An Autonomous Robotic System to Maintain Free Flowing Drains

Inspiring Excellence

A Thesis submitted to the

School of Engineering and Computer Science of BRAC University

by

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Declaration

We do hereby declare that the report titled “An Autonomous Robotic System to Maintain Free Flowing Drains” submitted to the Department of Computer Science and Engineering and Department of Electrical Engineering of BRAC University, is our original work and was not submitted elsewhere for the award of any other degree or any other publication.

Date: 20th December, 2015

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____

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Abstract

The aim of the project is to construct a mobile device which would remove waste materials such as leaves, bottles, polyethenes, etc. which we usually see disrupting the water flow in roadside drains. This causes dire problems in our society when the drain overflows, acts as breeding grounds for mosquitoes, produce undesirable smell and in turn becomes a reason for health risk in the community. Thus, our aim is to construct a robot which will help to overcome this problematic situation.

The device consists of a conveyer belt fitted with a fixed number of claws to pick up the waste material and it is driven by a chain bound to a DC motor. The claws will transfer the collected waste into a deposit box and from there it will be displaced in a desired location by means of an actuator.

Chapter 1 - Introduction

1.1 Introduction

During the liberation war Dhaka city had a population of nearly 7 million which now increased to approximately 12.5 million and is rapidly increasing. During the last 25 years rapid uncontrolled urbanization has taken place in Dhaka city. Substantial increase in areas has taken place due to insensitive developments of areas by private land developers and real estate business. The impacts of such unplanned development has its toll on environment, socio-economic and environmental requirements. One major impact being the sewage and drainage system and its management within areas of Dhaka city. Due to the absence of proper drainage facilities in the real estate projects, water logging is being created. Due to lack of proper solid waste management system in the real estate projects, environment situation is being degraded every day. The solid waste disposal management of Dhaka City is major area maintained by [11] DNCC and DSCC and cantonment area maintained by Dhaka Cantonment Board. Drainage facility management of Dhaka City is maintained by Dhaka City Corporations and Dhaka water supply authority (DWASA) and Cantonment area maintained by Dhaka cantonment Board. The inhabitants of the real estate projects are now suffering from problems due to lack of necessary urban amenities. The nature of solid waste is changing over time and with development. Nowadays, the solid wastes consists more of plastic and polyethylene goods also cause problems towards human health, environment and drainage system. These goods are cheaply and easily available in the markets. The users do not care to reuse them. They rather throw them out of the door and window into the environment. Due to resource constraints, lack of available dustbins and garbage box, shortage of funding and other institutional constraints, DCC in general has not been able to effectively collect and dispose of the waste properly. Most of the waste is visible on the streets and in the drains. About 400 tons out of average 3,500 tons of solid waste, generated in the City every day, remains on the roads, open spaces and in drains. So the streets remain unclean after daily sweeping and the drainage ditches and channels get blocked due to unwanted waste throwing. Moreover, rainwater also wash away these wastes and blocks the surface drains which hampers the natural flow of storm water and creates water logging in different place of the city. Therefore, in most of the area in Dhaka City, solid waste has become a serious problem with health and hygiene consequences for the city dwellers. Hence, our purpose is to build a robot which would effectively clean the roadside drainage lines and get rid of solid wastes like plastic and polythenes to prevent waterlogging and flooding and hence maintain a free flowing sewage line.

1.2 Purpose

The drainage system in most part of Dhaka is now in a dilapidated condition. This becomes clearly visible during the rainy season when even an hour of rain cause whole regions to be drowned under water. All the waste such as polythenes, bottles, paper, etc. flows into the drains and clogs up narrow spaces. This prevents an open flow of the water.

The disconnected authorities such as Dhaka Water and Sewerage Authority (DWASA), city corporations and Bangladesh Water Development Board (BWDB) are responsible to ensure proper drainage system in the capital, but their efficiency and reliability is under scrutiny.

Only 22 percent of the 360-sq km area under WASA in Dhaka is covered by storm drainage. So, more than one-fourth of the city area has to depend on narrow open drains and canals for water to recede [2]. Thus along with the deficiency of drains, the added problem of clogging is a severe threat to our society.

Therefore, we hope to make our neighbourhood clean, hygienic and water clogging free by removing waste deposits in the drains. Furthermore, we can remove the resulting stench and also breeding grounds for disease causing insects. Amongst many more, these are few of the problems we wanted to address and find solutions to.

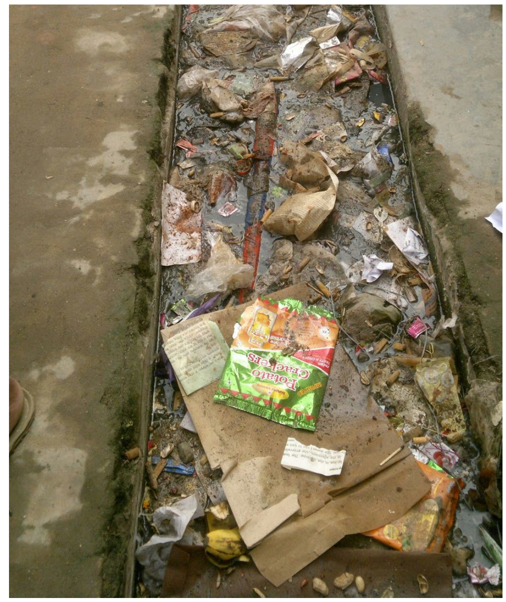

Figure 1.1 & 1.2: Photos showing clogged drains which obstruct water flow especially during rainy seasons.

1.3 Initial planning and designs

1.3.1 Discarded designs

In the first phase of the project a thorough study of the drainage systems was initiated starting with our surrounding area. This survey led us to discover the real scenario of the drainage systems. Approximately 70% of all the drains we looked into were in a condition of severe clogging. Especially the upper surface of the water flow were covered with numerous materials such as papers, foams, polythenes, bottles, leaves, etc. Layer upon layer of these waste cumulated over the years and in times of heavy rain will be the primary cause of waterlogging in the city.

A number of designs of a robot were formulated to solve this problem. One of which included a caterpillar track robot which would inserted into the drain. This would have to move forward shoving all the debris into its carrier. The first of the problems it faced was that the waterproofing system had to be perfected, without which, short circuits would be imminent. It would also require an extremely high torque motor for its wheel tracks to force through all the solid wastes. Lastly, the tracks would also have to be protected from being jammed up by all the surrounding garbage. Thus, this design was discarded.

The second design included a four wheeled robot which would travel by the side of the robot. It would also have a conveyor system on the side above the drain. This picks up the wastes and had to transfer those into a waste collecting box on the robot. This had an intricate mechanical problem to be solved. The transferring of waste from the conveyor on the side to the box would take complex mechanical structures and had a high chance of most waste not being able to be shifted.

A third design included a vacuum pump fixed to a robot. This would travel along the drain and suck out the materials it finds on its path. But this would involve a high powered pump which could suck out heavy water clogged materials. There was also the possibility of materials being stuck inside the pipe of the pump. So this design also met its end without success.

1.4.2 Finalized Design

Thus we decided on the current design of a four wheeled robot, two wheels on each side of the drain. The conveyor system is in the front which turns and picks up waste using the attached claws. This allows the waste to be easily displaced into the collecting box at the center of the robot. This design is as simplified as possible and minimizes chances of failure either of mechanical or electrical components. In effect this provided for a minimum cost of the robot and also requirement of materials.

Figure 1.3: Paper Model

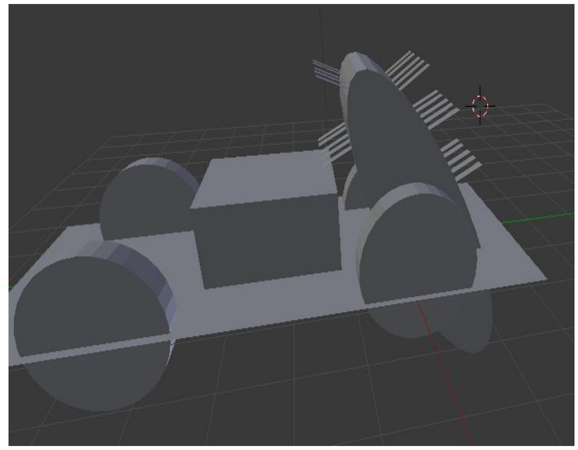

Figure 1.4: Simplified CAD Model

Chapter 2 - Literature Review

2.1 Impact of Solid Waste Disposal on Environment and People

In Dhaka, per capita solid waste generation is quite low; however, due to huge and densely populated City, solid waste problem in Dhaka City is very acute in comparison to many cities of the developing countries. Daily production of solid waste in Dhaka City is more than 4000 Metric Tons. Out of it, 15 to 20 percent are hospital and clinical waste – a mixture of toxic, pathological and radioactive waste as well [11]. This poses serious health hazard to the people abiding in Dhaka metro.

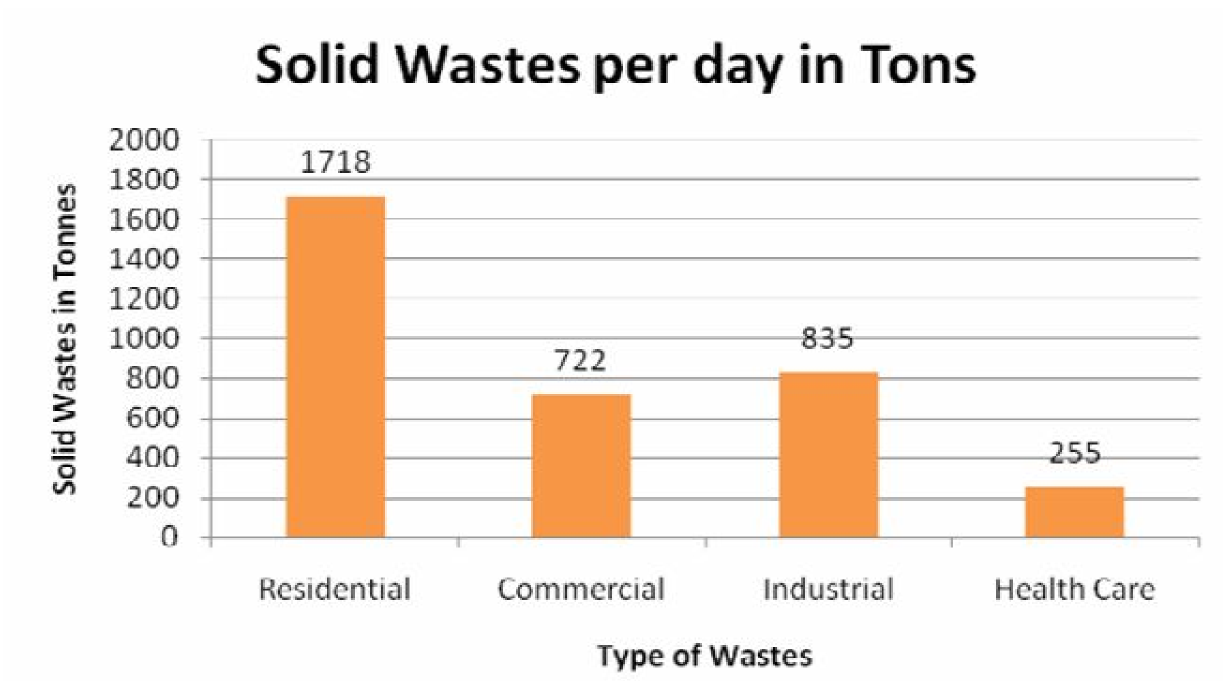

Figure 2.1: General solid wastes per day in Dhaka City[11]

In general, impacts of solid wastes on the environment and the people are:

- Open air dumping creates unhygienic and poses enormous threat to the people.
- Causes aesthetic problem and nuisance due to nauseating pungent odour.

· Promotes spreading of diseases.

· Carbon dioxide and Methane produced from solid waste are extremely harmful to the environment.

2.2 Water Logging in Dhaka City

As the growth of population of Dhaka City taking place at an exceptionally rapid rate, the city is unable to cope with changing situations due to their internal resource constraints and management limitations. Being a tropical nation, geographical prospect of Dhaka city ensures extensive rainfall about 2540 mm annually [13] during the monsoon (May to October). Hence waterlogging is a common and regular problem of Dhaka city. Rainfall induced flooding is caused by high intensity storm rainfall runoff in the City area that is inundated for several days mainly due to lack of proper drainage system and inefficient management. Without proper drainage system, water logging is taking place as different parts of the city remains inundated for several days. Inadequate drainage sections, conventional drainage system with low scarcity and gravity, absence of inlets and outlets, indefinite drainage outlets, lack of proper maintenance of existing drainage system, and over and above disposal of solid waste into the drains and drainage paths are accounted for the prime causes of blockage in drainage system and waterlogging [11].

Causes	Percentages
Excessive Rainfall	74
Population growth and unplanned development	95
Waste management system	82
Encroachment	76
Topography	46
Scarcity and gravity of drainage system	67
Drainage management system	83
Development works during rainy season	40
Storage of construction materials	37
Lack of public awareness	60
Lack of regulations and its implementation	45

Figure 2.2: Causes of Waterlogging[11]

2.3 SURVEY OF WATERLOGGING AND DRAINAGE PROBLEMS WITHIN DHAKA CITY

From a research paper of (Ali Ashraf,2009), the people's view of drainage, water logging and inland flooding problems had been taken into consideration through a questionnaire survey (Figure 2.3.1 & Figure 2.3.2). People from all part of the society had been taken into account – from local residents to businessmen living a lavish life, from students to people abiding in slums. The survey produced a clear result on the problems that Dhaka City dwellers has been living with due to unhygienic and unhealthy sewage flood.[12]

Aspects of enquiry	% responses
Level of Education	
Degree & above:	19.05 %
H.S.C:	14.29 %
S.S.C.:	09.52 %
Primary:	38.10 %
Illiterate:	19.04 %
Occupation of the respondents	
Business:	66.67%
Service:	28.57%
Student	04.76%
Duration of living in the area	
Above 10 years	14.29%
4 to 6 years	52.38%
1 to 3 years	33.33%
Response to Specific Questions on Drainage and Water logging:	
How do you drain your holding?	
Plot drain to primary drain / khal	31.60%
Plot drain to secondary drain	00%
Plot drain to tertiary drain	63.20%
Plot drain to vacant plot	5.20%
Whether the sizes of drain are sufficient to carry rainwater in his area?	
Drain size sufficient	73.68%
Drain size insufficient	15.79%
No drain	10.53%
Whether there is backwater flow/flooding from khals in your area during tide?	
Yes	85.71%
No	14.29%
Whether water logging occurs during long duration high rainfall?	
Yes	61.90%
No	38.10%

Figure 2.3.1: Survey Result[12]

What is the duration of submergence of main road in your area?	
No submergence	85.72%
More that 2 hours submergence	N
1 to 2 hours submergence	14.28%
What is the duration of submergence of secondary road in your area?	
No submergence	66.67%
More than 2 hours submergence	19.04%
1 to 2 hours submergence	14.28%
What is the duration of submergence of Mohalla road in your area?	
No submergence	28.57%
1 to 2 hours submergence	66.67%
More than 2 hours submergence	04.76%
How many times per year flooding/water logging takes place in your area?	
10 times and above	57.14%
7 to 9 times	04.76%
4 to 6 times	04.76%
1 to 3 times	23.81%
No Flooding	09.53%
How much area of your mohalla remains inundated for more than one hour?	
No inundation	23.81%
More than 30% inundation	52.37%
21% to 30% inundation	14.39%
0 to 10% inundation	09.52%
Did you notice any reduction in property value because of flooding and water logging?	
No reduction in property value	52.38%
5% to 20% reduction in property value`	28.57%
Above 20% reduction in property value	19.05%
What is the amount of loss per year to your property / commodity / shop etc. because of flooding?	
No Loss	52.38%
Tk. O/- to 1,00,000/-	47.62%
Tk. 1 Lac & above	NI
What in your opinion is the main cause of flooding and water logging in your area?	
Inadequate storm water drainage	45.00%
Indiscriminate dumping of solid waste	15.00%
Tidal effect	10.00%
Combination of all above	20.00%
Not applicable to our area	10.00%

Figure 2.3.2: Survey Result[12]

From the survey we can conclude that problems such as drain size sufficiency, waterlogging during heavy rainfall, long duration of submergence of main, secondary roads and even “*mahalla goli*”.[12] From this we can say, according to the people, the main cause of flooding is inadequate stormwater drainage. Hence along with solid waste dumping, these storm water drains gets blocked causing more hazard and problems to the society and environment.

Figure 2.4.1 & 2.4.2: Water logged areas in Dhaka Metropolitan

Chapter 3 - Structural Apparatus

3.1 Structural Apparatus

This section contains the materials we have used to build our robotic system. The variety of components were chosen based on their reliability, availability and also economic feasibility.

3.1.1 Stainless Steel (SS) box pipes for body

The structure has been built up using U.S.A Standard (304 Grade) stainless steel. It is the most widely used stainless steel with good performance. Its carbon content is lower and it is corrosion resistance. It is less susceptible to intergranular corrosion after welding and also non-magnetic. This is optimal for the design as the process includes numerous welding and non-magnetic property also proves vital in cases of interference with the electric motors being used. It has a density of 7.8x1000kg/ m^3 at 25℃. Elastic modulus at 190 - 210 GPa and tensile strength around 515 Mpa [2]. This material provided the strength of holding a rigid and strong body which could carry the heavy weights of both the motors and the waste collecting box. The welding resistant property proved extremely crucial. This allowed the solid attachment of the body parts, preventing undesired vibration and friction among the parts. As our working field consisted of water, corrosion resistance property of the steel enhanced our design even further.

Figure 3.1: SS Rectangular Pipe

3.1.2 Aluminium sheet metal

Aluminium sheet metal was used as the primary component of the waste collecting box. It is flexible so can be bent and mended easily. Also its size to weight ratio is feasible to the design, moreover its economic. For our prototype testing aluminium was ideal as we critically needed a smooth surface to unload the waste from the disposal box by sliding waste across the surface at an angle as well as the surface itself being immune to wear and tear by sharp objects like rocks and pebbles. It is also resistant to any kind of corrosion for a long period of time. The lightweight property makes it ideal for our actuator to operate on it releasing it from requiring heavy current.

3.1.3 FreeWheel 18T and Rickshaw chains

Bicycle free wheels of 18 teeth were used to connect the motors with the chain via an axle. The chains are strong which are formidable to take in the strain produced by the conveyor belt.

3.1.4 Polyurethane (Rubber) Wheels

These have a diameter of 18 cm, providing a suitable height of the robot above the drain. These four wheels bear all the weight of the machine.

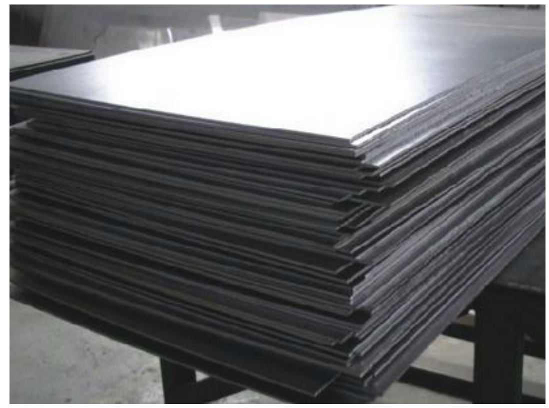

Figure 3.2: Polyurethane Wheel

Figure 3.3: Aluminium Sheet

3.2 Hardware components and Specifications

3.2.1 12 V DC Wiper Motors → Quantity - 3 (2 Rear Wheels + 1 Conveyor Belt):

- ➔ Input Voltage: 12 V, 24 V
- ➔ Braking Torque: 26 Nm
- ➔ Working Torque: 5 Nm
- ➔ Working Speed: 30 rpm
- ➔ Working Current: 4.3 A

DC motors has been in use from 1879 and small DC motors has been used in all types of applications ranging from aircraft to automobiles. In early days, brushed dc motors have been the conventional dc motors to use. Even though these brushed dc motors develops a full torque in static mode which linearly decreases with increasing velocity, these motors has its fair share of disadvantages. The principle disadvantage of brushed dc motor is excessive sparking and brush wear. The high rotational speeds of these motors causes increased brush wear and needs regular maintenance. This is why use of brushed dc motors, even though being cheap, they are not economically feasible.

Limitations of brushed motors can be overcome by brushless motors as they include higher efficiency and a lower susceptibility to mechanical wear brushless dc electric motor (BLDC motors) also known as electronically commutated motors (ECMs) are powered by a dc electric source. Brushless motors allows several advantages over brushed dc motors, including high torque to weight ratio, more torque per watt(increased efficiency), increased reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter.

The basic components of a brushless dc motors are

- A permanent magnet rotor
- A stator with three, four or more phase windings
- An electric circuit to control the phases of rotor windings.

Brushless dc motors functions by energizing one stator coil a time with constant dc voltage being applied. A stator magnetic field is produced when coil is turned on and the torque it produces is given by

$$\tau(induced) = kBr \times Bs$$

Br = Magnetic field strength of rotor,

Bs = Magnetic field strength of stator(armature/coil).

Brushless dc motors has two key performance parameters – Kv and Km. Km is the motor constant or specifically known as motor size constant. It is the ratio of motor torque in Nm and resistive power loss in Watts (W).

$$Km = {}^{\tau}/_{\rho}$$

Kv is the motor velocity constant measured in RPM per volt. It is the ratio of the motor's unloaded RPM to the peak (not RMS) voltage on the wires connected to the coils i.e. the *back-EMF*, Ke. By Lenz's Law, a running motor generates a back-EMF proportional to the RPM. Once the motor's rotational velocity is such that the back-EMF is equal to the battery voltage, the motor reaches its limit speed. On using a brushless dc motor operated at 12V dc line voltage, motor operates at an RPM of 45 RPM in no-load condition at 1.5A current. When pulling the load the dc motors operates at lower speed of 30 – 40 RPM, but the current increases to around 4A to 5Amperes.[8]

3.2.2 12 V Linear Actuators → Quantity - 3 (1 Conveyor Belt + 1 Waste Collector Box):

- ➔ Input Voltage: 12 V, 24 V
- ➔ Maximum Dynamic Load: 75 lb
- ➔ Maximum Speed: 3.0 inch/second
- ➔ Maximum Stroke Length: 6 inches

3.2.3 12 V Opto - Isolated Relays → Quantity - 5 (4 Rear Wheels Control + 1 Conveyer Belt Control):

- ➔ Working Voltage: 12 V
- ➔ Current signal: 3 mA
- ➔ Load Current: 30 A

3.2.4 L298N Motor Driver

- ➔ Operating supply voltage up to 46 V
- ➔ Total DC current up to 4 A

L298N is the most convenient motor driver for our prototype. It contains all three of driver logic, interlock, and power transistors featured in one package. Moreover it also has thermal-shutdown safety feature where it slows down and stops if overloaded. Per channel of L298N can handle up to 2A at 45V. Although we used an aluminium heat sink for our L298N, it can easily drive the 12V actuators we used without any stress.

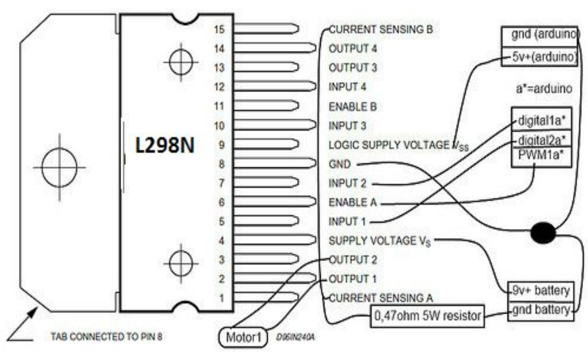

Figure 3.4: L298N connection with Arduino

3.2.5 Arduino Mega microcontroller based on ATmega 2560

- ➔ Operating voltage: 5 V
- ➔ Input Voltage: 6 - 20 V (Recommended 7 - 12 V)
- ➔ Digital I/O Pins: 54
- ➔ Analog Input pins: 16
- ➔ DC Current per I/O pin: 40 mA

The Arduino Mega is a microcontroller board based on the ATmega1280. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button.

For our thesis, Arduino Mega enabled us to control 5 relays, 2 actuators, sonar, proximity sensor and bluetooth module. The Mega was powered by a 9V battery and its digital pins were used to enable relays and actuators with precision and delays in systematic manner to make our system work. Arduino's Tx and Rx pins were used to send and receive data from bluetooth which was sent wirelessly by a Laptop. Arduino helped us to design a way where we could make relays, bluetooth module and analog sensors work together.

3.2.6 HC05 Bluetooth module

- ➔ Bluetooth protocol: Bluetooth Specification v2.0+EDR
- ➔ Frequency: 2.4GHz ISM band
- ➔ Emission power: ≤ 4 dBm, Class 2
- ➔ Sensitivity: ≤ -84 dBm at 0.1% BER
- ➔ Speed: Asynchronous: 2.1 Mbps(Max) / 160 kbps, Synchronous:1 Mbps/1 Mbps
- ➔ Power supply: +3.3 VDC 50 mA
- ➔ Working temperature: -20 ~ +75 Centigrade
- ➔ Dimension: 26.9 mm x 13 mm x 2.2 mm
- ➔ VCC 1.8 V to 3.3 V

HC-05 is the most economical and user friendly device we came across to communicate with our robot wirelessly. Only four connections were required between arduino and HC-05 to establish a connection between them.

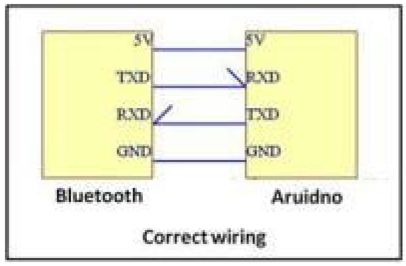

Figure 3.5: Connection between arduino and HC-05

3.2.7 HC-SRO4 Ultrasonic Sensor

- ➔ Working voltage: 5 V DC
- ➔ Working current: 15 mA
- ➔ Working frequency: 15 Hz
- ➔ Max range: 4 m
- ➔ Min range: 2 cm

This sensor sends out ultrasonic waves when a 10us high pulse is used in the IO trigger. A 40 kHz wave is transmitted through the transmitter and as the wave hits nearby objects it is reflected and comes back to the sensor. The waves are received by the receivers and the time duration from the sending and receiving is used to calculate the distance of the distant object using the following equation [9]:

Test distance = (high level time × velocity of sound (340 m/s) / 2

3.2.8 Infrared Proximity Sensor

- ➔ Operating voltage: 4.5 V to 5.5 V
- ➔ Analog output voltage: 0.25 V to 0.5 V
- ➔ Avg. current consumption: 33 mA to 50 mA
- ➔ Range: 10 cm to 80 cm

The 80cm Infrared Proximity Sensor is a General Purpose Type Distance Measuring Sensor, this sensor takes a continuous distance reading and returns a corresponding analog voltage with a range of 10 cm (4") to 80 cm (30").

This small sensor uses a connector called the Japan Solderless Terminal (JST) connector. These connectors have three wires: ground, vcc, and the output. The sensor fires continuously and does not need clocking to initiate reading [10].

3.2.9 12 V Battery

- ➔ Output Voltage: 12 V
- ➔ Capacity: 80 ah

Figure 3.6: Arduino Mega

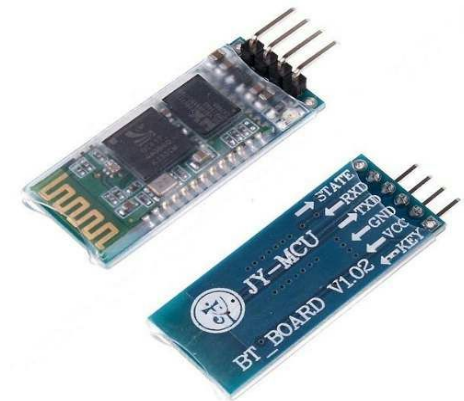

Figure 3.7: HC05 Bluetooth

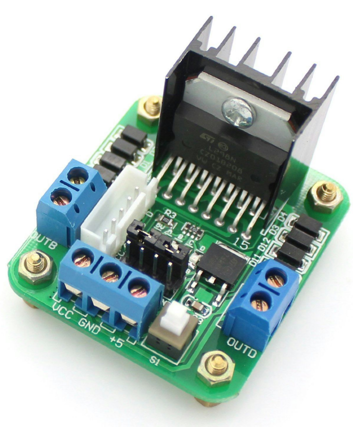

Figure 3.8: L298N Motor Driver

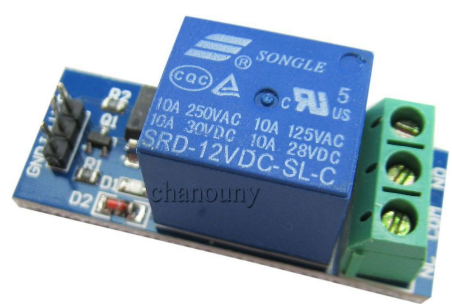

Figure 3.9: Opto-Isolated Relay

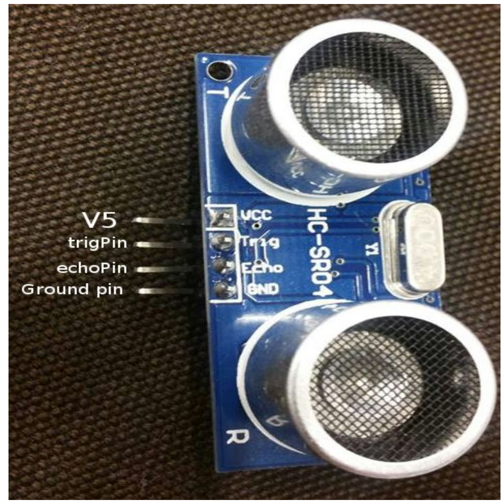

Figure 3.10: Infrared Proximity Sensor Figure 3.11: HC-SRO4 Ultrasonic Sensor

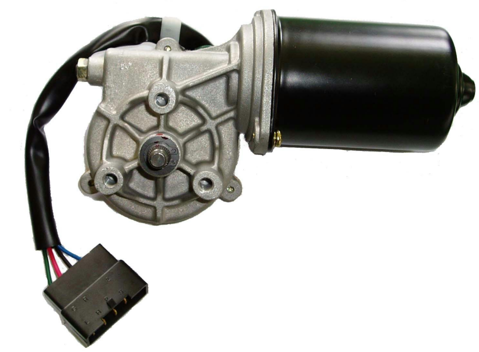

Figure 3.12: 12V DC Wiper Motor

Chapter 4 - Structural Design

4.1 Body

The main frame has a clearance of 8 cm from the surface. This is an ideal height for the machine as we must have a minimal height above the ground, decreasing the required length of the conveyor system. Furthermore, the lower to the ground our robot is the further we can reach into the drain and extract more waste increasing our efficiency.

The overall weight of the robot is 27 kg including the battery. The body width is 23 cm with each wheel connected via 12.5 cm axle with the body for greater stability. Wheel to wheel width is 46cm (18”) and the distance between the front to rear wheel is 77.5cm (30.5”). Exactly these measurements were selected was due to the fact that the survey data provided information about the widths of the drains which ranged from 20 cm to 50 cm. Thus, an optimal width was selected which provided us the ability to work with most of the neighbouring drains also keeping the cost of the robot at a minimum without losing any necessary functionality.

Keeping a clearance of 3” from the front, a separate body holding the conveyor belt is joined via hex bolts at an angle of 65°. The chosen angle gave it enough depth into the drain, and also provided the minimum height above the waste collecting box. This along with the momentum of the rotation of the conveyor causes the waste to fall into the box without much spill over.

The rear wheels are connected to two 12V dc wiper motors at each ends. This provides enough power and torque to push the whole structure forward.

FIgure 4.1: The main frame without the disposer box.

4.2 The Conveyor System

Half by one SS box pipes were used to make the skeleton of the conveyor system. This was the only material available which was of lower cost and would give both the strength and lightweight feature of the conveyor. It has a total width of 20 cm and length of 55 cm + 16 cm for the claws. This range enables the conveyor and the claws to reach at a depth of 12 cm inside the drain enabling the robot to extract materials up to that range.

A proper belt speed was necessary to extract the waste materials efficiently. Material with which the belt is made, its throughput, belt width and attachment method into the system, all effects the rotation speed of the conveyor belt. Fast belt speed is beneficial because it can reduce belt width and tension in belt when throughput is constant, and due to our requirement it is necessary to have a quick rotation. This economizes on investment in belt and power consumption [3].

Figure 4.2: The Exoskeleton of the conveyor belt. Chain and motors have been installed to the steel frame.

A 12V DC Wiper motor is attached to an axle at the top end which would drive the belt in any direction desired. The axle is connected with 18 teeth ring on which the chain is placed.

Figure 4.3: Final stage of conveyor belt without the claws attached.

An actuator is attached to the center of the conveyer body. This gives it a necessary mobility of changing the depth of entry into the drain. This actuator movement also provides a necessary space for the disposer box to tilt when removing the collected wastes.

The slanting angle of the conveyer system had to be carefully calculated using trigonometry and was set to be 65 degrees. This enabled it to reach a proper depth inside the drain and also dispose the waste into the disposal box.

Figure 4.4: Final stage of conveyor belt.

4.2.1 Power calculation

Overcoming resistance while running is the main cause of power consumption. And some power is used in elevating material in sloping conveyor. Power on driving roller axle can be calculated by the following expression [4]:

$N_o = PV \div 1000$

So the motor power is:

$N = KN_o \div \eta$

Where K is a factor of safety and η is transmission device efficiency.

4.3 Waste Collecting Box

The waste collecting box is made out of aluminium sheet in dimension of 25 cm x 20 cm x 15cm. One side of the box is joined to the main frame at a height of 5cm via hinge and its bottom is connected to one end of a linear actuator whose other end is attached to the base of the main frame using a screw. This design allows the actuator to fit under the box when in compressed state and in extended state, tilts the disposer as well. The disposer box collects waste from the conveyor belt and using an ultrasonic sensor placed on the top, the level of waste collected is taken as input. When the desired level is attained, which means the box is filled with waste it is tilted at an angle greater than 90° which is more than enough to slide off the waste into a desired location.

Figure 4.5: Waste collecting box (from above)

Chapter 5 - Circuit Design

5.1 Motor Connection

The motors driving the rear wheels are connected in parallel to the battery through electronic relays. Each motor needs two relays, so a total of four relays forms the motor connection. From the figure, we can see the forward movement, two forward relays F1 and F2 needs to be turned on and the two relays B1 and B2 used for reversing the polarity for backward motion stay open. From the circuit we can note that using two relays ensures no shortening of the circuit. Similarly for reverse motion, forward relays stay open and the other two are connected.

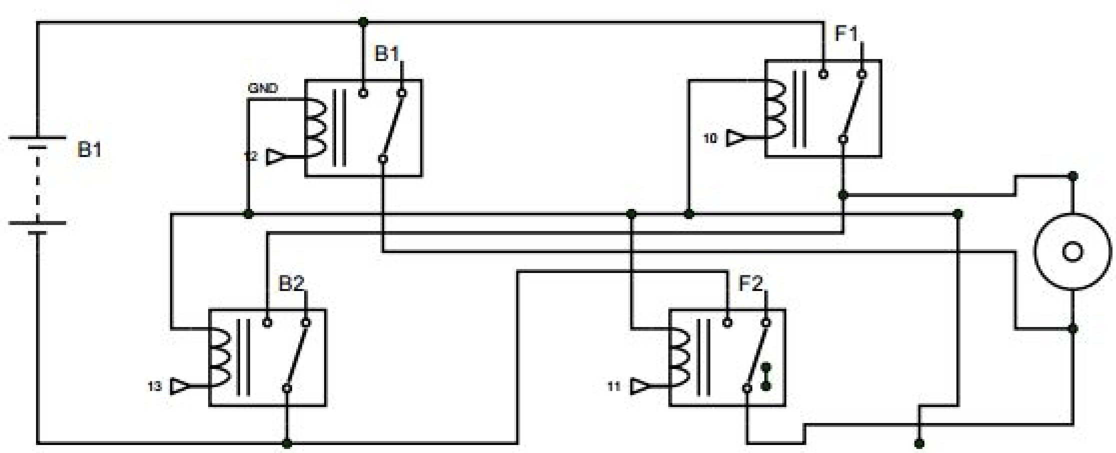

Figure 5.1: Motor Circuit Connection

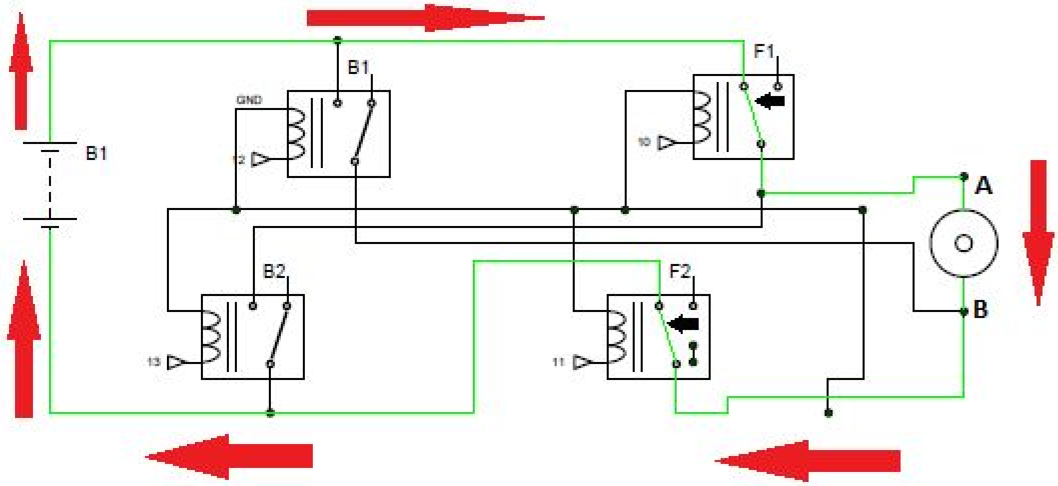

Figure 5.2: Current passes from points A to B through motor for forward Movement

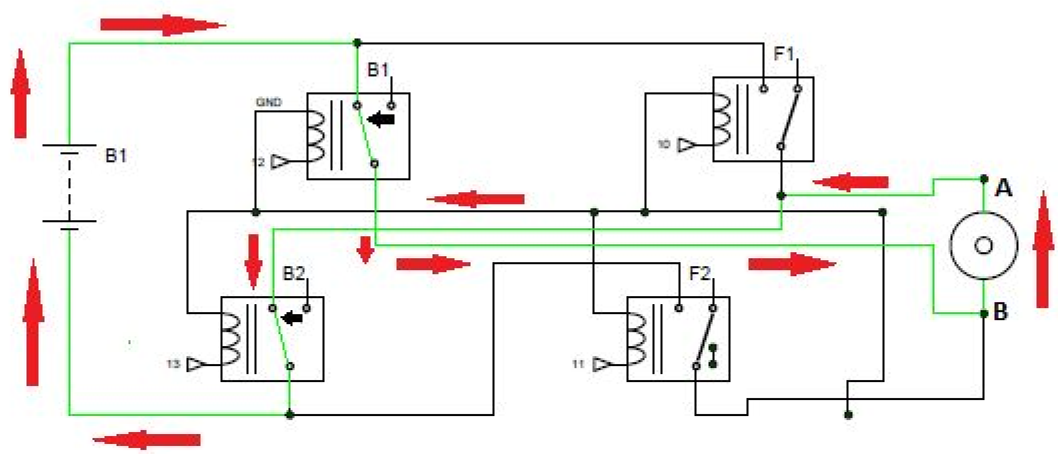

Figure 5.3: Current passes from point B to A through motor for backward movement

5.2 Conveyor Motor

The 12V dc motor used for running the conveyor motor is connected in series with an electronic relay to the battery. Since our design does not require the conveyor belt to move in reverse motion, using one relay to activate and deactivate the motor is sufficient.

5.3 Linear Actuator

The two actuators used in the circuit are connected to motor driver L298N which allows the actuators to be expanded and contracted through signals sent from the Arduino. L298N circuit can take load current of 4 amperes, thus using it for running both the actuators are feasible and economic.

5.4 Sonar Sensor

HC-SR04 is an ultrasonic sensor which sends an impulse of ultrasound and records the time it takes for the signal to bounce back and hence received. HC-SR04 has a range of 2cm to 400cm with resolution of 0.3cm. It operates at 5V DC at a standby current of 2mA. For the sensor to work properly, its trigger pin (connected to arduino mega) must be given 5V signal for a pulse of 10 microseconds interval. It allows HC-SR04 to issue 8 pulses of 40 KHz ultrasonic sound. The echo pin sends out a signal to the arduino when HC-SR04 receives the ultrasonic sound.

A sonar is used to check any obstacle beside the drain when disposing the waste. If there is any, the robot will not empty the box, instead it would move forward with its disposal box full of waste forward to find a place where there are no obstacle and then dispose them.

5.5 Arduino

This is the brain of our system. This integrates all the components together. It is powered by a 9 V battery. Analog A1 pin is connected to IR proximity sensor's analog input pin. Forward wheel relays connected to pin 10 and 11. Backward wheel relays in 8 and 9. Conveyor motor relay in pin 7. Pins 3 to 6 are connected with the L298N signal pins for the control of disposal box actuator and conveyor actuator. The trigger pin and the echo pin of sonar sensor are connected to pins 52 and 53 respectively. The bluetooth module through which signal is sent to the Arduino from the laptop is connected by the TX and RX pins.

Chapter 6 - Software

6.1 Arduino IDE

- This is an open-source Arduino Software (IDE), environment written in Java and based on Processing. This can be used with any Arduino based boards. The programs are written in C language and extremely easy to upload. It can be run on operating systems such as Windows, Mac OS X, and Linux [5] .

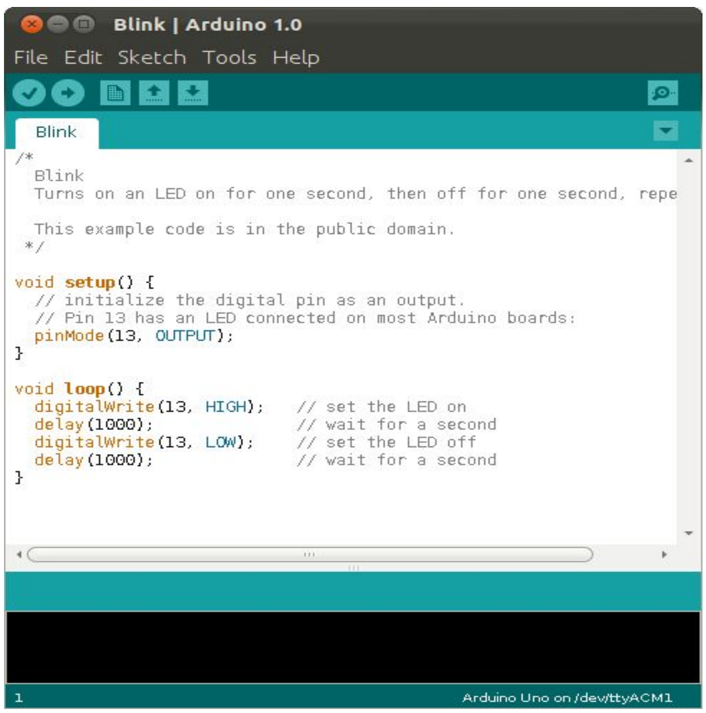

Figure 6.1: The Arduino interface

6.2 Tera Term

- Tera Term is an open source software which can emulate terminal mode allowing transfer to command from Laptop to Bluetooth Module to operate our device [6].

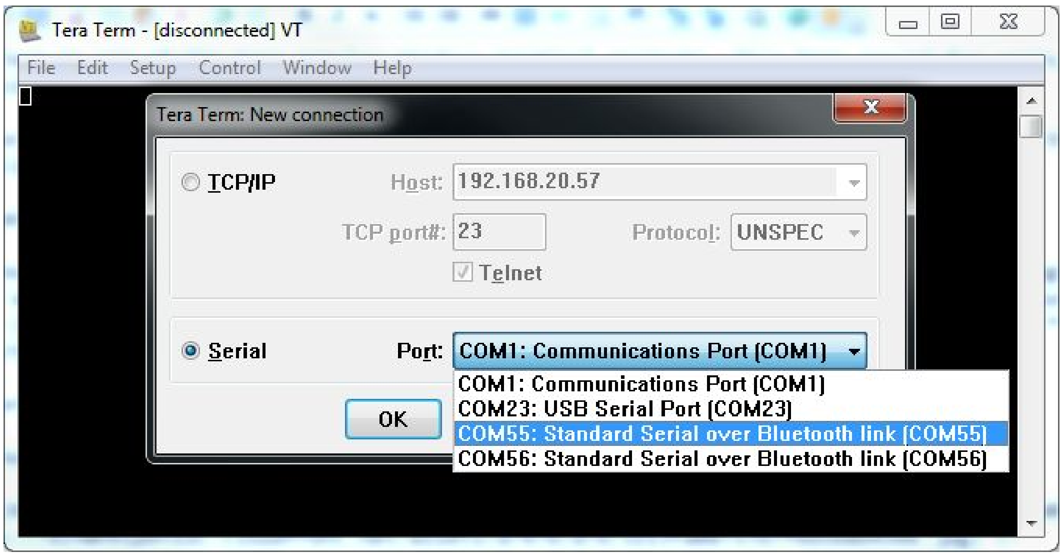

Figure 6.2: Tera Term interface

Chapter 7 - System Diagrams

7.1 Block Diagram

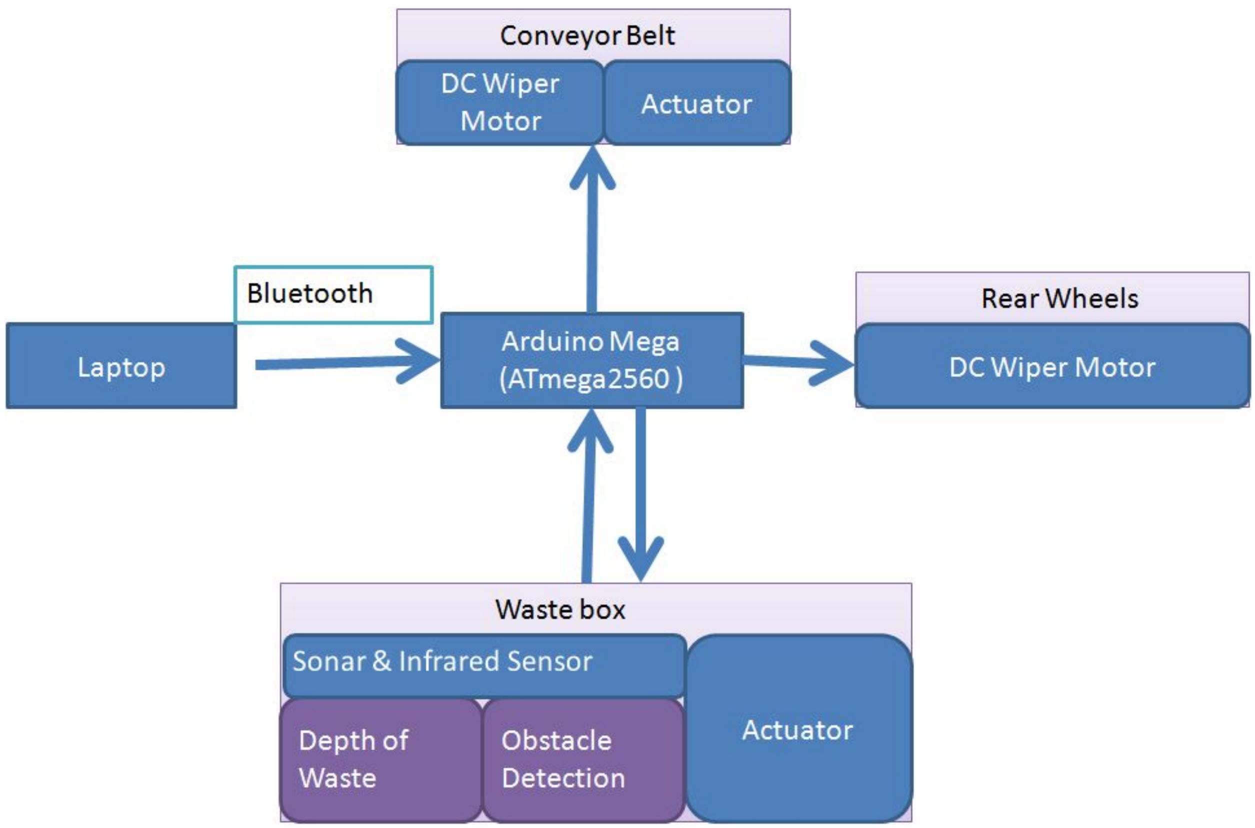

Figure 7.1: Block Diagram of the System

7.2 System Flow Chart

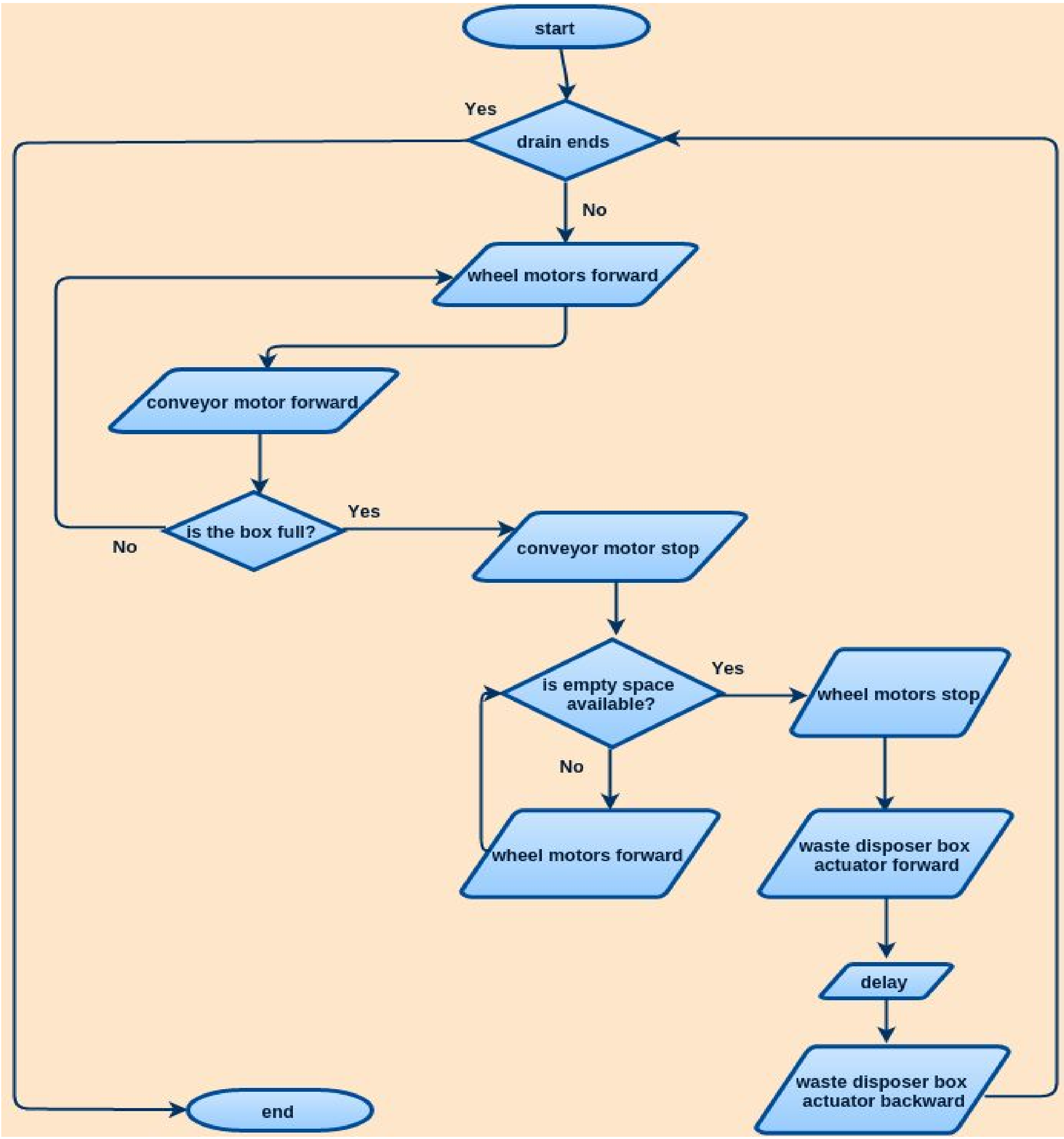

Figure 6.2: Flow Chart of the System

7.3 Circuit Diagram

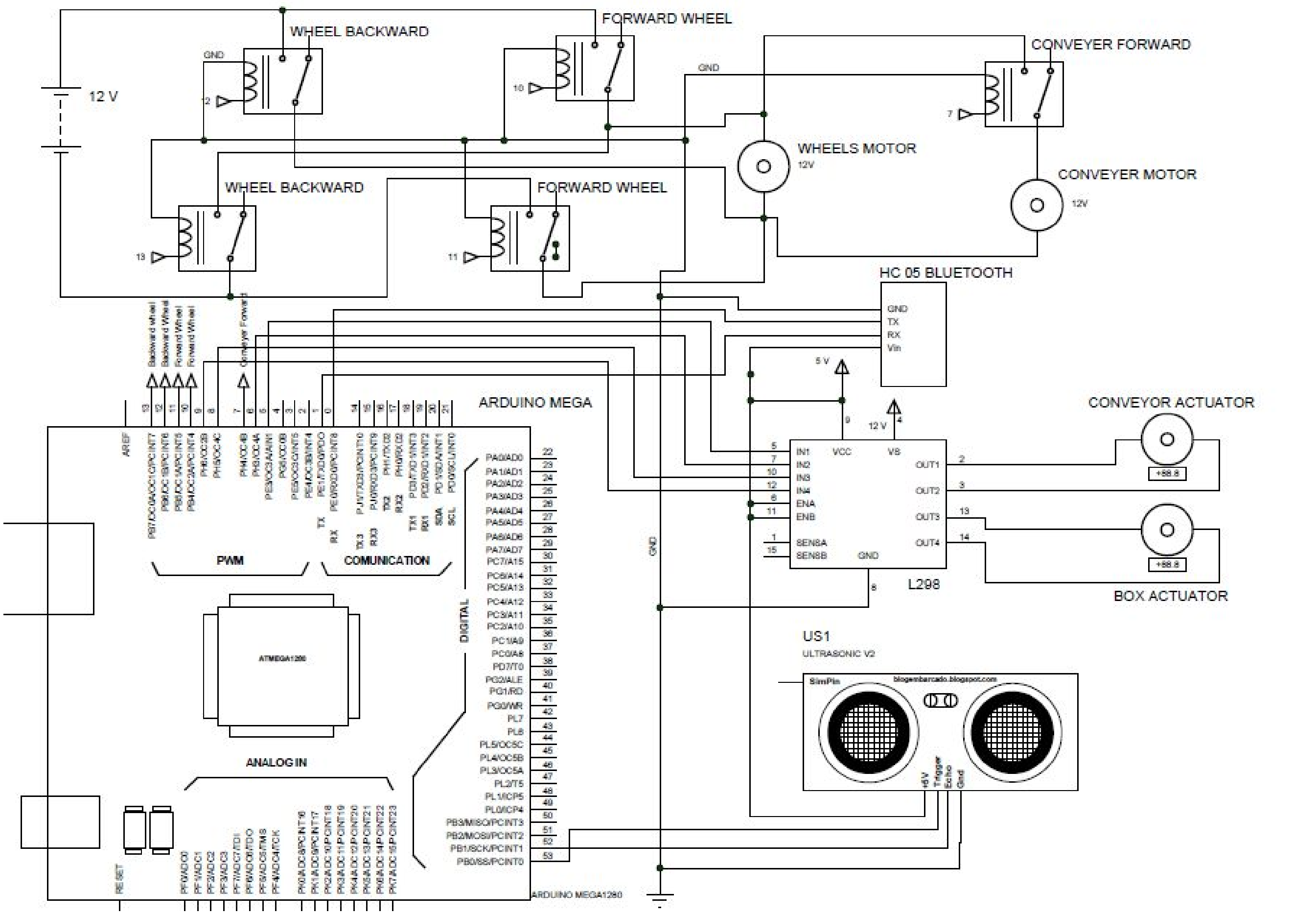

Figure 7.3: Circuit Diagram of the system made with Proteus

7.4 Final Circuit

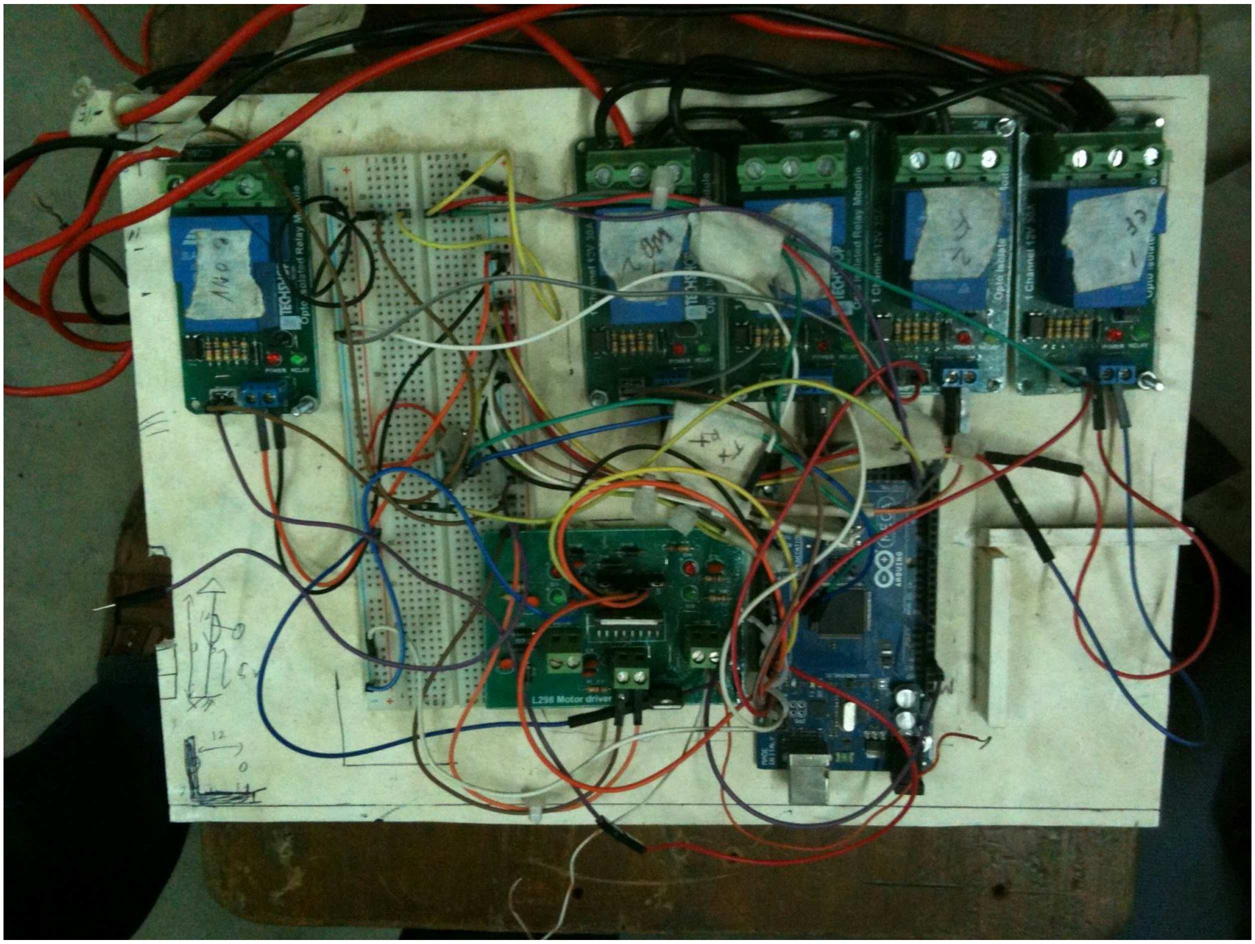

Figure 7.4: The Circuit used to run the system

We needed a strong, light and solid base to hold the circuit in place to overcome the vibrations of the machine when it is in motion. The microcontroller and relays were fixed with screws at the base made of hardwood. A baseless circuit box of roughly 10 inch length, 8.5 inch width and 3 inch height was made to act as a shielded cover for the circuit base since we did not want circuit to be exposed to too much dirt and moisture while in the field which could affect its performance and in the worst case damage it .

Chapter 8 - Miscellaneous

8.1 Testing Field

The ground on which our robot will be working on are the roadside drains in the local communities. The width of these drains usually vary from between 20 cm up to 50 cm (according to our survey in Uttara, Banani and Mogbazar). We have chosen a specific dimension of the drains to test our robot. Our conveyor belt is 20 cm and robot width is 46 cm, therefore our working dimension is above 20 cm and below 40 cm of drain width. The robot can reach a depth of 20 cm below the ground level which is sufficient to clear the floating solid materials which clogs up the drain. Furthermore, the sides of the drains must be on the same level so that the wheels are placed at equal heights.

Figure 8.1: Testing on a drain (in Banani, Dhaka)

8.2 Challenges and Hurdles

8.2.1 High Current

The 12V DC motors and actuators needs high current to operate (over 3 ampere each) so we had to ensure and design our circuit such that the high current does not pass through sensors and microcontroller by using high current rating relays. However, it did not prove to be enough as in some cases there is a surge in current when starting the circuit which damaged some of the relays itself.

8.2.2 Losing wireless control

Our robot can be operated wirelessly via bluetooth using a mobile phone, laptop or any device that supports bluetooth technology and can send commands wirelessly through it. We initially powered the bluetooth module with our microcontroller but the bluetooth connection with the laptop sometimes cut off as the microcontroller was also supplying power to sonar and infrared sensors resulting in the bluetooth module not getting sufficient power to operate and thus resetting wireless connection. To minimize this is issue we used the 5V voltage regulator provided by the motor driver to power the bluetooth module.

8.2.3 Sensor Errors

- Infrared Sensor: The infrared sensor sometimes produced erroneous readings due to the reflection of light from the disposal box and also due to the light in the surrounding environment. The readings had to be calibrated accordingly so that it performed flawlessly on the testing field.

- Sonar: When sonar and infrared sensors are run at the same time by the microcontroller, the readings from sonar is reduced to exactly half compared to when the microcontroller only runs sonar alone. This happens because the current supplied by the microcontroller became halved among the two sensors when microcontroller powers both at the same time. 5V voltage regulator on motor driver was used to power the sonar to give accurate readings without unwanted reductions.

8.3 Budget

We wanted our system prototype to be as much economically feasible as possible without compromising its quality, performance and efficiency.

Item	**Unit Cost**	**Quantity**	**Cost (BDT)**
12 V DC motor	1,100	3	3,300
SS Pipes			2,450
12V Opto isolated Relay Module	309	5	1,545
Arduino Mega 1280	1,486	1	1486
L298	250	1	250
Rickshaw Chain	200	1	200
Gear	50	4	200
Sonar	408	1	408
Bluetooth Module Breakout (HC-05)	634	1	634
Infrared Proximity Sensor	630	1	630
Linear Actuator	10,000	2	20,000
Others			600
Total			31,703

*** Price information taken from https://www.techshopbd.com/

Chapter 9 Conclusion

9.1 Results

We did a total of three field tests with our robot and upgraded it based on the performance after the first two tests. The third and final test provided satisfactory results where the robot performed positively in each aspect. The task was for the robot to collect as much waste material from the drain as possible in from of its moving path until it fills three-fourth of the box. At this point the infrared sensor detects the height and signals the arduino. The disposal mechanism is initiated and the disposal box displaces the waste at the side of the drain. Moreover everything is done automatically by the robot after the user gives the initiate command wirelessly via bluetooth. As the waste material we filled the path before the robot mostly with dead leaves along with plastic packets, polythene, etc. The robot managed to collect approximately 60% of the waste along its path. The waste stuck to the claws and the momentum of the rotation was used to throw the materials inside the box. The Infrared sensor successfully detected the height of the waste in the disposal box, when the box was approximately three-fourth full after which the wheel and conveyor stopped and the waste in box was displaced via extension of actuators. The tilt of the box produced by the actuator was sufficient enough to unload above 65% of the waste from the disposal box. Repeating this process over and over allows up to 80% of the waste to be removed from the drain.

Figure 9.1: The robot collecting leaves

Figure 9.2: Robot picking up polythene

Figure 9.3: The robot unloading the disposal box

9.2 Problems encountered on the final field test

- The claw area covered the middle section of the drain thus some waste would slip away by flowing in the region between the outer claws and the outer walls of the drain resulting in lower efficiency for the overall waste collected.
- Because of uneven terrain, the robot would sometimes move forward with the motion of single wheel only instead of two causing the alignment between the robot and moving path to break and the claws getting stuck at one side of the drain.
- After second field test we adjusted the height of the conveyor with the base of the robot so we could maximise the amount of waste collected by the claws. However the water level was at a reduced level on the final field test compared to the water level of the second test. This reduced the rate at which the waste was collected since the claws were not efficiently picking up waste below the water level.

9.3 Future Works

- Our system must be restructured to travel on flat, open space. For that, the conveyor system must be leveled to be above the ground. This will give us more mobility and it can also be transferred to different areas with much ease. This will bring further advantages of clearing garbage on land. A study by BRAC institute of Governance and development (BIGD) of BRAC University found that 57 per cent of the roads and open space of the capital are not cleaned daily [7]. Thus, we see huge land filled with garbage which is a great hassle to the neighbourhood. Our robot would be able to clean and manage these landfills much faster and save the workers from many diseases.
- Implementing a direction control is required. Once it is able to travel on flat land, direction control would be necessary. We would need further motor drivers to control speed of motor.
- An image processing algorithm which will enable us to detect a perfect place to dispose the waste. It will have to detect an open space and also with no human around. The algorithm would also help in detecting the garbage and directing the robot towards its objective.
- An efficient and lighter version of the robot which will consume less energy and will be able to carry more waste than before. The percentage of waste that can be transferred to the disposer box could be improved with more tilt to the conveyer and restructuring the disposer box.
- A damped wheel could later be added as the land surrounding the drain are uneven which causes the body to turn and eventually get stuck with the drain line. As another solution, two smaller wheels can be attached with the body which would move with the inner walls of the drain keeping the body of our robot in line with the drain.
- The waste disposing box made of aluminium sheet metal has a smooth surface, so the wet solid wastes like polyethenes, leaves has high coefficient

of friction with the box surface. Thus as a result, even though the box tilts at an angle of 90°, the efficiency of disposing is less as wastes tends to stick to the surface. Hence in the future, the disposing box could be made from other materials with lower coefficient of friction with wet wastes to increase the efficiency. Moreover, the box could also be coated with hydrophobic coating to reduce the friction with wet surface.

References:

1. "Product Catalogue Stainless Steel," *Product Catalogue Stainless Steel*, pp. 5,64–5,64, Sep-2013.
2. "Dhaka drainage system needs immediate attention of the authorities, experts say,"*The Daily Ittefaq*, Sep-2013.
3. Z. Zhang, F. Zhou, and J. Ji, *Parameters Calculation and Structure Design of Pipe Belt Conveyer*. 2008, pp. 614–617.
4. M. A.E, "Power and Capacity Review of Tubular Pipe and Trough Conveyors," *Bulk Solids Handling*, vol. 17, no. 1, pp. 47–50, 1997.
5. "Arduino," *Arduino*. [Online]. Available at: https://www.arduino.cc/en/.
6. "Tera Term", [Online] Available: https://www.ttssh2.osdn.jp/
7. A. H. M. M. Hossain, "Households in city dispose waste in open space: Study.," *The Financial Express*, 2015.
8. S. Chapman, "Three Phase Circuits," in *Electric Machinery Fundamentals*, Fourth., New Delhi: McGraw-Hill International Education Private Limited, 2012, pp. 674–677.
9. *Ultrasonic Ranging Module HC - SR04 Datasheet*. Micropik, 2005.
10. *Optoelectronic device GP2Y0A21YK Datasheet*. Sharp, 2005

11. M. Z. Islam and S. Chowdhury, “Solid Waste Management and Drainage Facility concerns in the Real Estate Management: A Study on Dhaka City,” *Journal of Bangladesh Institute of Planners*, vol. 13, no. 1, pp. 102–107, 2014.
12. M. A. Ashraf and M. S. Chowdhury, “Drainage Planning in the Cities of Bangladesh: Case Study of Drainage and Water Logging in Chaktai Commercial area, Chittagong,”*Journal of Bangladesh Institute of Planners*, vol. 2, pp. 55–57, 2009.
13. Q. A. Mowla and M. S. Islam, “Natural Drainage System and Water Logging in Dhaka: Measures to address the Problems,” *Journal of Bangladesh Institute of Planners*, vol. 6, pp. 28–32, 2013.

Appendix

Code in C

```
#define IR_PROXIMITY_SENSOR A1 // Analog input pin that is attached to the sensor
#define wheelF 10   //Wheel Forward     "W"
#define wheelFF 11
#define wheelB 8   //Wheel Backward    "w"
#define wheelBB 9
#define convF 7   //conveyer Forward   "C"

int actConvF = 3;  //actuator forward  "A"
int actConvB = 4;  //actuator backward "a"
int actBoxF = 6;  //actuator forward   "B"
int actBoxB = 5;  //actuator backward  "b"

int triggerPin = 53;
int echoPin = 52;
long duration, obstacleSonar;
float voltage;
byte incoming;

void setup() {
 Serial.begin (9600);
 pinMode(wheelB, OUTPUT);
 pinMode(wheelBB, OUTPUT);
 pinMode(wheelF, OUTPUT);
 pinMode(wheelFF, OUTPUT);
 pinMode(convF, OUTPUT);
 //pinMode(convB, OUTPUT);
 pinMode(actConvF, OUTPUT);
```

```
 pinMode(actConvB, OUTPUT);
 pinMode(actBoxF, OUTPUT);
 pinMode(actBoxB, OUTPUT);

 pinMode(triggerPin, OUTPUT);
 pinMode(echoPin, INPUT);

 Serial.println("F = wheels forward, C = conveyer, A = Conveyer actuator forward, a = 
Conveyer actuator backward");
 Serial.println("B = Box actuator forward, b = Box actuator backward, s = total off");
}
void loop() {

  if (Serial.available() > 0)
  {
   incoming = Serial.read();
   off();
   if (incoming == 'F')
   {
     int flag = 1;
     while(flag == 1)
     {
       incoming = Serial.read();

  digitalWrite(triggerPin, LOW);
  delayMicroseconds(2000);
  digitalWrite(triggerPin, HIGH);
  delayMicroseconds(15);
  digitalWrite(triggerPin, LOW);
  delayMicroseconds(10);

  duration = pulseIn(echoPin, HIGH);
```

```
  //duration = duration/1000000;//convert pingTime to seconds by dividing by 1000000 (microseconds in a second)
 obstacleSonar = microsecondsToCentimeters(duration);
 Serial.print("Obstacle sensor: ");
 Serial.println(obstacleSonar);
 delay(500);
 voltage = getVoltage();
 Serial.print("              sensor voltage  = ");
 Serial.println(voltage);

   Serial.println("Motors forward");
   ConveyerFor();
   delay(2000);
   WheelsForward();

  if(voltage > 450)    //box is full
  {
   ConveyerOff();
   Serial.println("Conveyer off");
   if(obstacleSonar > 50)
   {
     Serial.println("Dispose waste");
     WheelsOff();
     delay(2000);
     ActConvForward();
     delay(2000);
     ActBoxForward();
     delay(15000);
     off();
     ActBoxBackward();
     delay(10000);
     ActConvBackward();
```

```
    delay(4500);
    off();
    delay(2000);
    ConveyerFor();
    delay(2000);
    WheelsForward();
    flag = 0;
    Serial.println("Loop done.");
  }
 }
 if(incoming == 's')
    {
      Serial.println("s has been pressed");
      flag = 0;
    }
}
 }
 if (incoming == 's')
 {
   Serial.println("Off");
   off();
 }
 if (incoming == 'W')
 {
   off();
   Serial.println("wheels forward");
   WheelsForward();
 }
 if (incoming == 'w')
 {
   off();
   Serial.println("wheels backward");
```

```
  WheelsBackward();
}
if (incoming == 'C')
{
  off();
  Serial.println("conveyer forward");
  ConveyerFor();
}
if (incoming == 'A')
{
  off();
  Serial.println("ConvAct forw");
  ActConvForward();
}
if (incoming == 'a')
{
  off();
  Serial.println("ConvAct backwrd");
  ActConvBackward();
}
if (incoming == 'B')
{
  off();
  Serial.println("ActBox forward");
  ActBoxForward();
}
if (incoming == 'b')
{
  off();
  Serial.println("ActBox backward");
  ActBoxBackward();
}
```

```
 }
}
void WheelsForward()
{
 digitalWrite(wheelF, HIGH);
 digitalWrite(wheelFF, HIGH);
}
void WheelsBackward()
{
 digitalWrite(wheelB, HIGH);
 digitalWrite(wheelBB, HIGH);
}
void WheelsOff()
{
 digitalWrite(wheelF, LOW);
 digitalWrite(wheelFF, LOW);
 digitalWrite(wheelB, LOW);
 digitalWrite(wheelBB, LOW);
}
void ConveyerFor()
{
 digitalWrite(convF, HIGH);
}
void ConveyerOff()
{
 digitalWrite(convF, LOW);
}
void ActConvForward()
{
 digitalWrite(actConvF, HIGH);
 digitalWrite(actConvB, LOW);
}
```

```
void ActConvBackward()
{
  digitalWrite(actConvB, HIGH);
  digitalWrite(actConvF, LOW);
}
void ActBoxForward()
{
  digitalWrite(actBoxF, HIGH);
  digitalWrite(actBoxB, LOW);
}
void ActBoxBackward()
{
  digitalWrite(actBoxB, HIGH);
  digitalWrite(actBoxF, LOW);
}
long microsecondsToCentimeters(long microseconds)
{
  //speed of sound is 340 m/s or 29 microseconds per centimeter
  return microseconds / 29 / 2;
}
float getVoltage()
{
	int sensor_value;
	int sum;
	// read the analog in value:
	for (int i = 0;i < 20;i ++)//Continuous sampling 20 times
	{
		sensor_value = analogRead(IR_PROXIMITY_SENSOR);
		sum += sensor_value;
	}
	sensor_value = sum / 20;
	return sensor_value;
```

```
}
 void off()
 {
   digitalWrite(wheelF, LOW);
   digitalWrite(wheelFF, LOW);
   digitalWrite(actConvF, LOW);
   digitalWrite(wheelB, LOW);
   digitalWrite(wheelBB, LOW);
   digitalWrite(actConvB, LOW);
   digitalWrite(actBoxF, LOW);
   digitalWrite(actBoxB, LOW);
   digitalWrite(convF, LOW);
 }
```