AUTONOMOUS TRACTOR TO PLOUGH AND HARVEST WITHIN A LASER PERIMETER

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DECLARATION

We hereby declare that the thesis titled "Autonomous Tractor to Plough and Harvest within a Laser Perimeter" is submitted to the Department of Electrical and Electronics Engineering of BRAC University in partial fulfillment for the Bachelor of Science degree in Electronics and Communication Engineering.

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ABSTRACT

The world as we know is rapidly changing, the world population is ever growing and with this increased population growth the never ending need for food is also growing like never before. But on the contrary, our careers are getting more industrial or corporate based whereas it should be more agriculture based to cope up with the demand of food all over the world. One of the main reason towards this negligence towards agriculture is because farming requires a lot of manual labor and hard work, moreover the profit is also very limited compared to the hard work done, especially in Bangladesh. One of the most difficult task for the farmers in the agriculture field is the ploughing of the land. A lot of manual labor and hard work is needed to do this. Harvesting crops also takes a lot of time and energy. Thus to reduce this huge work load of the farmers we have introduced an autonomous ploughing and harvesting system for the farmers. The plough will be attached at the rear side of the tractor which can be lowered or raised with the help of an actuator. Two blades are attached at the front side of the tractor which rotates with the power of DC motors attached with the blades. It will help to cut down the crops for harvesting. To set a perimeter of the field we have used Laser diodes. To ensure the tractor stays inside the perimeter we added LDRs to the tractor so that it can turn itself when the laser rays hits it at each end of the field. In order to stop the tractor when it is done ploughing the field we used sonar sensor at the end point of the field and RF module to communicate with the tractor, in order to stop it when it reaches the end point and comes in range of the sonar sensor. The tractor is powered by rechargeable Lead Acid batteries. In order to ensure that all the components gets their required powers to complete their function, we used relays and switches. To automatically drive the tractor around the whole field and take the turns at the edges of the field smoothly, we installed glass motors to power the tractor in rotating its wheel in rough surface and IR sensors embedded with encoders in the wheels of the tractor which will help it to turn with precision at both ends of the field. With all these equipment combined our tractor can plough and harvest a whole field automatically without any human intervention, thus reducing the work load of the farmers for ploughing and crop harvesting to a great extent.

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Chapter 1: Introduction and Background

1.1. Introduction

“Food”, it is the 3rd most important thing that a human needs after oxygen and water for their existence or survival. [1] Most of the world’s food have always been obtained through agriculture. [2] In 2011 the International Labor Organization stated that approximately 1/3 of the total world population are employed in the agricultural sector. [3] In Bangladesh, Agriculture is the largest sector of employment. It was cited that in the year 2016, agriculture employed 47% of the total work force and comprised 16% of the GDP of Bangladesh. [4] From these facts it can be clearly stated that the world is dependent on agriculture for food production. However, the increase in the world food production is not growing at the same rate with the world population. There are many reasons behind this such as scarcity of Land and Water. [5] In Bangladesh, apart from these problems another problem is many farmers still use old or conventional methods of agriculture. For example, many farmers still plough their land by themselves (Fig 1) or with domestic animals. This requires a lot of manual labor and time. In our country many farmers quit agriculture and start to move towards cities to pull rickshaws or work in mills and factories as they can earn more there with comparatively less labor. [6]

Figure 1: Farmer ploughing his own land with the help of his wife

Thus, modernization of agriculture is necessary. Although tractors and power tillers are already in use by many farmers. But the system we designed modernizes the method of ploughing and harvesting to a great extent by automating it.

Figure 2: Carbon emission from a tractor.

Taking everything into consideration we can state that our autonomous tractor will be efficient in not only ploughing or harvesting a piece of land but it can also help a farmer in terms of:

Cost: The Autonomous Tractor will be cost effective as it will be cheaper than any other autonomous tractors system designed till now.

Time Saver: A huge amount of time is needed to plough a piece of land depending on its size. While our automated tractor ploughs the land all by itself, the farmer can do other tasks or take rest. In this way, the farmer gets some free time while the tractor takes care of ploughing the land.

Reduces Physical Strain: Ploughing requires a lot of manual labor. It takes away a lot of energy. Sometimes if the weather is extremely humid, the farmers get sick or fatigued after ploughing a piece of land. But our automated tractor can plough the entire land without creating any severe impact on the farmer's health.

Safety: Since our tractor will function in a field automatically without any human intervention, for safety purposes we have built a controller which works as the start button and the kill switch for the tractor. Moreover, we have used sensors which will detect wheter any obstacle comes into the path of the tractor during its operation and will stop the tractor instantly on its path so that no fatalities occur.

Hence our autonomous tractor will be efficient in both ploughing and saving the farmers from different negative factors of agriculture.

1.2. Motivation

In this age of technology, each and every country is changing their agricultural methods from traditional labor based agriculture to technology based agriculture. In order to cope up with the rising food demand and to contribute in food production all around the world, just like every other country, modernization of agriculture is inevitable in Bangladesh. We need to develop easy, reliable and fast means of agriculture, so that we can increase the amount of food production in a short amount of time. This is possible by modernizing agriculture. Hence from this perception, the idea of building an Autonomous Tractor came into view. Although the farmers of Bangladesh started to modernize their agricultural methods long before, but our Autonomous Tractor will be a platform of advanced mechanism in the field of agriculture in Bangladesh and it will also encourage others to expend more of their ideas and investments on modernizing the agriculture sector of our country. Humans are trying hard to make their living more effortless and comfortable. The Age of Automation has begun since the inception of Robotics. From Automated Pencil Sharpeners to Home Automation Systems, each and every system has taken the lives of human beings to one step closer to being effortless and comfortable. In the same way, with the motive of making the lives of our hard working farmers more effortless and comfortable, we decided to put our idea of building an Autonomous Tractor into effect.

1.3. Literature Review

The concept of building an autonomous tractor came into consideration in the early 1940s. [7] But no major advances were made until in 1994, a picture analysis system was developed by the engineers at the Silsoh Research Institute. The system was used to escort a driverless tractor small in size for root crops and vegetables. It was also designed to make the tractor handle small turns. [8] As the tractor was still needed to be guided to follow its route. It could not be termed as an "Autonomous" tractor.

The engineers then worked on semi-automatic tractors. "Semi" automatic because, these tractors needed drivers to turn the tractor at the end of each row. [9]

Finally the driverless tractors came into effect around 2011 and 2012, but that also needed a tractor with driver in it to guide the path. Full autonomous tractors have been developed recently but they are still undergoing research. Majority of the autonomous tractors are implemented with laser technologies, where the laser bounces signals off mobile transponders located around the field. 150 MHz radios are integrated with it for dealing with line of sight issues. The tractors are equipped with controllers also, so that the farmer can control the tractor when needed from outside the field. [10]

One of the main problems of autonomous tractors is that they are still way too much expensive for a farmer. Thus the future of autonomous tractors need to have such a technology which will reduce the work pressure of the farmers to a huge extent and will also be cost bearable for the farmers, especially for the countries where the farming population is poor.

The names or models of some Autonomous Tractor systems previously worked on are listed as follows:

1) Hakotrac 3000
2) ESX
3) Trimple AgGPS
4) Crossbow IMU
5) Geotec GT2000

6) SMR Demo

It should be noted here that most of the Autonomous Tractor systems previously worked on were mostly based on GPS navigation systems. Working with GPS navigation systems is a bit complex, time consuming and also expensive. Thus, in our project we avoided any sort of equipment that would require GPS Navigation. This made our project more efficient, precise and comparatively less costly.

Chapter 2: System Design

2.1. System Components

The system of our Autonomous Tractor is designed based on three major parts: Mechanical, Electrical and Coding. In the Mechanical part, we discussed about what aspects were considered while designing the prototype version of our tractor and the motors. In the Electrical part, we discussed about the Circuits that we built for operating our Autonomous Tractor. Finally, in the Coding part, we discussed what method was used to instruct our Autonomous Tractor to execute its autonomous operation.

The components that were used in the Autonomous Tractor are mentioned below:

a) Mechanical Components**:** In our Autonomous Tractor the Mechanical Components worked together to give the tractor full functionality in terms of control, power and activity. The Mechanical Components that were used in the tractor are as follows:

*i) Feedback Rod Linear Actuator***:** The actuator is a mechanical component that is functioned for controlling a system. In one word, it is a "mover". [11] It was responsible for raising and lowering the plougher situated at the rear end of our autonomous tractor.

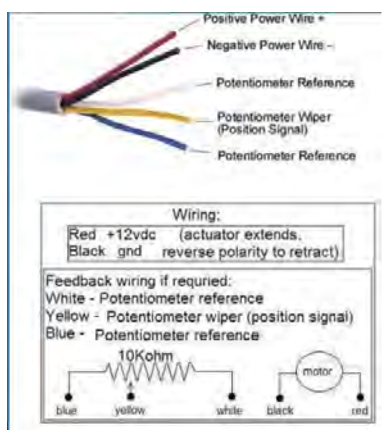

Figure 3: Wiring diagram of a Feedback Rod Linear Actuator

An Actuator needs a control signal and an energy source. When the actuator receives the control signal, it responds by converting the energy and the signal into mechanical motion. When the positive red wire is connected with the positive node of the battery the actuator extends and lowers the plougher, when the negative black wire in connected with the positive node of the battery, reverse polarity occurs retracting the actuator and thus the plougher is raised.

ii) Glass Motor: The Wiper Motor or Power Window Motor, locally known as Glass Motor is a 12V DC motor that has a Torque rating of 10kg. This motor has been installed in the rear side of our prototype tractor to assist the tractor in locomotion. The rear wheels of the tractor has been attached with the Glass motors. The motors rotates clockwise/counter clockwise to rotate the wheels of the tractors. Its main purpose is to provide the rotation force to the wheel so that it can provide locomotion to the tractor. The motor rotates due to the presence of Hall Effect. The power window motor consists of a Motor, Connector and Gear.

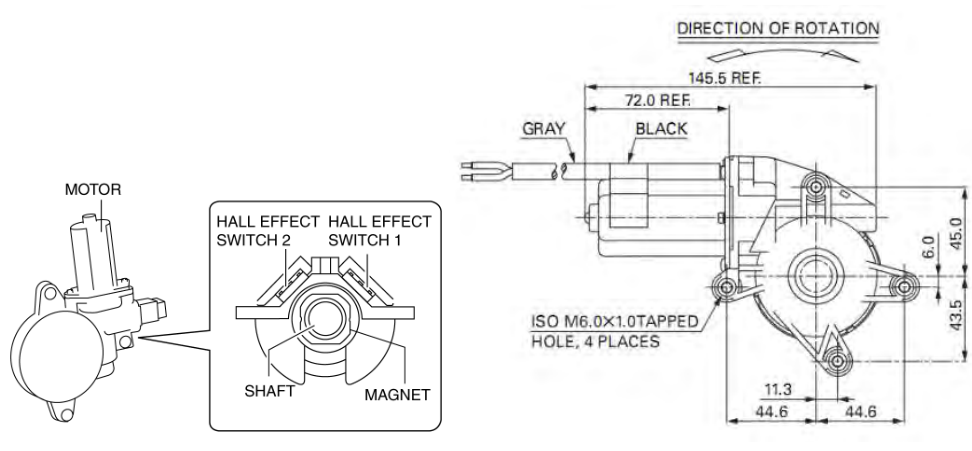

Figure 4: Diagram of Glass Motor.

Glass Motors were used as the rear wheel motor of our prototype tractor as the Motor is easily available, cheap and has enough torque or power to move the tractor over the ground even when the plougher is lowered to the ground for ploughing.

iii) Plougher: We molded the Plougher at the rear side of the body of our prototype tractor. It is also molded and attached to the actuator with a screw. The plougher can be lowered or raised with the help of the actuator that is connected to the plougher. Before the tractor starts moving, the plougher is lowered so that it can plough the field. The plougher can be adjusted with the actuator depending on the requirement of the farmer and the field condition. When the tractor interrupts the laser, the plougher is automatically raised from the ground in order to assist in rotating the tractor smoothly. As soon as the tractor rotates 180 degree and starts moving again the plougher is again lowered.

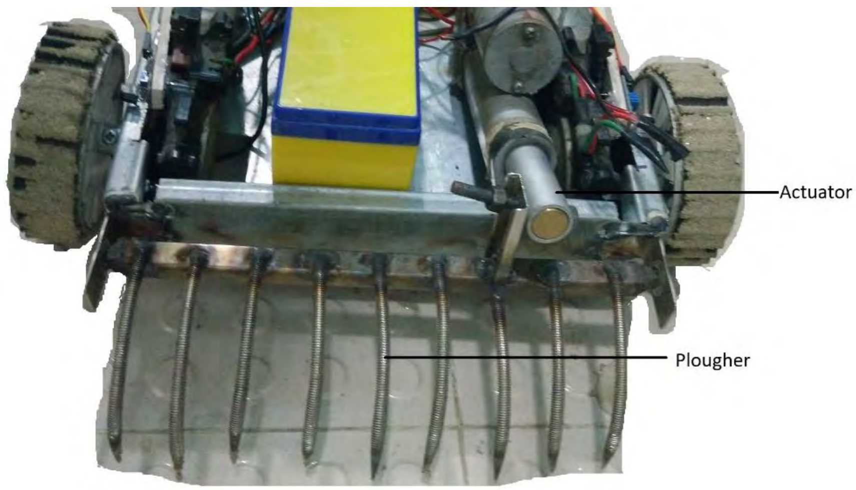

Figure 5: Diagram of Plougher and Actuator

iv) Brushed DC Motor: The Brushed DC Motor is molded to the front side of the tractor. The DC Motor operates from a direct power source provided by our 12V lead acid battery. The rotation speed of the DC motor can be varied by tuning the operating voltage or the strength of the magnetic field. A magnet is attached with the wall of the motor and another magnet is attached at the center of the motor with an armature which can rotate freely. When the input power is given to the motor, a magnetic field is generated around the armature. Then the left side of armature is repelled by the left magnet and is attracted by the right magnet. When the left side of the armature reaches the right magnet, the commutator reverses the direction of the coil thus reversing the magnetic field. In this way, the motors rotate at a very high rate of speed. Brushed DC motors have been used to provide the maximum torque required for the circular saw to cut down the crops for harvesting.

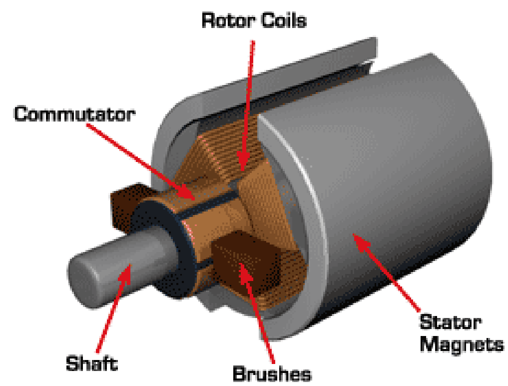

Figure 6: Brushed DC Motor

v) Circular Saw: The Circular Saw is attached with the Brushed DC Motor that is situated at the front side of our tractor. Two circular saws have been installed in our prototype tractor and attached with the DC Motor. The circular saws partially overlaps each other, in order to give more efficiency to the blades while cutting down or harvesting the crops. The Circular saw automatically starts to rotate with the help of the DC Motors while the tractor is in motion. When the laser is interrupted by the tractor, the circular saw stops rotating and until the tractor completely takes its 180 degree turn, it remains off. As soon as the tractor takes its 180 degree turn and starts moving again, the circular saw starts to rotate again.

Figure 7: Brushed DC Motor and Circular Saw

vi) Wheel: The **Rear Wheel** of our prototype tractor had been custom made by molding it from steel and giving it a circular shape. After molding the metal of the wheel, it was too heavy for the tractor and it could not be used as the wheel of the tractor as the extra load of the wheel refrained the glass motor from working properly thus creating problems in locomotion and rotation at the end of the fields. Thus in order to reduce the weight of the wheel we made some hollow spaces in the middle of the wheels. As a result, the weight of the wheels were reduced allowing the tractor to move and rotate around the field smoothly. One inch Round Polypropylene Castor Wheels were used as the **Front Wheel**. No Motors were used for the front wheels as, the tractor bears most of its weight on the rear side and the rear wheels of the tractor fulfill the function of rotating the tractor at the edges of the fields, so no motors were needed for the front wheels. Thus it was kept independent to allow the tractor to perform suave rotations.

vii) Wheel Grip: For providing grip to our tractor we have used tread grips on the rear wheels of our prototype tractor. This grips were used in order to provide enough friction to the wheels of the tractor so that it can run steadily on slightly muddy or uneven surfaces.

viii) Tractor's Chassis: The chassis of the prototype tractor is made out from molded steel and is simply rectangular shaped with having 15 inch length and 10 inch breadth. It stays 0.5 inch above the ground due to the wheels and considering the fact that it has to run on uneven surface. The body of our prototype tractor has a thickness of One inch and the side in which our Components will be kept was rectangular hollowed.

ix) Wheel Encoder: In general when it comes to turn a robotic wheel clockwise or anticlockwise automatically in any angle or direction, it is really hard to make the perfect turn especially when it is freely moving. Encoder provides the way of estimating the vehicle position for more perfect motion control. There are a lot of encoders available in the market but here we are only talking about incremental encoders. This type of encoder can only read white and black colors. Their main function is to count how many black and white colors are present in one rotation of the wheel.

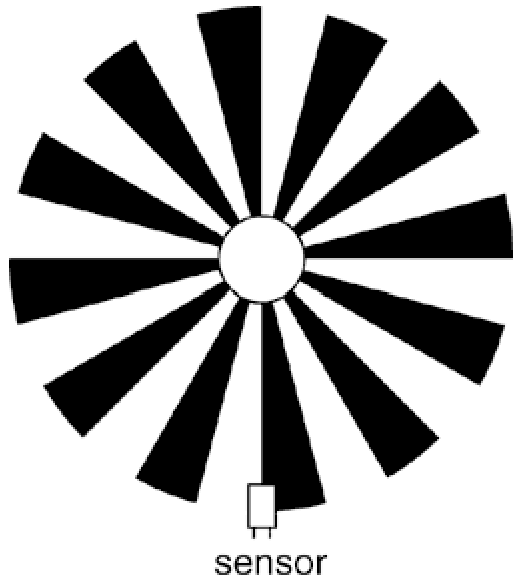

Figure 8: Wheel Encoders

Let's Say it's a wheel and one encoder sensor is positioned on one edge of the wheel. The sensor can tell anytime whether it sees black or white. If there is 24 divisions in the wheel where half of them are black and others are white, we can know how fast the wheel is turning by the sensors black/white reading. For 360 degree angle and 24 divisions here we get 15 degrees/division. That's how we can set and measure the turn or movement of the wheel. For only moving or turning we need only one sensor for one wheel. In our case we use two sensors for our two motor wheels. Initially the car goes straight but when the LDR contacted with laser light then the encoder sensor measured the degree/division needed to turn the car right or left in 180 degrees. That's how the encoder sensor works in here.

b) Electrical Components

*i) RF module***:** An RF Module is a small electronic device used for communication purposes using Radio Signals. RF Module is a commonly used device to serve the purpose of wireless communication in any embedded system. It consists of a transmitter and a receiver. [12] In our Autonomous Tractor we used the FS1000A 433 MHz RF Module. It requires an operating voltage of DC 5 Volt. It can communicate at a distance from 20 meters to 200 meters. The Transmitting frequency is 433 MHz and the receiving frequency is 433.92 MHz and the data transfer rate in this module is 4 kbps. The Receiver sensitivity is -105dB and the Transmitting power is 10mW. It operates in AM frequency. The transmitter of the RF Module was placed in the Controller that was used to start and stop the tractor. The receiver of the RF Module was placed in the prototype tractor. It was used to fulfill the function of communicating with the tractor wirelessly by sending radio signals. The transmitter of the RF module is connected to a controller where the controller acts as a start or kill switch for the tractor.

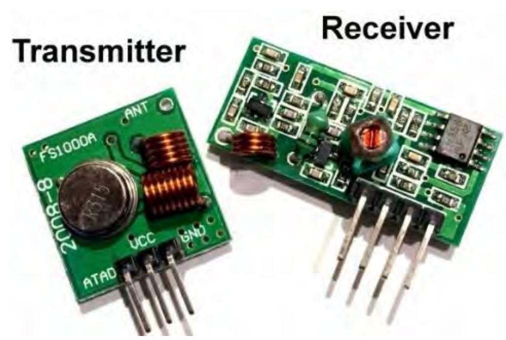

Figure 9: RF Module Transmitter and Receiver

When the Start button is pressed, the RF transmitter sends Radio signal to the tractor from the controller which is received by the RF receiver placed in our prototype tractor. As soon as the RF receiver is able to receive the signal from the transmitter, the tractor starts to move and perform its function as provided in the coding part. Again, if the stop button is pressed, the RF transmitter sends the signal to the tractor which is received by the RF receiver. As soon as the RF receiver receives the stop signal sent from the transmitter, it immediately stops the tractor barring it from performing any of its function. Again when the tractor reaches at the end point of the field, a sonar sensor is placed to detect the presence of the tractor. As soon as the sonar sensor senses the presence of the tractor, a command is sent to the RF transmitter via Arduino telling the Tractor to stop. The RF receiver then receives this command and acknowledges it by stopping the tractor instantly. RF module was used for the wireless communication as it has good penetration capability, it is cheaper than other communication modules, it has a long range of communication, it is easy to integrate with Arduino and easily compatible with other devices. The RF Transmitter has 3 output pins: Data, VCC and GND. The RF Receiver has 4 output pins: VCC, Data, Data, GND.

ii) LDR Sensor: LDR or Photo resistors are light sensing resistors that is able to change its resistance depending upon the incident light. The photo resistor decreases its resistance with increasing incident light intensity. [13] The LDRs that were used in our prototype tractor are 25mm in diameter and has a resistance capacity from 10kΩ to 20kΩ. The LDRs are placed to the front side of the tractor in such a way so that it can receive the laser ray at first hand as soon as the tractor reaches the end of the aisle. Two hatch has been made on the front side of the tractor, one hatch is faced towards the left and the other hatch is faced towards right. Each hatch consists of 6 LDRs that is connected in parallel with each other. The LDRs are then connected in series to the Arduino via Resistors. The function of the LDR is to sense the laser. Whenever the laser falls on any one LDR, its resistivity decreases thus its luminous value changes and it notifies the Arduino that the laser light is incident on the LDR due to the change in its luminous intensity. The Arduino then instructs the tractor to stop in its track and rotate to carry on ploughing or harvesting in the next aisle. The LDRs were used in the prototype tractor because the sensing mechanism we used to turn the tractor to plough or harvest from one aisle of the field to another becomes very simple with the use of LDR.

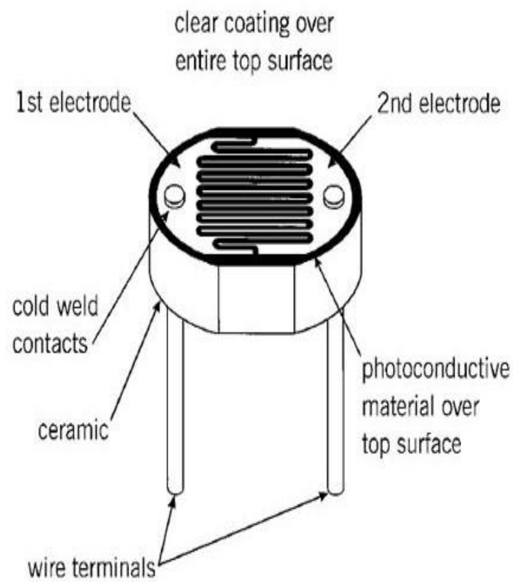

Figure 10: LDR basic Diagram

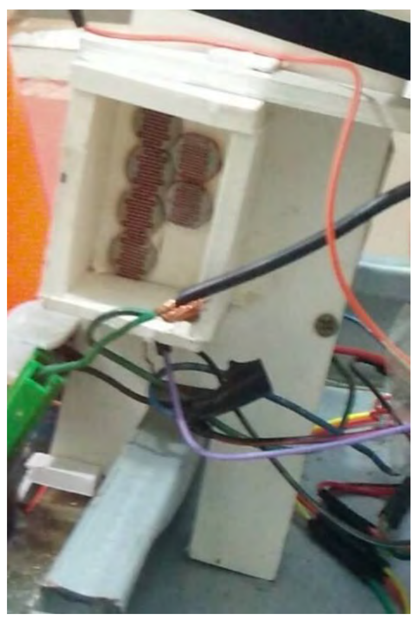

Figure 11: LDR setup in prototype tractor

Moreover, LDRs are very cheap and easily available and they require very low amount of power and voltage to operate. Moreover the Arduino becomes very easy to code with the use of LDR as the LDR shows finite values which the Arduino can easily read and interpret it to the tractor to follow certain commands. Thus all these factors make the use of LDR very efficient and effective.

iii) Dot Red Laser: A Laser is a device that performs the process of optical amplification based on the principle of stimulated emission of electromagnetic radiation to emit light. [14] For our Autonomous tractor system we used two 5V dot lasers. These two lasers are attached individually with two cones that are used for parking. A hole is made in each cone so that the laser can be put inside the cone and the light can come out through the hole made in the cone. Each laser is connected with 9V battery with battery adapters. A push switch has been used in the cone to turn the Laser on or off when necessary. The cones are light, small and easily portable. So, when we needed to do field tests we placed the cones at the two ends of the field or the testing area and both were placed facing the same direction. It should be noted here that both the cones must be placed in such a way so that the lasers fall on the LDR of the car.

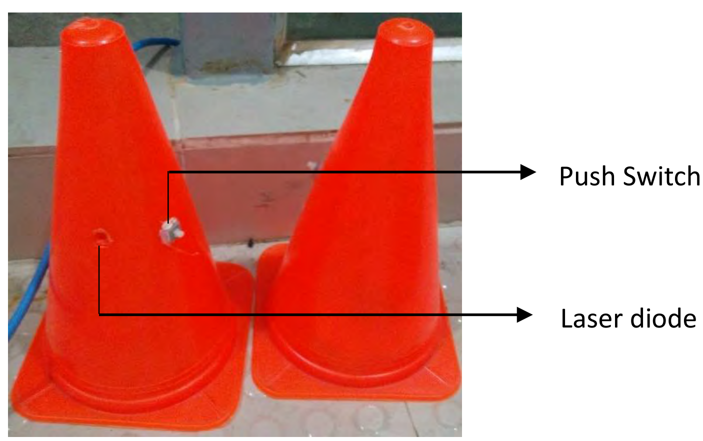

Figure 12: Cones with Battery and Laser diode inside

iv) Relay: A relay is a switch that is operated electrically. Many relays are used with electromagnets for mechanically operating a switch, but other operating mechanisms are also used in case of solid-state relays. Relays are used in places where it is required to control a circuit by using a separate low-power signal, or in places where several circuits must be controlled by one signal. [15] Relays are crucial for building embedded systems. In our Autonomous Tractor system we have used relays to provide power to the mechanical and electrical components. The relays ensure that each and every components meets the demand of getting its required power to operate. In our prototype tractor we have used Two Single Relay board and One 2 Channel 5V Relay Modules.

Figure 13: 5V Single Relay Board

Figure 14: 2 Channel 5V Relay Module

Relays have been used as they provide smooth switching operations. It is cheap, easy to use and is available in the market. It is one of the widely used components in electric circuits, especially in the field of robotics or embedded systems.

v) Arduino: Arduino is an open source computer hardware or software company that designs microcontrollers. [16] A microcontroller is a mini sized computer implemented on a single integrated circuit. It is a system on a chip, also known as SoC. Microcontrollers are designed for embedded applications. [17] Our Autonomous Tractor system is based on the microcontroller, Arduino. For our Autonomous Tractor system we used two Arduino Uno boards. One of them is placed in the prototype tractor and the other has been placed in the Controller that has been made for controlling our prototype tractor. Arduino has been used as the microcontroller for our Autonomous tractor system as it is easy to work with, coding with Arduino is much easier than coding with other microcontrollers and many codes are available in the library for easy access. Thus it takes less time to work with Arduino.

Figure 15: Arduino UNO

vi) Buck Module: Buck converter is a DC-to-DC voltage converter which steps down voltage from its input power supply to its output or load. It is a type of switched-mode power supply (SMPS) containing at least two semiconductors and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors are normally added to such a converter's output and input. Buck converters are highly efficient, making them useful for tasks such as converting high power for circuits that requires low power to run. [18]

Figure 16: Buck Converter

While designing our Autonomous Tractor most of our Electrical Components require 5V to operate. But on the other hand the components need to work for a long time thus we had to provide it with batteries that will be sufficient to power the whole tractor for a sufficient period of time for fulfilling its tasks. For powering our tractor we used 12V Lead Acid batteries which were converted to 5V to power each components separately. This conversion of voltage was done using our Buck Converter. Buck converters were used as it is easily available in the market, low cost and efficient in converting power. Thus we used it to convert voltage in our prototype tractor.

vii) Sonar Sensor: A Sonar sensor also known as Ultrasonic Sensor is a device that measures the distance of an object by using sound waves. It measures the distance by sending out sound waves at a specific frequency and listening for that sound wave to rebound. By recording the elapsed time between the sound wave being generated and the sound wave bouncing back, it is possible to calculate the distance between the sonar sensor and the object.

Figure 17: How a sonar sensor works

Based on the above explanation and we can write the equation for calculating the distance covered by the sonar sensor. The equation is as follows:

$$\boldsymbol{distance} = \frac{\boldsymbol{speed\ of\ sound} \times \boldsymbol{time\ taken}}{\mathbf{2}}$$

In our Autonomous tractor design we placed the sonar sensor with the controller. The sonar sensor (HC-SR04) is a small object and can be easily fitted into the controller along with an Arduino. It requires a DC 5V working voltage and 15mA current. It operates on a frequency of 40 Hz. While operational the module automatically sends eight 40 kHz signals to detect whether there is a pulse signal back. Its maximum range is 4m and minimum range is 2cm. It measures with an angle of 15 degree. In our Autonomous tractor system, after turning on the prototype tractor with the controller, the tractor starts working on the field as commanded. We then place the controller at the very last point on the field where the tractor needs to stop. As the Sonar Sensor is attached with the controller, when the tractor reaches at the very last point of the field and the sonar sensor detects the tractors presence, it sends data to the Arduino which tells the tractor to stop. This command is passed to the tractor using the RF transmitter. As soon as the tractor receives the command of the Arduino through the RF receiver, the Arduino on the tractor commands it to stop. It has 4 output pins: VCC, Trig, Echo and GND.

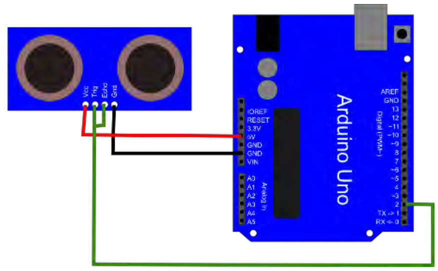

Figure 18: Sonar Sensor and Arduino Connection

viii) L298 Motor Driver: The L298 Motor driver module is based on the L298N H-bridge, which is a high voltage, high current, dual full bridge driver manufactured by ST Company. It can drive up to 2 DC motors each containing 2A current. [19]

Figure 19: L298 Motor Driver

The L298 Motor Driver has been used in our prototype tractor to control the actuator. In our prototype tractor the actuator has to extend and retract in order to lower and raise the plougher. But the polarity between the connection of the actuator and the battery needs to be changed every time the plougher is lowered or raised. So this dual performance of reversing the polarity of the actuator is done by the L298 Motor Driver.

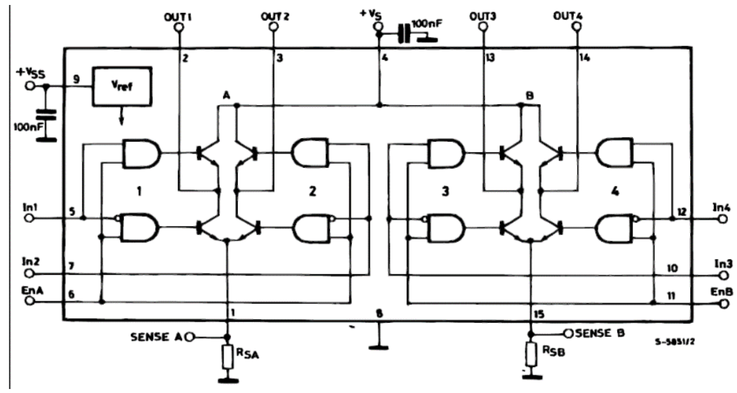

Figure 20: L298 Motor Driver Circuit Diagram

ix) IR obstacle avoidance module: The Infrared Obstacle Avoidance Proximity Sensors module has IR Transmitter and IR Receiver built in. It sends out IR energy in search of reflected IR energy to detect the presence of any obstacle in front of the sensor. The sensor has very good and stable response even in ambient light or in complete darkness. The sensor module can be interfaced with Arduino, Raspberry Pi or any microcontroller having IO voltage level of 3.3V to 5V. The model we used as IR obstacle avoidance in our prototype tractor is FC-51. It has an operating voltage of 3V to 6V and detection range from 2cm to 30cm. It was operated on 5V in our prototype tractor consuming 43mA current. It shows output low when it detects obstacles and output high when obstacle is not detected.

Figure 21: Infrared Obstacle Avoidance Module

In our prototype tractor we used the IR Obstacle avoidance module as a counter. Since it has the feature of counting objects, we used it to count the black and white marks of our Wheel Encoder. Its function was to count the black and white marks and give the Arduino a calculation on how many black and white marks are encountered for one full rotation of the wheel. This data was used for rotating our prototype tractor at the end of each aisle. The FC-51 module as used as the counter due to its low cost, low power consumption. It is easily available in the market and requires very simple coding in order to operate, thus making it easy to use. There are 3 pin outs of this module: VCC, GND and Digital Output Pin.

2.2. Tractor Schematic Overview

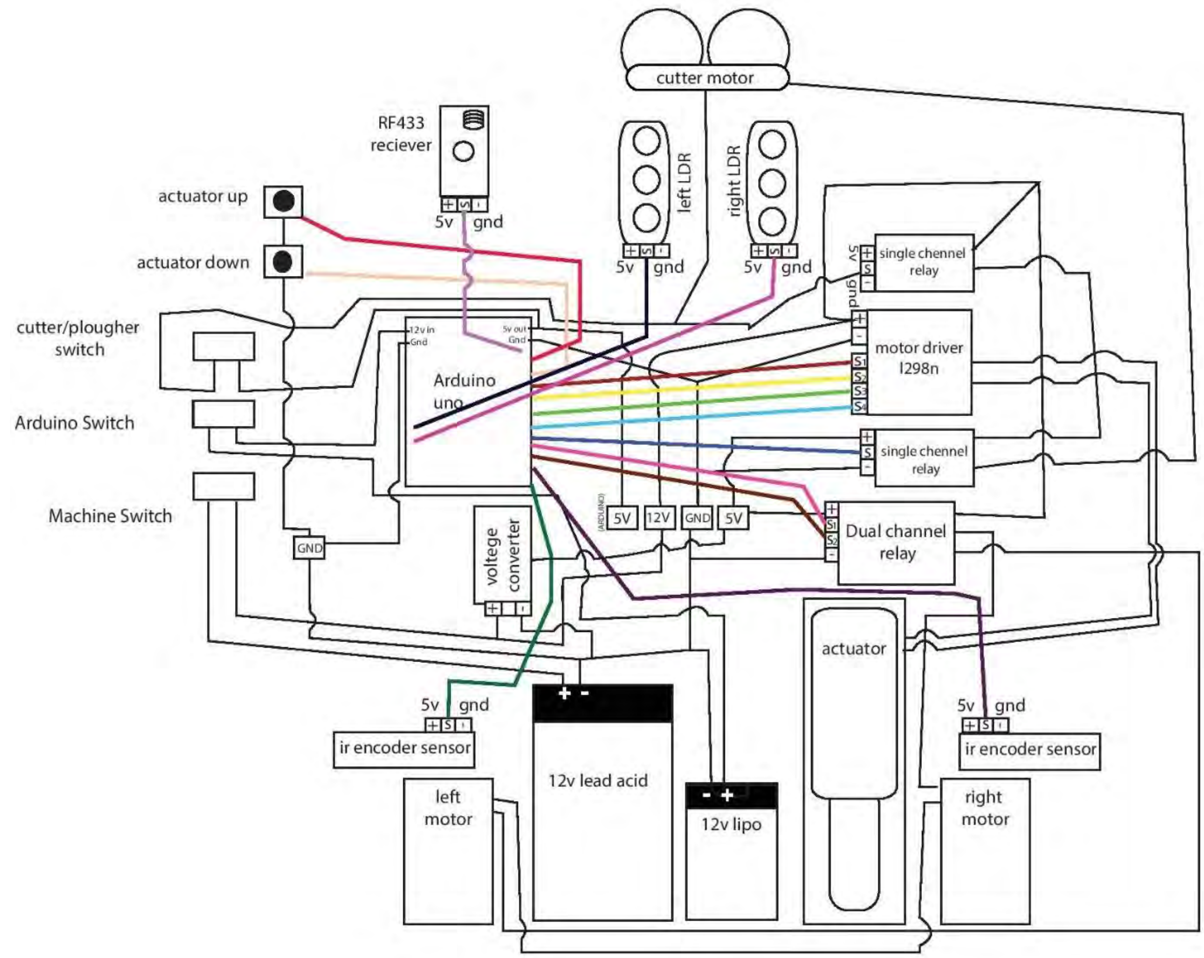

Figure 22: Autonomous Tractor System Schematic Diagram

a) Connections with Arduino: The Arduino can be compared to the processor of a computer to make understand its value in our Autonomous Tractor Design. The Arduino consists of Analog pins, Digital pins and Power pins. These 3 pins plays three different roles in the build-up of an electronic embedded system. The power pins control the power flow through the Arduino microcontroller. The Vin pin is connected to the 12V Lipo Battery via the Arduino On/Off switch. The 5V pin of the Arduino is connected to the Cutter/Plougher mode switch. The Ground pins are connected to the GND of Lipo and Lead Acid Batteries. The Analog Input pins perform the functions of connecting with the Analog Devices in the circuit. The Analog pins of the Arduino A0 and A1 are connected with the right and left LDR panels situated in the car. The Digital pins powers different Electrical and Mechanical parts of our Autonomous Tractor. Pin 2, Pin 3, Pin 12 and Pin 13 of the Arduino are connected with the Actuator via the L298 Motor Driver. Pin 4 and Pin 5 are connected with the Actuator down and up switch respectively. Pin 6 and Pin 7 are connected with the Wheel motor right and left respectively via the Dual Channel Relay. Pin 8 is connected with the Cutter motors via the Single Channel Relay. Pin 9 and Pin 10 is connected with the IR Obstacle avoidance module as right and left wheel sensors respectively. Pin 11 is connected with the RF Receiver pin.

b) Connections with Cutter Motor**:** The Cutter Motors are connected with two Single Channel Relays and the Cutter/Plougher Mode Switch.

c) Connections with Single Channel Relay-1**:** The S pin of the Single Relay-1 is connected with the Cutter Motor. The +ve and –ve pins are connected with the 5V and GND coming from the Buck Converter via a breadboard. One output of this Relay goes to the +ve pin of the L298 Motor Driver Module. Another output of this Relay goes and connects with the Double Channel Relay. The Third output of this relay connects with the Single Channel Relay-2.

d) Connections with Single Channel Relay-2: The S pin of the Single Relay-2 is connected with Pin 8 of Arduino. The +ve and –ve pins are connected with the 5V and GND coming from the Buck Converter via a breadboard. One output of this Relay goes and connects with the Cutter Motors. Another output of this relay connects with the Single Channel Relay-1.

e) Connections with Double Channel Relay**:** The S1 and S2 pins of the Double Channel Relay are connected with Pin 6 and Pin 7 of the Arduino for operating the right and left wheel motors respectively. The +ve and –ve pins are connected to the 5V of the Buck Converter and GND respectively. One of the output from this relay is connected with the right wheel glass motor. Another output is connected with the left wheel glass motor. The Third output is connected with the +ve pin of the L298 Motor Driver.

f) Connections with Actuator: The two wires from the Actuators are connected with the outputs of the L298 Motor Driver.

g) Connections with L298 Motor Driver: The S1, S2, S3 and S4 pins of the L298 Motor Driver is connected with the Pin 2, Pin 3, Pin 12 and Pin 13 of the Arduino. The +ve pin of the Motor Driver is connected with the +ve pin of the Buck Converter via the 12V pin of the breadboard. The –ve pin is connected to the GND. The Output pins of the Motor Driver are connected with the two wires of the Actuator.

h) Connections with Buck Converter: The +ve OUT pin of the Buck Converter is connected with the Machine switch and the 12V pin on the breadboard. The IN +ve pin is connected with the 5V pin on the breadboard. Thus it can be said here that the Buck Converter takes 12V input from the Lead Acid batteries and converts it to 5V DC voltage for other components to use. The –ve pin of the Buck Converter is connected with the GND.

i) Connections with the Batteries: The +ve pole of the 12V lead acid battery is connected with the Machine Switch and the –ve pole of this battery is connected to GND. The +ve pole of the 12V Lipo Battery connects with the Arduino switch and the –ve pole is connected to the GND.

j) Connections with IR Obstacle avoidance Modules: The +ve and –ve pins of the IR Obstacle Avoidance Module are connected with the 5V and GND pins drawing power from the breadboard. The S pins of the modules are connected with Pin 9 and Pin 10 of Arduino which controls the right and left wheels respectively.

k) Connections with RF Receiver: The +ve and –ve pins of the RF Receiver is connected with the 5V and GND pins on the breadboard. The S pin of the RF Receiver is connected with Pin 11 of Arduino. The RF Receiver can only operate when it receives commands from the RF Transmitter.

l) Connections with LDR**:** The S pins of the LDR are connected with the right and Left LDR respectively via Pin A0 and Pin A1.

2.3. Controller Schematic Overview

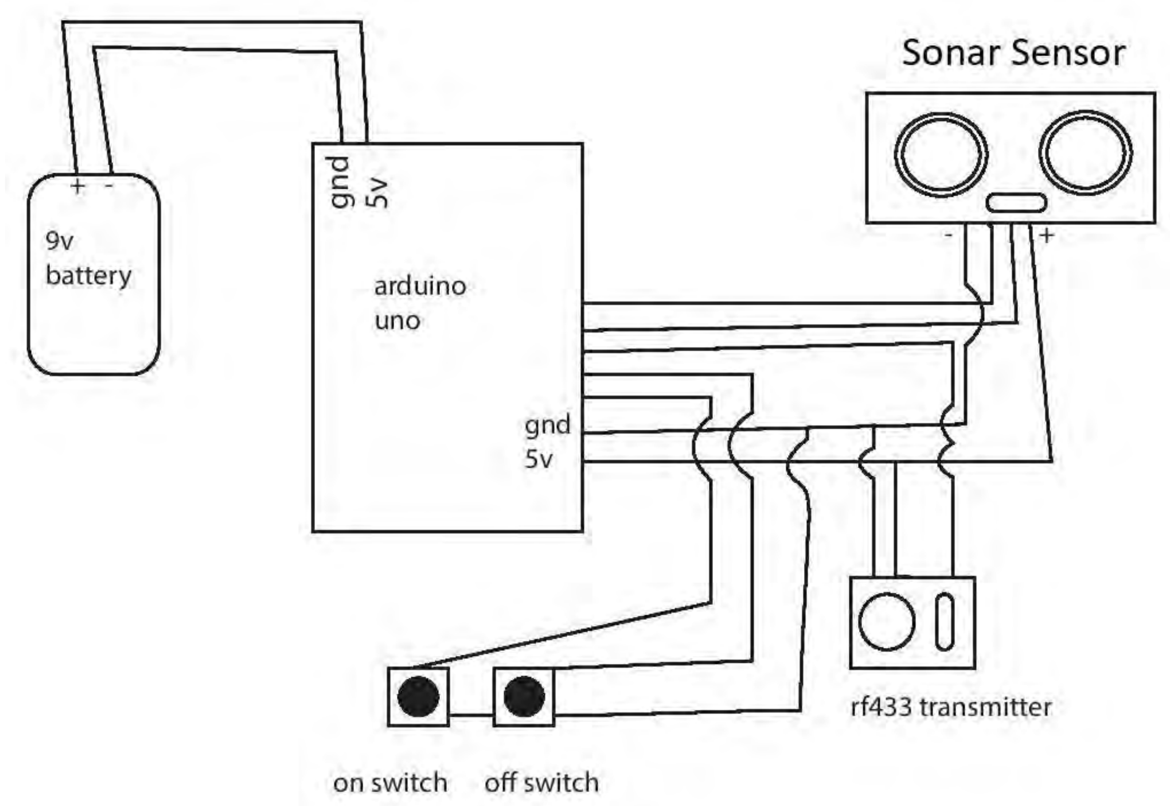

Figure 23: Schematic Diagram of the Controller

Connection within the Controller**:** The 5V pin and the GND pin of the Arduino is connected with the +ve pin of the 9V Battery in the Controller and the –ve pin of the 9V Battery is connected to the GND pin of Arduino. The Vin pin of the Arduino is connected with the +ve pin of the Sonar Sensor and the –ve pin of the Sonar Sensor is connected with the GND pin of Arduino. The Trig and Echo pins of the Sonar Sensor are connected to Pin 2 and Pin 3 of Arduino respectively. The RF Transmitter Data pin is connected with Pin 12 of Arduino and the VCC and the GND pins of the RF transmitter is connected with the 5V and GND pins.

2.4. Block Diagram of Tractor:

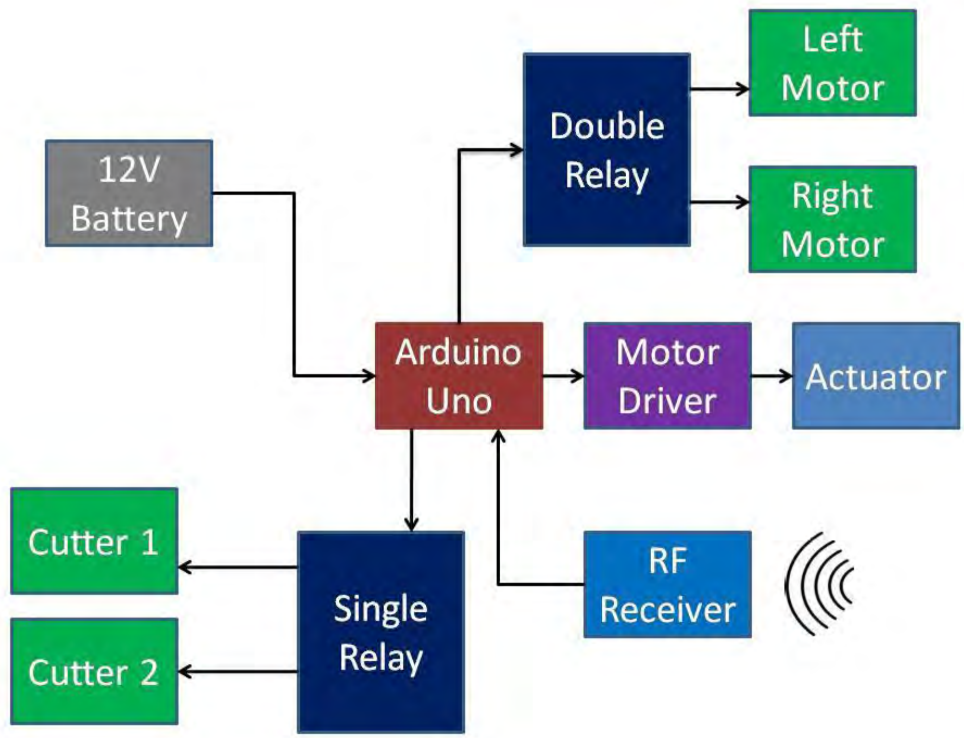

Figure 24: Block Diagram of Autonomous Tractor

Let us discuss the facts that can be understood from the block diagram. If we understand this block diagram, it will be easier for us to understand the Working Mechanism of our Autonomous Tractor. The 12V battery powers the Arduino. This 12V power from the battery is converted by the Buck Converter to 5V and the power is passed onto different components used in our Tractor via Arduino. The 12V power from the battery is passed in 5 Volts through the Arduino to the Right and Left Motor of the prototype tractor by using Double Channel Relay. This enables the Motor to drive the tractor forward. As the tractor intends to move forward the Plougher needs to be lowered, this function is performed by the Actuator. The 12V power from the battery is passed in 5 Volts to the Motor Driver through the Arduino and is used by the Actuator to lower and raise the plougher. This enables the Actuator to raise and lower the plougher automatically according to its required need. The Cutters are powered by the 12V power from the battery which is passed in 5 Volts through the Arduino using the Single Channel Relay. It enables the cutter to turn it off/on according to its required need when it needs to harvest the crops. When the tractor reaches at the end of the field it needs to stop and this function is done by the RF Receiver which is connected to the Arduino in order to run the code that will make the tractor stop.

2.5. Block Diagram of Controller:

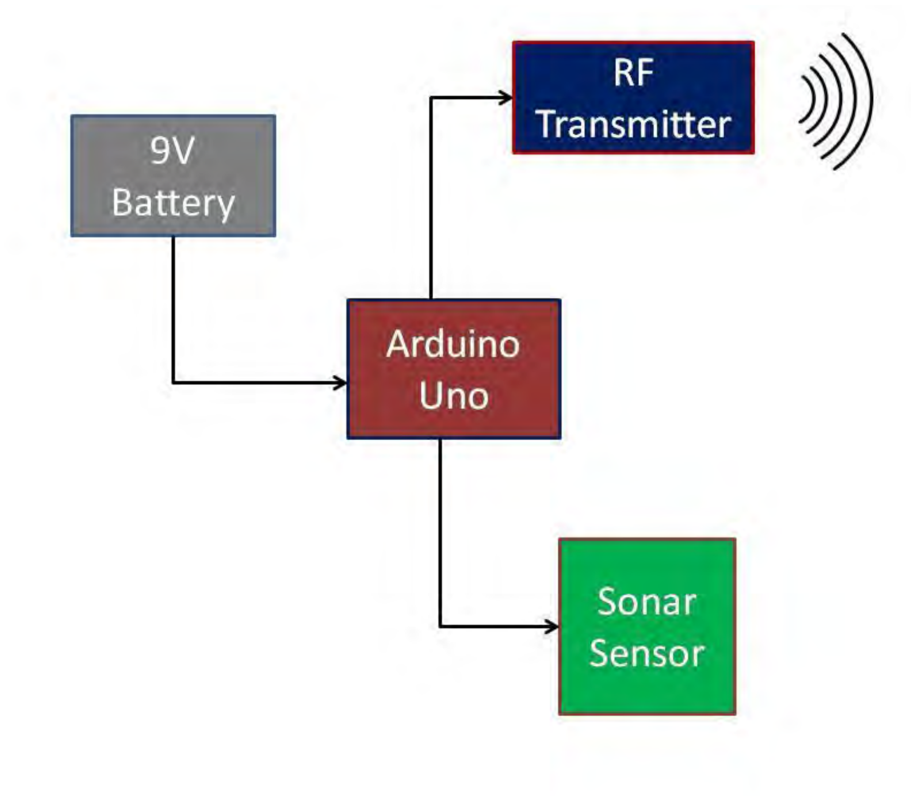

Figure 25: Block Diagram of Tractor Controller

Now let us understand the Controller's contribution in making our Autonomous Tractor System work more efficiently. The Arduino Uno of used in the Controller is powered by the 9V battery. The Controller performs 3 important functions for our prototype tractor. At first, it starts the tractor. Secondly, it communicates with the tractor telling it when to stop using the RF Transmitter which is connected to the Arduino. The code used in the RF transmitter simply sends a wireless command to the RF receiver in the Arduino telling it to break from its loop. Thirdly, it performs the function of stopping the tractor by using the Sonar Sensor. The Sonar Sensor is connected with the Arduino and it detects whether the tractor is within its 10cm range. As soon as the tractor reaches within the 10cm range of the Sonar Sensor it sends message to the Arduino acknowledging it that the tractor has reached within 10cm of its range. As soon as the Arduino gets this information it commands the tractor to stop by communicating with it using the RF Module.

Chapter 3: Autonomous Mechanisms

3.1. Setting and Selecting the Mode

Our Autonomous Tractor System has the ability to work in two different modes:

a) Plough
b) Harvest

The prototype tractor was equipped with switches. First comes the Machine Switch, the Machine switch is responsible for turning the power of the tractor on/off based on the required demands. If the Machine switch is off, then under no circumstances will the tractor be able to move. Thus, in order to use the tractor, first the Machine must be turned on. Secondly comes, the Arduino Switch. The Arduino Switch is responsible for turning the microcontroller on/off based on required needs. If the Machine switch is on but the Arduino switched is turned off, even then the tractor will not be able to fulfill what has been commanded in its system, thus it will not function. Thirdly, comes the Mode switch. As our tractors have two different modes. Users can choose the mode they need to perform their work. If the user wants to use the tractor for ploughing the field then the Machine switch must be on, the Arduino switch must be kept on and the Mode Switch must be set to "Plough" mode for ploughing the field. Again if the user wants to use the tractor for harvesting the crops, then the Machine switch must be kept on, the Arduino switch must be kept on and the Mode Switch must be set to "Cutter" Mode for harvesting the field.

3.2. The Ploughing Mechanism

In the plough mode, the user needs to set at first how much deeply they need to plough their land. In that case, the user has to manually set the plougher level using the Plougher up and down buttons. After the level of the Plougher is set, the user needs to push the "ON" button placed in the controller. As soon as the user hits the start button on the controller, the tractor starts to function. It goes straight and continues to plough its way forward until the LDRs in the tractor hits the Laser situated at the field boundary. When the Laser hits the LDR, the plougher is raised to its default height and after turning the tractor to move to the next aisle, the plougher is again lowered to the height it was ploughing before. It must be mentioned here that the up and down mechanism of the plougher is performed by the actuator. If we notice the schematic diagram of the actuator in Fig 2.6 we will notice that the plougher is connected to the actuator via L298 Motor Drivers. Now in order to raise and lower the plougher the polarity of the actuator needs to be changed every time the plougher is lower or raised. But, it is not possible as we have to raise and lower the plougher multiple times in the field. Thus, keeping this as a manual option will increase the list of things to do for the users for operating our prototype tractor. So, in order to change the polarity according to the requirement of the tractor's position in the field, we have used the L298 Motor driver. If we notice the circuit connection of the Arduino, L298 Motor Driver and the Actuator, we will notice that the connection between the Arduino and the L298 Motor driver has been given in such a way so that the L298 Motor Driver and the Actuator can adjust its polarity based on its need. In this way the Ploughing Mechanism is completed by our Autonomous Tractor system.

3.3. The Harvesting Mechanism

In the harvest mode, the user needs to select the "Cutter" mode from the Plough/Cutter switch. After selecting the Cutter mode and placing the tractor in the field, the "On" switch is pressed on the Controller. As soon as the switch is pressed the Cutter starts spinning and the prototype tractor starts to move forward. As the cutter starts to spin and the tractor starts to move forward, any crops or grass that comes in the way of the tractor is cut down and made ready to be harvested. The tractor moves forward until the LDRs in the tractor detect the presence of Laser in the field. As soon as the LDR detects presence of laser on the tractor it stops instantly, turns off the cutter motor, takes a turn to move to the next aisle and again automatically turns on the cutter motor. In this way the Cutter motor will harvest the crops on the field and complete the Harvesting Mechanism on our Autonomous Tractor system.

3.4. Taking the Turns

Now we will discuss about that part of our Autonomous Tractor System which was most difficult to work on. Previously many Autonomous Tractor Systems have failed to reach the market as products due to their inability to turn perfectly in the field. Taking the turns at the end of each aisle in the field is the most difficult task as this has to be done perfectly without any sort of error. In this part everything depends on the angle in which the car turns itself. If the angle of the car is even slightly off the required angle to which it should turn, then it will create a huge mess in the field doing ploughing and harvesting in a random manner. As a result it will be devastating for both the farmers and our Autonomous Tractor system will lose its credibility due to this. Thus in order to ensure that the Tractor turns itself smoothly without creating any error on the angle at the end of each aisle, we used IR obstacle avoidance Sensor and Wheel Encoders. The work of the Wheel Encoder is to present the black and white marks given on the wheel, to the IR obstacle avoidance sensor. The IR obstacle avoidance sensor does not need to count the black and white marks when the prototype tractor is moving inside the field. But when the prototype tractor hits the laser, the IR obstacle avoidance sensor starts counting the black and white divisions marked on the wheel encoder. The black and white divisions on the wheel encoder is the most vital factor in turning the tractor properly to work in the next aisle. These black and white divisions can be increased or decreased according to our need. But the more black and white divisions made, the more accuracy will be there in the turning of the tractor. In our prototype tractor we used 8 black divisions and 8 white divisions on each wheel encoder. So, in order to complete one full rotation of the wheel the IR obstacle avoidance sensor need to count 16 divisions on the wheel encoder. Our prototype tractor needs 3 rotations of the wheel to complete one 180 degree rotation on each aisle. The direction in which the tractor will turn will depend on which panel of the LDR the laser hits. If the Laser hits the right panel of the LDR, the prototype tractor will rotate right. If the Laser hits the left panel of the LDR, the tractor will rotate left. While turning the tractor at the end of each aisle only one wheel of the tractor. If the tractor has to turn right then the right wheel of the tractor will perform the function in rotating the tractor. In this case, the right wheel has to complete 3 rotations in order to perform a 180 degree turn. So, to complete one rotation the right wheel IR obstacle avoidance sensor needs to count 16 divisions on the wheel encoder. Therefore, to complete 3 rotations the IR obstacle avoidance sensor on the right wheel will need to count (16 X 3=) 48 divisions. So when the IR obstacle avoidance sensor will finish counting 48 divisions, the right wheel will have completed 3 rotations and the tractor will finish rotating 180 degree right and again starts its ploughing or harvesting from the next aisle. The same mechanism has been applied for the left wheel. When the left panel LDR of the tractor is hit by the LDR, the tractor stops and the IR obstacle avoidance sensor on the left wheel starts rotating the wheel and counting the black and white divisions. By the time 48 divisions have been counted, the wheel will have finished completing 3 rotations enabling the tractor to take a 180 degree left turn and continuing its work of ploughing or harvesting on the next aisle. By following this method, we have made our Autonomous Tractor system to take efficient and errorless turns at the end of each aisle. This mechanism was crucial to make our tractor an automated system.

3.5. Knowing When to STOP

Now the question might arise as to how this automated system will understand that it has ploughed or harvested crops in the whole field and needs to stop? Running a tractor in a field is not something to be taken lightly. If proper measures are not taken things might go out of hand and cause fatalities or accidents. Thus we equipped our tractor with a kill switch which is placed on the controller. But again the question arises how it is "Automated" then if I need to press a switch to stop it? To give a solution to this problem we have equipped our Controller with a Sonar Sensor. From the rotation directions of the tractor and from the size of the field we can easily understand where by visualizing where the end point of the field will be and that is where the tractor will need to stop. Hence we take our controller and put it at the end point of the field. As mentioned earlier that the controller has been equipped with the sonar sensor and the sonar sensor was coded to detect the presence and to stop it when it comes within 10 cm range of the sonar sensor. Hence, this is the time when the Sonar Sensor will perform this function. The Sonar Sensor sends ultrasonic waves to determine the position of any object, how it performs this function has been showed previously. Hence, when the tractor is ploughing or harvesting the last aisle and it has reached near the end point of the field, the sonar sensor detects the tractor when it comes within 10 cm range of the sonar sensor and sends signal to the Arduino commanding the tractor to stop. This command is sent to the tractor from the controller by the RF Module. This is how our Autonomous Tractor is designed to know when to STOP.

Chapter 4: Results and Implementation Challenges

4.1. Result Analysis

In the Result Analysis section we can write that although we faced a lot of problems in implementing our Autonomous Tractor design, most of the problems were solved by continuous research and study of the techniques. Our tractor worked perfectly in executing the Start command. The Stop Command was also tested both manually and automatically with the Sonar Sensor and it executed perfectly both the commands. While the tractor was in motion it worked perfectly in moving forward. It did not steer right or left when it is supposed to move straight. Thus it can be said that the tractor performed the command of moving forward perfectly without any issues. But the tractor height from the ground needed to be increased more as the tractor gets stuck to the ground when the surface is very rough or uneven. For increasing the tractor height from the ground the wheel radius needs to be further increased also. Now when it came to the part of rotating the tractor the tractor rotated smoothly without errors in medium rough surfaces. But in plain surfaces or heavily rough surfaces it showed some errors while turning. This problem can be solved by increasing the radius of the front wheel and increasing the height of the tractor from the ground. So it can be said that by analyzing the above mentioned results we can conclude that our tractor has a 90% efficiency rate. If the minor problems can be solved it can be made fully efficient and can be led into production.

4.2. Problems Faced During Implementation and Solutions

a) Problems with NRF Module: During the implementation of our project we faced a lot of problems from the beginning. Firstly, for the communication purpose we used NRF modules. The NRF module worked perfectly in executing simple circuit codes but when it was implemented to run big circuits, the code became more complex and the NRF module could not run the codes efficiently as it was doing with the simple codes. Moreover, the NRF module was expensive so at any time when we had to replace it or buy a new one it became costly for us. Thus to solve these two problems we replaced the NRF module with RF module. It had lesser range than NRF module but had perfect program execution capability than the NRF module. Thus, the RF module was used to solve the problem with NRF.

b) Problems with using too many Arduino**:** Previously during the implementation of our project we used too many Arduino microcontrollers for our project. Our concept was to use 4 lasers and 4 LDRs, the Laser would hit the LDR during the regular time when the tractor is within the field, but when the tractor would intercept the laser then using RF modules we were to rotate our tractor. This also required 2 RF modules and total of 6 Arduino microcontrollers. 4 of them placed at 4 corners of the field, one in the tractor and the other one in the Controller. But this previous concept of our project made the design very complex and expensive. Thus to reduce the cost and to make the project simple we installed the LDRs on the prototype tractor, this also reduced the need of using 4 Arduino microcontroller and 4 lasers. This made the project more efficient and cost effective.

c) Problems with Stepper Motor**:** When using the Stepper we faced problems in the locomotion of our tractor. The Stepper motor could not provide enough torque to move our tractor. Thus we had to replace it with Glass motors or otherwise known as Power Window Motors.

d) Minor Problems**:** Other than the problems mentioned above, we faced minor problems such as sometimes our components got short circuited or damaged, some components got old and needed to be replaced in order to make them work efficiently. Sometimes we faced problems with our circuit connection and they had to be fixed. But these problems were solved and our system worked perfectly in the end.

4.3. Benefits of Using our Automated Tractor Design

From the beginning of this project our main vision and objective was to use this project in making farming easier, comfortable and cost efficient. We have succeeded in fulfilling all these 3 objectives. Firstly our priority was to make it cost effective. Since there are many autonomous tractor systems being developed, so we had to make our design cheaper from other Autonomous tractor technologies. For making the design cost effective we used very simple electrical and mechanical components that are easily available at the market and also available at a very low price. Our project can be made by spending only 10,000 to 15,000 taka. For an autonomous system this amount is very cheap compared to other autonomous tractor systems. Secondly, we prioritized on making our autonomous tractor easy to use and comfortable. We know that ploughing a field requires a lot of physical strength and labor if the farmers do it by themselves. At the same time it is also time consuming. Moreover, if the farmers use domestic animals to plough their fields or hire labors that will be also costly for them. But by using our Autonomous Tractor the farmers can easily plough the fields comfortably and effortlessly. It will also take less time compared to the conventional methods. Thus all these factors point to the fact that our Autonomous Tractor design will be beneficial for the farmers.

Chapter 5: Conclusion and Future Development Scopes

In this era with the rapid development and expansion of technology, Autonomous systems have become the new trend of World Revolution. With the invention of new Autonomous technologies we are stepping one step ahead into making our lives easier and comfortable. But in Bangladesh, the designing of Autonomous systems needs to be increased further more so that new ideas and systems are developed. Our Autonomous Tractor system shows significant promise and prospects as a platform for the development in the field of agriculture and furthermore bringing in Automation technology in the field of agriculture and it is anticipated that with development of the underlying systems completed future work will focus on refining and improving the methods presented here. If our government and private investors have the willingness to grant fund in this field of research, it would be a very propitious sector.

With proper initiatives, guidance and funding we can improve our project furthermore. In future Bluetooth module can be installed in the system so as to drive the tractor manually with smartphone remotes, if needed. For further safety precaution a Passive Infrared Sensor can be installed in the tractor which will detect the presence of any unwanted object in the field and will stop the tractor so that no fatality occurs. A solar panel can also be installed on top of the tractor so that it stores solar energy to power the batteries used in the system. Apart from these, there are many more prospects where this project can be further developed.

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Appendix

Tractor Code:

```
#include <VirtualWire.h>
//L293 Connection
int acdown  = 2;  // leftmotor
int acup  = 3;  // leftmotor
int acdsw  = 4; // rmotor
int acusw = 5;  // rmotor
int mr = 6;
int ml = 7;
int cc = 8;
int rs = 9;
int ls = 10;
int rl = A0;
int ll = A1;
int val_new;
int val_old;
int clicks = 0;
int turns = 1;
int stp = 0;
int j = 0;



void setup() {
  // Set pins as outputs:
  vw_setup(2000);  // Bits per sec
  vw_set_rx_pin(11);    //Rx Data pin to Digital  Pin 2
  vw_rx_start();       // Start the receiver PLL running
  Serial.begin(9600);  // Debugging only
```

```
  pinMode(acdown, OUTPUT);
  pinMode(acup, OUTPUT);
  pinMode(acdsw, INPUT_PULLUP);
  pinMode(acusw, INPUT_PULLUP);
  pinMode(mr, OUTPUT);
  pinMode(ml, OUTPUT);
  pinMode(13, OUTPUT);
  pinMode(cc, OUTPUT);
  pinMode(rs, INPUT);
  pinMode(ls, INPUT);
  pinMode(rl, INPUT);
  pinMode(ll, INPUT);
  val_new = digitalRead(ls);
  val_old = val_new;
  //  Serial.begin(115200);
}

void loop() {

  uint8_t buf[VW_MAX_MESSAGE_LEN];
  uint8_t buflen = VW_MAX_MESSAGE_LEN;

  if (vw_get_message(buf, &buflen)) // Non-blocking
  {
    int i;
    Serial.println(" ssssss");
    digitalWrite(13, true); // Flash a light to show received good message
    // Message with a good checksum received, dump it.
    for (i = 0; i < buflen; i++)
    {
      Serial.print(buf[i]);//print received command
```

```
    if (buf[i] == '1') //if button 1 is pressed.... i.e.forward buton
    {
      turns = 1;
      Serial.println(" run");
    }
    if (buf[i] == '2') //if button 2 is pressed.... i.e.back buton
    {
      turns = 3;
      Serial.println(" stop");
    }

    Serial.print(" ");
  }
  Serial.println("");
  digitalWrite(13, false);

}




Serial.print(analogRead(rl));
Serial.print("turns ");
Serial.print(analogRead(ll));
Serial.println("turns ");
// Serial.print(turns);




if (turns == 1 ) {
  clicks = 0;
  if (analogRead(rl) > 1000)
```

```
  {
    digitalWrite(mr, LOW);
    digitalWrite(ml, LOW);
    digitalWrite(acup, HIGH);
    delay(700);
    turns = 0 ;
  }

  if (analogRead(ll) > 1000)
  { digitalWrite(cc, LOW);
    digitalWrite(mr, LOW);
    digitalWrite(ml, LOW);
    digitalWrite(acup, HIGH);
    delay(700);
    turns = 2 ;
  }
  digitalWrite(mr, HIGH);
  digitalWrite(ml, HIGH);
  digitalWrite(cc, HIGH);
  digitalWrite(acup, LOW);
  digitalWrite(acdown, LOW);
  if (digitalRead(acusw) == LOW ) {
    digitalWrite(acup, HIGH);
  }
  if (digitalRead(acdsw) == LOW ) {
    digitalWrite(acdown, HIGH);
  }
}

if (turns == 3 ) {
  digitalWrite(mr, LOW);
```

```
  digitalWrite(ml, LOW);
  digitalWrite(cc, LOW);
  digitalWrite(acup, LOW);
  digitalWrite(acdown, LOW);
  if (digitalRead(acusw) == LOW ) {
    digitalWrite(acup, HIGH);
  }
  if (digitalRead(acdsw) == LOW ) {
    digitalWrite(acdown, HIGH);
  }

}

if (turns == 0 ) {
  digitalWrite(cc, LOW);
  digitalWrite(acup, LOW);
  digitalWrite(mr, HIGH);
  digitalWrite(ml, LOW);
  val_new = digitalRead(ls);
  Serial.print(digitalRead(ls));
  if (val_new != val_old) {
    clicks++;
    if (clicks == 48) {
      digitalWrite(mr, LOW);
      digitalWrite(ml, LOW);
      digitalWrite(acdown, HIGH);
      delay(700);

      turns = 1;
```

```
    }
  }



  else

    Serial.print("CLICKS: ");

  Serial.println(clicks);

  val_old = val_new;
}

if (turns == 2 ) {
  digitalWrite(cc, LOW);
  digitalWrite(acup, LOW);
  digitalWrite(ml, HIGH);
  digitalWrite(mr, LOW);
  val_new = digitalRead(rs);
  Serial.print(digitalRead(rs));
  if (val_new != val_old) {
    clicks++;
    if (clicks == 48) {
      digitalWrite(mr, LOW);
      digitalWrite(ml, LOW);
      digitalWrite(acdown, HIGH);
      delay(700);

      turns = 1;

    }
```

```
    }



    else

      Serial.print("CLICKS: ");

    Serial.println(clicks);

    val_old = val_new;
  }



  Serial.println();
}

//void rcc() {
//
//  uint8_t buf[VW_MAX_MESSAGE_LEN];
//  uint8_t buflen = VW_MAX_MESSAGE_LEN;
//
//  if (vw_get_message(buf, &buflen)) // Non-blocking
//  {
//    int i;
//    Serial.println(" ssssss");
//    digitalWrite(13, true); // Flash a light to show received good message
//    // Message with a good checksum received, dump it.
//    for (i = 0; i < buflen; i++)
//    {
//      Serial.print(buf[i]);//print received command
//      if (buf[i] == '1') //if button 1 is pressed.... i.e.forward buton
```

```
//      {
//        turns = 1;
//        Serial.println(" run");
//      }
//      if (buf[i] == '2') //if button 2 is pressed.... i.e.back buton
//      {
//        turns = 3;
//        Serial.println(" stop");
//      }
//
//      Serial.print(" ");
//    }
//    Serial.println("");
//    digitalWrite(13, false);
//
//  }
//
//}
```

Controller Code:

```
#include <VirtualWire.h>
#include <Wire.h>
#include <NewPing.h>
#define TRIGGER_PIN  12
#define ECHO_PIN     11
NewPing sonar(TRIGGER_PIN, ECHO_PIN);

void setup()
{
  Serial.begin(9600);    // Debugging only
```

```
  vw_setup(2000);  // Bits per sec
  vw_set_tx_pin(6); //Transmitter Data Pin to Digital Pin 3
  pinMode(4, INPUT_PULLUP);
  pinMode(5, INPUT_PULLUP);
  pinMode(13, OUTPUT) ;
pinMode(10, OUTPUT) ;
digitalWrite(10, LOW);
}
void loop()
{
  digitalWrite(10, LOW);
  delay(50);
//  Serial.println(sonar.ping_cm());
  int sonar1 = sonar.ping_cm();
  char *msg2;
  digitalWrite(12, LOW);

  if  (digitalRead(4) == LOW) {
    Serial.println(1);
    char *msg2 = "1";//send 1 to the receiver
    digitalWrite(13, HIGH); // Flash a light to show transmitting
    vw_send((uint8_t *)msg2, strlen(msg2));//send the byte to the receiver
    vw_wait_tx(); // Wait until the whole message is gone
    digitalWrite(13, LOW);
  }

  if  (digitalRead(5) == LOW) {
    Serial.println(2);
    char *msg2 = "2";//send 1 to the receiver
    digitalWrite(13, HIGH); // Flash a light to show transmitting
    vw_send((uint8_t *)msg2, strlen(msg2));//send the byte to the receiver
```

```
    vw_wait_tx(); // Wait until the whole message is gone
    digitalWrite(13, LOW);
  }

  if  (sonar1 > 5 && sonar1 < 30  ) {
    Serial.println(2);
    char *msg2 = "2";//send 1 to the receiver
    digitalWrite(13, HIGH); // Flash a light to show transmitting
    vw_send((uint8_t *)msg2, strlen(msg2));//send the byte to the receiver
    vw_wait_tx(); // Wait until the whole message is gone
    digitalWrite(13, LOW);
  }
}//close loop
```