

# Open Source, Low Cost Combine Harvester



A Thesis submitted to the Department of Electrical and Electronic Engineering in partial fulfillment of the requirements for the degree of Bachelor of Science in Electrical and Electronic Engineering

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# DEDICATION

This project is sincerely dedicated to

*Our prophet*

**MOHAMMAD [PBUH]**

The mercy of all humankind

*Our parents*

Who have supported and encouraged us throughout the years

&

Our beloved Motherland

# DECLARATION

We, hereby declare that this thesis titled, "Open Source, Low Cost Combine Harvester" is our own original work. The research work is done by us and no other. Materials of work from research conducted by others have been properly mentioned in the Reference section. Our thesis, neither in part nor in whole, has been previously submitted anywhere else for assessment. This is to affirm that this thesis report is submitted by the authors listed for the degree of Bachelor of Science in Electrical and Electronic Engineering to the Department of Electrical and Electronic Engineering under the School of Engineering and Computer Science, BRAC University.

Signature of Supervisor

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# ABSTRACT

Bangladesh is widely known as an agricultural country. A large number of its population depends on it to earn their livelihoods be it directly or indirectly. A major portion of this country's earnings comes from this sector. Even though Bangladesh has one of the most fertile land in the world, it still lag behind in terms of the crops production [15]. A major reason behind this is the lack of modern technology. The lack of proper technique, substance and machine keep us from the optimal production value. Being a developing country, the use of modern machinery in this sector is very low. Farmers of our country still use traditional tools like a hoe, sickle, fork etc. This is a huge wastage of time and capital. The reason behind the absence of modern machinery in our farming sector is the shortage of capital. Being poor the farmers can hardly support their family let alone spend tens of lakhs behind high tech machinery. With is in mind, we are proposing to build a single piece of a machine which will not only cut the paddy but also extract and store the rice in real time on the field with zero wastage of the crops and time. The main goal here is to make the machine within a low budget so the common farmer can afford it.

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# CHAPTER 1: INTRODUCTION

The use of machinery in agriculture sector started far back in the early 20<sup>th</sup> century which has only increased since then. Self-propelled harvester, planters, transplant have been developed that further revolutionized the agricultural sector. The modern combine harvester is one of the most popular machines used in the agricultural sector. This single machine performs three primary harvesting operation of reaping, threshing, and winnowing of a variety of grain crops. Now developed and many developing countries are using this machine to increase productivity. Though Bangladesh is known as an agricultural country the use of any modern machine in agriculture is surprisingly low. Being a developing country the farmer cannot afford the sky-high price of the industrially made combine harvester. They spend a few days just to harvest the crops which in turn lower the productivity and increase the expenditure. With this in mind, the main goal of our project is to build a combine harvester within an affordable price.

## 1.1 PROJECT OVERVIEW

---

The main goal of this research is to make a harvester that can lower the paddy collecting cost. As the labor cost during the paddy collecting time is too high this eventually increases the cost of production. Therefore, we intend to introduce electric equipment that can bring good pace in harvesting rice. The second goal is to make a harvester at the lowest possible cost with the equipment we have in our country so that our farmer could afford it and maintain it. Thirdly, instead of fuel power we intend to use rechargeable electrical sells to power the machine so that diesel engine can be replaced with the electric motors which do not only reduce cost but also allows us to control motor action with digital signals. Therefore, automation of the system gets easier eventually providing us the opportunity of controlling the machine remotely. Besides, we intend to develop an android application to control the machine, as an Android mobile is cheaper nowadays and easy to operate even for the farmers of our country.

## 1.2 MOTIVATION

---

Bangladesh is a land of agriculture which works as the biggest motivation for us to work on the development of agricultural equipment. Majorities of the country's population are engaged in this sector. Furthermore, Bangladesh is ranked fourth in the world in producing rice [4], therefore, we can expect more investment in using as well as developing agricultural machines, but this is not the scene nowadays. Unlike many developing and developed countries using modern technologies to cultivate or to harvest rice is still not very much popular among rural people. The majority the farmers are poor and totally unable to pay the cost of modern machines even though our government is offering a huge subsidy. So, the objective is to build a combine harvest at a lower cost so that the farmers can buy it. In addition, using a harvester instead of manpower can help reducing production costs and time needed; this creates an opportunity for us to contribute to society with the idea of an electric harvester.

## 1.3 HISTORY OF HARVESTER AND THE PRESENT SCENARIO

---

Combine harvester is a large-scale multi-functional agricultural equipment integrating functions of picking, conveying, threshing and separating, and its working mechanism and electrical system are complicated (Sun, Chen, Wang, & Wang, 2018)[8]. Earlier in the past harvester were only able to reap crops and were driven by various animals. But Modern harvesters are capable of reaping, threshing and winnowing while those are powered by an engine. The 1<sup>st</sup> reaper machine was invented in Scotland by Patrick Bell in 1826. The 1<sup>st</sup> combine harvester is invented in the USA by Hiram Moore in 1835 and it was driven by 20 horses [5].

In 1911, the Holt Manufacturer Company of California produced a self-propelled harvester. After the Second World War combine harvester and tractor became popular in agriculture.

Presently there are so many companies manufacturing combine harvester.



Fig. 1.1: Early 1990 horse-drawn reaper harvester [2]

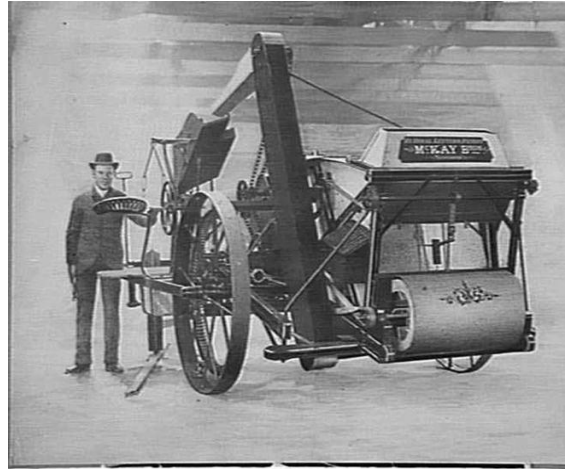


Fig. 1.2: Early Sunshine harvester [1]



Fig. 1.3: First prototype Fox forage harvester in the 1930s [3]



Fig. 1.4: John Deere T-series Harvester 2018

John Deere an American manufacturer made the 1<sup>st</sup> electric tractor in 2017. Till now, there is no automated or electric combine harvester is manufactured.

#### 1.4 ECONOMIC IMPACT OF HARVESTER IN BANGLADESH

---

Still, most of the people of Bangladesh are engaged in the agriculture sector and rice is the main crop here. Around 75 percent of agricultural land is used in rice production [6]. According to BBS (Bangladesh Bureau of Statistics) report of 2018 agriculture sector is contributing 15 percent to the GDP and providing employment to 43 percent of the whole population [7]. Currently,

Bangladesh is the fourth largest country among the Asian country and sixth largest in the world in terms of rice production. Though there are so many people are involved in this, productivity is still low compared to other Asian countries like Malaysia and Indonesia. There is a big scarcity of technology in our agriculture field. Even now, our farmers use the conventional method of farming with conventional equipment. Meanwhile, the technology we import from other countries is too costly for our farmers. This is the big reason that our agriculture is not growing enough even though we have better land and more manpower than other countries in this sector.

During harvesting season, the labor cost is too high. A harvester can reduce cost and time both. Not only it can reap the crop but also can separate the grains from paddy too. As it is made in our country it will be cheaper than imported pieces of machinery. Moreover, an electric harvester will cost lesser as the cost of electricity is lower than diesel.

## 1.5 METHODOLOGY

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We have divided the whole project into three stages and we will complete each stage respectively.

- 2 Stage 1: Developing paper model.
- 3 Stage 2: Constructing 3D model of each module using Autodesk Fusion 360.
- 4 Stage 3: Implementation of the real machine in robotics work shop.

## 1.6 SCOPE OF WORK

---

Due to the lack of time, funding and experience, we could not finish the project as we first envisioned. Many features can be upgraded to make this machine easier to operate. Through the use of the solar panel, the harvester can be self-sufficient in energy. By using a servo motor with pitman arm the steering system can be made. On top of that, by using lightweight metal the energy consumption can be greatly reduced.

# CHAPTER 2: SYSTEM DESCRIPTION

## 2.1 INTRODUCTION

---

Before designing the main machine, we decided to divide the working of the machine into three parts reaping, threshing, and winnowing. Besides that, we need to determine the size of the machine and how reaping, threshing, and winnowing will be done by the machine. The most important thing is to hold the paddy inside the machine and carry it to the threshing section. As no one shares the working principles of the harvester it becomes very difficult to decide what to do at first. We have gone through some videos and articles of harvester that can collect paddy and made an assumption of the working principle. After visiting a fair on combine harvester in the premises of KIB (Krishibid Institution Bangladesh) Complex in February 2018 at Farmgate, Dhaka, we made the final decision of the design and construct a demo paper model of the machine. The system description of the machine is given below.



Fig. 2.1: Primary paper model

## 2.2 REAPING

---

In the agricultural sector by reaping we mean the cutting of crops when they are ripe. It involves cutting and often gathering of crops. The crops are most of the time is cereal grass like rice and wheat. Now in a harvester reaper involves both cutting and gathering. To make the whole process simple we divided it into three distinct part. They are windrow, push in gear and cutting blade.

Before designing a cutting module, we took the height of the crops into consideration. With rice as the main target for our machine, some simple data had to be gathered. The maximum height of the plant is around 2-2.5ft. The grains are usually at the top 0.5-1ft. area. So the position of push in gear and cutting blade cannot be more than 1ft. of the ground.

### 2.2.1 WINDOW

---

Before the crop enter into the machine, we have to be sure that it is not leaning towards any side. If the crop doesn't enter into the machine in a straight manner then it may cause complications in the conveyor lines. There is a gate with 10-inch width and 24-inch height through which the crops will enter the machine. Now to make sure the crops enter straight, we are using 2 belts with 2 motors separately running it at each side of the gate. The belts have moderately long and thick wooden teeth attached on its outer surface. Now the motor on the right will run in a clockwise direction and motor on the left will run in the anticlockwise direction.

### 2.2.2 PUSH-IN GEAR

---

After window, we have push-in gear. In our machine, the push in gear is 2 iron gear run by a single motor. The main objective of this is to hold a batch of crops tightly for the cutting blade. Otherwise, there is a possibility that the crops will just brush past the blade edge without cutting. The gear also ensures that the crops will enter the chain line which will take it for the threshing part.



### 2.2.3 CUTTING BLADE

---

The last part of the reaper is the cutting blade. It is positioned right under the push in gear. The blade is two circular shaped disks with sharp edges. One of the disks is stationary while another one is rotating by a motor. Both the power and rpm of the blade had to be optimal with neither high rpm low power nor low rpm high power. Otherwise, the complication could arise in the cutting process.

## 2.3 THRESHING

---

Threshing is a major part of the harvesting of crops. This is a process of loosening or gathering the edible part of grain from the husks or straw to which it is attached. This process is expected to be executed immediately after the reaping part. In our project threshing is divided into two parts which are the chain line travel and the threshing drum [11] [12].

### 2.3.1 CHAIN LINE TRAVEL

---

From the push in gear and cutting blade, the crops directly enter the chain line. This chain grid line takes the crops from the blade to the threshing drum. For making the process more convenient and easy, we used two chain grid line. We used two chain line to keep the width of the harvester to a minimum. The first grid line is angled towards the far left side of the machine where the second line starts immediately. Now almost at the end of the first line, there is a frame which will make the part of the crop with grain horizontal to the ground. The second line is parallel with the threshing drum.

### 2.3.2 THRESHING DRUM

---

The final part of threshing is the threshing drum. Our threshing drum was designed in such a way that it would separate and store the grain at the same time. Our threshing drum consists of a half-cylindrical shape drum with a small roller stationed at the centre of it. The roller has U shape hoop all over its surface. The roller is programmed to rotate clockwise direction by a motor. When the paddy travels alongside the line, the horizontal part of the paddy will enter the threshing drum. Paddy will be hit continuously by the spikes of threshing drum and by those hits the paddy grains will be separated from the paddy. In the end part of the threshing drum, the whole paddy grains will be separated from the paddy and paddy will leave the threshing drum and will be released from the chain line as well as the machine.

### 2.3.3 COLLECTING PADDY

---

Collection of the paddy grains will be done in two steps. The two steps are described below.

#### 2.3.3.1 CONTAINER DRUM

---

The paddy grains that are separated from the threshing drum will be stored in a container drum. The container drum will surround the threshing drum, confirming that no paddy grains waist during threshing. In the demo model, we do not add the container drum because it will be difficult to understand the working process of the threshing drum but we decide to build a container in the main machine.

#### 2.3.3.2 COLLECTOR PIPE

---

There is a collector pipe attached to the container. Paddy grains will leave the machine through this collector pipe. We need to set a container at the end of the collector to collect the paddy grains. We will create an air pressure inside the pipeline through a motor and for that air pressure the paddy grains will come out of the harvester.

## 2.4 WINNOWING

---

Along with paddy grains, threshing can collect some other part of the paddy which we do not want take. So, before it goes to collector pipe for collection, we need separate those part from the paddy grains with the help of a colander [9]. The colander will only allow the paddy grains to pass. This process is known as winnowing. After winnowing the paddy grains will be ready to be collected.

## 2.5 CONCLUSION

---

In the demo model, we only try to build up a design that will reap the crop, separate the grains and collect the paddy grains. The different part of the model is not movable. We just make an assumption of the shape of the machine that we are going to implement. In the beginning, we decided to make two windows for the machine but later on, we decide to implement one window. We make the parts by cutting down plywood and attach those parts with glue.

# CHAPTER 3: SYSTEM DESIGN

## 3.1 INTRODUCTION

---

After completing the demo model, we approved the design from our thesis advisor. Then we made a 3D model using the Autodesk Fusion 360 software. In that model, we included every part of the real machine except the container of the threshing drum and circuit diagram. We didn't add any the motion graphics in the model.

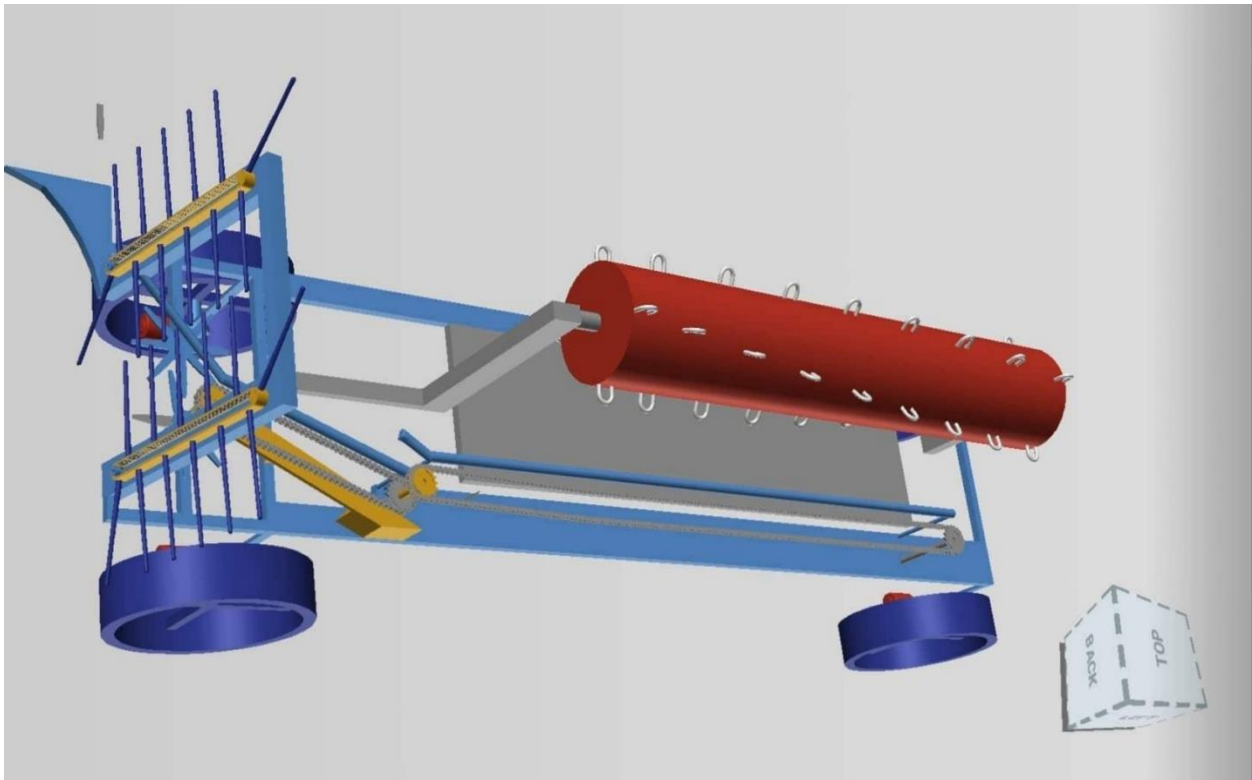


Fig.3.1: 3D design constructed with Fusion 360.

## 3.2 REAPING

---

We divided the reaping section into three parts and which are the window, the push-in gear, and the cutting blade. Details of these parts are discussed in the following paragraphs.

### 3.2.1 WINDOW

---

The window is built on the gate leading to the machine. The length of the window is 25.2-inch and the width is 10-inch and it is inclined towards the machine by 73.4 degrees. Two rubber timing belts with gear and pulley are placed on both sides of the gate. The length of the timing belt is 18.8-inch and the radius of gear is 2.2-inch. Both of the belts are run by two separate wiper motors. Several 5.5-inch wooden teeth are placed on the surface of the belt.



Fig.3.2: Window with several spikes circulating in the clockwise direction.

### 3.2.2 PUSH-IN GEAR

---

We have two push-in gears in this system; they are placed right below the window. Both are gear-shaped and made of iron. The length of each tooth is 4-cm and situated 16.2-inch above the ground. A single wiper motor runs these push-in gears.

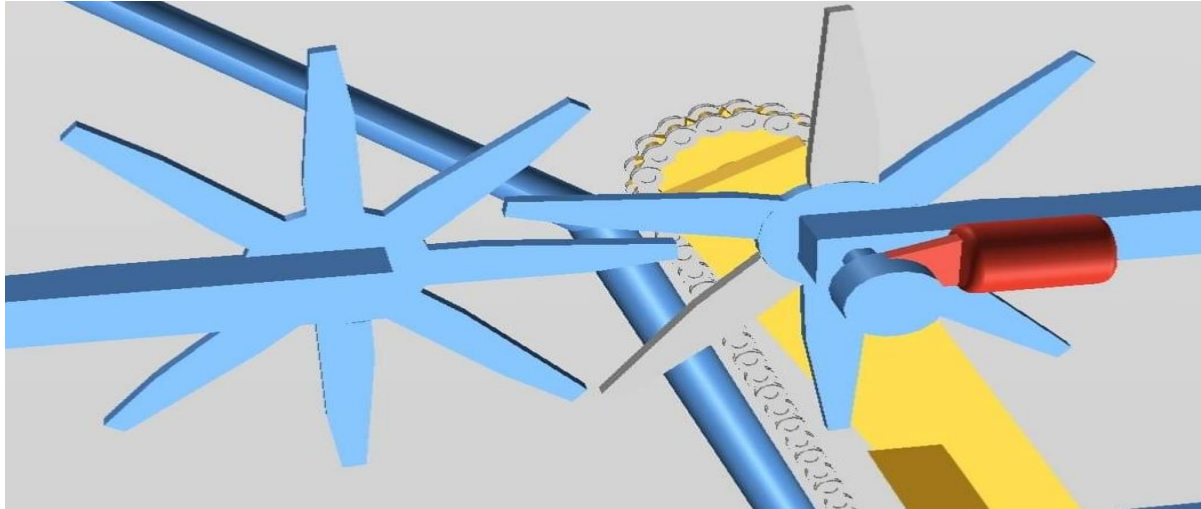


Fig. 3.3: Push-in gears for pushing the crops into the machine.

### 3.2.3 CUTTING BLADE

---

The cutting blade is directly under the push-in gear. The blade is situated 8.5-inch above the ground and has a radius of 5-inch. The gap between the push-in gear and the blade is 7.7-inch. The cutting blade consists of two circular disks where one is rigid while the other run by a window motor.

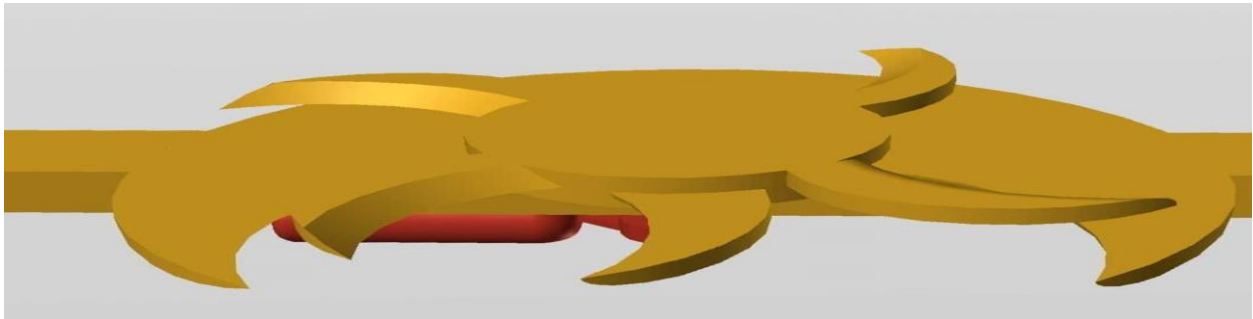


Fig.3.4: The blades for cutting the crops before entering into chain line.

## 3.3 THRESHING

---

Threshing is divided into three parts. They are described below.

### 3.3.1 CHAIN LINE TRAVEL

---

The chain line is with the push-in gear. The whole travel line is divided into two chain line path. The first chain line is situated 20.2-inch above the ground with a length of 19.5-inch. This line is angled 28 degree to the left side of the machine. Second chain line starts immediately after the first chain without giving any interval. The height of the second chain line is 23-inch and the length is 27-inch. This chain line runs parallel to the threshing drum. The gap between the 2<sup>nd</sup> chain line and the threshing is 5-inch. Both of the chain lines run by a single cycle motor. The motor is connected with a 4-inch long shaft. Two-cycle gear is connected with the shaft which aligns with the two chain line. Both of the chain lines share the same speed.

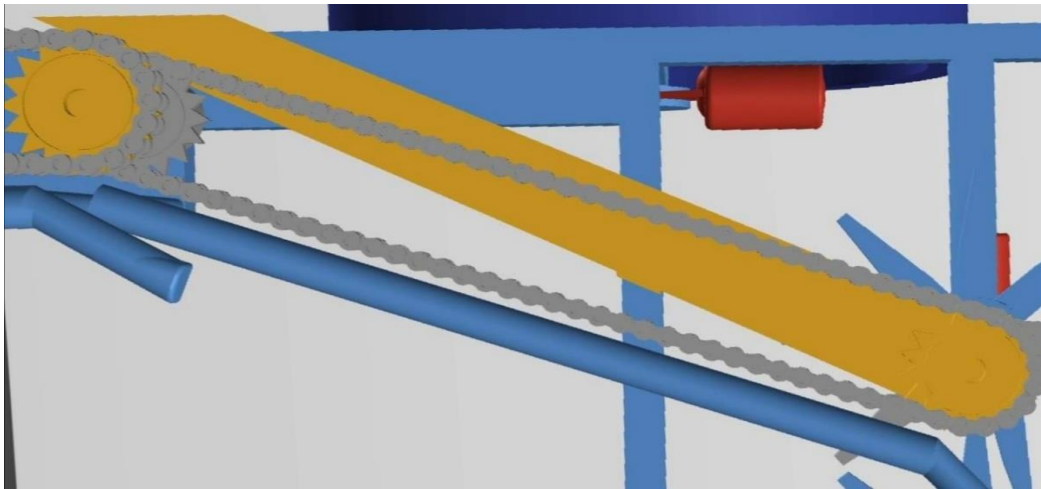


Fig.3.5.: Chain line for entering the crops into the threshing line.

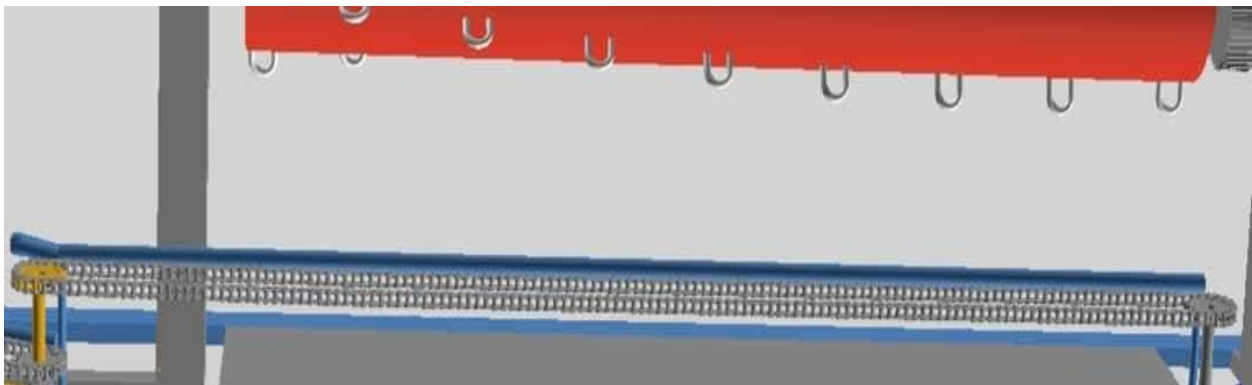


Fig.3.6: Threshing line for entering for extracting paddy grains from the crops.

### 3.3.2 THRESHING DRUM

---

The threshing drum consist of two part. These are roller and container drum. The container is half of a cylindrical shape drum. It has a length of 27.2-inch and height of 15.5-inch. The container is connected with the main body. The roller is at top of the container drum connected with a shaft. The shaft is connected to a cycle motor through two cycle gear. The gears are connected with a cycle chain. The roller is 26-inch long and have a radius of 3.125-inch. The surface of the roller is covered with 'U' shape spike. The spikes are made iron with the height of 1.8-inch. The roller is programmed to rotate at clockwise direction.

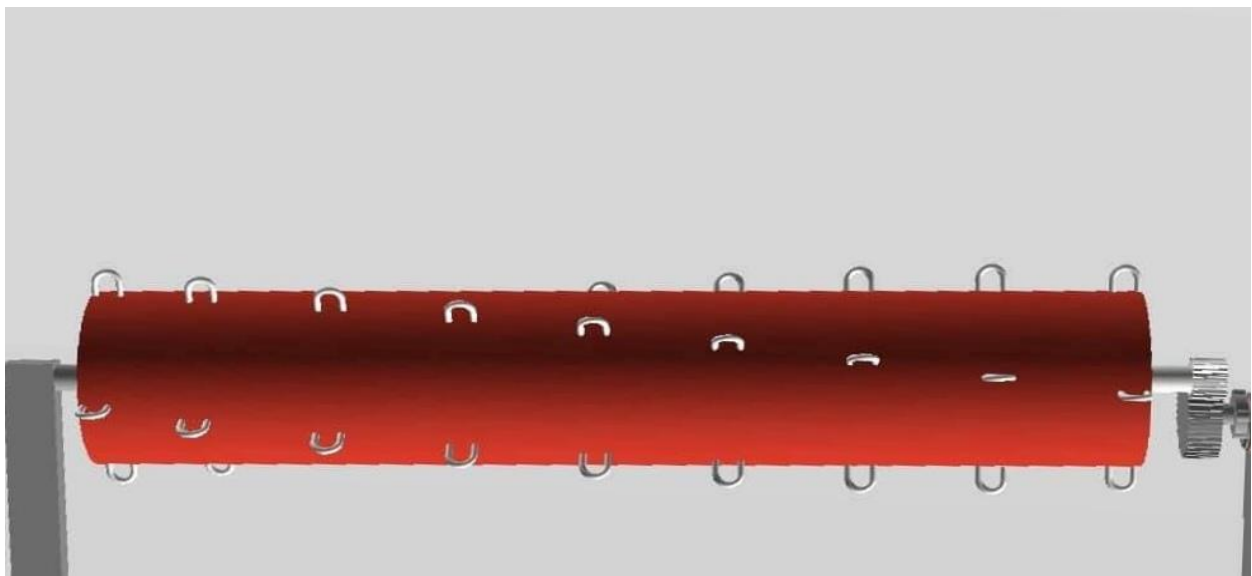


Fig.3.7: The threshing drum for extracting paddy grains from crops.

### 3.3.3 COLLECTING PADDY

---

Collecting paddy is divided into two section here too. They are described below.

#### 3.3.3.1 COLLECTION DRUM

---

In the 3D design, we did not add the collector drum for the visibility of the threshing drum but we finalize the measurement for collection drum. The length of the collection drum is 27.2-inch with a 7.25-inch radius. The drum is situated 15.5-inch from the ground.



### 3.3.3.2 COLLECTOR PIPE

---

We make a collector pipe in the 3D model. But we did not set the measurement for the pipe. The working type is same as described in chapter 2.

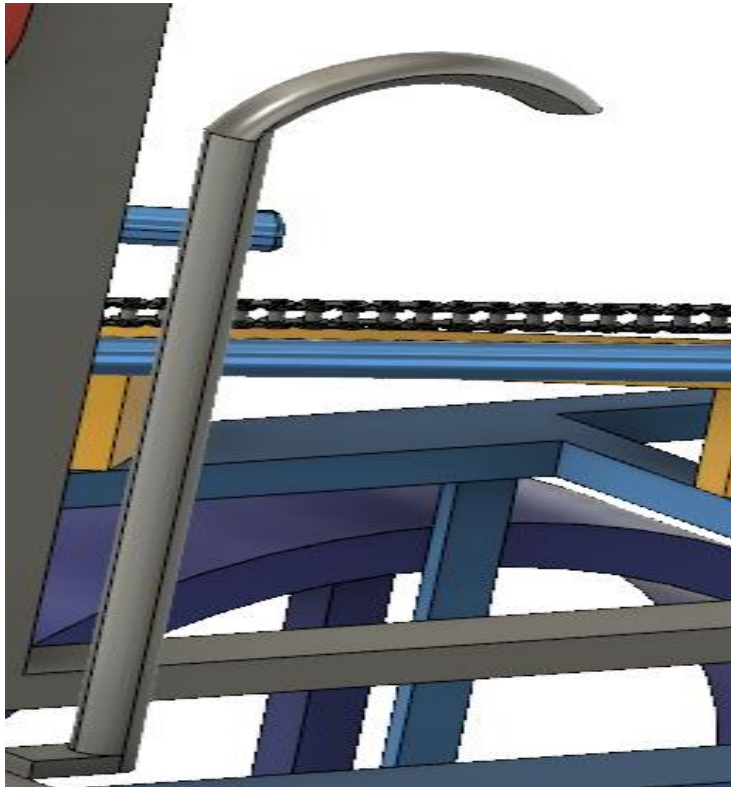


Fig.3.8: A pipe attached under the container for collecting paddy into packets for storing.

### 3.4 CONCLUSION

---

There are two changes in the 3D model comparing the demo model. In the demo model we design two windows and in the 3D we design only one window. The second change we make is the position of the collector pipe. As the research is done in Dhaka, we face difficulties to find any paddy field. So, practical experience of a paddy field and the availability of the parts of the machine may compel us to do some changes.

# CHAPTER 4: SYSTEM IMPLEMENTATION

## 4.1 INTRODUCTION

---

After studying and designing each of the modules we started developing the proposed machine. Our primary focus was on perfecting each of the modules in such way so that the machine can actually cut and harvest paddy on the field in real time. We started with the first module which is the window. After that we developed push-in gears, chain line and threshing drum as well as the chassis of the machine simultaneously. The arc welding, gas welding as well as all the mechanical support we got from the robotics workshop of BRAC University.



Fig 4.1: Final implementation of the proposed machine.

## 4.2 IMPLEMENTATION

---

Developing this type of agricultural machine was not easy for us. We had to bring changes over and over again until we were satisfied with the working method of each of the modules.

However, our cutting blades is not capable of cutting a bunch of crops as it is made of SS steel and not sharpen enough but we are satisfied with the other modules like the push-in gears and the chain line. Besides, our threshing drum works pretty good as it is designed as like as some traditional threshing machine. However, the alignment of the teeth we implemented over the threshing drum enables us to extract paddy grains from crops so that the more teeth the more effective the threshing would be. As we were only focusing on developing equipment that is capable of collecting paddy grains from crops not on the efficiency of production we were satisfied with these end result. We believe with more time and investment these modules will work more effectively and collectively.

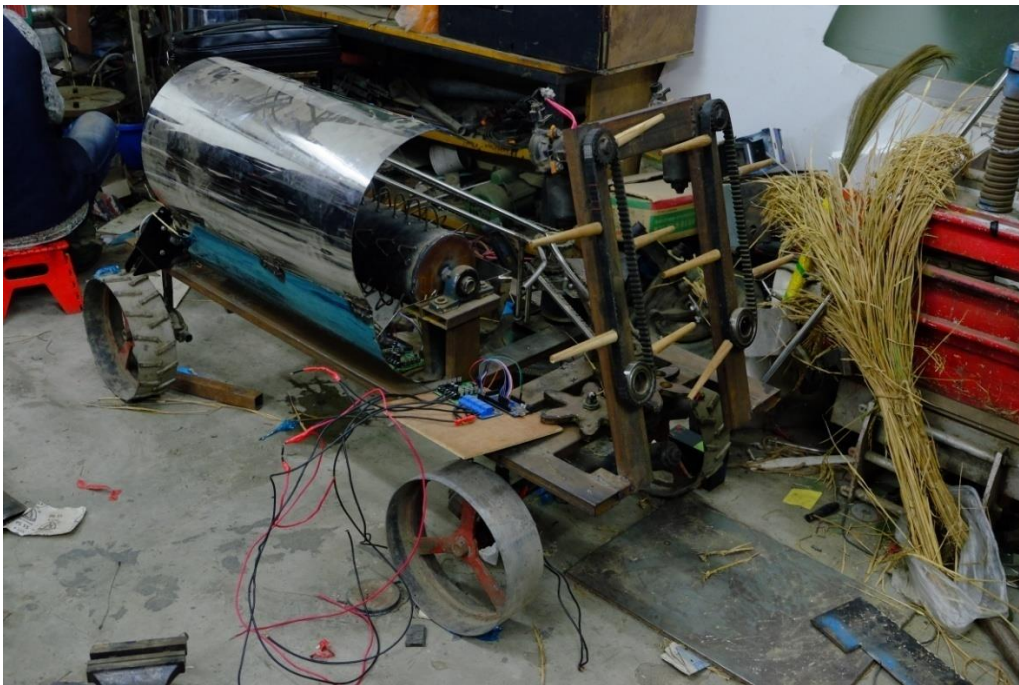


Fig 4.2: Installing the control system into the machine.

There are several guide lines made of SS pipes to ensure the crops after entering the machine does go inside the threshing drum so that we can extract paddy grains and collect them from the container surrounding the threshing drum. The guide lines are attached to the chassis of the

machines in such way so that the crops enter from first chain line to second chain, and before that it forces the crops to be bended towards the threshing drum.



Fig 4.3: The top view of the machine.



Fig 4.4: Threshing drum driven by 12v DC brush motor.

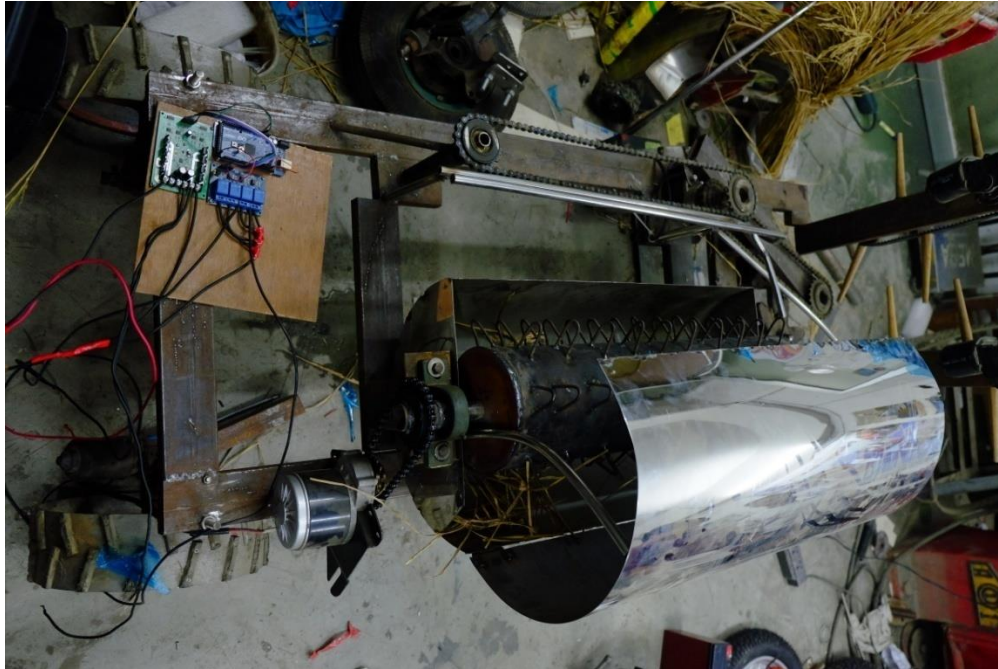


Fig 4.5: The paddy grain collecting container alongside the chain lines.

We had to make sure the chain line motor drives at a slow speed, because we want the crops to travel alongside the threshing drum slowly so that the machine can extract all the paddy grain from crops. However, our modules work in this fashion but we see left over in the crops. Therefore, we can say the process of extracting rice from crops needs more improvement. However, the push-in gear works much better compared to the other modules, they simply push the crops into the machine after cutting and leads them towards the chain line, in the meantime the guide lines force the crops to be fall into the chain lines.

All of these processes are controlled by our control system designed in such way so that chain line motor drives slowly, threshing drum motor drives at its full speed, and the other DC motors are supplied with necessary power as per their requirements.

## 4.2.1 THE CIRCUIT

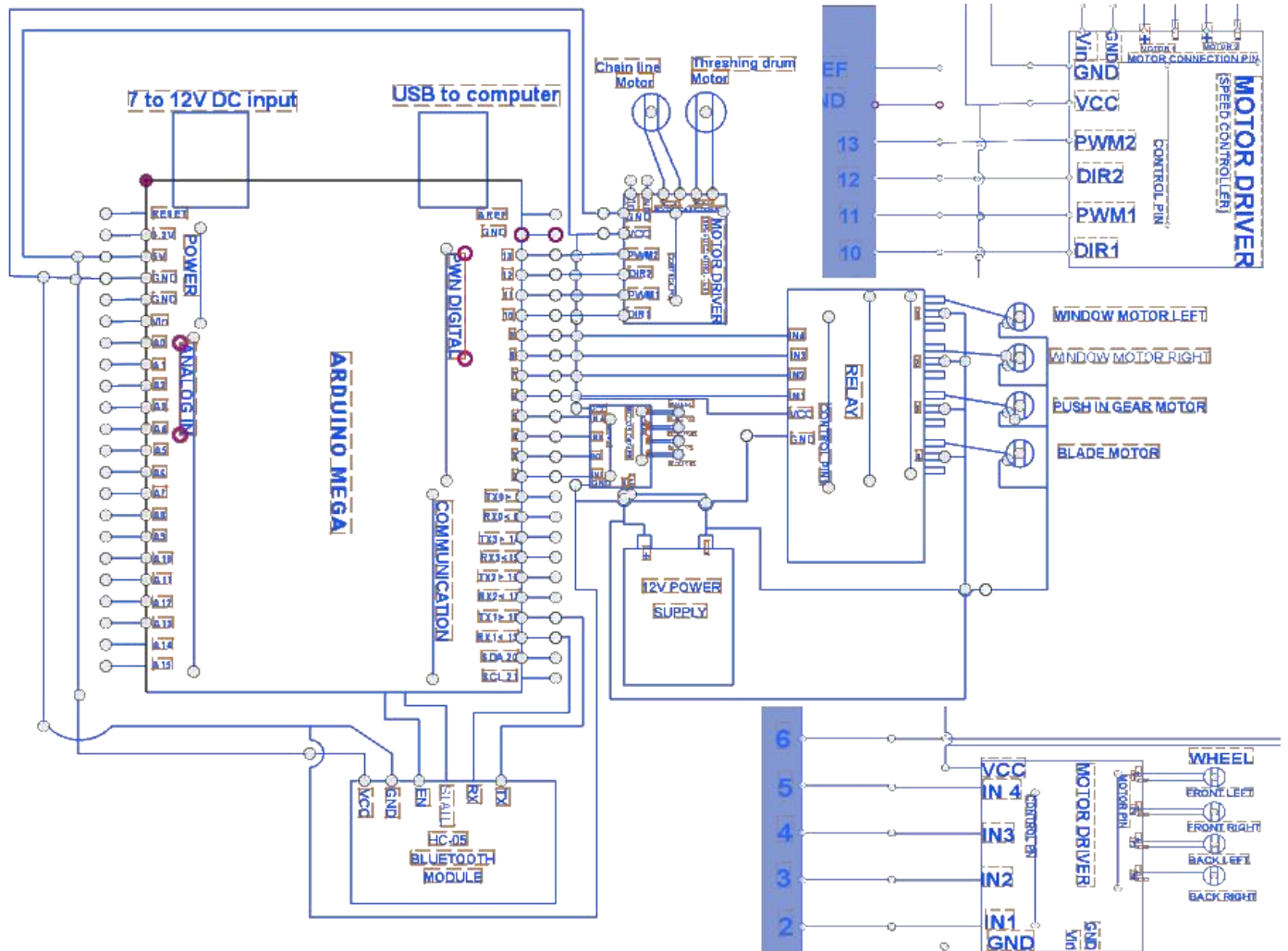


Fig.4.6: Circuit diagram of the control box.

## 4.2.2 BLOCK DIAGRAM

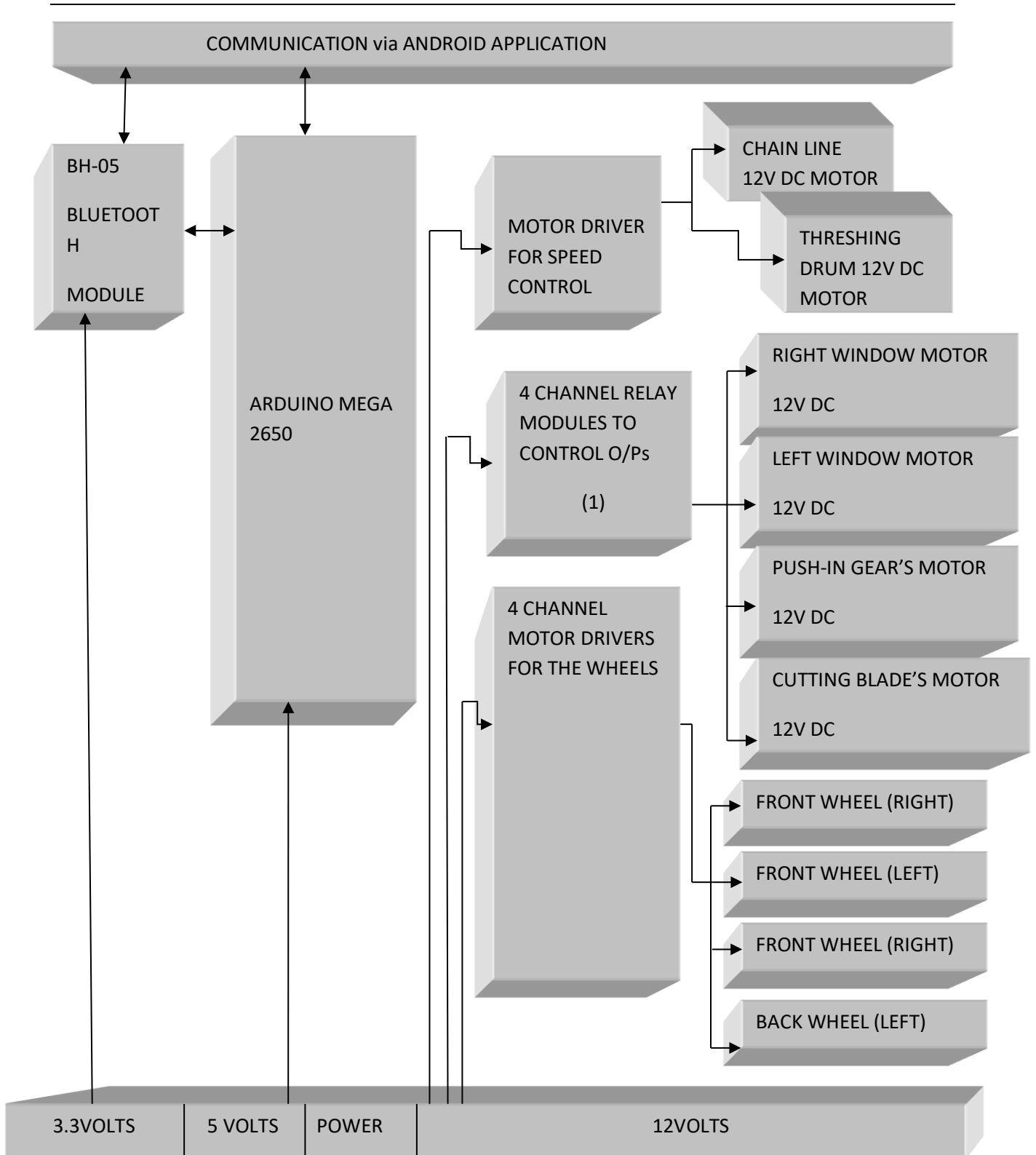


Fig.4.7: The system's block diagram.

### 4.2.3 ALGORITHM

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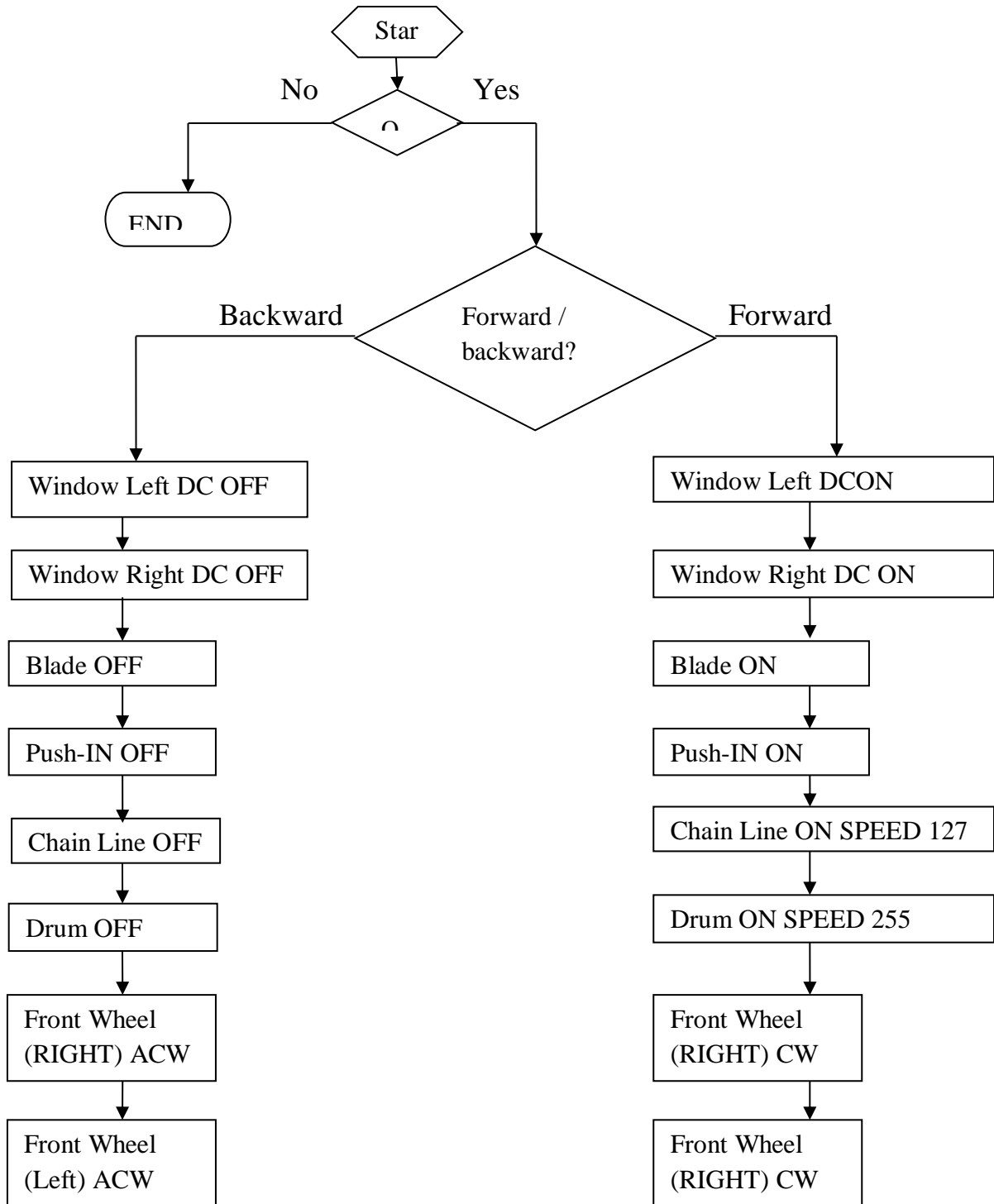


Fig.4.8: The system's algorithm.



#### 4.2.4 PIN DIAGRAM

**Table 1: Connections between hardware & Pins**

Hardware	Pin no. Arduino mega 2650	Source (5v)	Source(12v)	GND	Device(others)
Motor Driver	10,11,12,13	√	X	√	X
4 Channel Relay (1)	6,7,8,9	√	X	√	X
4 Channel Relay (2)	2,3,4,5	√	X	√	X
HC-05	0,1(Tx,Rx)	√	X	√	X
Current module	A0	√	X	√	X
12volts DC motor (1)	X	X	X	√	Relay Channel 1
12volts DC motor(2)	X	X	X	√	Relay Channel 2
12volts DC motor(3)	X	X	X	√	Relay Channel 3

12volts DC motor(3)	X	X	X	√	Relay Channel 4
12volts Cycle Motor (1)	X	X	X	X	Motor driver +ve& -ve
12volts Cycle Motor (2)	X	X	X	X	Motor driver +ve& -ve

## 4.2.5 COMPONENTS AND PIECES OF EQUIPMENT

### 4.2.5.1 SYSTEM'S COMPONENTS

This time, the Arduino Mega was selected as the brains of the operation since the ATmega2560 microcontroller chip has a more powerful processing speed, clocking at 16 MHz compared to the ATmega328 on the Arduino Uno. It contains 256 KB of flash, 8KB of SRAM, 4KB EEPROM; not to mention 54 digital I/O pins (consisting of 15 PWM pins among them) and 16 analog pins. Hence an array of options and pin outs.

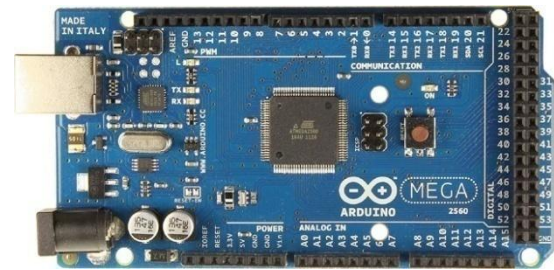


Fig. 4.9: Arduino Mega 2560

One Motor Drivers of the model 3V-36V 30A Dual H-Bridge DC Motor Driver selected because of its high current capacity of 15A and an input voltage of 6V-36V; it can well handle the powerful cycle motors. This Dual Dc motor driver focuses on high efficiency and can withstand the high current load, the maximum current up to 30A.

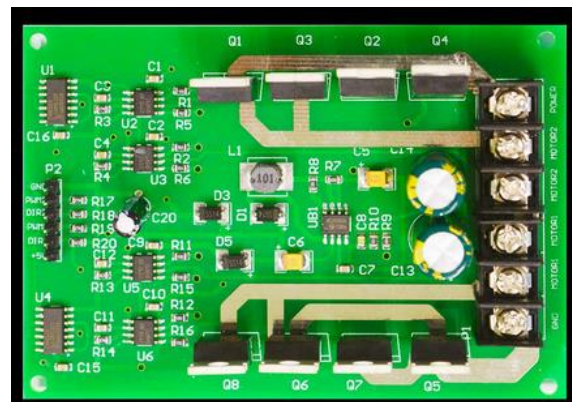


Fig. 4.10: Dual H-Bridge DC Motor Driver

The driver can operate at 0% -99% of the duty cycle of the PWM modulation.

It uses N-channel MOSFET IRF3205 MOSFET to form 2 full H bridge to control 2 DC motors simultaneously which improve

motor acceleration curvature, but also fast motor brake.

Motor forward: DIR = 1, PWM = PWM signal

Motor reversal: DIR = 0, PWM = PWM signal

Brake: DIR = X (1 or 0), PWM = 0

Driving high current brushed dc motors, battle robot, soccer robot and similar.

ACS712 provides economical and precise solutions for AC or DC current sensing in industrial, commercial, and communications systems.

This module features an onboard ACS712 hall current sensor along with a tantalum capacitor for filtering.

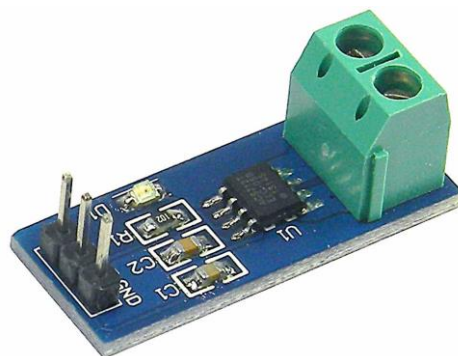


Fig. 4.11: Current sensor module

Each of the modules (motor driver and the relays) was provided an 11.1V 1500mAh Li-po (Lithium Polymer) battery as a Power source. The batteries have high charging density, max charging rate of 2C and a continuous discharging rate of 30C.



Fig. 4.12: 11.1V Li-polymer Battery

Connecting wires are used as logic supply to each module from the Arduino mega2650. Also used as 5volt supply cable for the motor driver and relay modules.



Fig. 4.13: Jumper cables male-female.

In order to drive the machine by an android app, a Bluetooth module was chosen for this case of manual control. Work specifications include a voltage 4V-6V, 30mA operating current, range no less than 100m for serial interface, works with USART and TTL compatible and follow the IEEE 802.15.1 standardized protocol.



Fig 4.14: HC-05 Bluetooth Module.

We are using 4 channel relay module. Channel 5V Opt to Isolated Relay Module is a simple relay board. 4 channel relay board works from a 5V supply to JVCC for the relays and 0V for the switching signal to relays activate. It uses a transistor to drive the relay & opt to coupler used to separate the output. Using these relay board you can easily control high power DC 30V/AC 250V devices or appliances using Arduino or microcontroller. It can be connected directly to a microcontroller pin. It has 3 pin terminals each relay output NO COM NC. NO normally open with relay common pin. NC Normally connected with common.

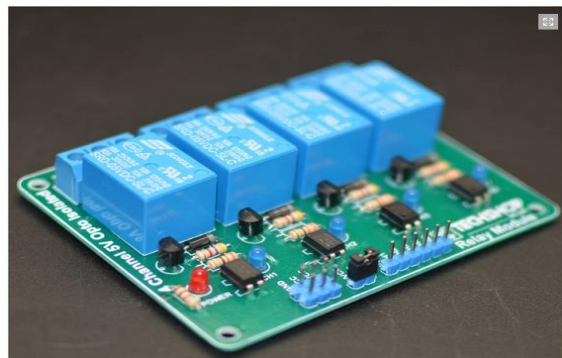


Fig. 4.15: 4 channel relay module.

#### 4.2.5.2 HARDWARE PIECES OF EQUIPMENTS

---

##### i) 12Volts cycle motor



Fig 4.16: Cycle motor (Brushed DC)

- Motor Specification:

Operating Voltage	12 V DC
Motor Magnet Type	Permanent
Torque	22 N.m i.e. approx. 225 Kg.cm
Maximum Current	approx. 13.4 to 19.2 A
# of Teeth on Sprocket	9
Sprocket Chain Pitch	1/2" x 1/8"
Type of Motor	DC
Rated Current	19.2amp
Rated Speed(after reduction)	300RPM

- Description:

This motor runs at 12 volt, gives output of 250 watt. This motor is great for those wanting to make their own custom electric vehicle, whether it's a scooter, electric bicycle or something the world isn't even ready for. This electric motor with gear reduction produces more low-end torque than standard motor. It's

Note: This motor is capable of rotation in either the clockwise or counterclockwise direction by reversing the motor's power wires.

## ii) 12Volts Glass Motor

Windshield wiper motor it's power is 240watt. Operates at 12volts and draws maximum 20A current. Its rated speed is 30-40 RPM.

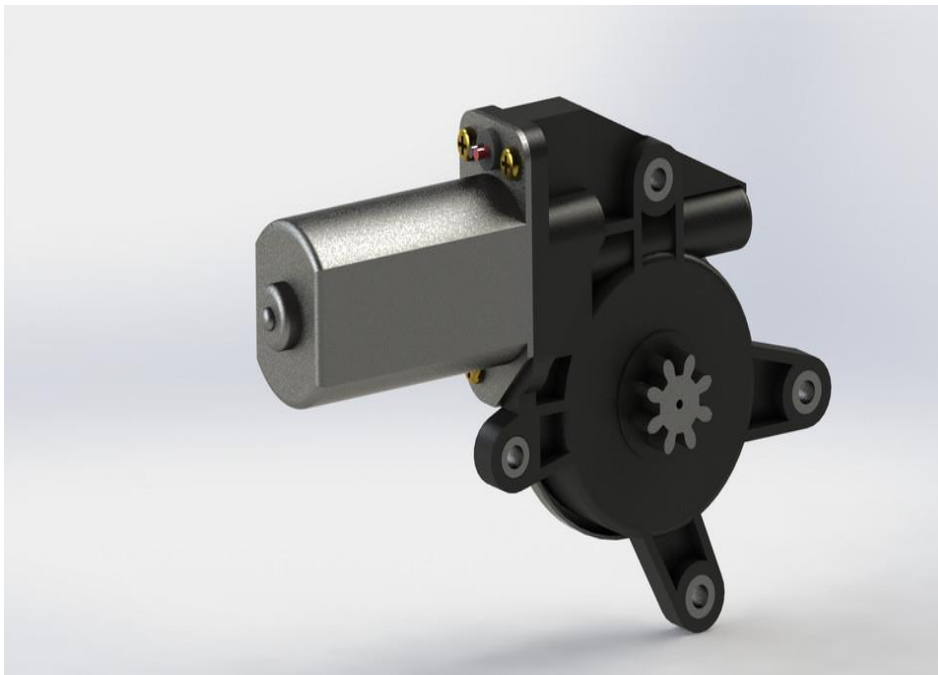


Fig 4.17: Powerful Glass motor (Brushed DC)



ii) 12Volts Wiper Motor







Fig 4.18 Wiper motor (Brushed DC)

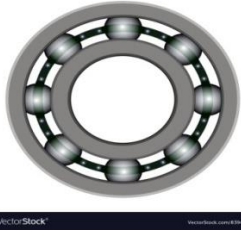


- Motor Specification:

Operating Voltage	12 V DC
Motor Magnet Type	Permanent
Rated Torque	2.9 N.m i.e. approx. 30 Kg.cm
Rated Current	approx. <15 Amp at 12v
Stall Torque(locked)	9.8N.m (100kg.cm)
Stall Current (Locked)	<28A at 12V
Type of Motor	DC
Rated Speed	60 RPM

#### 4.2.5.3 OTHER PIECES OF HARDWARE EQUIPMENTS

<p>i) We used SS steel to build the guide lines alongside the chain lines.</p>	 <p>Fig 4.19: SS Steel</p>
<p>ii) We used MS steel to build the chassis for the machine and the modules.</p>	 <p>Fig 4.20: MS Steel</p>
<p>iii) SS sheet was used for making the container drum.</p>	 <p>Fig 4.21: SS Sheet</p>
<p>iv) We made threshing drum's shaft with SS pipe.</p>	

	<p>Fig 4.22: SS Pipe</p>
<p>v) Threshing drum was built with MS 3 inch radius pipe.</p>	 <p>Fig 4.23: MS Pipe</p>
<p>vi) We used cycle chain to make conveyor line and to run threshing drum with a cycle motors.</p>	 <p>Fig 4.24: Cycle Chain</p>
<p>vii) Several cycle gears are used as essential part of chain line and threshing drum.</p>	 <p>Fig 4.25: Cycle Gear</p>
<p>viii) To attach the threshing drum with the chassis of the machine we used two 25mm block bearings.</p>	 <p>Fig 4.26: Block bearing</p>

<p>ix) Several free ball bearing was used in different motor's shafts.</p>	 <p>Fig 4.27: Free-ball Bearing</p>
<p>x) Two timing belt was used for constructing the window, each with length of 20inch.</p>	 <p>Fig 4.28: Timing Belt</p>
<p>xi) Two timing pulley was used to make timing belt working synchronously.</p>	 <p>Fig 4.29: Timing Pulley</p>

4.3 COST ESTIMATION

Table 2: Lists of expenditures.

Components	Specification	Quantity	Price	Lab Support
Arduino Mega	2560(Italy)	1	4200	
Relay	4 channel	1	350	

Battery	12volts, 20A	1		1500
Motor Driver(Cycle motor)	H bridge 15A Dual DC motor	1	1650	
Connecting Wire	Jumper Wire Set	2	100	
Wiper Motor	12volts	7		7000
Cycle Motor	12volts	2	5400	
Timing Pulley	3''	2	1000	
Timing Belt	40''	2	300	
Wooden Spike	5.5'', Radius ½''	12	200	
Cutting Blade	16''	1	2600	
Cutting Gear	Diameter 6''	2	1500	
Ball Bearing	Diameter 3.5''	2	1000	
Cycle Chain	40'' + 80''	2	150	150
SS Pipe	20feet + 5 feet	1	480	
SS Sheet	20x20feet	1		2000
Chassis Metal	Length 20 feet	1	3500	
Wheel	Metal	4		8000
Threshing drum spikes	Welding	-	500	
Threshing Drum	MS Pipe 26inch 3inch radius	1	1000	

Nut and Bolt	Different sizes	Several	10	50
Cycle gears and bearings	Different sizes	Several	350	
Block Bearing	25mm	2	300	
Other Gear	Various	6		500
Welding	Metal + Gas			2000
Wires	30Amp BRB cables	45feet	375	
<b>Cost</b>			<b>Total=24,965</b>	<b>Total=21,200</b>

#### 4.4 EXPERIMENT

We run few experiments with the intention of finding out the efficiency of the machine by measuring each motor’s operating current at approximate given load. However, in real scenario loads will be different from the experimental assumptions but these experimental findings helped us to understand how much power each of the module draws and how much power we need to supply for running every modules together.



Fig 4.30: Measuring Cycle motor (Threshing drum) current at approximate load.



Fig 4.31: Measuring Cycle motor (Chain line) current at approximate load.



Fig 4.32: Glass motor (cutting blade) current at approximate load.



Fig 4.33: Measuring Wiper motor (Push-in gears) current at approximate load.

## 4.5 RESULTS

---

### 4.5.1 Threshing and Chain Line Motor

---

The motor we use in chain line and threshing can draw approximately 250W power at its full load from a 12V dc battery but in our machine, it is not operating in full load. We connect it under a 12V 60Ah battery. The experimental calculations are given below an approximate load.

- Threshing motor calculation:  $P1 = VI$  watt  
 $=12* 3.06$  watt  
 $P1 = 36.06$  watt
- Chain line motor calculation:  $P2 = VI$  watt  
 $=12* 5.19$  watt  
 $P2 =62.28$  watt

### 4.5.2 Window and Push in gear Motor

---

The motor we use in window and push-in gear can draw approximately 108watt power at its full load from a 12V dc battery but in our machine, it is not operating in full load. We connect it under a 12V 60Ah battery. The experimental calculations are given below for an approximate load.

- Left window motor:  $P3 = |V|*|I|$  watt  
 $=12* 1.88$  watt  
 $P3 =22.56$  watt
- Right window motor:  $P4 = |V|*|I|$  watt  
 $=|-12|*|- 1.88|$  watt  
 $P4 =22.56$  watt
- Push-in gear motor:  $P5 = |V|*|I|$  watt  
 $=|-12|* |-1.35|$  watt  
 $P5 = 16.2$  watt



### 4.5.3 Blade Motor

---

The motor we use in blade can draw approximately 200 watt power at its full load from a 12V dc battery but in our machine, it is not operating in full load. We connect it under a 12V 60Ah battery. The experimental calculations are given below an approximate load.

- Blade motor:  $P6 = |V|*|I|$  watt  
 $= 12 * 7.31$  watt  
 $P6 = 87.72$  watt

### 4.5.4 Wheel motor

---

There are 4 wheel motor in the machine and every wheel motor can draw approximate 108w alone in its full load. We connect it under a 12V 60Ah battery. The experimental calculations are given below an approximate load.

- Wheel motor:  $P7 = 4*|V|*|I|$  watt  
 $= 4*12*7$  watt  
 $P7 = 336$  watt

### 4.5.6 Total calculation and efficiency

---

We used a 1500mAh lithium-polymer battery to power the circuit, supplying 5v to the arduino and it draws 1mA current.

$$P8 = |V|*|I| \text{ watt}$$
$$= 5 * 1*10^{-3} \text{ watt}$$
$$= 0.005 \text{ watt}$$

According to the manufacturer the rated efficiency of the cycle motor is 94%. Wiper motor efficiency is 94% and the efficiency of the glass motor is 95%.

$$\begin{aligned} \text{Approximate Total input drawn } P_{in} &= 36.06 + 62.28 + 22.56 + 22.56 + 16.2 + 87.72 + 336 \text{ watt} \\ &= 583.38 \text{ watt} \end{aligned}$$

$$\begin{aligned} \text{Approximate Total output power } P &= [ ( P_1 + P_2 + P_3 + P_4 + P_5 + P_6 + P_7) * \text{efficiency} ] \text{ watt} \\ &= 36.06 * 94\% + 62.28 * 94\% + 22.56 * 94\% + 22.56 * 94\% + \\ &\quad 16.2 * 94\% + 87.72 * 95\% + 336 * 94\% \text{ watt} \\ &= 33.89 + 58.56 + 21.20 + 21.20 + 15.22 + 83.3 + 315.84 \\ &= 549.21 \text{ watt} \end{aligned}$$

$$\begin{aligned} \text{Power supplied by the battery } P_9 &= |V| * |I| \text{ watt} \\ &= 12 * 60 \text{ watt} \\ &= 720 \text{ watt} \end{aligned}$$

$$\begin{aligned} \text{Supply power } P_s &= P_8 + P_9 \\ &= 0.005 + 720 \text{ watt} \\ &= 720.005 \text{ watt} \end{aligned}$$

$$\begin{aligned} \text{Efficiency} &= (P / P_{in}) * 100\% \\ &= (549.21 / 583.38) * 100\% \\ &= 94.14\% \end{aligned}$$

The machine will discharge the 12v 60Ah approximately in 1 hour, so if we want to run it more than one hour than we need to connect more 12v 60Ah battery in parallel with each other's.

#### 4.5.7 Cost Measurement for charging the battery

---

According to Bangladesh Power development board (PDB) per unit charge of electricity is 3.84BDT in rural area. We need to connect the battery charger to 220v AC current and it will supply 14v with a maximum 12.5A current the supplied power factor is 0.9 to 0.95. It will take

approximately 8 hour to charge the battery. For the battery of the arduino it will take approximately 2 hour at a rate of 1.5A to charge the 5v 1500mAh battery.

Power factor =  $\cos A$

$$\begin{aligned}\text{Power drawn to charge } P &= (VI * \text{hour } \cos A + VI * \text{hour } \cos A) \text{ watt hour} \\ &= [(220 * 12.5 * 8 * 0.9) + (220 * 1.5 * 2 * 0.9)] \text{ watt hour} \\ &= 20394 \text{ watt hour} \\ &= 20.39 \text{ kilo watt hour} \\ &= 20.39 \text{ Unit.}\end{aligned}$$

$$\begin{aligned}\text{Cost} &= (20.39 * 3.84) \text{ BDT} \\ &= 78.29 \text{ BDT}\end{aligned}$$

## 4.6 CODE FOR CONTROLLING MOTOR

---

```
//initializing motor driver control PINs.  
  
int motor_A_speed = 11;  
  
int motor_B_speed = 13;  
  
int motor_A_direction = 10;  
  
int motor_B_direction = 12;  
  
//initializing 4 channel relay module's control PIN  
  
int motor_frontA = 6;  
  
int motor_frontB = 7;
```

```

int motor_push_in = 8;

int motor_cutting_blade = 9;

void setup() {

  //Declaring MOTOR pins as output.

  pinMode(motor_A_speed, OUTPUT);

  pinMode(motor_B_speed, OUTPUT);

  pinMode(motor_A_direction, OUTPUT);

  pinMode(motor_B_direction, OUTPUT);

  //Declaring relaycontrol PINs as Output.

  pinMode(motor_frontA, OUTPUT);

  pinMode(motor_frontB, OUTPUT);

  pinMode(motor_push_in, OUTPUT);

  pinMode(motor_cutting_blade, OUTPUT);

}

void loop() {

  //chain motor low speed.at 50% PWM.

  digitalWrite(motor_A_direction,HIGH); // direction anti-clockwise

  analogWrite(motor_A_speed,100);

  //Thresing drum motor at full speed at 255 PWM. Direction clockwise.

  digitalWrite(motor_B_direction,LOW);

  analogWrite(motor_B_speed,255);

```

```
//All the other motor's are ON by rellay module

digitalWrite(motor_frontA,LOW);

digitalWrite(motor_frontB,LOW);

digitalWrite(motor_push_in,LOW);

digitalWrite(motor_cutting_blade,LOW);

}
```

## 4.7 ADDED FEATURES

---

We developed an Android application with one on-line platform named AppInventor (<http://ai2.appinventor.mit.edu/>).

We intend to make life easier for farmer therefore, we only gave three buttons in the application. First button is named 'OFF' this will simply turn the machine 'ON' or 'OFF'.

The second button is named 'F' which will allow the machine to move forward when pushed.

The third button is named 'B' which will allow the machine to move backward when pushed.



Fig 4.34: Screen of android application.

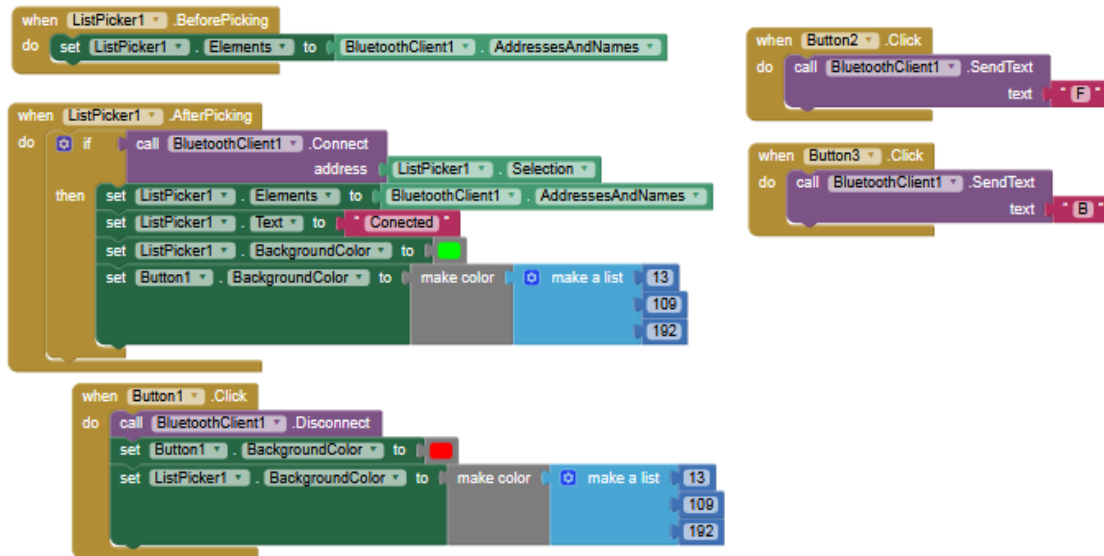


Fig 4.35: Application's blocks.

When pushed, button 1 disconnects the HC-05 Bluetooth module from the app. And whenever the button 2 & 3 pushed they return 'F' & 'B' respectively to the Arduino via serial communication.

# CHAPTER 5: DISCUSSION

## 5.1 LIMITATION

---

Because of the shortcomings of our experience, there are some slight problems with our harvester. Several teeth attached to the belts of window often come off. This happens because of the teeth of the gears. The push in gear sometime stuck as the surface was not smooth enough. In this case the gear had to be manually pushed. Due to some design fault the cutting blade sometime cannot cut the crops properly and the crops just tears apart. We design the chain line to run by a single motor. Therefore, both of the lines run at same speed. But to properly complete the threshing of the crops needs some time. For this the either the speed of the 2nd line had to be reduced or the length of the roller had to be increased.

Now because the whole system need high power to function properly, we could not run it by a single “5V 1500mA” battery.

As harvester has a very good market value, no one shares the working idea of a harvester. So, in the beginning, we face difficulties to design the working idea of the harvester. Another limitation is selecting a suitable motor. There is no dc motor manufacturer in our country we have to select which is available in the market. If we could make a motor with the RMP and power we need to operate different parts of the machine than we do not need those extra lines of coding to control the system. This will eventually reduce the production cost of the machine and will make the machine more user-friendly for the farmers.

## 5.2 ADVANTAGES

---

The most apparent advantage of our harvester is that it is entirely made and assembled in our country. As our goal was to make the harvester affordable to our farmer we had to minimize the production cost. For this we used the component that is available in our market. It goes for both the body parts such as the gears, belt, chain, motor etc. and the circuit component like arduino, relay, motor gear etc. Because of using the common material the cost is much less than the industrially made harvester.

It may sound harsh but the farmers of our country are poor. They still use age-old tools for harvesting. On top of that their crop field is not big enough to use the popular combine harvesters which are usually used in larger field. These larger harvesters lose their maneuverability in a small size field. As our harvester is small in size, it has much more freedom in its movement.

Most of the modern harvester completely shred the entire plant during the harvesting process. But our farmers use the husk or straw as food for their livestock. Our machine will keep the straw undamaged for further use.

Our harvester is powered by dry cell. Cost of electricity is definitely lower than diesel and the gap will only increase as fossil fuels are limited. This will lower the maintenance cost for the farmer. On top of that this machine can be controlled via any smart device such as android phone. As smart phone is becoming common in the rural area too, the farmer will have much easier time controlling it. Therefore, a harvester with a low buying and maintenance cost is easily affordable by our farmer. On top of it, harvester can definitely work faster than human and save time.

.

### 5.3 DISADVANTAGES

---

The biggest disadvantage for our harvester is its performance against other industrially made combine harvester. Though it is fast compare to the human labors, it is much slower than industrially made harvester.

The layout of the rice fields in our country is quite complex. Here farmers own the average of 1.62 acre as a farm [14]. A farmer often owns his farming land surrounded by land of other people. In such event it is problematic to use the harvester on those lands.

The circuit module of the harvester was entirely done by hand. This makes it highly susceptible to damage during the harvesting process. Now in such event the farmer will be completely helpless as neither the circuit components nor the electrician can be found in the rural area. On top of that, our system did not include any way to find the voltage charge of the dry cell battery.



## 5.4 POSSIBLE FUTURE IMPLEMENTATION

---

As this research is based solely to make a harvester that will work properly, we did not work on the thing that can increase the machine efficiency. Now we only tried to build a structure that can harvest the crop. So there are still many things that can be implemented in the future to increase the efficiency of our harvester.

### 5.4.1 SOLAR PANEL

---

The most prominent thing that can be added is a solar panel to recharge the battery. Though will increase the initial production cost but in the long run, it will greatly decrease the maintenance cost for the farmer. By using Wireless Sensor Network (WSN) the battery charging process can be made more efficient [10].

### 5.4.2 HYDRAULIC RAM

---

We can use a hydraulic ram or servo motor with pitman arm to make the front wheel turn in left and right. This will enable the harvester to move more perfectly.

### 5.4.3 MACHINE EFFICIENCY

---

Another important thing is we need to improve the machine efficiency in terms of circuit quality, motor efficiency, and machine structure. As the modules are not available in the rural area, therefore, we need to select the most durable modules at a lower price.

### 5.4.4 VOICE COMMAND CONTROLLER

---

It may be a bit difficult for a farmer if he does not have any smart device. A voice command controller system will be much easier for them to control. Then there will be no need for a separate device to control the machine. Moreover, adding Bangla voice command to this system may be more convenient for our farmer.

### 5.4.5 SENSOR

---

We can use few IR (inferred) sensors to control every modules more precisely so that whenever a particular module does not need to run the system can shut it down immediately and can turn it on

when necessary[9]. This way the system can minimize its power acquisition. However we developed our system in such way that as soon as the machine starts each of the module starts working collectively until we shut down the machine. On the other hand, we designed our container to collect paddy but did not use any sensor which can indicate us whether the container is full or not.

Moreover, we can add “Rotating Pickup Sensor” and “Harvest Quality Sensor” in the threshing and storing sector. These sensors will measure and calculate the harvesting quantity [11].

#### 5.4.6 CUTTING BLADE

---

The efficiency of our cutting blade is very low. To reduce the production cost, we use blade that was built by us. Now bionic blade can be used to increase the cutting efficiency [13].

## **Chapter 6: CONCLUSION**

Bangladesh is an agricultural country with an abundance number of fertile land. Even the seasons have a great positive influence over our agriculture. The cereal type crops, like rice and wheat are the major crops of our country. But even with all these fertile land and huge manpower, the quantity of the harvested crops is very low. The poor farmer of our country still uses traditional tools like a hoe, sickle, and fork. The use of machinery in agriculture is close to zero in our country. These poor farmers can hardly afford such machine with sky-high price. But at the same time, the absence of modern machinery increases the wastage of time and capital. Now the usage of modern machineries will reduce the required manpower in this sector. Keeping this in mind, we design, build and assembled a low cost combine harvester. This harvester will not only cut the crops but also collect and the grains of the harvest. We believe, with proper investment on our proposed design it is possible to develop combine harvester in our country at a minimal cost in terms of mass production.

# REFERENCES

1. Dale-Hallett, L. (2010) Sunshine Stripper Harvester in Museums Victoria Collections <https://collections.museumvictoria.com.au/articles/2969>
2. Past, P. O. (2010, October 23). Early 1900s farming scene - horse drawn reaper / harvester. Retrieved from <https://www.flickr.com/photos/whatsthatpicture/5107417674/>
3. Fox Choppers. (n.d.). Retrieved from <http://agriculturalmachineryengineering.weebly.com/fox-choppers.html>
4. Agriculture in Bangladesh. (2018, October 12). Retrieved from [https://en.wikipedia.org/wiki/Agriculture\\_in\\_Bangladesh](https://en.wikipedia.org/wiki/Agriculture_in_Bangladesh)
5. Combine harvester. (2018, December 03). Retrieved from [https://en.wikipedia.org/wiki/Combine\\_harvester](https://en.wikipedia.org/wiki/Combine_harvester)
6. Rice production in Bangladesh. (2017, January 16). Retrieved from [https://en.wikipedia.org/wiki/Rice\\_production\\_in\\_Bangladesh](https://en.wikipedia.org/wiki/Rice_production_in_Bangladesh)
7. <http://www.bbs.gov.bd/site/page/453af260-6aea-4331-b4a5-7b66fe63ba61/%E0%A6%95%E0%A7%83%E0%A6%B7%E0%A6%BF>
8. Sun, D., Chen, D., Wang, S., & Wang, X. (2018). Development on electrical system performance test stand for combine harvester. *IFAC-PapersOnLine*, 51(17), 363-367. doi:10.1016/j.ifacol.2018.08.195
9. Baerdemaeker, J. D., & Saeys, W. (2013). Advanced Control of Combine Harvesters. *IFAC Proceedings Volumes*, 46(18), 1-5. doi:10.3182/20130828-2-sf-3019.00069
10. Ibrahim, R., Chung, T. D., Hassan, S. M., Bingi, K., & Salahuddin, S. K. (2017). Solar Energy Harvester for Industrial Wireless Sensor Nodes. *Procedia Computer Science*, 105, 111-118. doi:10.1016/j.procs.2017.01.184
11. Kanatani, K. (2015, October 27). Development of the Intelligent Combine Harvester which Contributes to Increase in Productivity of Agriculture | YANMAR Technical Review | Technology | YANMAR. Retrieved from [https://www.yanmar.com/global/technology/technical\\_review/2015/1027\\_3.html](https://www.yanmar.com/global/technology/technical_review/2015/1027_3.html)
12. Threshing machine. (2018, July 03). Retrieved from [https://en.wikipedia.org/wiki/Threshing\\_machine](https://en.wikipedia.org/wiki/Threshing_machine)

13. Tian, K., Li, X., Zhang, B., Chen, Q., Shen, C., & Huang, J. (2017). Design and Test Research on Cutting Blade of Corn Harvester Based on Bionic Principle. *Applied Bionics and Biomechanics*, 2017, 1-8. doi:10.1155/2017/6953786
14. Quasem, M. (2011). Conversion of Agricultural Land to Non-agricultural Uses in Bangladesh: Extent and Determinants. *The Bangladesh Development Studies*, 34(1), 59-85. Retrieved from <http://www.jstor.org/stable/23342764>
15. Hix, Hannah. "Bangladesh: A Country at Risk." *The World Food Prize*, Retrieved from [www.worldfoodprize.org/](http://www.worldfoodprize.org/).