will be presented in a way that reflects those distinct elements.

First we will be looking at the full intended functionality of the Automated Guided Dispenser (AGD) once it has been completed. Then we will consider the design process as the first element that has to be completed to provide a physical platform for all the other components.

Third, we will be looking at the AGD body fabrication process. This section will capture the actual process of cutting and making the body of the AGD. Next we will consider how the mobility problem was solved. This will include a look at motor selection, the drive train, and the wheels used.

The fifth element considered will be the electronics developed for controlling the AGD. We will be looking at the complete circuit and also the major components used in the circuit. Last but not least will be the brain, the program that controls the AGDs function.

3.2 INTENDED FUNCTIONALITY OF THE AGD

From the flowchart below we can see the actual way the AGD is supposed to behave when completed.

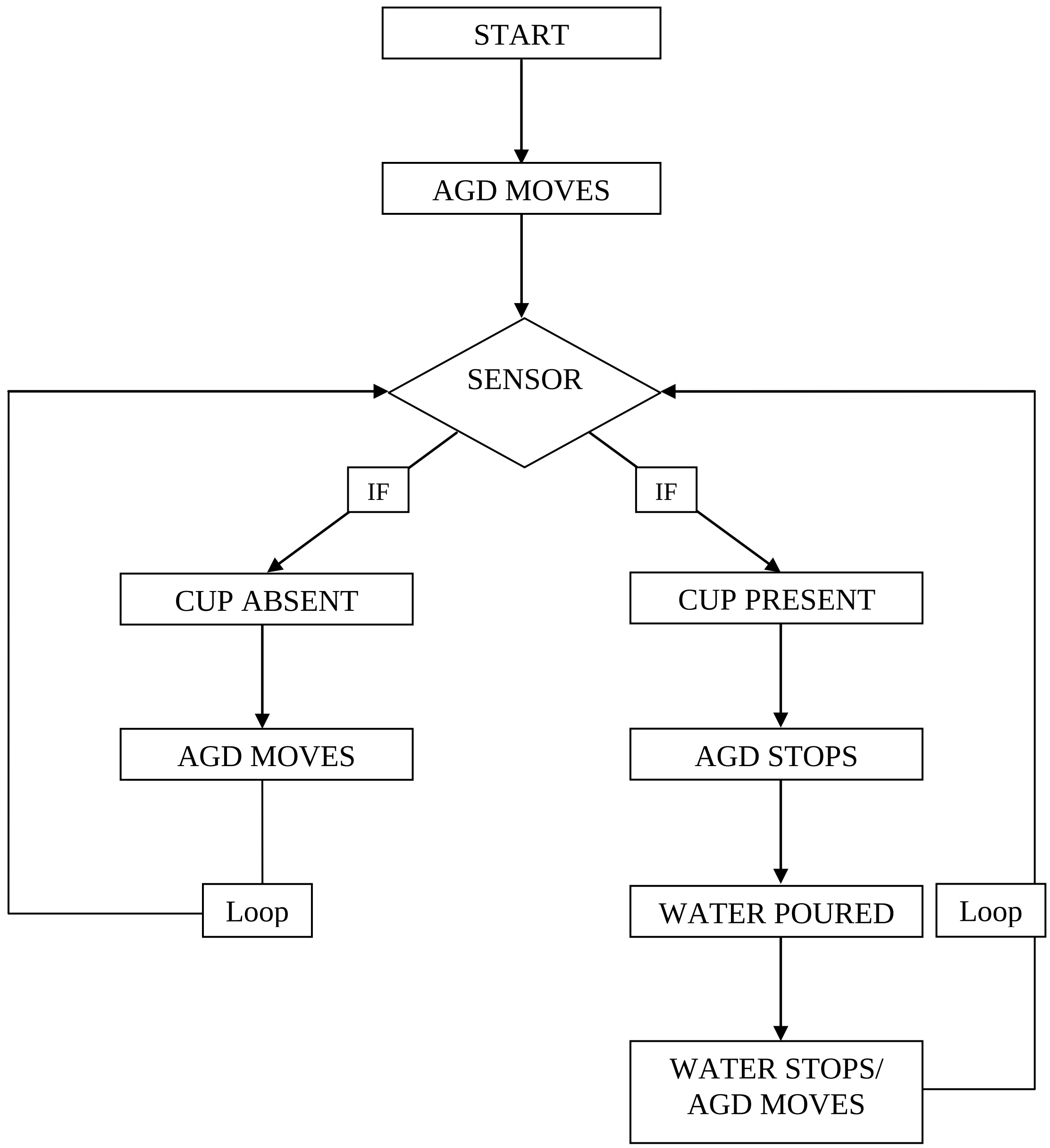

Figure 3.1 Intended Functionality of AGD

The AGD will be continuously moving along the intended path once turned on. When a cup is placed in its way, the AGD has to recognize the obstacle and pour water. Having done that, it has to start moving again.

3.3 AGD BODY DESIGN PROCESS

The design process consists of a few steps. We start off by coming up with a concept for the AGD. This particular AGD is intended to be used on conference tables in offices. It is expected to move around on the table and pour water into any cup that might be placed in its way. Obviously there has to be a tank in which the liquid will be carried. There has to be room for this.

The AGD will also be carrying the circuit board inside. There must be a water-proof compartment in which this is to be placed. Furthermore there has to be proper room to attach the drive train and the wheels. Wiring and tubing also have to be taken into account as there will have to be connections to the power supply.

Needless to say, the AGD has to be stable so as not to topple over. It has to be relatively strong as it has to carry a certain amount of water. Add to that the body's weight, and all the other things carried by the AGD, the total weight could be significant. So this too has to be considered.

Furthermore the design has to be simple enough to be fabricated. After taking all these into account, I started working on the design.

Oncee the basic concept of what the final design is going to look like is achieved, that concept is translated into an actual design through SolidWorks. This is done by drawing the individual components of the body as Parts (*.sldprt), then assembling those individual parts as an Assembly (*.sldasm). Both these steps can be done in SolidWorks itself.

After that those Parts are converted into a Drawing (*.dwg) for use in the next step of the process.

3.3.1 FLOW OF DESIGN PROCESS

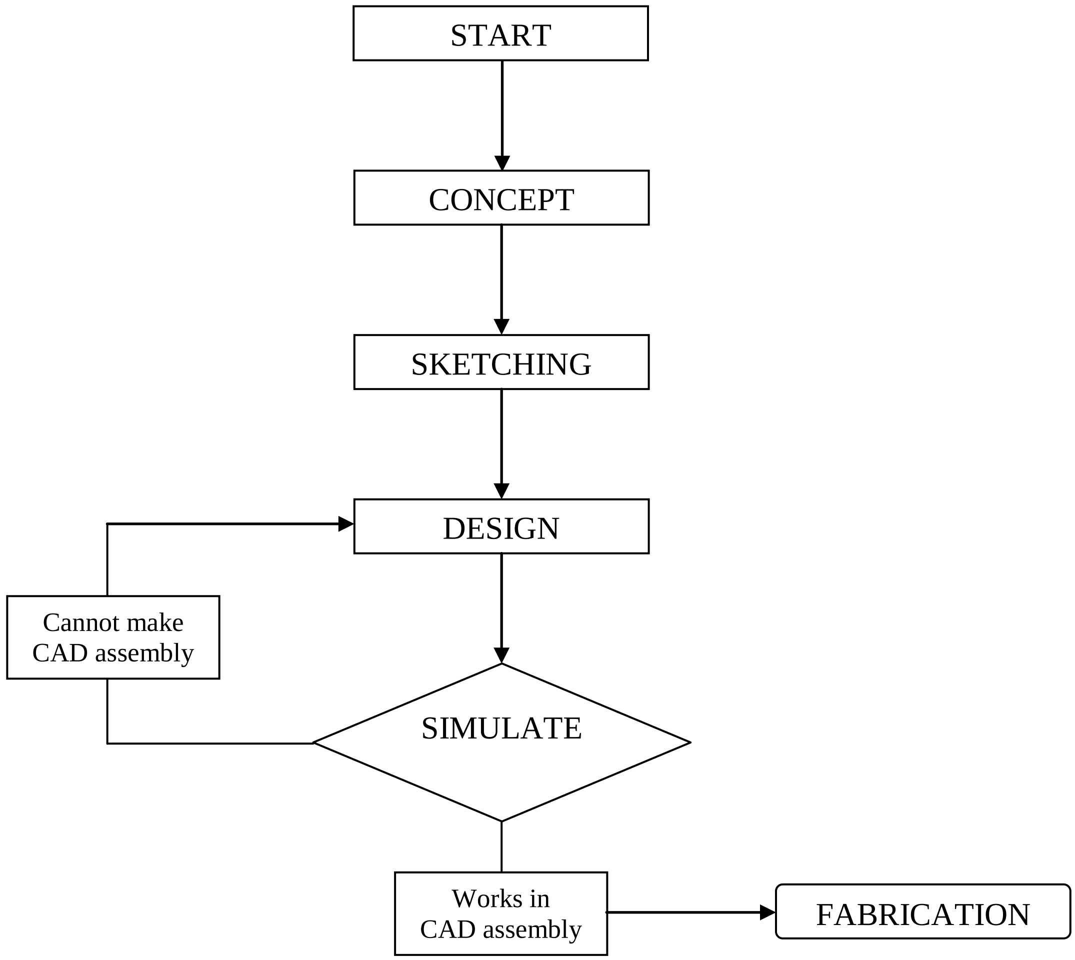

Figure 3.2 Design Process Flowchart

3.3.2 FINALIZED SOLIDWORKS BODY DESIGN IN 3D VIEW

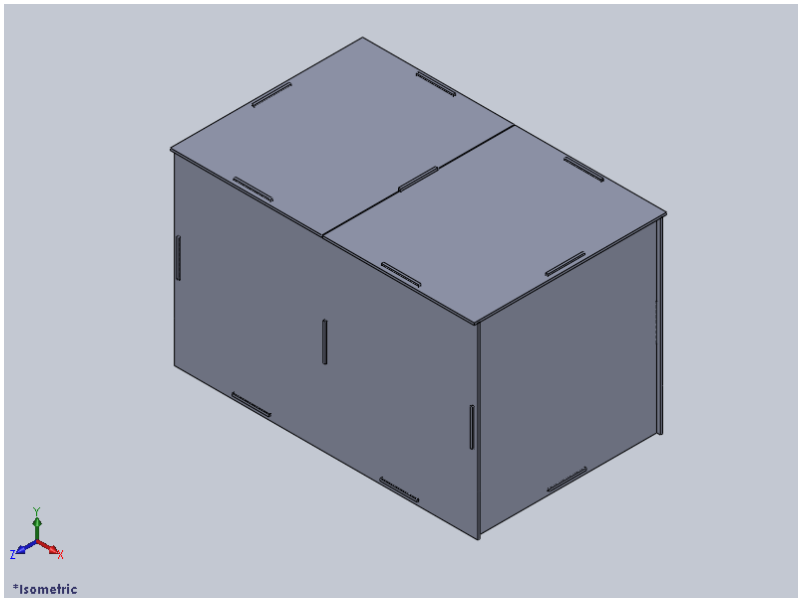

Figure 3.3 Isometric View of Final Design

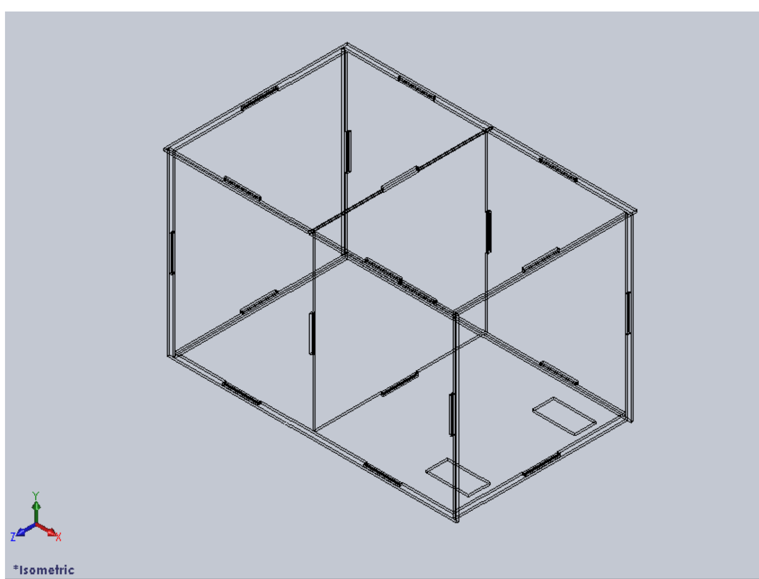

Figure 3.4 Isometric Outline View of Final Design

3.4 AGD BODY FABRICATION PROCESS

Once the body design of the AGD has been finalized, we can move on to the next stage. This will be the fabrication of the body based on the design. This process consists of multiple steps. We will look at these processes one by one.

3.4.1 FLOW OF FABRICATION PROCESS

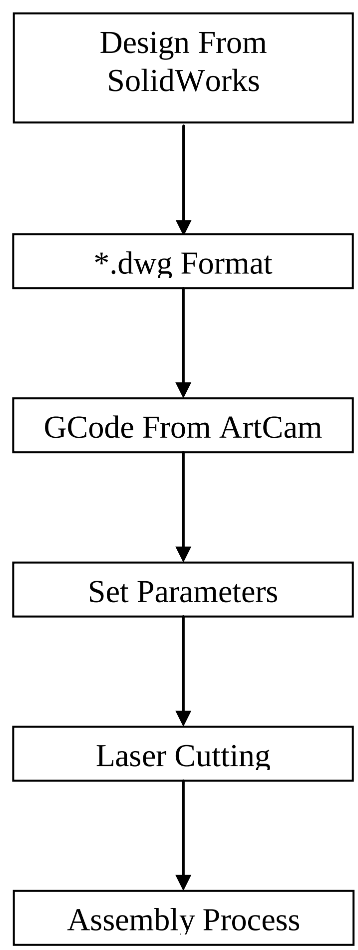

Figure 3.5 Fabrication Process Flowchart

We converted the parts into Drawing (*.dwg) format because the software used in the next process requires the design to be in this format.

3.4.2 G-CODE GENERATION USING ARTCAM PRO

From SolidWorks designs such as these, we generate a drawing (*.dwg) file of the individual parts on the same sheet.

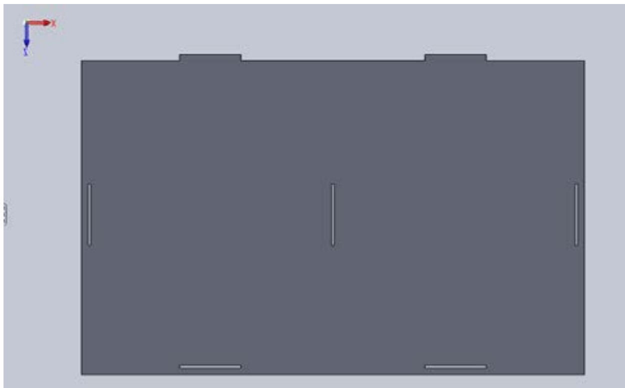

Figure 3.6 SolidWorks Part for the Side Panel

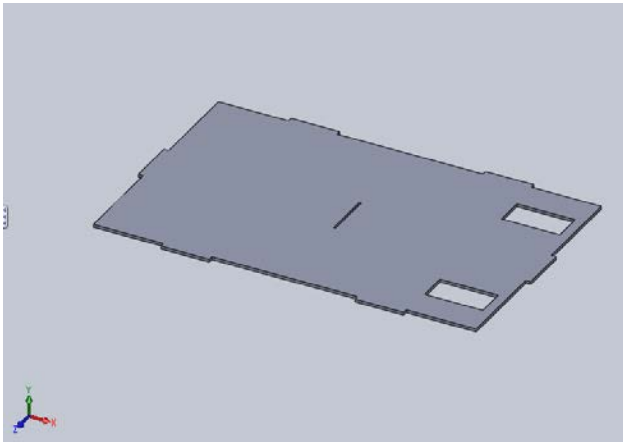

Figure 3.7 SolidWorks Part for the Bottom Panel

This is the Drawing (*.dwg) file which will be exported to ArtCam Pro. This software will generate the GCode which will determine the cutting movements of the Cutting Tool of the Laser Cuting Machine.

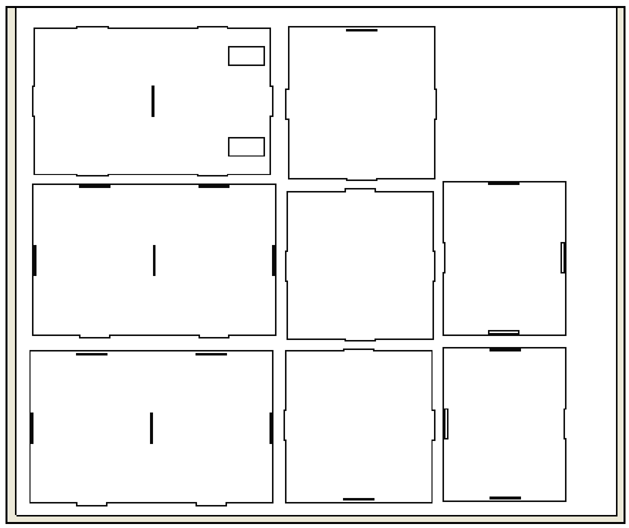

Figure 3.8 SolidWorks Drawing of all the individual Parts

Next we have to do the Cutting Tool selection to instruct the Laser Cutting Machine on what type of tool is being used. For our purpose we use a Conical 0.125 Flat – 10 degrees Cutting Tool.

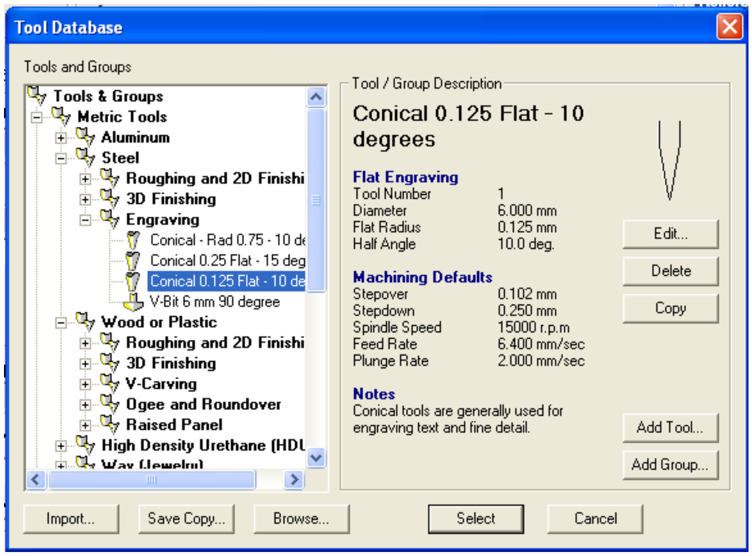

Figure 3.9 Tool Selection for the Laser Cutting Tool

The picture below shows ArtCam Pro Simulating a Tool Path for the laser cutting tool to follow. The red lines are cutting paths the tool will use. We can manipulate the Tool Path or Machining Vector to minimize wastage of the raw material.

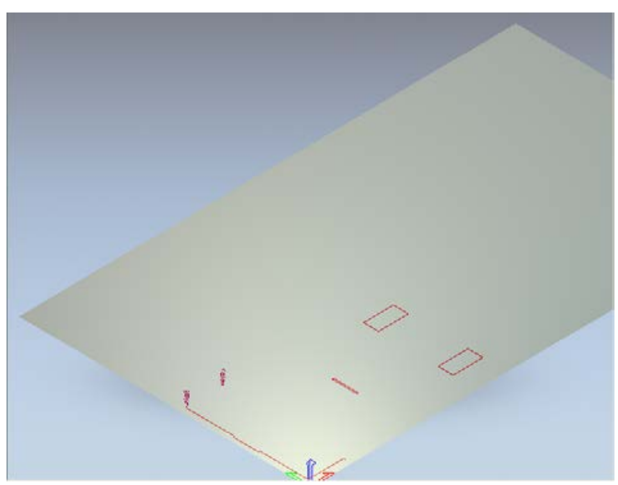

Figure 3.10 Tool Path Vector Simulation for the Bottom Plate

Once that is done we can save the Tool Path in coordinate format that the machine will understand. Below is an example of the Machining Vector in coordinate form. This is also known as the GCode

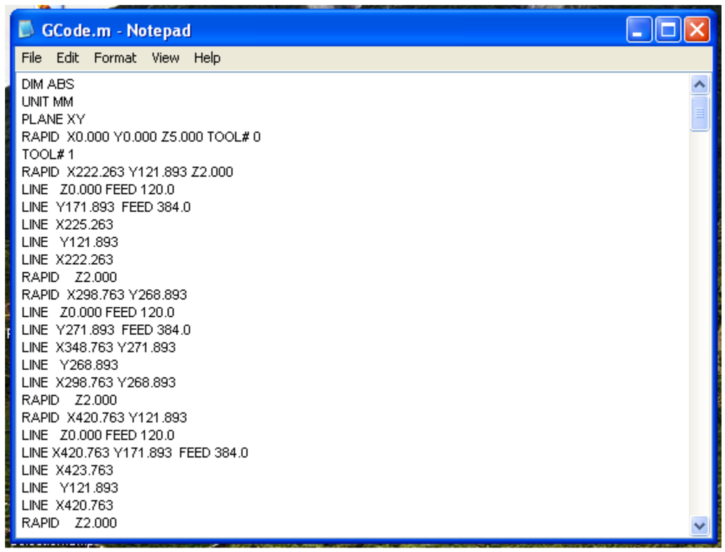

Figure 3.11 GCode for the Bottom Plate

The GCode is the instruction for the cutting process. Within the code there are various instructions. ‘Rapid’ means the Tool will move to that coordinate rapidly without making any cuts. This is usually a starting point to make a new cut.

The following ‘Line’ code indicates the coordinates for which cuts will be made. In this particular instance all the cuts made are straight lines. So the cutting will be done along those lines.

3.4.3 BODY MATERIAL

The body of the AGD will be fabricated using Polymethyl Methacrylate (Acrylic). Acrylic is a transparent plastic. It is cheap and widely available. Acrylic is also easy to machine. Furthermore acrylic is strong enough to support the projected weight of the entire AGD while being relatively light. This is an important trait as I am looking to use a relatively small motor.

Figure 3.12 3mm Acrylic Cut to the Top Plate Specifications

The general properties of the acrylic used for the AGD body are as follows:

Table 4.1 PMMA Specifications

[Source: http://www.ides.com/generics/Acrylic/Acrylic_typical_properties.htm]

Properties	**Acrylic (PMMA)**
Specific Gravity (*g/cm³*)	1.15 to 1.19
Melt Mass Flow Rate (*g/10 min*)	0.30 to 4.6
Flexural Modulus (*MPa*)	1120 to 3450
Tensile Strength (*MPa*)	36.6 to 81.1
Tensile Elongation (*%*)	0.0 to 7.3
Rockwell Hardness	44 to 102
Notched Izod Impact (*J/m*)	10.7 to 61.9
DTUL at 66 psi (0.45 MPa) (*°C*)	80.0 to 103
DTUL at 264 psi (1.8 MPa) (*°C*)	76.5 to 104
CLTE, Flow (*cm/cm/°C*)	0.000045 to 0.00011

3.4.4 PCNC LASER CUTTING

Figure 3.13 PCNC Laser Cutting Machine

Figure 3.14 PCNC Laser Cutting Machine cutting 3mm Acrylic

3.5 MOBILITY SOLUTION

In this section, we will look at how mobility of the AGD was achieved. Beginning with the selection of a suitable motor, we will also see how a drive train was combined with the AGD body. We will also take brief look at the wheels that were use to enable the AGD to move. Lastly the guidance system will also be considered.

3.5.1 MOTOR SELECTION

For this project a DC Motor is used. The rotation in this type of motor is accomplished by forcing current through a coil and producing a magnetic field that spins the motor. This particular motor is used commonly in RC Hobby Cars.

Table 4.2 Specification of the DC Motor

Description	**Specifications**
Dimensions	Length = 6cm; Diameter = 3cm
Output shaft	Built-in in the drive train
Voltage	12 V – 24 V
Ampere	0.5 A – 3.5 A
Gear ratio	1/65
Weight	50 g

3.5.2 DRIVE TRAIN

The drive train used in this AGD was taken from a RC Hobby Car. The drive train was stuck to the rear of the bottom plate using an epoxy adhesive. Brackets were added to prevent the body of the drive train from spinning in the opposite direction when the wheels are turning.

The wheels were a part of the drive train. However they had to be modified to add to the diameter so that contact with floor is possible. The original wheels were slightly small and did not touch the ground when mounted inside the body.

3.5.3 WHEELS

The wheels used in this AGD are from the same RC Car as the drive train. These were attached to the body by first mounting the shaft onto a bracket and then attaching the bracket to the side body panel using an epoxy adhesive.

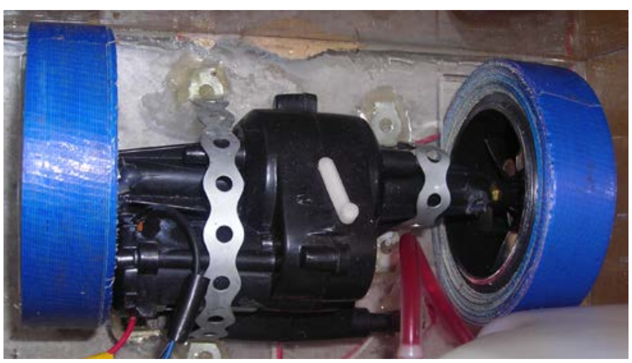

Figure 3.15 Drive Train

Figure 3.16 Left Front Wheel

3.5.4 GUIDANCE

As planned, a rail was used to guide the AGD along the length of the table. A bracket is attached to the bottom of the AGD. This bracket encompasses the sides of the rail and this keeps the AGD moving along the path set by the rail.

Figure 3.17 Guide rails

3.6 WATER DISPENSING

Another important part of the AGD is the dispensing of water. The concept was to have the AGD carry its own water tank and dispense water from it. This section explains how that function was achieved.

3.6.1 WATER TANK AND PUMP

The water tank used in the AGD is commercially available and is made of plastic. It has a volume of 1 Liter. The water tank is available as a set with the pump. The pump itself is a centrifugal pump with a power rating of 12V. It operates on about 2 to 3 Amperes of current.

The Figure 3.19 shows the mounting of the Water tank. Figure 3.20 shows the hold for the water pump.

Figure 3.18 Water Tank

Figure 3.19 Water Tank Mounting

Figure 3.20 Water Pump

3.6.2 SENSOR AND NOZZLE

The sensor used is a touch switch. This is a common switch with normally open (NO), normally closed (NC) and common (C) pins. The water nozzle is the type used in automobiles such as cars. It is connected to the pump using a slender rubber hose.

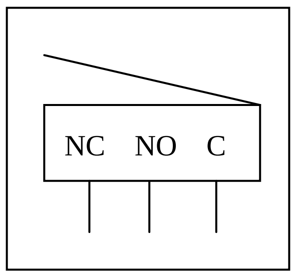

Figure 3.21 Touch Switch

Figure 3.22 Water Nozzle

3.7 ELECTRONICS

This section will look at all the electronic components used in the circuit designed to control the AGD. The major components will be reviewed one by one.

The components used in this circuit are a PIC16F877 microcontroller, two 2pF capacitors, a 20 MHz oscillator, a L7805 power regulator, two L298 drivers, and a 4.7 kΩ resistor. The most critical component of the system is the Programmable Integrated Circuit which acts as the control centre for the system. The components are assembled as shown in Figure 3.23.

The capacitors are used as complementary supply to compensate for any fluctuation that might occur in the power supply. The crystal oscillator uses the mechanical resonance of a vibrating crystal of piezoelectric material to create an electrical signal with a very precise frequency. This frequency is commonly used to keep track of time to provide a stable clock signal for digital integrated circuits, and to stabilize frequencies for radio transmitters/receivers (Bottom, 1981).

Resistors are placed between the PIC and the ULN2803 driver, and the PIC and power source. This is to make sure that, in the event of current feedback or overload, the PIC will not be damaged.

3.7.1 CIRCUITRY

Overleaf is Figure 3.23 which shows the entire electronic circuit as assembled. All the individual components are shown.

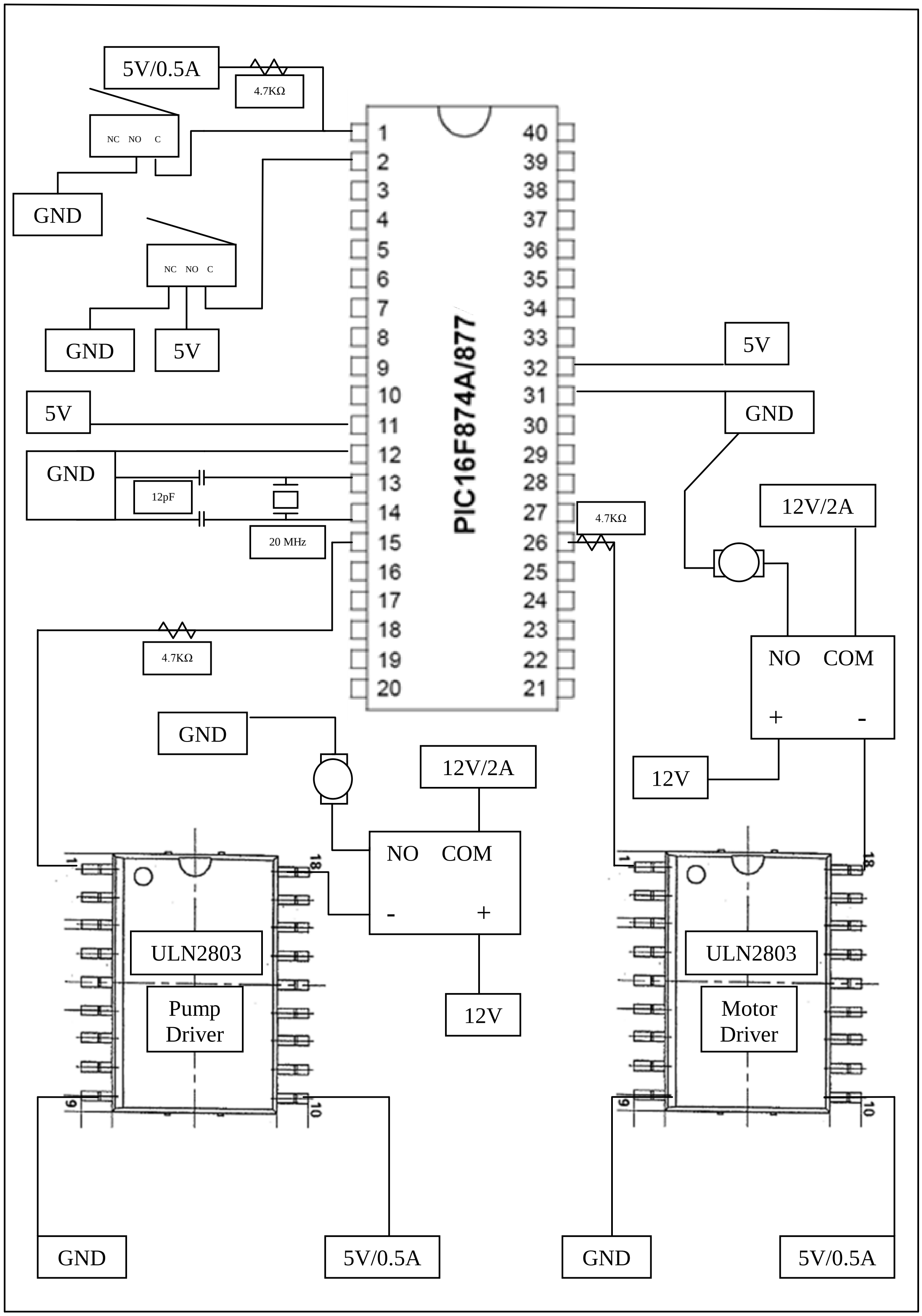

Figure 3.23 Complete Circuit Diagram

3.7.2 MICROCONTROLLER

PIC stands for Programmable Integrated Circuit. A PIC is basically a controller that can be programmed to do various functions. It can run sequential instructions, perform mathematical operations and control displays. This is a basic computer. In the instances where a computer cannot be used to control a system, such as in an Automated Guided Dispenser, the PIC can act as a mini computer.

The PIC used in this project is the 40-Pin PIC16F877. This is not a very advanced type of PIC. At the same time it is also relatively sophisticated compared to lower-end PICs. This PIC is quite commonly available and is made by Toshiba Corp.

From Figure 3.24, we can see the various ports on the PIC. These ports will act as input or output according to the program. This circuit uses Port C0 at number 17 to control the Pump Driver and Port C7 (23) to control The Motor Driver. The touch switch as sensor is connected to A0 (2).

All the other connections as seen in Figure 3.23 are standard enable connections for this type of PIC.

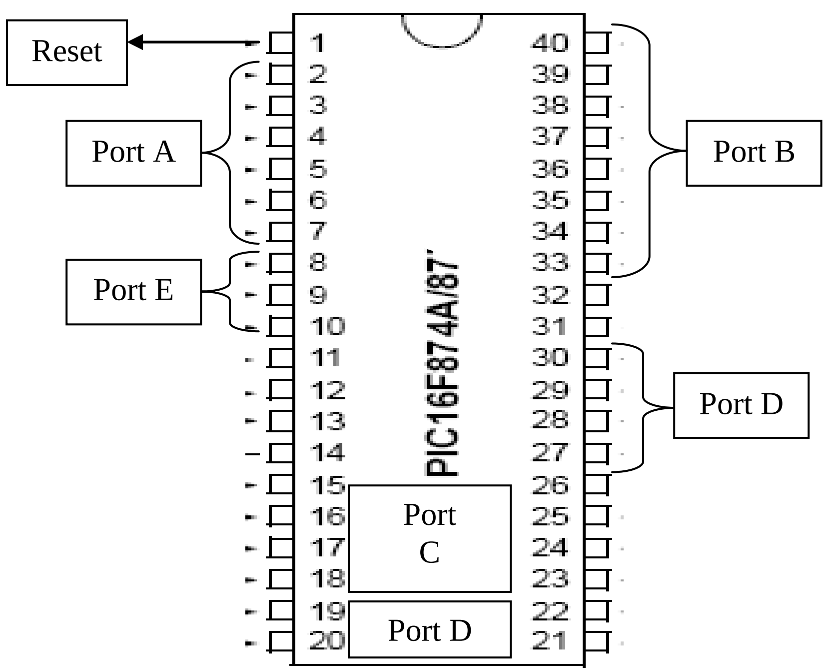

Figure 3.24 PIC Pin Diagram

The PIC can be easily programmed using program a program code such as C++ Language. This is a simplified language used to write the code for programs. The program is the compiled and turned into code. This code is converted into a HEX file.

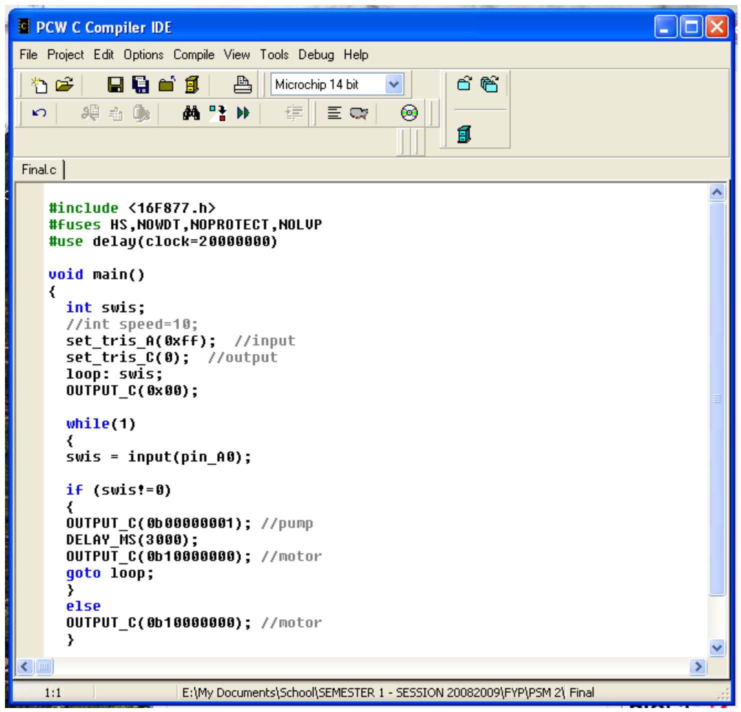

Figure 3.25 C Compiler

3.7.2.1 PIC KIT

The HEX which contains the coded instructions is then downloaded into the PIC using HEX Downloader software and a PIC Kit. The programming of the microcontroller in this instance was downloaded using a Cytron USB ICSP PIC Programmer UIC00A downloader.

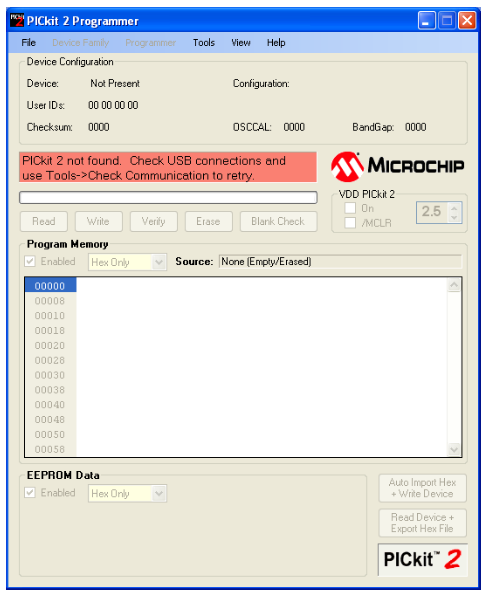

Figure 3.26 PIC Programmer

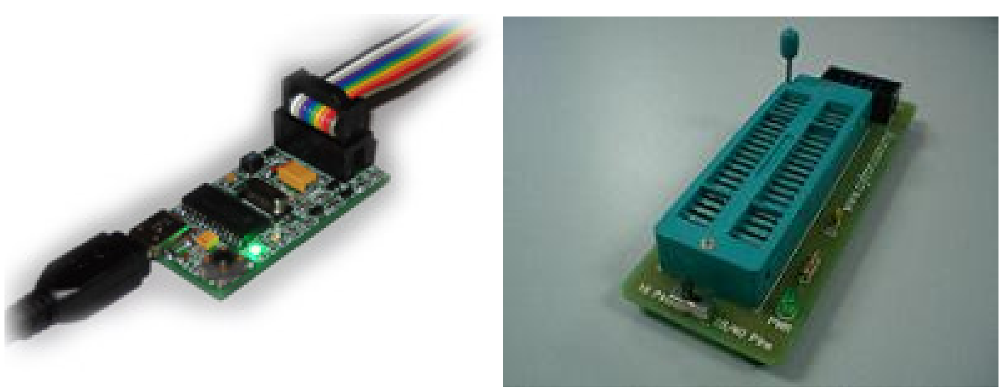

Figure 3.27 Cytron USB ICSP PIC Programmer and UIC00A Socket

3.7.3 DRIVER

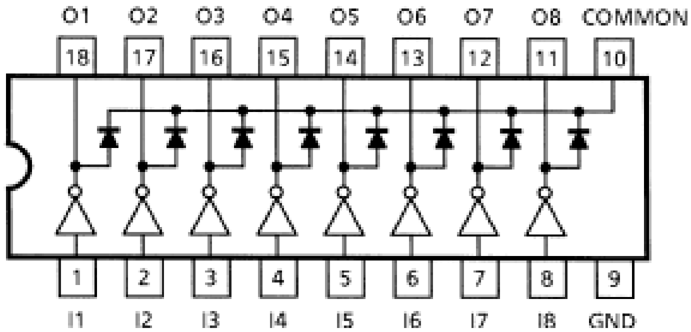

Figure 3.28 ULN2803 Driver Pin Connections

The figure above is the ULN 2803 Driver. There are two such drivers in the AGD's circuit. These control the relays that supply the high Amp current to the Motor and Pump. These drivers receive the input instruction from the respective C ports and enable the relevant relays. In this circuit, the motor driver is connected to port C7 and the pump driver to port C0

3.7.4 RELAY

In this circuit, two Single Pole Double Throw relays are be used. These are used to supply the motor and pump with a high ampere current. This cannot be supplied directly through the ULN2803 Driver as it has only a 0.5A current rating. The ULN Drivers will activate the relays by supplying a low Amp voltage.

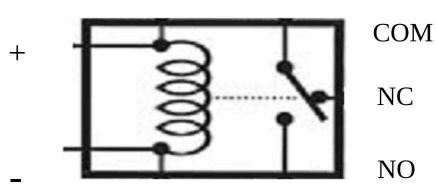

Figure 3.29 SPDT Relay

3.8 PROGRAMMING

In this section we will be looking at the program code used to control the AGD. This code is written in C++ Programming language. This is an easy to use programming language. At the same time it gives us the functions that are necessary.

3.8.1 PROGRAM CODE

In ‘void main’, the inputs and outputs are declared. Here also, the switch is declared as the interrupt function with ‘int swis’. So the PIC will register an interrupt when the switch is touched. A loop is also created with ‘loop: switch’ so that the program resets itself and comes back to check the switch status. This is basically an automatic reset button.

```
void main ()
{
int switch;
//int speed=10;
set_tris_A(0xff);  //input
set_tris_C(0);  //output
loop: switch;
OUTPUT_C(0x00);
```

Figure 3.30 Void Main

The second part of the code has a while function. The ‘while(1)’ means that the program will keep running as long as the power is on. The next line declares the switch as input. As shown in Figure 3.23, the switch is connected to Pin A0. So any signal coming to A0 becomes the input.

The ‘if’ function decides what is supposed to happen when the switch is in a certain status. According to this code, if the switch is pressed, hence not equal to zero, the Pump Driver is activated.

The Pump Driver is connected to Port C at Pin C0. The Motor Driver is connected to Port C at Pin C7. These two are declared as outputs by the line ‘OUTPUT_C’. This state lasts for three seconds because of the ‘DELAY_MS’ function. Then the motor is activated and the program loops back to check the switch status again. If the switch status is zero, the program goes to the ‘else’ function. This function causes the motor to run and the pump to be inactive.

```
while(1)
 {
 switch = input(pin_A0);

 if (swis!=0)
 {
 OUTPUT_C(0b00000001);  //pump
 DELAY_MS(3000);
 OUTPUT_C(0b10000000);  //motor
 goto loop;
 }
 else
 OUTPUT_C(0b10000000);  //motor
 }
}
```

Figure 3.31 Code Body

3.8.2 PROGRAM FLOW

The flowchart below depicts how the program is supposed to run.

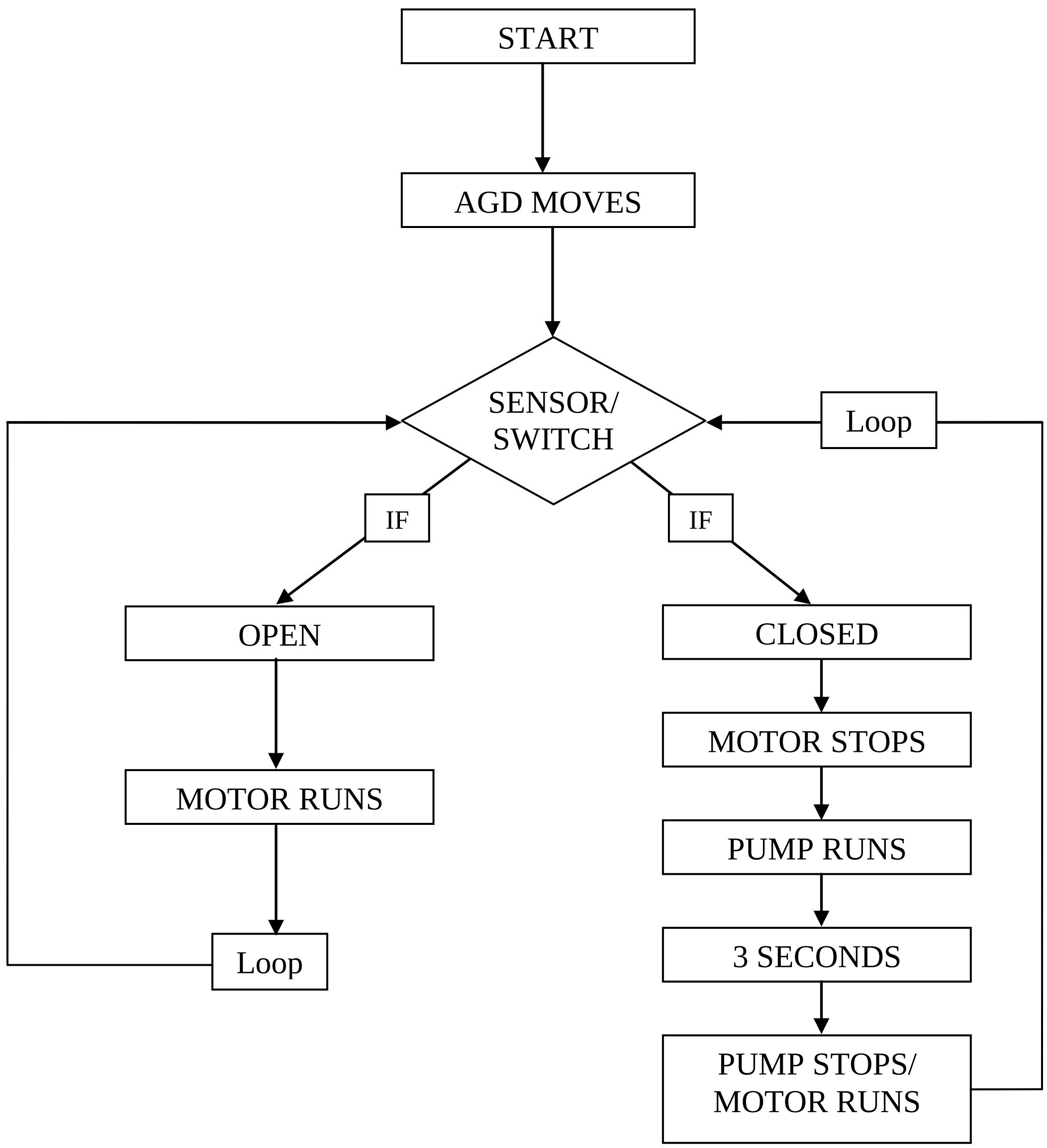

Figure 3.32 Program Flow

3.9 ASSEMBLY

This stage is the last stage in the completion of the AGD. The body was assemble first as this would be necessary to place all the other components. The body assembly is relatively straightforward. It is a snapping mechanism. The extruded part is pushed into the corresponding slot. This is then strengthened with epoxy adhesive.

The water tank with the pump is mounted on a bracket that is attached to the separating wall by means of strong epoxy adhesive. The front wheels are attached the same way. The drive train is attached to the rear of the bottom plate using modified brackets. Lastly the circuit board is placed inside the front compartment. This rests flat on the front of the bottom plate.

3.10 CONCLUSION

In this chapter we have seen how every aspect of the AGD was developed. Starting from conceptualizing a suitable AGD design based on the requirements, the next stage was putting it into an actual design. Once CAD simulations were successful, the next step is fabrication. Fabrication comprises multiple steps, many of them requiring various CAD software.

The electronic components were fitted together as a circuit and tested. Then the program code was written and downloaded into the PIC. Once all these steps were completed, assembly was done and the AGD was tested.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will present the results of the project. There will be analyses regarding the design, fabrication, and functionality of the final product. A force analysis will also be done to determine the forces being experienced by the AGD. These are being done to evaluate how much of the original objectives have been achieved throughout the developmental stages of the AGD. There will also be a discussion on some of the elements that have been critical in the course of completing the project.

Figure 4.1 Side View of Completed AGD

Figure 4.2 Isometric View of Completed AGD

From the above figure we can see the completed AGD. All the components are in place in the two compartments of the body. The following is an analysis of the different elements of the entire project.

4.2 DESIGN ANALYSIS

Design-wise, the objectives set out at the beginning have been achieved. The AGD is capable holding all the components within its body shell. The tank and the drive train are placed in the rear compartment. This section is separated from the front by a wall. This wall also serves as a mounting surface for the water tank - pump set.

The front compartment meanwhile, houses the circuitry and most of the wiring. This is also a safety measure to ensure that the circuit is not affected if there are any leakages from the tank or tubing.

Figure 4.3 Rear Compartment

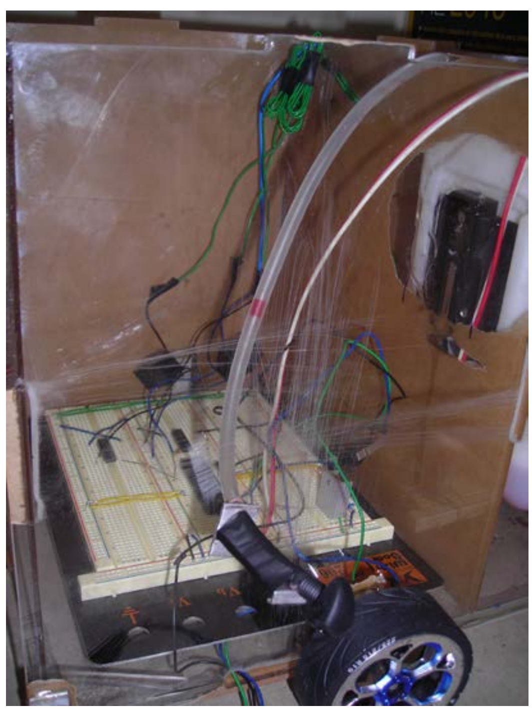

Figure 4.4 Front Compartment

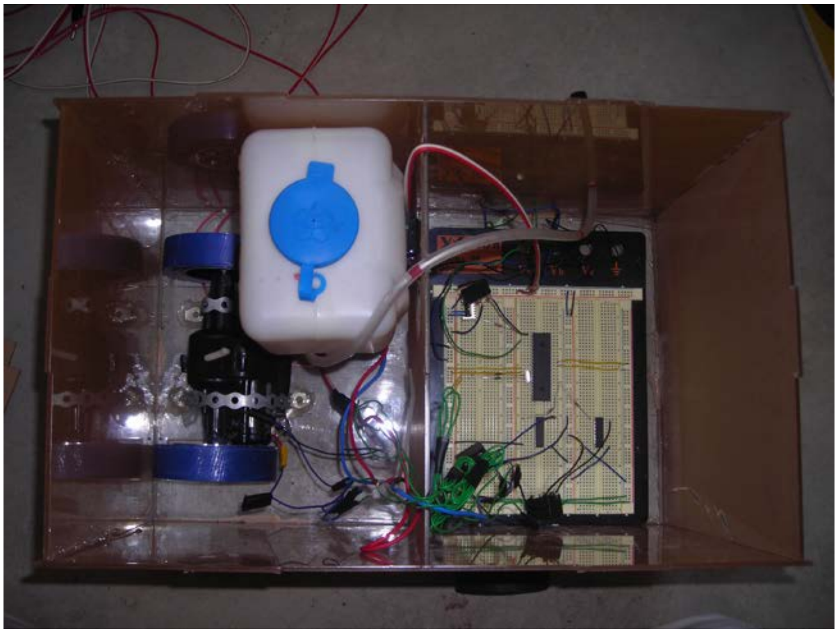

Figure 4.5 Top View of Internal Layout

This separation also makes it easier to work on one element of the AGD's system if the need to make any change arises. The box-like configuration maximises space inside the AGD body. As a test bed, the basic box shape works well. It is stable, strong spacious and works on pretty much any surface.

4.3 FABRICATION ANALYSIS

The PCNC Laser Cutting Machine was used to cut the acrylic. This type of machining is much more accurate and clean compared the conventional cutting processes such as sawing or drilling. Below is a table that shows some general data for the cutting process.

Table 4.1 General data for cutting process

Description	**Specifications**
Machine	PCNC Laser Cut
Laser Class	Class 1
NC Program	C:\Desktop\pcnc-guna\pcnc.cpp
Material	3mm Acrylic
Blank Dimension	123cm x 245cm
Weight of Blank	± Depending on thickness
Laser Power	95%
Tolerance	± 0.01mm
Air Pressure Supplied	2.1 Bar
Machining Duration	Average 12minutes/part
Scrap	5%

The laser cut machine can be highly accurate in its cutting if set up properly. Even the tolerance of ± 0.01mm achieved in this instance can be improved upon. The speed of the cutting tool and feed rates of the acrylic are among the important parameters that must be set according to requirements to acquire good accuracy.

With a delay of 800 set in PCLINE, which is the speed control part of the PCNC Program, the duration to cut one part of the body was about 12 minutes on average. The cutting time was similar for all the parts. This was due to the fact that all the individual parts were similar in design and dimension. This duration can be considered as quick. The AGD body design was of a simple design and this helped minimize cutting time.

When the input is given to cut the acrylic, the user has to select a ratio setting of drawing to actual part. Since the drawing for this AGD was done in *.dwg format, the ratio was set to 1:1.

The last thing to consider would be the air pressure supplied. A hose is connected from the portable compressor to the nozzle provided on the cutting tool. A pressure of about b Bar is supplied. This pressure helps focus the laser beam and prevents scatter. This causes the cutting done to be highly accurate and precise.

4.4 FUNCTIONALITY ANALYSIS

This section will analyze the function of the AGD to evaluate whether it works according the intended steps properly. As explained in Section 3.2 and Section 3.8, the AGD is supposed to stop and pour water into the cup if it is placed in the path of the AGD. Otherwise it should be continuously moving.

The finished AGD successfully does this. It moves smoothly along the guide rail and stops when the sensor touches the cup. In the sequence of figures below we can see the AGD on the guide rail and the AGD Nozzle pouring water into the cup.

Figure 4.6 AGD on Guide Rail

Figure 4.7 Touch Sensor

Figure 4.8 AGD Water Nozzle

Figure 4.9 AGD Pouring Water

However, since AGD uses a DC Motor, it is not very exact. The motor stops when the Touch Sensor is triggered, but not quickly enough. This sometimes causes the AGD to overshoot slightly past the cup. 90% of the time however, the water correctly goes into the cup.

The guide rails, while a simple design, works very well for this AGD. The rails, which are attached to the table, guide the AGD smoothly along.

4.5 FORCE ANALYSIS

In this section we will look at the force experienced the AGD due to the weight of the water carried in the tank.

- Mass of water = ρV
  $= (1000 m^3\ kg^{-1})[\{(0.12 \times 0.10 \times 0.02) - (0.03 \times 0.03 \times 0.02)\}\ m^3]$
  $= 0.213 kg$
- Mass of AGD Body ≈ 0.5 kg

- Combined mass of the drive train, circuit board, and the wheels ≈ 0.5 kg

- Overall Weight = mg

  $= (0.213 + 0.5 + 0.5)\text{kg} \times 9.81\ \text{ms}^{-2}$

  $= 11.89953$ N

  ≈ 12 N

- Weight Distribution is even Among 4 Wheels

  Force on each wheel = 12 N ÷ 4

  = 3 N

The overall weight and the force on each wheel are not significantly large. The AGD's movement in not impeded in any way by the weight carried.

4.6 CONCLUSION

From all the analyses done in this section, all the systems and components are working as they should. No major problems are found in any aspect of the AGD. However there are a few things that can be improved upon in the design and individual components. These will be enhancements of the basic AGD that has been built. These improvements will be discussed in the next chapter.

CHAPTER 5

CONCLUSION AND RECCOMMENDATION

5.1 CONCLUSIONS

This project was started by doing some basic background research into AGVs. There are many types of AGVs available in the market to perform a multitude of functions. They come in many varied designs and make use of a wide variety of relevant systems. This research gave a basic idea of the elements to be considered.

5.2 PROJECT OBJECTIVE ACHIEVEMENT

The systems involved in this project can be divided into four separate elements. They are the mechanical, electrical, electronic and software systems. These systems were developed in completing this project.

The AGD works as planned. The design is successful as it is capable of fulfilling all the requirements set out earlier. The functionality is also as intended and the program works correctly in the planned sequence. Based on this, the circuit too is fully functional. The mechanical components, which are controlled by the electronics, work as intended.

The AGD is capable of moving along the guide rail at a medium speed, which is suitable for the intended environment. It stops when the touch switch, which functions as a sensor, is closed. When this happens, the pump starts working, forcing water through the nozzle into the cup for 3 second. When this is done, the pump stops, the motor starts running, and the AGD starts moving again.

5.3 RECOMMENDATIONS FOR FUTURE DEVELOPMENTS OF THE AGD

Many enhancements can be made to make the AGD more sophisticated. With enough development, this will be a viable commercial product. Following are some recommendations for future development of the project.

5.3.1 DESIGN

The current design works well enough. But the AGD is slightly bulky. For a commercial product, more emphasis has to be placed on the aesthetics of the design. The AGD has to look attractive and non-intrusive if consumers are to use it in meetings.

5.3.2 MECHANICAL SYSTEM

The mechanical system can be improved by using more advanced type of motors such stepper or servo motors. These would be quiet and more exact compared to a DC Motor. The noise level is an important consideration for indoor equipments and the AGD is intended as one.

5.3.3 CONTROL SYSTEM

The control system used for this AGD in terms of guidance was a basic one. It was a simple rail attached to the top of the table. This can be changed to a variety of systems. Some of those systems are reviewed in the Literature Review. The electronics and the programming can be changed to accommodate this.

5.3.4 SENSORS

Many forms of advanced sensors can be used to detect the presence of a cup in the way. At a very advanced level, even 3D mapping can be done to determine the volume of the cup so that the AGD pours water to the exact volume of the cup.

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APPENDIX A

COMPLETE PROGRAMMING

```
#include <16F877.h>
#fuses HS,NOWDT,NOPROTECT,NOLVP
#use delay(clock=20000000)

void main()
{
  int swis;
  //int speed=10;
  set_tris_A(0xff);  //input
  set_tris_C(0);  //output
  loop: swis;
  OUTPUT_C(0x00);

  while(1)
  {
  swis = input(pin_A0);

  if (swis!=0)
  {
  OUTPUT_C(0b00000001);  //pump
  DELAY_MS(3000);
  OUTPUT_C(0b10000000);  //motor
```

```
  goto loop;
  }
  else
  OUTPUT_C(0b10000000);  //motor
  }
}
```