



Vehicle for Smart Factory Model with Principle of Industry 4.0 Controlled by Arduino.

Diplomová práce

Studijní program: N2301 – Mechanical Engineering
Studijní obor: 2302T010 – Machines and Equipment Design
Autor práce: **Vaira Prakash Muthu Mariappan**
Vedoucí práce: Ing. Radek Votrubec, Ph.D.





TECHNICAL UNIVERSITY OF LIBEREC
Faculty of Mechanical Engineering ■

Vehicle for Smart Factory Model with Principle of Industry 4.0 Controlled by Arduino.

Master thesis

Study programme: N2301 – Mechanical Engineering
Study branch: 2302T010 – Machines and Equipment Design
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DIPLOMA THESIS ASSIGNMENT

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R u l e s f o r e l a b o r a t i o n :

1. Meet Arduino development board, its accessories and its shields.
2. Construct a vehicle for smart factory model controlled by Arduino which is able to transport small subjects.
3. Invent a system to control its position and equip it with appropriate sensors. The vehicle has to be able to reach desired position.

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[2] **Arduino Learning: Getting Started with Arduino. In: Arduino [online]. 2014 [cit. 2015-01-09]. available from: <http://arduino.cc/en/Guide/HomePage>**

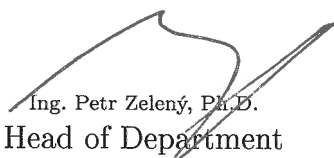
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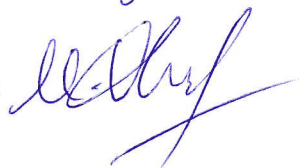
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Podpis:



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Abstract

The aim of this project is to verify the possibilities of implementation of Artificial Intelligence (AI), Cloud Computing and Internet of Things (IoT) into the current industry to achieve the Industry Concept 4.0. The main goal is to develop a smart factory with modular structured units controlled by cyber-physical systems that monitor physical processes by creating a virtual copy of the physical world with decentralized decisions. In this project, a vehicle is developed that can transport the materials inside a factory using principles and conditions of Industry 4.0. Many possible ideas were analysed and a one practical solution was developed. A robot named T-Bot (TransBot), a vehicle, has been constructed from two Arduino boards that communicate wirelessly when programmed in the Integrated Development Environment (IDE). One Arduino act as the mini computer and the second Arduino serves as control system which executes the simulation of Industry concept 4.0. Bluetooth is used as the way of communication. DC motors drive the vehicle.

Abstrakt

Cílem tohoto projektu je zabývat se možnostmi implementace Umělé Inteligence (UI), Cloud Computing a Internetu věcí (IoT) do současného průmyslu, aby bylo dosaženo úrovně Průmyslu 4.0. Hlavním cílem je vytvořit inteligentní továrnu s modulárními strukturovanými jednotkami ovládanými kybernetickými systémy, které monitorují fyzické procesy vytvořením virtuální kopie fyzického světa decentralizovanými rozhodnutími. V tomto projektu je vyvinuto vozidlo, které může přepravovat materiály uvnitř továrny za použití zásad a podmínek průmyslu 4.0. Bylo analyzováno mnoho možných nápadů a bylo vyvinuto jedno praktické řešení. Robot nazvaný T-Bot (TransBot) je vozidlo, které bylo vybaveno dvěma deskami Arduino, které vzájemně komunikují bezdrátově. Programování se provádí v Integrovaném vývojovém prostředí (IDE). Jedno Arduino se chová jako mini počítač a druhé slouží jako řídicí systém vozidla s koncepcí průmyslu 4.0. Pro komunikaci se používá Bluetooth. Vozidlo je poháněno pomocí stejnosměrných motorů.

Keywords

Industry 4.0, Internet of things, Artificial Intelligent, Arduino Yun Mini, Arduino Orion, Evolution of Industries, Different navigation systems, Bluetooth

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List of used Abbreviations

CPS	Cyber Physical Systems
IoT	Internet of Things
AI	Artificial Intelligence
LPS	Local Positioning System
WAAS	Wide Area Augmentation System
DGPS	Differential Global Positioning System
GNSS	Global Navigation Satellite System
C/A	Coarse Acquisition
ipV6	Internet Protocol Version 6
CCTV	Closed Circuit Television
AR	Augmented Reality
VR	Virtual Reality
IDE	Integrated Development Environment
EEPROM	Electrically Erasable Programmable Read-Only Memory
I/O	Input / Output
UART	Universal Asynchronous Receiver/Transmitter
I ² C	Inter-Integrated Circuit
PAN	Personal Area Network
SPP	Serial Port Protocol
ADHF	Adaptive Frequency Hopping Feature
BPM	Blinks Per Minute
BLE	Bluetooth Low Energy
AMR	Anisotropic Magneto-Resistive

1 - Industry 4.0

A transformation by which the conventional techniques are superseded by the trending technologies over a period of time to boost production, increase safety and enhance security is called Evolution. Since the Industrial Revolution, there were two transformation in industries. The first one with the induction of electricity and the second one with the introduction of electronics. The factories are built up with sophisticated machines since the third revolution. With an idea of how machines will behave when they are capable of communicating among themselves seeded this shift in the field. Advancement in the technology makes it possible to integrate various information and communication technologies in the name “Industry 4.0” concept assisted by Internet

One of the most discussed topic in the Germany and its surrounding countries since 2011. Since the reveal of technology in Hannover Fair, A group of people has put forward certain principles and recommendations for the implementation. Hence no proper definition has been provided so far. With the introduction of modular factory including Cyber Physical Systems (CPS) and cloud computing contributes the transition. Over the time, with the usage of Artificial Intelligence (AI) and Internet of Things (IoT), the technology also called as “Smart Factory”. Recently there are numerous academic publications and articles, and many conferences have been published and conducted respectively.

1.1 - Evolutions of Industry

Ancient humans started to produce goods and ornaments with the invention of fire making and wheel. With the information they had, they were capable of extracting metals from ores and utilize them. It took them a lot of time and more human effort to work. This drives them to develop machines which can ease their work. Industrial revolution was the only solution for them. It not just reduced the human effort but also implements the huge productivity improvements. Which results in higher output and more profitable economy. For the growth of the society, production should be more. To improve the production, we need more labor or more capital. This pushed them to the verge of change.

1.1.1 - Steam Engine

In the middle of 19th century was the beginning of first revolution in the manufacturing industries. It is called Industrial Revolution. This industrial revolution was driven by the discovery that one can use steam engine to powerup all the works. It started with the development of power loom. It completely transformed the way how the things were done earlier (i.e.) from manual work to machine work.

1.1.2 - Linear Assembly System

Mass production model is the other word for the Linear Assembly System. It commenced in the beginning of 20th century. Idea was initiated and introduced into production area by Mr. Ford in Ford motors. This evolution is assisted by introduction of electricity in the past industry environment. Electricity fixed the most common problem of location of power source. In this era, the production plant is kept somewhere and the current is transferred to the companies in the remote area where the cheap labor is available.

1.1.3 - Automated Robots

The first automation wave hit the industries in the 1970s. With the development of computers and microcontrollers, humans made robots that do specific job over time with almost zero fatigue and error. These formed the base for the Industrial revolution again in the beginning of 20th century. These microcontrollers are given more feature and power to control various information.

1.2 - Core elements of industry 4.0

There are certain implements of elements into the current industry so that it helps us to design and develop Industry 4.0.

1.2.1 - Autonomous Robots

With the size of humans, they actually collaborate with them, and can be programmed in order to perform complex, non-repetitive task. Recent studies reveal that only 8 percentage of the task are automated. The less complex and the most repetitive ones. It will become 25 percentage in the next 10 years. This denotes, in future advanced robots will complement workers together and produce 20 percentage goods. This helps to achieve 20 percentage additional growth for company and economy of the country. The robots that work for us right now. For example, in vehicles manufacturing industries like TESLA, many robots are implemented to produce the vehicles. These robots help them to produce many cars at cheaper price. The quality of the product produced are similar to that of them they produced on the day one.

1.2.2 - Additive Manufacturing

3D printing has already improved plastic manufacturing and it is now making its way through metal. Plastics and metals accounts for the 25 percentage of the global manufacturing production. In the aerospace industry, fuel nozzles are some of the most important and complex part to manufacture for the simple reason that they made up of 20 different parts, that has to be manufactured separately and need special care to assemble them. With the help of 3D printing, these companies merge the 20 components into one component and produce them. This result in increased productivity, output, and growth of the industry. This technology made the production more flexible.

1.2.3 - Industrial Internet

All the components are connected to a common Internet inside a factory. It brings together intelligent machines and advanced analytics and creativity of people at work. Industrial machines are equipped with enormous number of growing sensors, to make them hear, see and feel a lot and converting them into a huge amount of data. Increasing the sophisticated analytics then shift through the data provides insight that allow people to operate the machines in the entirely new way and lot more effectively [1]. A rapid decrease in the cost of storage system and processing data, enables them to utilize the all

the available sources. They are becoming smarter and can predict, self-aware, react and social [1]. By deploying the embedded visualization, multicore processing technology and advanced cloud based communication throughout the factory makes the machine to virtualize the working condition in software. Also, decoupling the software from the hardware allowing us to communicate with the machine remotely and automatically.

1.2.4 - Simulation and Augmented Reality

Humans work efficiently when they can feel the work environment around them. This need some kind of software and hardware technique. With the introduction, of virtual reality systems, people are communicating with the virtual world in a better way than expected. This results in realizing the working environment identifying the possible improvements to produce more output.

1.2.5 - Cyber Security

When it comes to security, all the data in the computer should be safe from the eyes of the predators. with the introduction, of internet, it will become easy for anyone to enter office network and access their information. To avoid such problem, we need to upgrade our systems from the old storage and data transfer to the recent encryption system. In encryption, all your data is converted into some language which has to decoded to extract the information. To decode, we need a key. The key is sent as separate data with which the person can read into it. Encryption is made more secure by the data mining systems. These systems can arrange the data inside a file and able to recover them. This prevents the data leaks from the company. Even one get the encrypted data he cannot decrypt them [10].

1.2.6 - Software Integration

The companies are developing software that a machine can understand and work with it. It helps them to control and communicate with the machines effectively. The software should be capable of collecting all the possible information from the machine and provide it to the workers. It enables them to communicate with machine remotely.

1.2.7 - Cloud Data

The data is usually stored in the hard disk in the computer. It is safe and secure. Though it has enough advantage, it lacks one important thing. That includes the sharing the information among the other systems to improve work. Everyone need to access to use that data. One centralized system to control the flow of data. This is the cloud Storage. All the devices that are connected to the internet can utilize the internet to obtain data.

1.2.8 - Big Data & Analytic

The data that are collected from the machines are need to be analyzed. They are huge that human cannot go through each of them to locate the particular information. The advanced software can do this work. They virtualize the result on the display. The possible information should be taken from the collected data and the information are stored for future reference.

1.3 - Industry 4.0 in the University

The model of Industry 4.0 is started in the year 2016 under the supervision of Ing. Radek Votrubec Ph.D. The concept is construction of automated manufacturing factory by implementing the industry concept 4.0. So, the factory is made up of small modules. There are CNC machines inside the factory. CNC machines come with a predefined program that are capable of executing the program once fed into them. In order to modify the CNC machines into industry 4.0, we need a computer to automate the raw material feeding process. This work is done with the help of robot arm that is capable of feeding the raw material into the CNC machine effectively.

Internet connection is available throughout the industry. The worksheet is fed into the machine either by the user by the website or by an employee of the factory. The data process starts in the mainframe computer which distributes the individual work to the respective machines. This distributed work is stored in the online cloud storage. From the online storage, each machine that is capable of executing the task, collects the information and execute them.

The Mainframe computer monitors the activities of the other devices in the network. When an order is fed into the system, the device analysis the input and identifies the machines to be operated. First it enquires about the availability of the raw materials. When there is enough stock, it gives the control to the transporting vehicle. When there is no stock available, it requests the transportation vehicle between the storehouse and the factory to refill the stock. When the stock is less in the storehouse, it automatically gives order to the suppliers for the parts. The authorized person has to verify the request form. Once he authenticated the form, it will be sent to the supplier.

In this scenario, there is stocks available in the factory. So, the computer informs a transportation vehicle to transport the goods from storage to the CNC machines. The computer asks for information from the CNC machine, which one is available and it should be capable of doing this work. The CNC machine responds to the query form the computer. Once the computer identifies the machine which one is free, it requests one of the transportation vehicle to transport the material to the machine. Available vehicle accepts the request and do the task. It goes to the storage unit and collects the material and transport it to the machine.

This vehicle calculates its own path and travel in it. When it reaches the final position, it informs the machine about the task and material. The machines request a handler like robot arm to transport the goods from the vehicle to the machine. The arm take the produce and place it in the respective machine. Once it is placed, the work commences. The finished product is taken from the machine in same way loaded. The robot arm take the part from the machine and put it back on the vehicle. Once it is loaded, vehicle takes the part to the next machine. This process continues till the final product is produced. The same vehicle takes the part to the delivery unit. There can be people or machines pack the product and send them to customers. All the work is automated inside the factory.

1.4 - My Task

The vehicles that shuttles between the warehouse and the stock is to be designed based on the industry 4.0. There are several working possibilities are considered for the task. Among them line follower is found to be best one for this simple task. To achieve this task, I have taken two Arduino boards one act as the mainframe computer and another

one act as the guidance for the vehicle. Once the task is given to the robot, it calculates the path it needs to travel. Once the calculation is over, it identifies the best possible solution and it travels in that route. More information is explained below.

2 - Design Possibilities

Certain possibilities concepts are considered to design the vehicle. the detailed information about the implementation of these ideas and their benefits and possible improvements are explained below

2.1 - Assistance by Global Positioning System

Global positioning systems are used by many devices across the world. They enable them to locate and identify their position on the earth. GPS systems usually work together with compass. When a vehicle is fitted with the GPS system, they create a virtual system of the environment in them and follows them. For instance, car fitted with GPS system can display the roads and lanes in which the car is moving [2]. The similar technique can be implemented in the factory. The automated vehicles can move inside the factory on the tracks programmed in them. They follow lanes. They can be monitored from office room.

This idea can be realized in two steps. First creating a virtual factory then teaching the vehicle to travel. The first step is made by converting the physical factory into the virtual world. This can be done with the available hardware and software system. A 3D model of the factory is drawn in the cad software and the lanes and rules are also designed. This data is fed into the vehicle through internet. Once the vehicles are set into the factory it moves in all the possible directions under the law defined [2]. It learns and identifies the best and the shortest route inside the factory.

This system is easy to implement as it is readily available in the market. Many consumer devices are using this technology. They are popular for accuracy outdoor, but factories are indoor and they have huge machines. This is common problem with GPS signal reception. With developing technology, people are capable of creating the better the reception system in future. Another popular problem with this technology is the

2.2 - Assistance by Local Positioning System

In order to overcome the disadvantage of using GPS for navigation, there can be a Local Positioning System (LPS) which is assisted by low power devices like Wi-Fi or Bluetooth. These devices have the ability to communicate with other devices with standard wave length helps them to identify the distance between them. These devices

can be distributed among the factory at certain distance so that the vehicles calculate their position in the factory. For the industrial concept 4.0, all devices in the factory should be connected to the internet. For a moving vehicle, it is little difficult to use them. Hence wireless system should be used for communication. These devices can do the work of communication and position location at the same time. This can be achieved by MoVie system. This system consists of 3 units. They are

- ❖ NetMoVie – This protocol is used for data transfer among the devices. The information is fed through this channel.
- ❖ GeoMoVie – This protocol is used to track the vehicle in the factory. It contains the positioning data. It can predict the direction of motion with frequent communication.
- ❖ SysMoVie – This protocol is used to collect the analysis data from the vehicle. this data is used by workers to identify any malfunction in the vehicle

This system is cost effective and is more accurate than the GPS system. When there are huge machines in the factory, these devices can be positioned around them for better accuracy. All the communication is done through different protocols, he no chaos.

2.3 - Assistance by Image Processing Systems

Tracking of objects by image processing system is a recent development which require camera to take photos and a processing system to convert them into data which can be used for navigation. With the sophisticated technologies, the camera is capable of shooting photos at a speed of around 100fps. The camera can be either mounted on the vehicle or on the factory walls. These cameras can be used for surveillance too. The algorithm for decoding the photos is explained well in the next chapter [12].

2.3.1 - Active Tracking

In active tracking the camera is mounted on the vehicle. So, the vehicle is capable of tracking the location of it by taking the machines or the symbols on the wall. It will recognize the distance by an infrared proximity sensor then it travels. Throughout the way, the device records all the photos it captured for future reference. When the vehicles are at corner or some inaccessible location then it needs assistance from some other rescue

system. When there is poor lighting in the factory, this also cause some travelling problems. This concept is suitable for large scale industries. It takes lots of time to prepare it for first time.

2.3.2 - Passive Tracking

In passive Tracking, the camera is fitted throughout the factory. All the machines and the employees are tracked under the camera. Along with the workers, the vehicles are also monitored. The Main frame computer is capable of decode the picture and send signal to the vehicle. The vehicle moves in the factory. During corner and some remote location, it gets assistance from various cameras to find the travel direction. This idea is suitable for small factories where there is surveillance camera every corner for tracking.

2.4 - Rail Follower

This concept includes the implementation of rail tracks throughout the factory. This tracks act as the guidelines for the vehicle to move. This vehicles travel is perfect and predetermined path. These vehicles can be powered from wheel. So, the vehicles can travel the whole day. The other vehicles need some kind of power source. The vehicle is guarded by rails. So, it is impossible for them to swerve or pull over. This makes them the safest method to transport goods inside the factory. Also, these vehicles are carefully controlled. And it is the computer responsibility to control them, this indirectly applies to the person who is programming it. This enables them to operate the vehicles in the correct route. This is made possible by diving the rails into blocks. Each block is programmed to allow one train at a time. To prevent a collision, due to some system error. There is an interlocking system protects the vehicle from damaging the machines.

2.5 - Line Follower

The line follower robot is constructed with the infrared proximity sensors. There sensors are made up of two LEDs. Among the two LEDs, one LED is used to transmit the signal and the second one is to receive them. The IR transmitter is usually transparent in color while the IR Receiver is dark in color. This sensor guides the vehicle to travel in the prescribed path. The working principle is simple and is explained below.

Working Principle of IR Sensor,

1. Infrared Spectrum: The LED is built up to emit certain frequency of light. The duration of the light and the reception of signal should be programmed in this stage.
2. Transmission: The IR rays are blasted from the diode. It hits all the objects before them.
3. Reflection: All the objects reflect some amount of light fell over them.
4. Reception: The reflected light will fall over the IR receiver. It is a photo resistive sensor and it creates a potential difference when reflected falls on them.
5. Analyzing voltage level: the reflected light is analyzed by the Arduino and the output signal is mapped in the memory.

For the task assigned, I choose the Line follower because of its simple construction. The purpose of the vehicle is to transport the goods from the storehouse to the stock. It moves in the fixed path (not like the other vehicles that has to travel in different direction). In order to travel in a fixed path, rail follow and line follow can be used. Rail follow requires a lot of time for installation and it cost more too. During the reorganisation of stocks, rail tracks has to be removed and lied again in the new path. It costs more time. To minimise the time consumption and cost, line follower is chosen as the guide for transportation in the factory.

3 - Elaboration of Technology

3.1 - Global Positioning System

Global positioning System (GPS) is the navigation system used by millions of devices across the world to identify the location and travelling. It was introduced to public in 1980s. GPS work all the day even with varied weather conditions and position. A compass assisted GPS can be used for navigation. Now a day, all the mobiles, vehicles like cars, trucks etc. are fitted with GPS devices. Initially, The Satellites were put into orbit originally by U.S. Department of Défense (USDOD). Later the satellites are opened for public because of its benefits. There is a total of 24 satellites orbiting 24 hours a day.

The GPS system works on the concept of Triangulation. That means the echo signal from three satellites are used to identify a position on earth. This includes simple mathematical calculations to solve it. With the signal from fourth satellite one can identify the altitude. The process starts from the satellites. The satellites are orbiting the earth in the precise orbitals. These satellites emit signal frequently. These signals reach the devices. The devices are equipped with the suitable decoders to identify the hidden information from the satellites. The data is time dependent contains the position of the satellites while they emit them. Using the time lag between the position and the time of received code, the position is identified. The frequency of the signals waves is standard and they travel at same speed at all climatic conditions. Now a day, with advance technology, these data can be visualized on the screen. With the geographical data of earth, travelling becomes easy.

The benefits of GPS don't stop with the locating a position, it has the followed benefits too

- Tracking of object
- Monitoring Speed
- Distance Calculation
- Bearing
- Sunrise and Sunset (based on the location)
- Time of travel

Accuracy of GPS can be question because of the distance between the user and the satellites. Today's GPS are very accurate. The reason that they use some other sources

around them for precision. One of the technology source is parallel multichannel design. This design enables them to receive and decode the location literally with zero error. This works under the condition like standing in a dense. Some GPS devices gets assistance from the Wide Area Augmentation System (WAAS) for better accuracy. This system doesn't need any new equipment or charges to use them.

With the evolution of technology, Differential GPS (DGPS) is invented. This corrects GPS distances to within an average of 1 to 3 meters. The U.S. Coast Guard operates the most common DGPS correction service. This service consisting of a series of towers that conduct a corrected signal through beacon towers. Global Navigation Satellite System (GNSS) is a new technology introduce by Russia. When America launched their first satellite, it was just for the military operations. This technology was used to find the lost soldiers on the earth. This useful technology is also required by people for the sophisticated life style. Hence the system is introduced to public. Few years after opened for public, the government felt it was not secure for national security. Hence, they withdrawn the licenses to use them. Once they are found not a thread to the national security, they are offered to public again.

The unprecedented navigational capabilities of GPS are triangulation is the principle. The first used Navstar system uses 575.42 megahertz (civilian) and 1227.6 megahertz (military). The carrier waves are modulated by two pseudo-random binary pulse trains. one 1 megabit per second (mbps) civilian C/A-code (coarse acquisition code) and a 10 mbps military P-code (precision code). Recently three new bands are agreed for civilian's usage - 1176.45 MHz, 1227.6 MHz, and 1575.42 MHz. The time taken by a signal to reach earth is around 10^{th} of a second. Speed of the wave is 300,000 km/s. It is calculated like a ball places on the imaginary sphere with radius of earth. When the satellites are considered as the compass with some position on space. The radius the time taken be them to reach the ball. Each satellite send their codes. The receiver receives all codes and compare them with each other to determine how long the object is away from the satellite. Once it identifies how far is it from the satellite, it draws an imaginary circle. The meeting point of the circles with the radius (explained before), the meeting point of the curves gives the exact position of them.

A GPS signal contains 3 different types of information:

Pseudorandom code: This is the Identity code of the satellite. The device can identify which satellite has sent this data. This information helps them to identify the location of device.

Ephemeris data: This data contains the health report of a satellite. This data contains the date and time information of the satellite.

Almanac data: This data is conveyed most among the satellites. This contains the information about the location of satellite in the orbit the whole day. These data are conveyed mostly among the satellites to find out whether they are travelling in predefined path.

Some of the common problems with the satellite are listed below,

- Delay: The satellite signals becomes slow once they pass through the earth atmosphere. The built-in technology in the receivers is capable of rectifying these errors.
- Multipath: When the signal is sent by satellites, it gets reflected by the buildings and other surfaces. These signals take some longer time to reach the user which results in an error.
- Visibility: Some environmental factors may affect the satellite visibility to the receivers. For example, standing inside a building or underground results in poor reception. But with improving technologies, this error is reduced.
- Geometry: If the receiver is capable of catching the signals from satellites positioned in different angle, the results will be better than from the satellites positioned in straight line
- Orbital Error: Since the satellites orbits the earth in free space. All the time, their position cannot be accurate. This result in small errors which is negligible.
- Clock Sync: The most common and biggest mistake is the clock sync with the atomic clock, the satellites use atomic clock for time. The signal bear the time of satellite. When there is time difference between the device and satellite, this result in decoding errors.

3.2 - Digital Image Processing

Digital Image Processing shortly known as DIP is a recent development in the information technology. In this technology, the information about an object is identified using the matrix system of byte arrangement. The data to be analysed is converted into matrix. Using the mathematical methods of solving the data is solved to find the result. It is a kind of artificial intelligent that can convert any form of image either taken or live videos into computer data that can be processed by a computer. The popular example for Digital signal processing is face reorganization.

When the technology is launched for the first time, many bio metric systems used this technology for secured access. This includes the finger print scanning and iris scanning. When a person stands in front of these system, a photo of his face is captured by the camera which is then converted into an image. This image is processed with the certain identification marks on his face. So, they can recognize a face like human does. In the warfare, they use highspeed cameras to track the pathway of the missiles and to identify the moving target and hit them with perfection [7].

Once the data is programmed, it has the source codes that helps them to understand the images better to avoid the errors. This technology is also used in resource identifying. When an unexplored area is need to be explored. People send satellites. These satellites take various photos from different angles. These photos are converted into graphs and colour charts This is an advancement in the image processing sector. Many engineers all around the world are working on this concept for the betterment. Each one approach it in different way. Hence resulted in various reorganization system where one is better than other in some aspects [7].

Some scanning system recognize face faster with less marks while the other take too much time but better identification. Therefore, these systems are very popular among the consumer. Toshiba is the popular company that introduced first mobile with finger print scanner. This system become very popular and all the mobile companies in the world adopted this technology. Some mobile manufactures believed in face reorganization. Recently mobiles from Microsoft with iris scanner and laptops with face and iris scanner works well too [8].

The way how the data are processed consists of following steps

- 1) The possible helpful information is collected with the image for better solving
- 2) The hidden data in the photos are extracted
- 3) The extracted data are analyzed by the intelligent software to find the information in it.
- 4) The repeated units are grouped together for easy solving. The similar units are solved parallelly.

3.3 - Artificial Intelligent

The ability of the computer to act like human is called Artificial Intelligence (AI). In simple words, artificial intelligence means learning and problem solving. Human created some mapping methods how our brains map and store the data. This idea with the development of better programming languages, helped the program developers to write the codes of logic that made the computer to behave as humans [5]. They store the data in the array which act as experience for the computers. When there is a problem or task, it searches in the array for experience. If there is some experience, it sees how much similarity is there between the current task and previously done.

When the similarity is more, it solves them in the same way otherwise it finds a new solution. It stores the solution method. So, it learns from the experience like humans. This helps them to understand the human who is using them. Therefore, in future these computers can think and solve like humans doing now. Current trend in all the computers field they are trying to implement these codes so that they can write, compile and design the codes [5]. This technology helps to reduce the errors occurred and sophisticate the developers to repeat certain codes again and again.

One of the best examples is human speech reorganization. In this technology, the machines understand how the user speak to it like patterns, mood and content. This helps them to communicate with the user to talk to them in the same manner. This make them to feel that they are speaking to a real world. This technology is now available in the market. Some examples are Google's Voice, Microsoft Cortana, Amazon Alexa, and Apple Siri. The autocorrection feature in the Microsoft word is also a good example. You can understand the text pattern and correct the mistakes. This engine is capable of learning through games. Many games use this technology to understand how the users are playing

the game like their strategy and the way how they think. In the upgrades, the game is capable of fix the faults that occur during the gameplay.

For example, if there is some loophole in the game through which the player is getting benefited. It can either report the developer about this or make some temporary solution to avoid the user to get benefit. Best example is the computer Chess game. In the earlier days, the chess game contains the codes for possible move [5]. So, the user can move the pieces in the way how the game is not coded to win the computer. In the recent version, they uploaded the codes like the computer learn the possible position to move. They were programmed only with the possible moves of each piece like king, queen etc. rest of the game is let to understand from the games. So, the thinking ability is going beyond the developer. Hence these games are hard to defeat.

In online shopping, the companies use some technology like this which helps them to improve the sales. This is one of the trending technology of this decade. Many people quoted this is the era of computers because of this technology. AI support the archaeologist to identify the ancient sculptures to which era it belongs to. Also helps them to compare the different discoveries across the world. It knows most of the historical events and their results. If such events are repeated over time they will notify.

"Machines will be capable, within twenty years, of doing any work a man can do."
- Herbert Simon. By repeating the two binary codes 0 and 1, computer is capable of solving complex equations. This technology is also known as the fifth generation of computers. Technology first introduced by japan. But during the time of announcement, it was a failure. But in the later days, people took interest and made the technology a trending one.

3.4 - Internet of Things

The Innovation which has great impact on the human life as well as our work. Broadband is the popular internet system available in most of the home. They offer higher data transfer up to 1gbps which is good to transmit huge sum of data with great bandwidth. So, all the devices are created with Wi-Fi built-in or with ethernet port. Efforts to bring the world into the hands resulted in the IoT. So, in simple words devices that are capable of receive and send data via internet. Automated Teller Machines (ATM) is the first

developed device with IoT. When a user request money to be withdrawn, it gets approval from the bank and then deliver the money to the concern person [11].

With the Cloud as the source of information, the digital universe of information is readily available as a destination for devices to communicate. The internet has reached around 90% of the land area now either through wired broadband or wireless mobile signals. It is a global phenomenon. The engineers are working on the possible ways how this technology can transform the life of individuals and our society. The way of connecting the Physical world with the internet world to enable the human to interact with machines is called Internet of Things (IoT). The word things in the name IoT denotes everything and anything. That includes goods and objects we use every day, machines and applications we use in our jobs and home, the building in which we are living in, and the vehicles we travel everything becomes a part of internet of things [11].

Steps to convert an object to IoT includes Unique Identity, Communication, Senses, and control

- ❖ Unique Identity – This identity helps the user to identify a particular object among the others in the world. Current addressing protocol for internet is ipV6 gives unique identities without practical limitations.
- ❖ Communication – Once a device is assigned an IP, it needs some mode of connection to communicate with the internet world.
- ❖ Senses – Sensors should be put on the devices that will produce the data about the environment, health, operations and periodic diagnosis.
- ❖ Control – It defines the possible way to control the devices from remote location through the predefined address.

All the above-mentioned work is achieved through the very small embedded electronic circuits. These components are getting cheaper and cheaper every day. To know the full potential of IoT, the following illustration can demonstrate the impact on our life and society. There are six task these IoT are effective in. They are Connecting things, monitoring things, Searching for Things, Managing Things, controlling things, and Playing with thigs.

3.4.1 - Connecting things

Someday our mobile devices are capable of connecting with any things on the earth. They are capable of communicating information. The nutritional value of a product in a supermarket, calories of a food in a restaurant, origin of groceries we cook along with allergy advice just by a device that is connected. Information's about the used products, their origin and history of usage like an old car can be collected. A new way of communicating with the world and learning about the things that you encounter. Sharing a business card along with the interest and more info that a paper card can't hold.

3.4.2 - Monitoring things

IoT constantly monitor the task assigned to them. They store report in the cloud that can be accessed by authorised person to utilize them. In hospital, the patient reports are constantly monitored and stored for reference and prediction. An electronic chip with cardiac monitoring system can monitor the heart rhythm along with high and low pressure and transmit the data to the mobile device so that the patient need not to go to doctor. In some case the data is also shared with doctor which helps them to prescribe medicine. This is called eHealth and Telemedicine. This is one of the big area of IoT.

3.4.3 - Searching for Things

With IoT, new generation of search begins, it is entirely different from searching an information among data. This new way enables IoT to search for physical objects like keys, mobiles, pen and other devices through cameras. This is called reality search. Parents who missed their children can identify them even in the heavy crowd with help of transmitters also prevent them from losing again by distance monitoring. One can search for the temperature of the boiler in a factory, who is 1000kms away.

3.4.4 - Managing Things

Recent statistics informs that around 50% of the world people live in cities. They need a better way to manage the cities which are quickly becoming mega cities. The proper planning of where the public vehicles are and where they want to go. Energy

department can analyse how is the energy flowing and where the energy is used by understanding the where the inhabitants are and what they are up to. There will be better traffic management with the elimination of congestion. Usage of renewable energy sources in effective way to meet the demands. Security of people become has an important criterion, where the Closed-circuit television (CCTV) plays a vital role in identifying antisocial elements.

3.4.5 - Controlling Things

Decentralization of decision is one of the keyword of IoT and Industry 4.0. A trail run of automatic electric grid is introduced in Ireland. During the first decade of 21st century many of the household electronics are automated. They were provided with intelligent system to improve efficiency. This system helps the washing machine to communicate with the electric grid to provide green energy to run them or to provide any electrical power source. The user need not to power down the system from the grid instead the grid decided when to shut down the machine. The grid decides what type of energy should be given to them, by balancing the load with the available energy improves efficiency and reduce the user current cost by utilizing the cheap electricity.

3.4.6 - Playing with things

The name clearly explains the activity we do with IoT. Playing doesn't relate only to the playing of computer games but to the playing of things in the imaginary world in the real world. This is called Augmented Reality (AR). Recently launched game Pokémon Go is powered by augmented reality. The Pokémon characters started to appear on the mobile screen where the real world is displayed. Virtual Reality (VR) is another technology where an imaginary world is created with the VR headset make the users to feel the reality. A person who is not in a factory can watch and feel like he is working there in the factory through these headsets. This technology transforms the real world into an imaginary world where one can interact with the internet world.

4 - Construction of Vehicle

Construction begins with the assembling the individual components like frames, motors, Arduino and other components. These components will be explained in the next chapter. This chapter clears the assembly and wiring circuits. To explain the assembly in the better way, assembly diagrams are used. These diagrams are standard sketches from a company from whom the components were bought. This base structure is creating as like they are described by the company. In the final stages, some of the designs are customized for the needs. They will be explained at the later stages in this chapter.

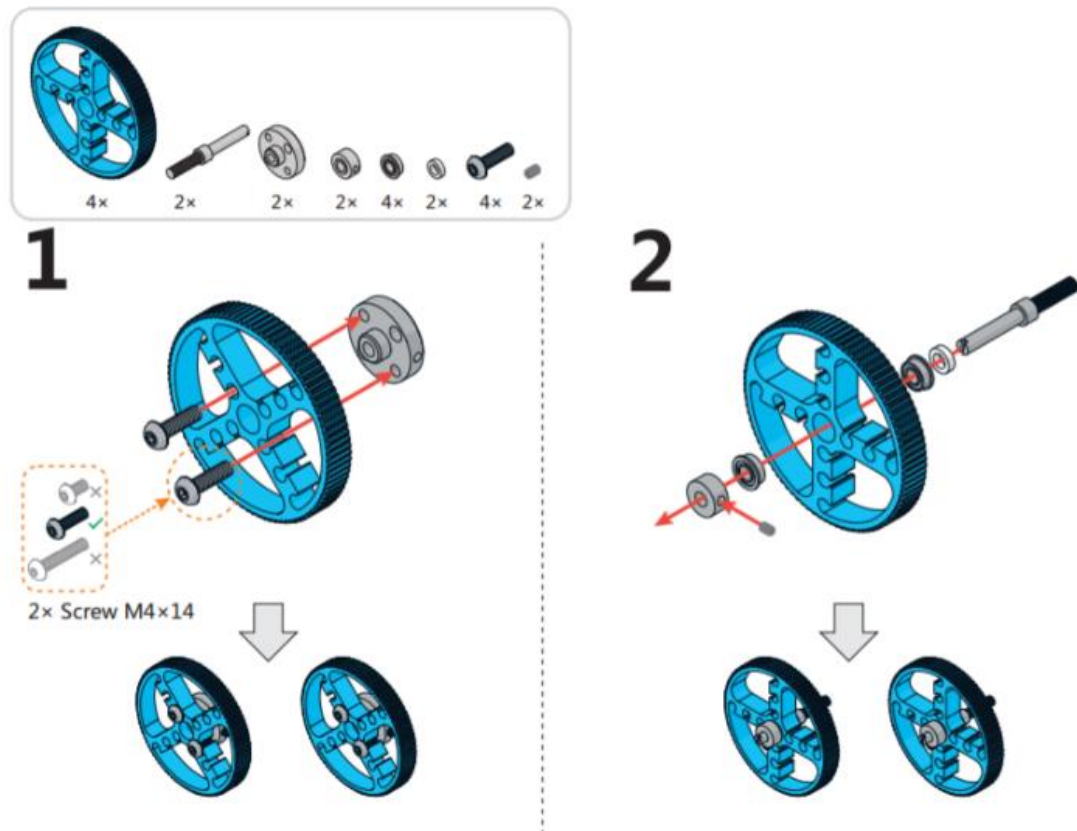


Figure 1 - Assembly of Wheels

In the figure, steps 1 and 2 clearly explains how the wheel is assembled to the linkage. This gives the free motion of the wheel. The first wheel assemble gives the information about the assembly procedure of the driving wheels. These wheels are connected to the driving DC motors. While the second picture explains the assembly of the free wheel or dead axle. This wheel is to provide support for driving.

Diagrams 3 and 4 are the most important assembly where the motors are attached to the frames. Two motors are connected to the frame with two joint frames by 2 screws. The motors are positioned like the way shown in the picture before they are screwed to the frames. One end of the motor should face downwards and another one face upwards. This affects the direction of the rotation of the motor if they are connected in the other way. The motor is attached firmly to the small frame through the screws.

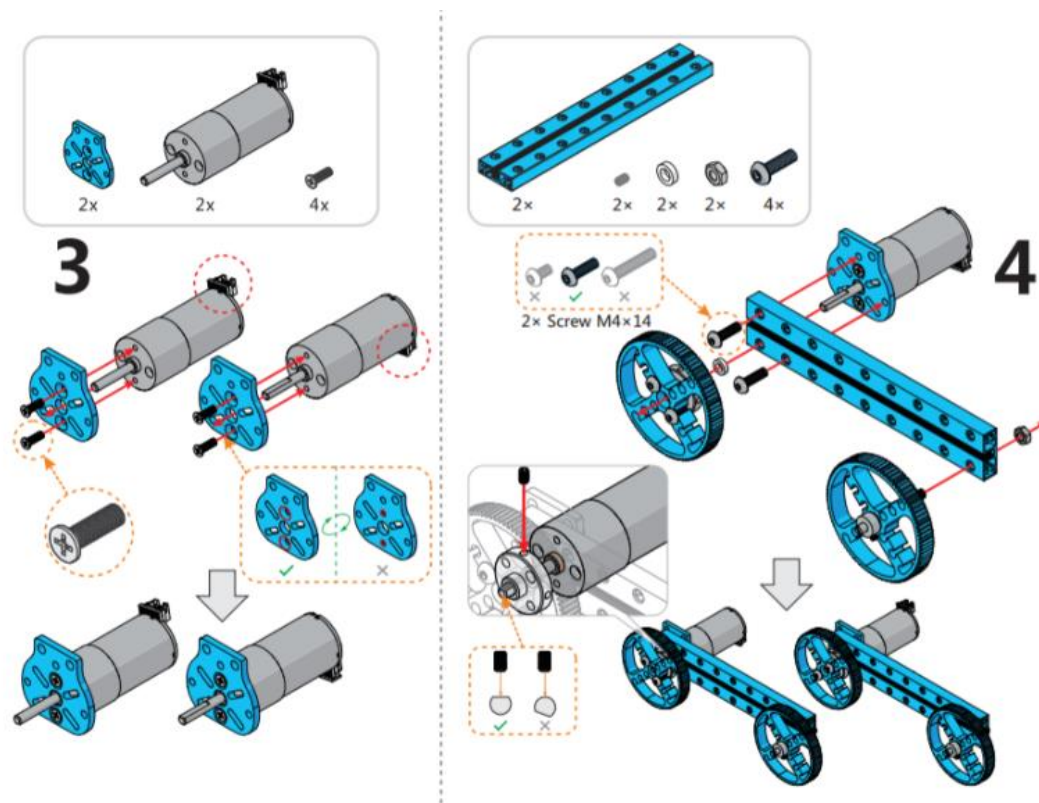


Figure 2 - Assembling motor to the frame

In the picture 4, the motor is attached to the frame and the frames are interconnected so that the frame assembly is created. In 4 the process of assembling the frame starts. This is done with the help of two long frames to which the motors are connected. Since the wheels need some kind of lubrication. So, the small plastic rings are used to provide lubrication between the frame. In the following step, the two individual parts are connected to each other by a cross member which are connected by four screws. Two screws on either side holds the wheels in the fixed position.

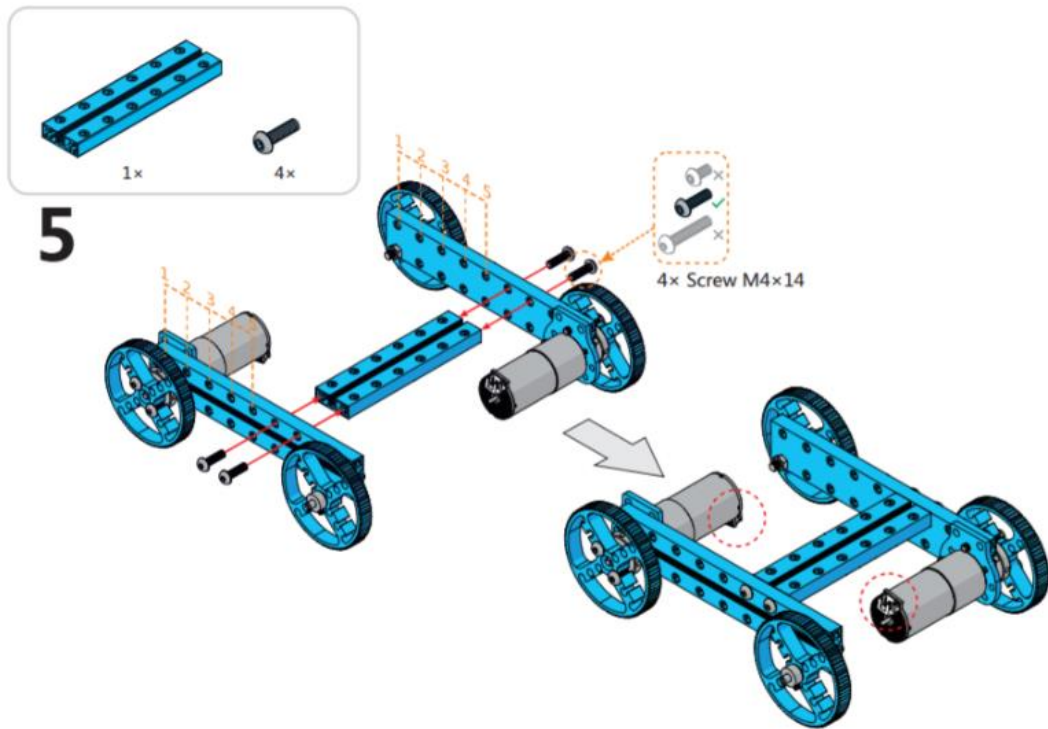


Figure 3 - Constructing the base assembly

This is followed by the assembly of the track. Tracks are available as some individual blocks that has to be connected by a metal rod.

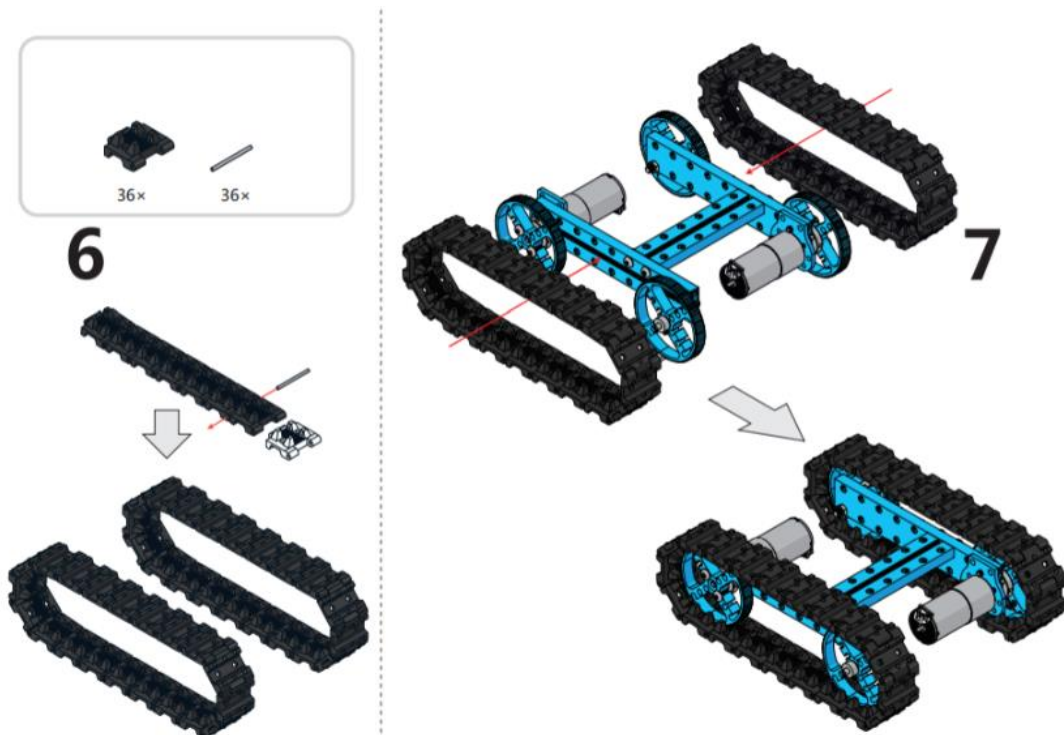


Figure 4 - Assembling tracks on wheels

Once they as assembled track is made, they have to envelop the wheels. These assembly forms the base of the vehicle. The controlling and the sensors are placed on the top of the bot. This begins with the assembly of the Arduino Orion to the boards. They use M4x22 screws to assemble the product on the board. The long frame block act as the backbone for the assembly. The rubber rings help to reduce the pressure on the Arduino boards. When the pressure is more, it may damage the board. In order to avoid this problem, the rubber rings ae used. These screws are bolted at the bottom. This is controlling assembly. Above the controlling assembly locates the powering unit, that provides the power to the whole robot.

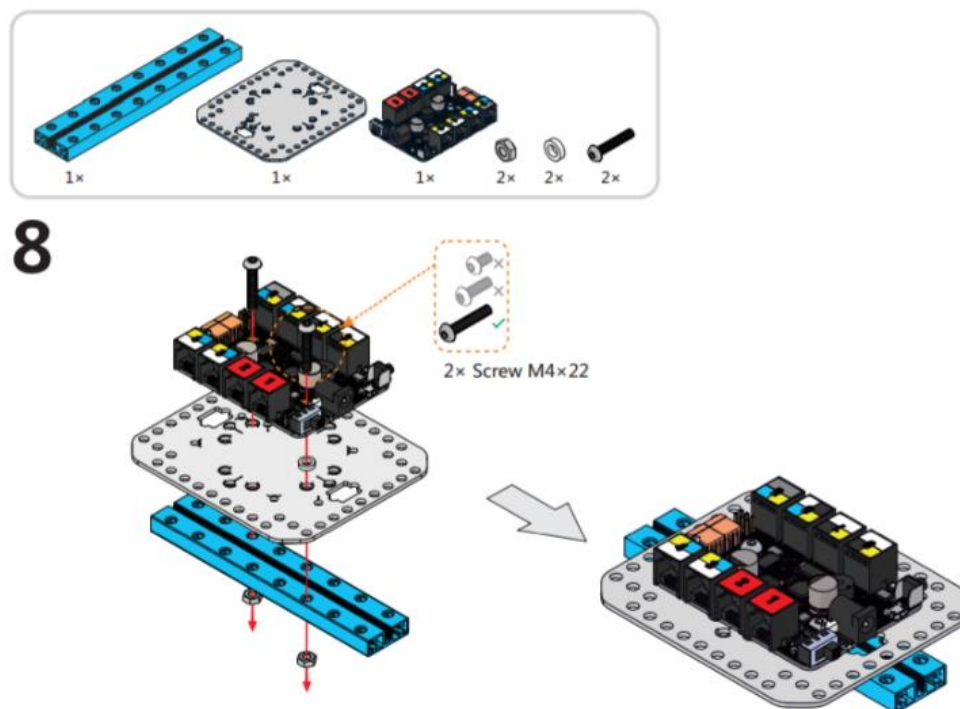


Figure 5 - Assembling the Arduino to the frame

The battery assembly is provided in the second deck. To create a second story robot, some vertical pillars are used along with screws to bind the two plates together. They are clearly explained in the diagram. The Bluetooth module is given another floor for better communication from preventing distortion. The battery pack is assembles using the 2 screws and bolt while the Bluetooth module is connected with just 2 screws.

Two assemblies are connected to each other with the help of vertical pillars that are connected by the screws. A pack of 8 screws are needed to make this connection. The boards are fastened from both the sides through the screws.

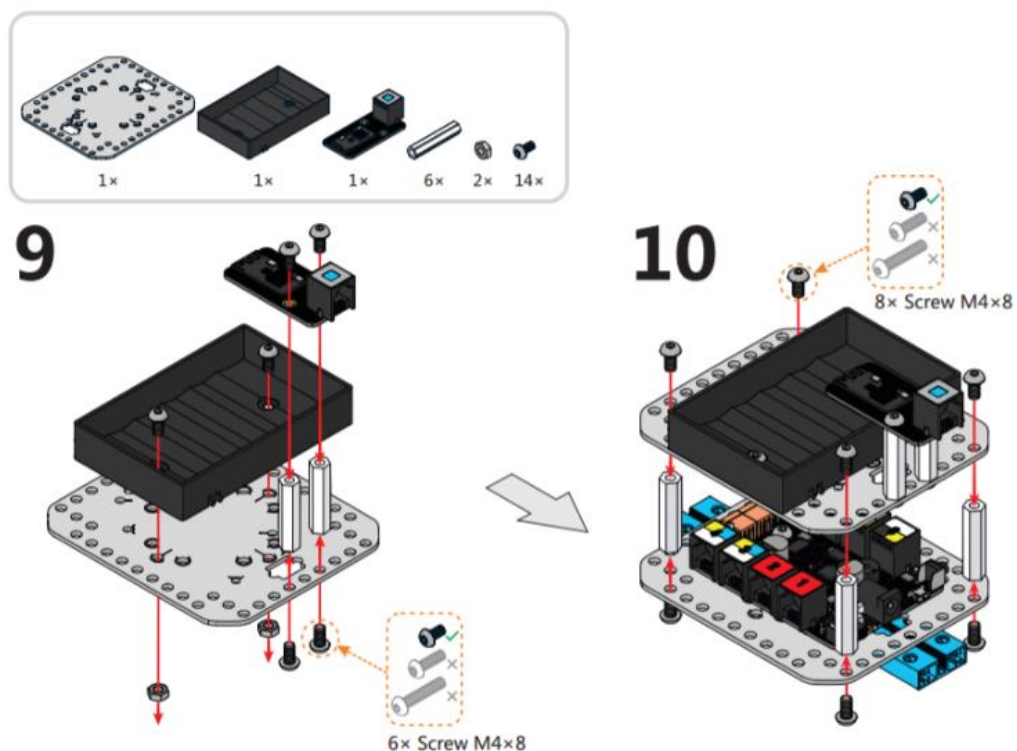


Figure 6 - Assembling the battery component over Arduino

This provides better stability for the vehicle and prevent the box from falling out of the robot. The top assembly now looks like a three story with base consists of Arduino while the second story consists of battery source and the final with the Bluetooth assembly.

Finally, the ultrasonic sensor is attached to the robot on the front. This is fixed with the help of the vertical block that is shown in the picture. There are series of screw assembly that holds the sensor in the position. This sensor prevents the vehicle from collision with some object that is before them.

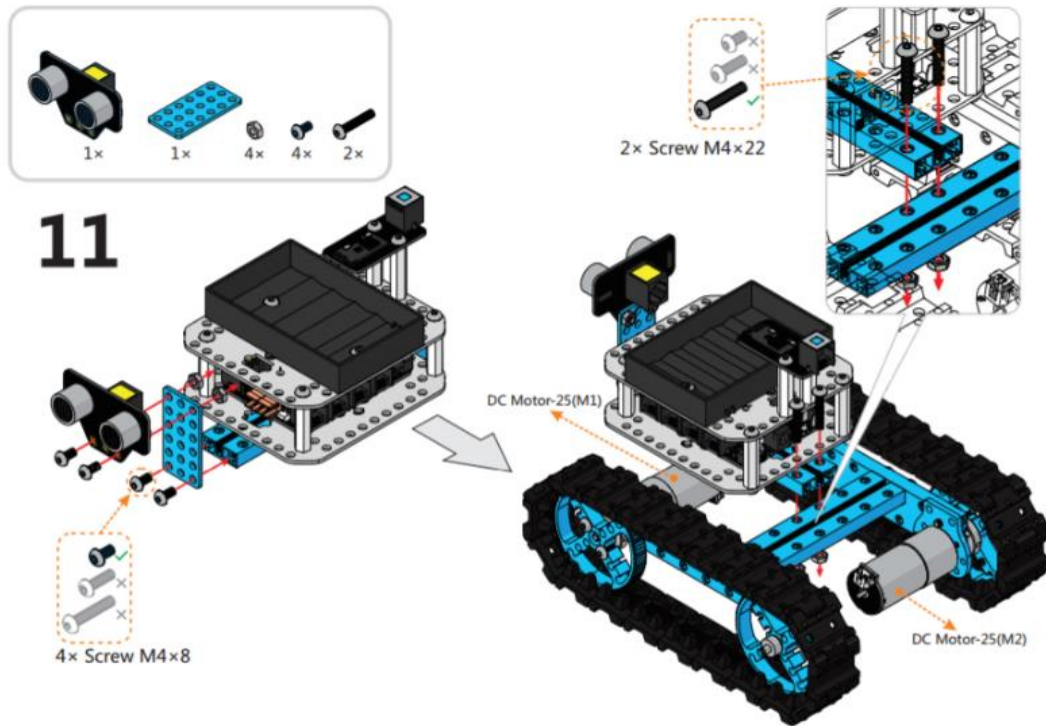


Figure 7 - Assembling Arduino block with base assembly

The wiring diagram is explained here. The RJ25 cables connects the ultrasonic sensor and Bluetooth module with the Arduino. The power cables to the DC motor is connected to the power plug in the Arduino board. The power source to the robot is given through the universal DC adapter.

Wiring

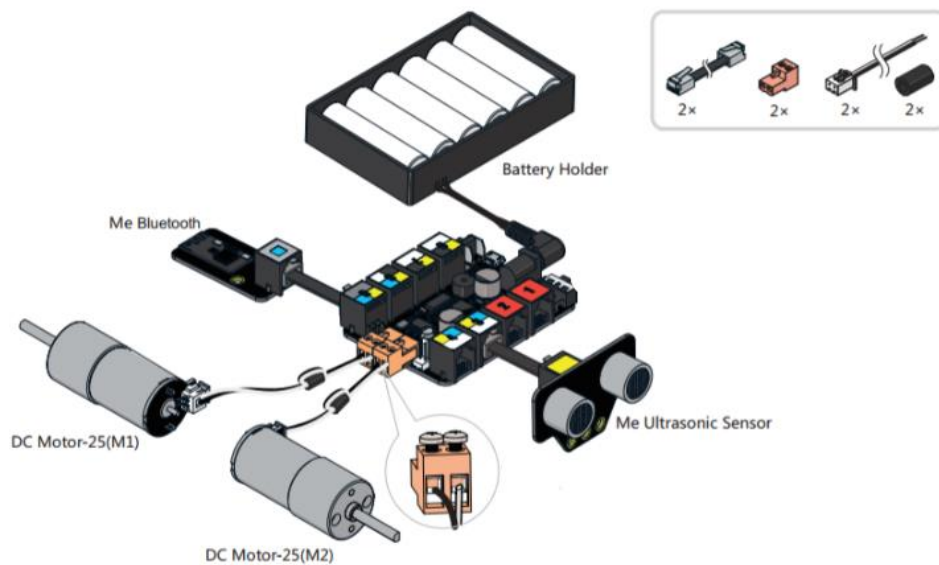


Figure 8 - Wire connection of the Robot

5 - Components of Vehicle

5.1 - Arduino

Arduino board is the brain of the project. Two different boards are used in this project. One is used to do the collect information from sensors and process them while the other is to execute the processed codes through the peripherals. The detailed information about the boards are listed below

Arduino Yun Mini is a ATmega328P microcontroller board has 14 digital I/O pins (with 6 PWM output capable pins), 6 analog I/O. The board components include a 16MHz quartz crystal for clock signal. Additional attachment includes a USB connector which can be connected to a computer for uploading the codes on to the board. Power for the board can be given through the onboard connector pins or through the power jack at the end of the board. Board works on 5V. So, series Battery or USB output from a computer is enough. Another reliable source of power (AC) can be converted into DC through the transformer and bridge rectifier combination where the portability is the common problem. When a fault or failure with board occurs due to the wrong code execution or short circuit, it can be replaced easily. One can consider this as a biggest advantage of the Arduino Boards.

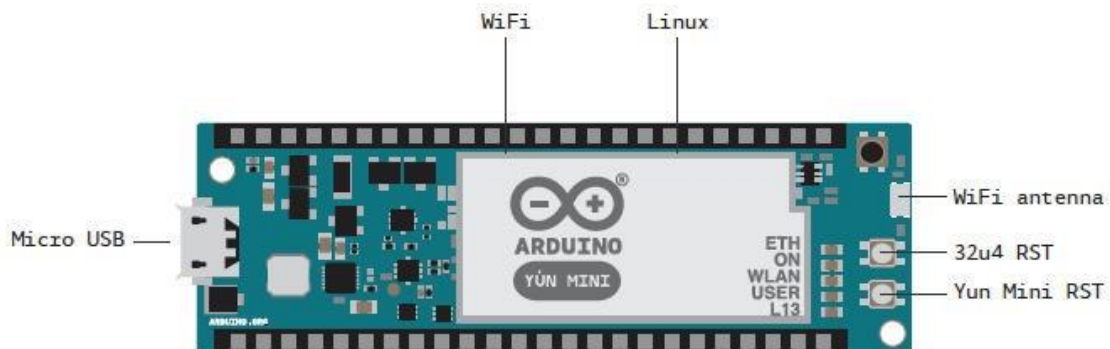


Figure 9 - Layout of Arduino Yun Mini

Programming a microcontroller requires some in-depth knowledge about the controller and connectors connected to it. This scenario won't be a problem while working with Arduino. The sophisticated program developed by the Arduino company named Arduino Software (IDE) v1.0 helps beginners to program with ease.

Due to the lot of benefits, there are thousands of code developers online who developed millions of codes. Some of the codes are included in the software and rest is available on the websites “GitHub” and “Arduino”. Code execution in these boards are more like a computer. They have their bootloader and it takes fraction of a second to boot up and run the program. So, they are quite fast and great to hand the basic operations.

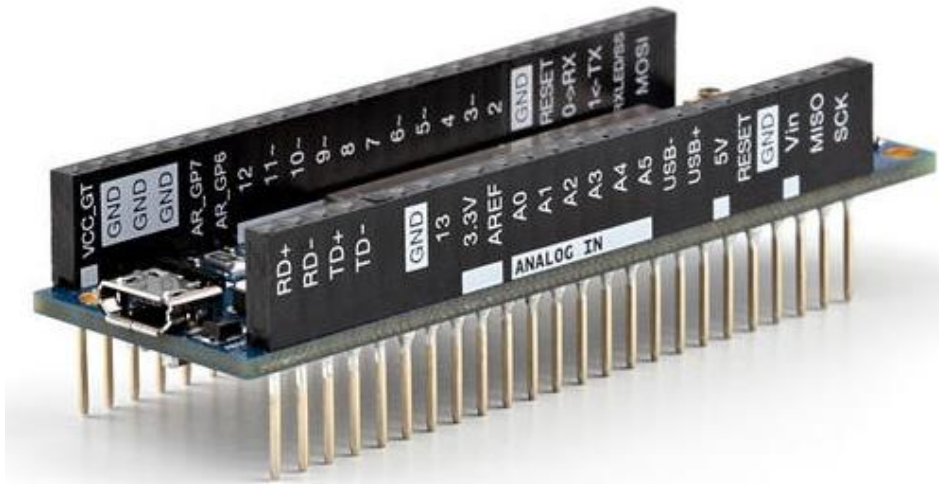


Figure 10 - 3D view of Arduino Yun Mini

The ATmega328 has 32 KB (with 0.5 KB occupied by the bootloader). It also has 2 KB of SRAM and 1 KB of EEPROM (which can be read and written with the EEPROM library). A 3.3-volt supply generated by the on-board regulator from which one can withdraw a maximum current of 50 mA. Communication seamlessly with a computer through the USB port, programmers can visualize the ongoing work on the board. The fully developed code in the editor is easy to upload to the board from the editor through the upload button. The board has a LED on the top of it. The LED blinks according to the work. A Wi-Fi antenna included in the board helps it to communicate with the outside world through the IoT. Hence the device can be controlled by the supercomputer in the factory and the information are shared at ease, thereby identifying the errors and finding a solution for them.

Arduino Uno Orion custom built with ATmega328P microcontroller board is used in the robot. Board is constructed with 8 RJ25 plug for peripherals. Dedicated power plugs are provided to drive the servomotors. It needs a 16Mhz clock crystal to run the microcontroller. The resistance to be provided along with the processor is 10K ohm and two capacitors with capacitance of 18 and 22 picofarads. Once the construction is made the codes can be fed though the IDE. Standard I/O cables RJ25 provides better communication between the device and the peripherals. USB micro port is used to

program the board. Orion works on 5V 3A DC from an input voltage of 6V to 12V DC done by a linear voltage regulator LM7805. Methods of communication with the board are Universal Asynchronous Receiver/Transmitter (UART), Inter-Integrated Circuit (I²C), Digital I/O and Analog I/O Pins.

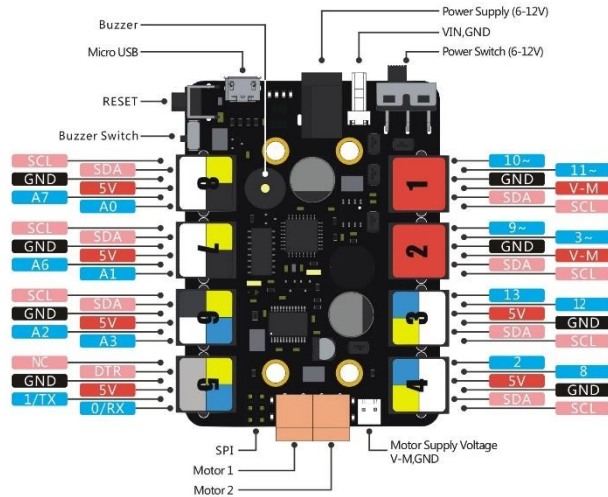


Figure 11 - Layout of Arduino Uno Orion

Advantages of using this custom built includes easy to connect with a variety of sensors, electronic modules, and drive modules. It is capable of drive two motors simultaneously. 5V voltage and 2A current can be supplied. Onboard buzzer for fault detection. Over-current and over-voltage protection is included in this built. It is provided specific Arduino library functions to simplify programming.



Figure 12 - 3D View of the Arduino Uno Orion

5.2 - Infrared Sensor (YL 73)

Infrared light has the ability to travel through dense fog and other climate conditions. This is the reason many sensor uses infrared light as the source. Infrared Search and Track sometimes known as infrared sighting and tracking is a method of detecting and tracking objects. One of the vital task of the robot is to follow the black line on the white background. 3.3V to 5V as an operational voltage, the sensor can detect obstacles from 2mm to 60cm. The results are better when the object is white and near.

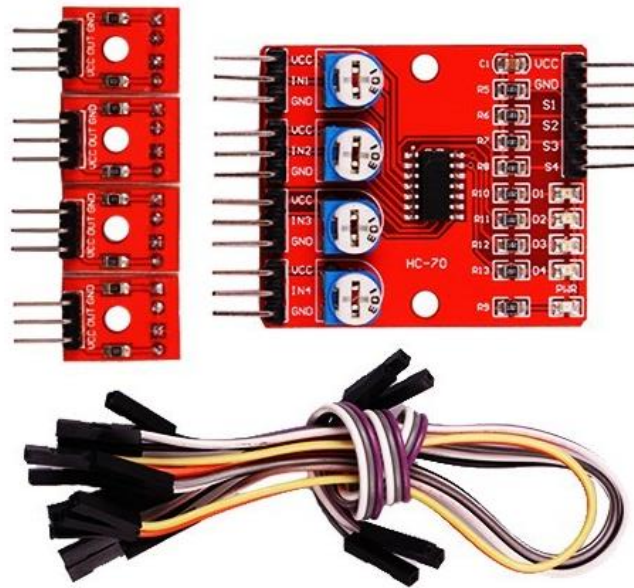


Figure 13 - Infrared Sensor YL 73

The detection range of the sensor ranges till 35 degree. The common control board on the sensor act as the hub for controlling each photo electric diode and detector. Working part of the sensor is made of two elements they are separated using a baffle. On the left a LED with emits the infrared light of 940nm wavelength, while on the right a photoresistor which changes the resistance based on the reflected light from the object. This combination detects the obstacles and the pulsating wave find the distance. Output can be directly connected to Arduino board using digital I/O pins. By adjusting the screw on the top of the chip, length of the detection range can be adjusted.

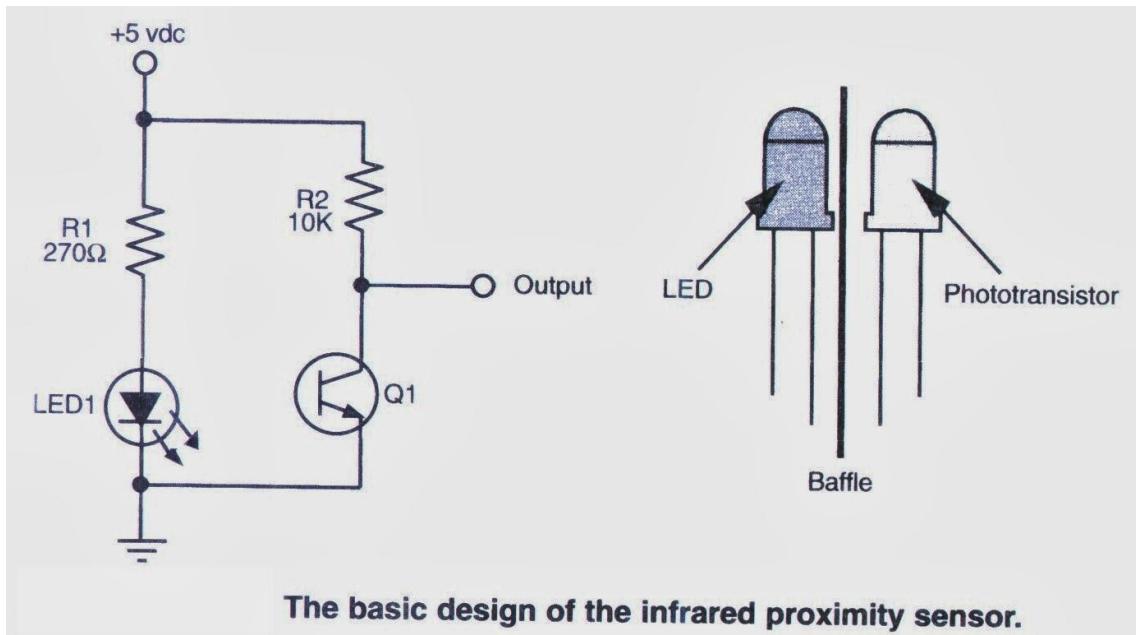


Figure 14 - Infrared proximity sensor head layout

5.3 - Ultrasonic Sensor

Ultrasonic Sensor is an electronic module to measuring distance. This working principle is used in Radio Detection and Ranging (RADAR) and Sound Navigation and Ranging (SONAR). It works in the range of 3cm to 400cm. This transducer converts the electrical current into ultrasonic wave. The wave is projected from the transducer, hits the object and returns back.

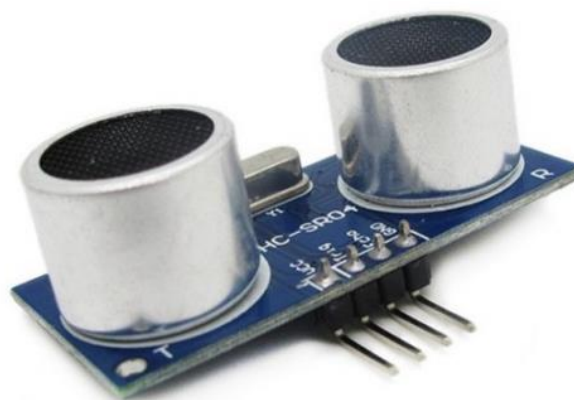


Figure 15 - Ultrasonic Sensor HC SR04

To evaluate the distance between the object, the three-step procedure should be followed. The three steps are Ranging, Reception and Calculation

- ❖ Ranging – The sound waves produced by the transducer are emitted into the space. These waves hit the object and bounce back
- ❖ Reception – Reflected waves are collected. The number of waves reflected provides more information about the object.
- ❖ Calculation – The crucial part of the navigation detection is to measure the time precisely. The time of ranging and reception is recorded. Difference in time is the time taken by the waves to hit the object and shatter back to the sensor. Knowing the frequency of the wave used, it is calculated using this formula. Speed of sound in air is 343 m/s. The value obtained is the distance travelled by the wave in two direction. Halved value is the actual distance of the object.

$$\text{Distance of Object} = \frac{\text{Time taken} * \text{Speed of sound}}{2}$$

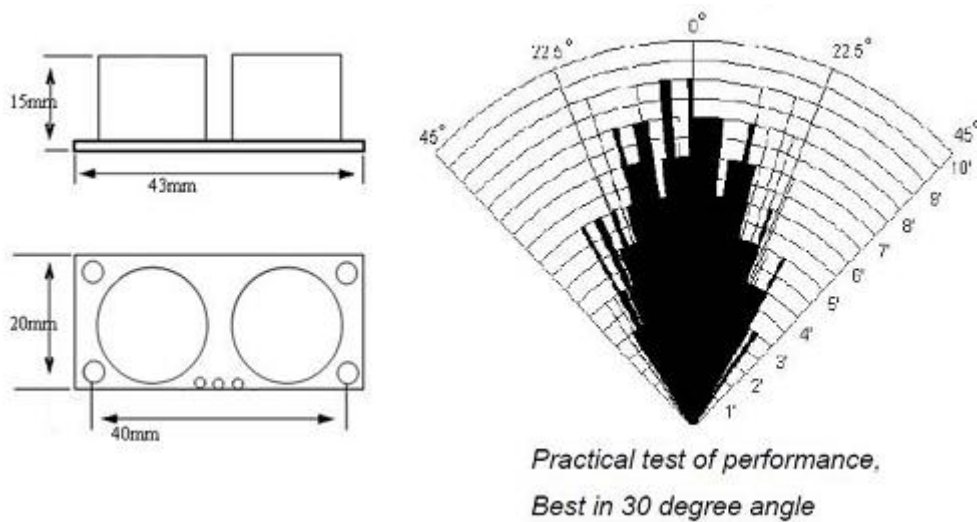


Figure 16 - Practical test for better performance

At time 0, A short ultrasonic pulse is generated and transmitted. These waves hit the object and scattered all over the space. Some of the waves will be reflected on the same direction of transmitter. The sensor recognizes the signal and converts them into an electric signal. Once the signal is received the time is noted. This is the time taken by the sound waves. There will enough time so that the transmitted wave disappears completely.

This prevents the mistake of inaccurate reading. The time taken for the whole process to complete is called Cycle period. About 50ms a sound wave requires to vanish. This indicates that, the minimum cycle period should be not less than 50ms. To produce eight sound waves of 40kHz, the module requires a trigger pulse of width of 10 μ s. This include the detection of the echo wave. The above formula is used to calculate the distance of the object which is proportional to the echo pulse.

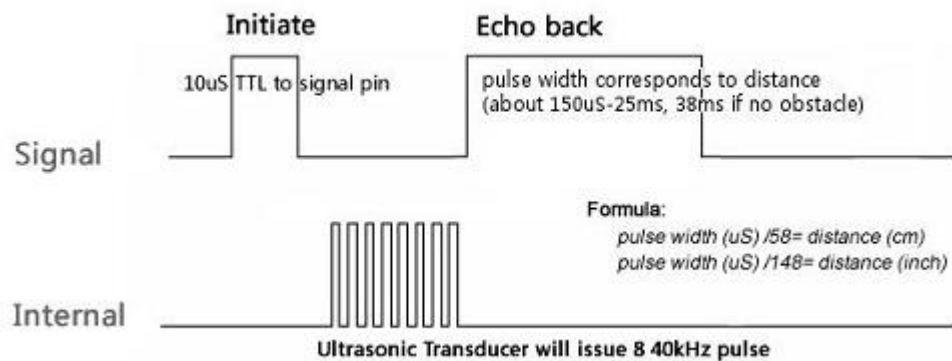


Figure 17 - Working of Ultrasonic sensor

Piezoelectric transducers are usually used. The crystal has the unique ability to accumulate electricity in response to mechanical stress. Electricity produced from pressure is known as piezoelectricity. Oscillation of the crystal due to the external energy source usually electricity results in shape and size change. This is related to the frequency of current applied. So, to produce ultrasonic waves, the crystals should be oscillated at frequencies more than 20kHz. This resulting in vibrating the atoms around the crystal and produce sound waves.

Capacitive transducer is used to detect the ultrasonic sound wave. It has a static plate surrounded by insulation material with a dielectric on one side. Diaphragm holds the dielectric. When the sound waves hit the diaphragm, it vibrates the diaphragm. This vibration moves the diaphragm forward and backward. This change of distance between the diaphragm and the static plate produce varied capacitance. The accumulated charges are measured to find the number of waves bounced back to the transducer.

5.4 - Bluetooth Module (HC-05)

Wireless communication over short distance without loss of data can be achieved through the Bluetooth. This technology uses the 2.4 GHz to 2.485 GHz for transferring data between the devices. This device is introduced to create personal area network (PAN). Bluetooth devices suppositionally can communicate with 7 devices at instance but in action this limit can't be reached. During the transmission, one of the devices become master and another one become slave. For instance, pairing up a Bluetooth device to the computer needs the following procedure. The device that tries to connect becomes the master and the slaves searches for the master. Once the master is found and the pairing up procedure started, they change their position as master and slave. Now the computer becomes master and gives command/data to the other device [9].



Figure 18 - Bluetooth module HC 05

One of the recent innovation in the Bluetooth module includes the Scatternet. A same device can communicate with two devices at the same time like master to one and slave to another. This innovation brings the possibility of communicating with many devices in a factory. The concept of Industry 4.0 includes the agreement between the devices that they should pass the information from one device to another and with the main systems. Though internet is a great source of communication it has its disadvantages. The whole factory should be rewired when the factory is upgraded. Not all the machines are compatible with communicating though RJ45 cables. But Bluetooth can overcome this problem. It is compact and easily programmed in any language. This places Bluetooth ahead of ethernet in the list of reliable ways to communicate. Though it

doesn't offer the higher bandwidth like the ethernet, the offered bandwidth is enough to transfer the small piece of information [9].

The communication starts with assigning an address to the components. Once the address is created, it acts as the channel for them to communicate. In the wired connection, there will be data loss because of signal overlapping. In Bluetooth, the data are transferred in the space to no possible for data overlapping. Security features in the Industry 4.0 require a private communication of devices among themselves. With encrypted data and predefined address, the data are secured.

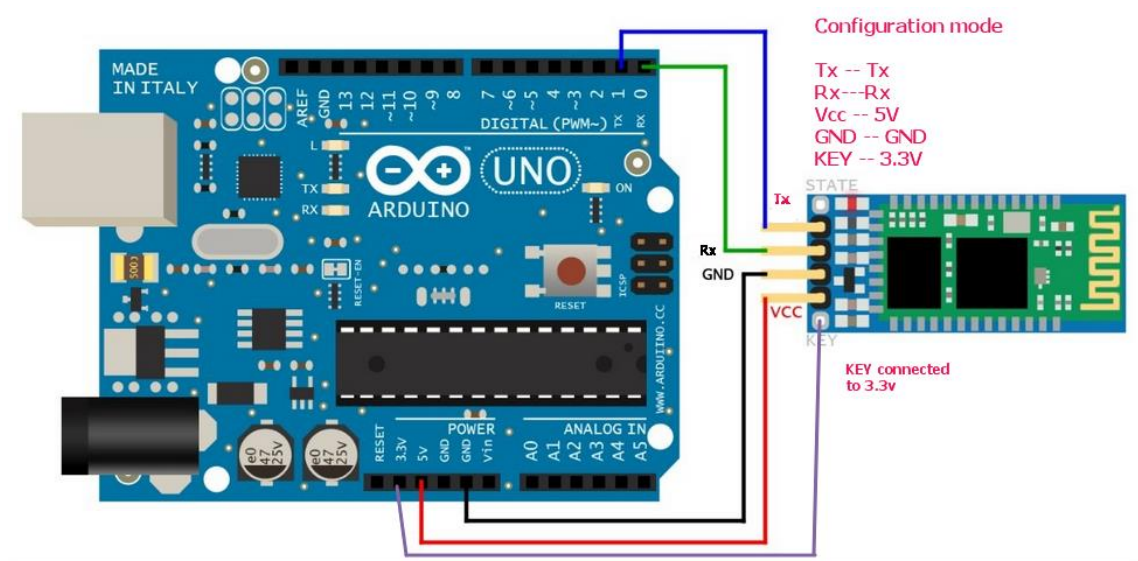


Figure 19 - Bluetooth Connection with Arduino

With the sensitivity of -80 dBm, and transmission power of +4 dBm, the module support the Serial Port Protocol (SPP). This 2.0 version with Enhanced Data Rate (EDR) offers data transfer till 3Mbps in the operational frequency of 2.4 GHz. The special features include the use of CSR Bluecore external single chip in the Bluetooth system and Adaptive Frequency Hopping Feature (ADHF). The compact size of 12.7mm X 27mm with integrated antenna and edge connector make them to operate at low power like 1.8V and operating voltage of 1.8V to 3.6V for I/O. The default baud rate is 38400 with 8 data bits and 1 stop bit. It has data control and also supports these baud rates - 9600, 19200, 38400, 57600, 115200, 230400, and 460800.

Simple instructions are good to work with this module like rising pulse in PIO0 results in disconnecting the device. Status information on the port PIO1 tells whether the device is disconnected or connected. The high value indicates the connection while the low shows the device is disconnected. Two LED are given on the module to identify the working condition like master or Slave. LED on the port 10 glows red resembles the master biased while the blue on the port 11 shows the slave biased. This module has the auto-connect feature by which the device can connect to the previously connected device. The LED also indicate the state of the connection. When the devices are paired, LEDs blink at the rate or 30 Blinks per second (BPM). When the devices are not paired only the blue LED blinks at the rate of 120 BPM.

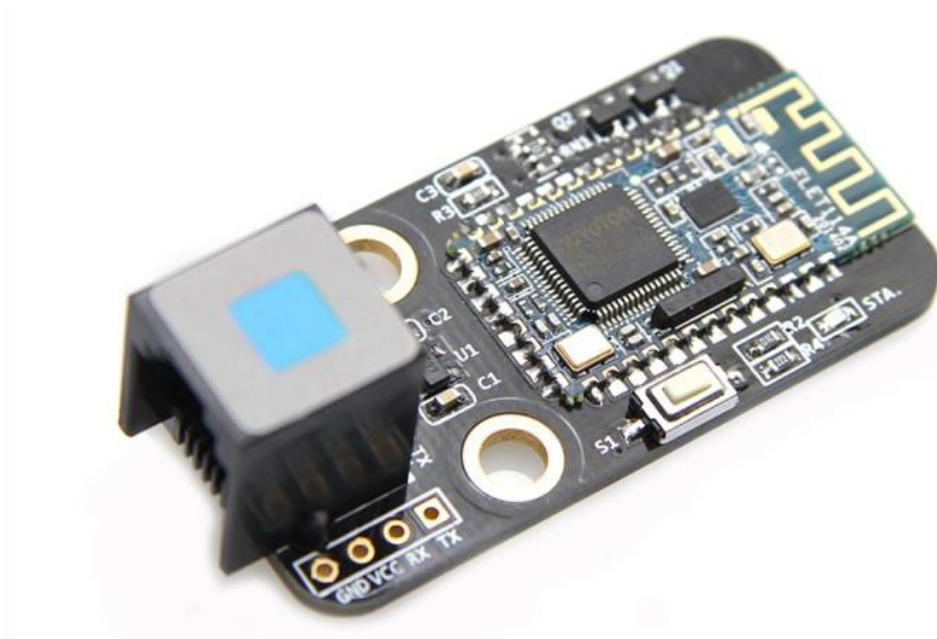


Figure 20 - Bluetooth Module for Arduino Orion

The universal pairing code is set to 0000. This value can be configured during the setup process. During motion, the device can move far apart. This results in discontinuity in the connection link. As a fix to this problem, the minimum time for auto-reconnect is set to 1s. This doesn't apply to the unpaired situation where the minimum auto-reconnecting time is 30 mins. The board contains the following pin for connection. VCC for power input and GND as ground with 4 more pins for data transfer. Two AIO0 and AIO1 are used as programmable I/O line. The I/O on the pin 23 and 24 has control output for LNA and PA. PIO2 to PIO11 on the pins 25 to 34 respectively are bidirectional and programmable.

The reset button provided at the bottom of the board. It helps to reset and restart the device when there is some flaw during the execution of the codes. The clock signal from the Arduino board is used to power up the device. This signal is the frequency at which the device communicates with one another. The program headers are programmed in such a way that these devices meet the world standards during the operation. If the standards are not met, there are lot of problem with pairing and communication. There is custom version of the Bluetooth are available for a specific purpose. These don't need the standards because they are programmed for a specific purpose and need not to interfere with the other bands.

Another Bluetooth module is attached on the robot. This 4.0 version with EDR and BLE (Bluetooth low energy) operates in 3.3V powered by 5V DC. Operation frequency of 2.4GHz with the baud rate of 115200 offers high data transfer speed within the distance of 15m. This module has only blue LED and it is configured in the way that blinking LED denotes the no connection while the steady glow defines the well-established connection. Rapid blinking occurs during the data transfer. It is highly compatible with Arduino because of the following configurable pins for programming RX, TX, VCC, GND. It has RJ25 connector to connect the module with the custom-made Arduino Uno Orion.

5.5 - Compass (HMC5883L)

The Honeywell HMC5883L is a low field magnetic sensor, mounted on the surface with the multichip module with a digital interface. It is used in low cost compassing magnetometry. HMC118X uses the magneto-resistive sensor along with ASIC. ASIC consists of Amplification and automatic degaussing strap drivers with offset cancellation and a 12bit ADC which facilitates the accuracy of the compass to 1°. This module also contains I²C serial bus which support the flow of data. A 16pin Leadless Chip Carrier (LCC) used in Mobile phones, Netbooks, Consumer Electronics, Auto Navigation System, and Personal Navigation Devices.

Anisotropic Magneto-Resistive (AMR) technology developed by the Honeywell has many unique advantages over the other sensors. Output data about the linearity and in-axis sensitivity are very precise with these sensors. Some more advantages include the very low cross-axis sensitivity that refers to the measurement of both direction and the

magnitude of Earth's magnetic field. These sensors are very sensitive and among the other in the market. The output rate from this compass is more as 160Hz with low working voltage of 2.16V to 3.6V. This accounts for the low power consumption of 100 μ A.

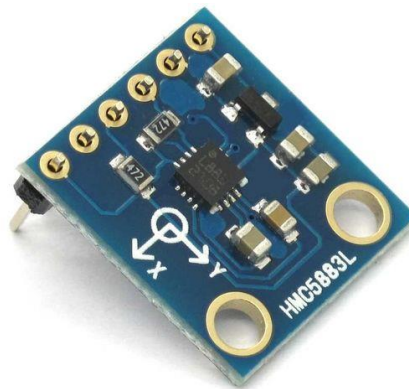


Figure 21 - Compass for Arduino Yun Mini

A Trio of sensors, application and supported circuit responsible for the measurement. This technology is also known as the AMRS. On the application of powers source, the compass aligns itself to the sensitive axis which results in varied output voltage due to the resistance in the circuit. The magneto resistive sensors are made of a nickel-iron (Perm alloy) thin film and patterned as a resistive strip element. The resistive

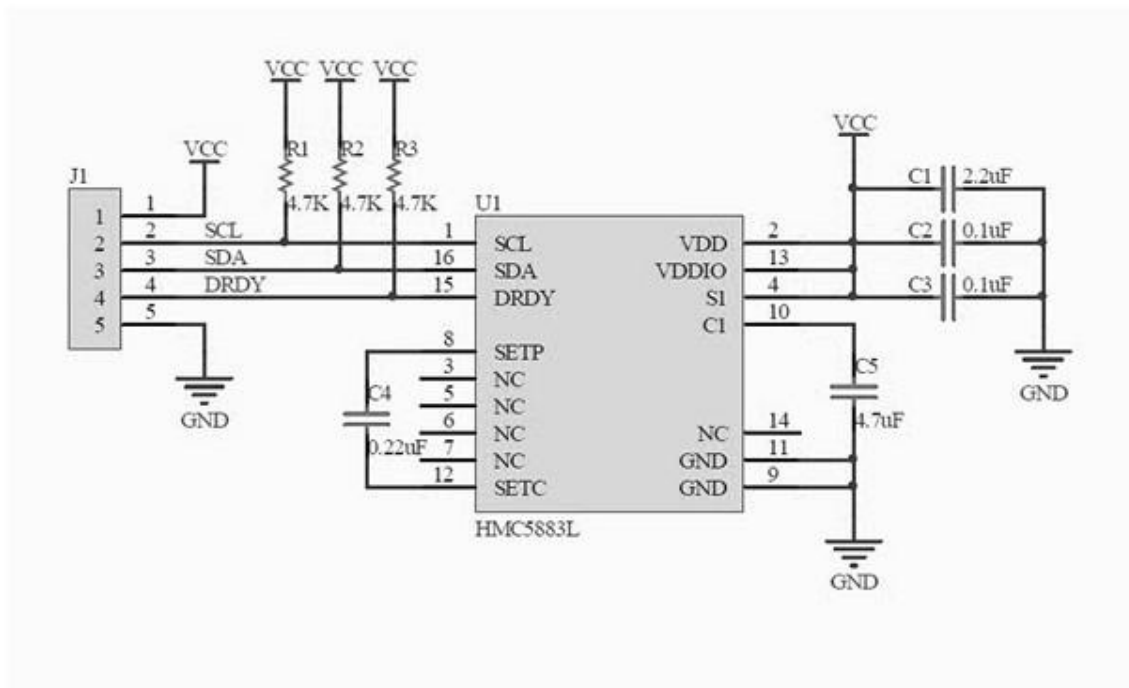


Figure 22 - Layout of Compass module

element is used in the combination with bridge circuit to measure the different in voltage. The magnetic compass is aligned only to the earth magnetic field. By comparing the resistance from various bridge elements, the information about other axis are calculated in any orientation.

Honeywell compass are famous for their power management. Power supply to the board can be done through two pins. First one is VCC. This provides power for internal operations. And the second one is VDDIO. It supports the power supply only to the I/O pins. Since it is possible to work with VDDIO like VCC, the compass is configured to work with single supply mode resulting in extended computability with other component on board. 7-bit serial address that supports I²C protocols are also included. This aid the standard and fast modes at the rate of 100kHz and 400kHz respectively. They have their own clock to execute the digital logic functions and time management. But to sync the data with the Arduino, external Clock signal is fed into the board to begin the operation.

5.6 - Voltage Regulator (YwRobot 545043)

The Purpose of the voltage regulator is to provide a constant voltage across the terminals. They are biased either in Feed-Forward mode or Negative Feedback control loops. Each of them has their own advantage. In older days, mechanical regulators were used which are replaced by the electronic components. They are used predominantly used in Automobiles, central power stations, and in most of the consumer electronics. When these regulators work in AC current, they are called as Stabilisers. Series or Shunt regulators are used in case of DC current. Zener Diode, avalanche breakdown, and voltage regulator tube uses the shunt regulators. They are connected in parallel to the working circuit. When there is current over flow through any of the circuits, these elements allow the excess current to flow through them there by protecting the other electronic components in the circuit. The design is to support the maximum amount of current to flow through them. The design of Monolithic integrated circuits provides voltage regulation for lower voltage like 12V.

The safety features in this component include the thermal shutdown and internal circuit limiting. Output up to 1A is achieved by using the proper heatsink. The possible output voltage ranges from 5V to 24V with current up to 1A. They have three connector pins – Input, Output and Sink. The input power is given though the input pin. The

transistor is forward biased, so it allows the flow of charges through them. When the current exceeds the limiting voltage, the transistor is reverse biased. This results in the

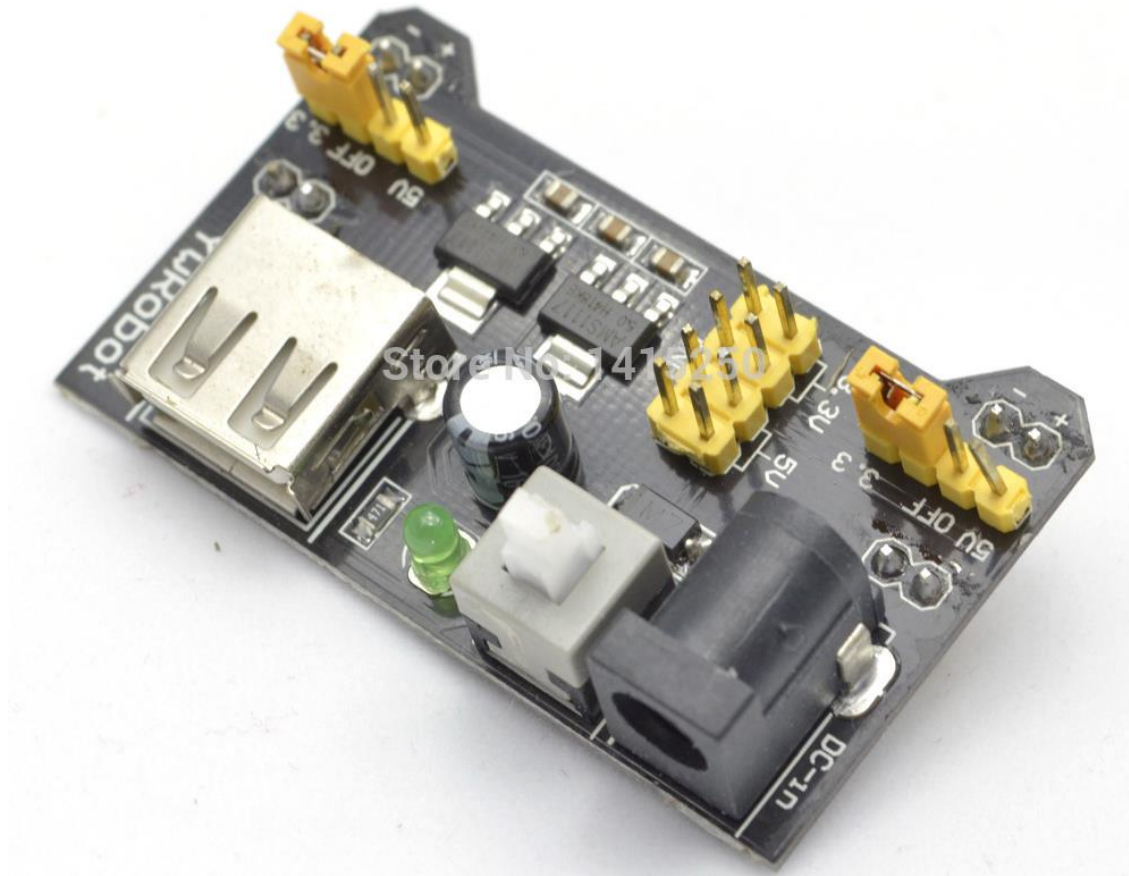


Figure 23 - Voltage Regulator for the Arduino Yun Mini

flow of excess current into the sink. In this project, the Arduino is powered by 5V input. Hence YwRobot 545043 component is used. It drops the voltage from a power source of 9V to 5V. Also, it has capacitors, they provide a constant output voltage in case of fluctuation in the input.

5.7 - DC Motors

The device that makes to travel from one place to another. It works on the Flemings left hand rule. Motors generally produce mechanical energy when an electric energy is applied. The basic components include the Rotor and the Stator. The rotor is the rotating component usually the arm the coils mounted on them while the stator is the magnet. There are two types of motor are there in the market one is Brushed motor and

the another one is Brushless. The main difference between them is the location of the magnet. In brushed motor, there are brushes through which the current can flow through the rotor arm. Therefore, the magnets are placed in the stator. These magnets can be either



Figure 24 - DC Motors that drives the vehicle

Permanent magnet or Electro Magnets. While the another one has no brushed to the coils are mounted on the stationary and the rotor has a permanent magnet. Though both has benefits over one another, I prefer the brushless one for my operation. It is simple and powerful to work with.

The motors are bought from a manufacturer name MakeBlock. These motors have gear arrangement inside them with a gear ratio of 1:45. The maximum speed of the motor is 185RPM providing a torque of 5.8 kg/cm. Accuracy of the motor is $\pm 10\%$ for speed. The speed during the unload operation is 185RPM with the current consumption of 220 mA (approximately). When loaded with torque of 1.5 kg.cm weight, they operate at the speed of 150RPM with the current consumption of 1.1A (approximately).

5.8 - Frame

Frames provides the rigidity to the robot. The frames are very robust and made of hollow I beams. They contain threaded holes for the screw. These frames are purchased from MakeBlock. These are made from 6061 Aluminium by extrusion process. The surface is anodized then painted with blue. So, the frames are resistance for longer time to corrosion. The extrusion process provides excellent strength and resistance to torsion. The threads are up to industrial standard with M4 size. The holes are placed uniformly on the beam at a distance of 16mm. The end holes are 8mm away from the edges. The cross-

section shows the two hollow I section with thickness of 8 mm and breadth of 24 mm. The frames are available in varied length from 64 mm to 496 mm with hole counts from 8 in shortest to 30 in the longest one. Some small brackets and plates from the same manufacturer is used.

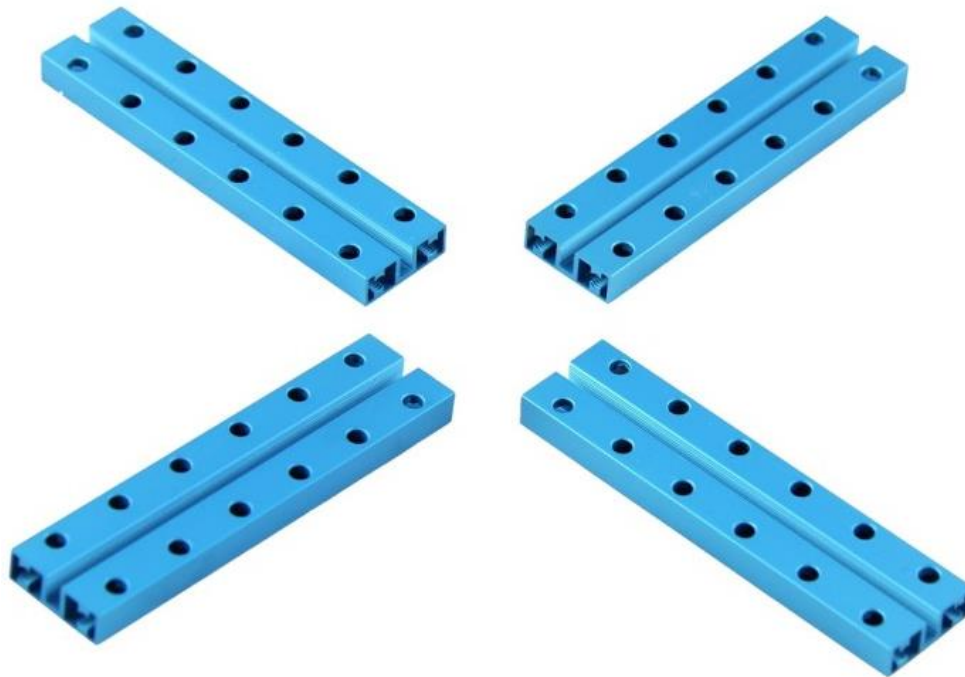


Figure 25 - Frame Components used for Construction

5.9 - Wheel

Motors drives the vehicles but they are connected with the surface. There should be some product that convert the rotational torque into the linear motion. The wheels are made from the same material as frame and they can move the vehicle. Two types are driving units are used in the vehicles namely Tires and Tracks. At cheap and compact size, tires provide great comfort to the vehicle. But they have more wear and improper transmission of power when the motors run at different speed. Hence, I considered the tracks. They offer less comfort than tires but great stability during mobility. These tracks are made of silicon rubber connected to each other by connecting pin called track axle.

6 - Arduino Codes

Arduino Programming becomes very simple with the introduction of their Integrated Developing Environment (IDE). It has a green color framework with white background in the typing area. There are few frequently used buttons on the top of the console. They include Verify, Upload, New, Open, and Save.

- ❖ Verify – This option helps users to verify that the codes are able to compile. If there is some syntax error or not predefined values, it notifies the user.
- ❖ Upload – The written codes are uploaded into the Arduino board using this button. Once the button is pressed, the codes are compiled and then they are transferred through the device either through USB cable or Wi-Fi
- ❖ New – Opens a new document
- ❖ Open – Opens an existing document
- ❖ Save – to save the current document

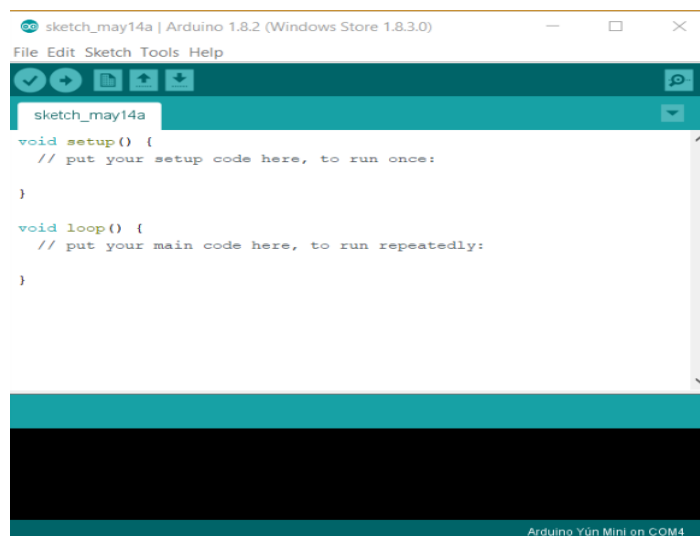


Figure 26 - Layout of Arduino IDE

Arduino IDE is well developed programming language, where they have colour codes to differentiate user codes from the commands. The welcome page

of the IDE (Fig 6.1) gives the location of the five icons on the top of the white box. Beginners are given with few examples and are very useful to play with them.

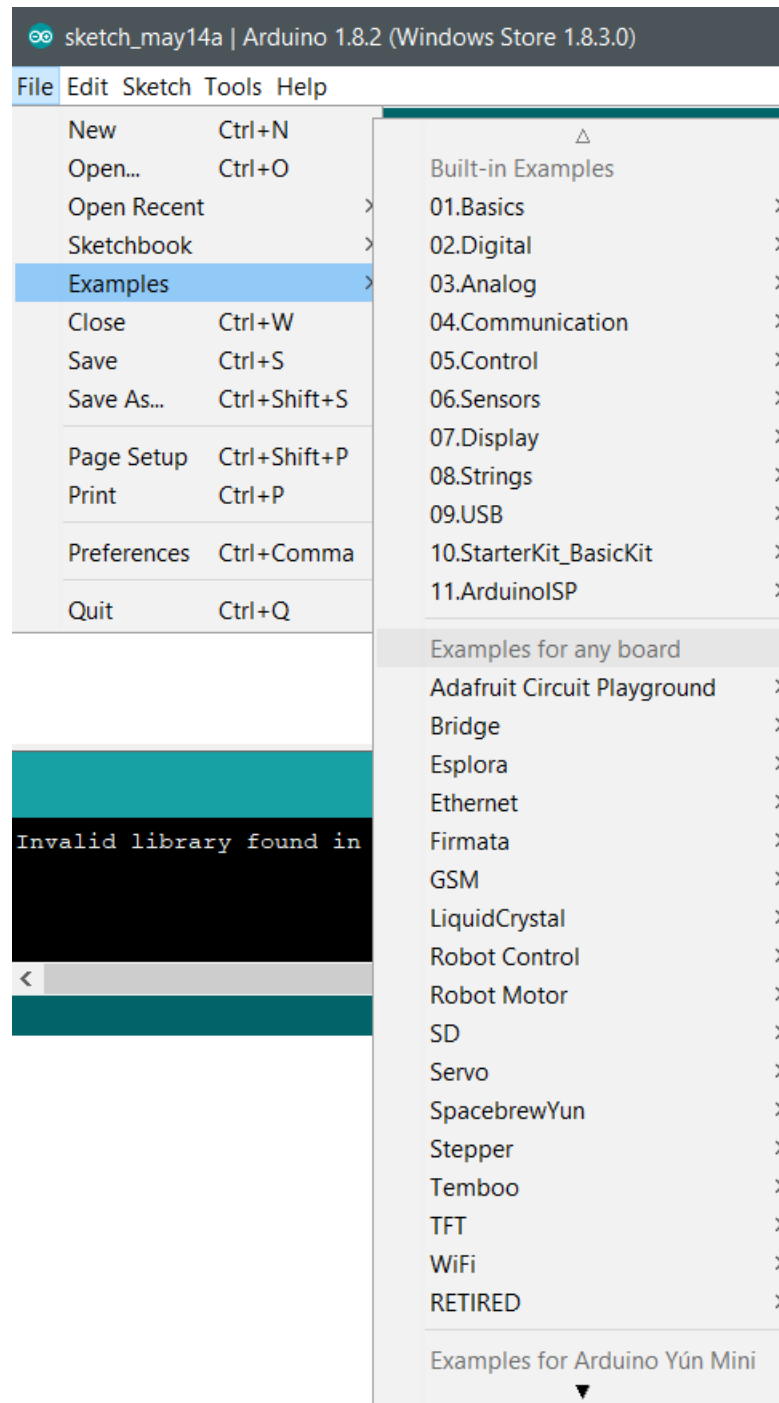


Figure 27 – Example programs provided in the Arduino IDE

The codes are very simple. The code that required to control the motor drive is written below. Here the LS and RS are left sensor and right sensor respectively. Also, LM and RM are left motor and right motor respectively. digitalRead helps to read the value

from the sensor and digitalWrite helps to write the value to the actuators. In the following code, digitalRead reads the value from the infrared sensor while the digitalWrite provides signal to the DC Motor. One can use the analogWrite is used to control the speed of the motor. The motor is controlled by H Bridge since the power output of the sensor is low.

```
void setup ()
{
  pinMode(LS, INPUT);
  pinMode(RS, INPUT);
  pinMode(LM, OUTPUT);
  pinMode(RM, OUTPUT);
}

void loop ()
{
  if(digitalRead(LS) && digitalRead(RS)) // Move Forward
  {
    digitalWrite(LM, HIGH);
    digitalWrite(RM, HIGH);
  }

  if(!(digitalRead(LS)) && digitalRead(RS)) // Turn right
  {
    digitalWrite(LM, LOW);
    digitalWrite(RM, HIGH);
  }

  if(digitalRead(LS) && !(digitalRead(RS))) // turn left
  {
    digitalWrite(LM, HIGH);
    digitalWrite(RM, LOW);
  }

  if(!(digitalRead(LS)) && !(digitalRead(RS))) // stop
  {
    digitalWrite(LM, LOW);
    digitalWrite(RM, LOW);
  }
}
```

The comparison operator if works with predefined cases. The brackets are used to write the loop program. This program will be executed when the case is achieved. The double and operator is used to combine the results. For example, digitalRead(LS) && digitalRead(RS) recognise the input from the two inputs and compares them whether they

are the same or different. By switching the values with the if operator, the results are achieved.

The ultrasonic sensor works with mathematical logics; hence the program includes some codes that calculate the distance of the obstacle. It starts with the emission of signal waves by writing the high signal in the transmitter. This is given by `digitalWrite(trigPin, High)`. Before proceeding with the task, the sensor should be resettled.

```
void setup ()
{
  pinMode(trigPin, OUTPUT);
  pinMode(echoPin, INPUT);
  Serial.begin(9600);
}

void loop ()
{
  digitalWrite(trigPin, LOW);    // Reset the Trigger Pin
  delayMicroseconds(2);

  digitalWrite(trigPin, HIGH);   // Sending the signal
  delayMicroseconds(10)
  digitalWrite(trigPin, LOW);   // Receiving of Signal

  duration = pulseIn(echoPin, HIGH); // Timen taken

  distance= duration*0.034/2;     // Calculation

  Serial.print("Distance: ");
  Serial.println(distance);
}
```

By raising the pin to higher output, the transmitter is given a high signal that helps the transmitter to send a signal out in the space. The signal transmitted is received in another sensor. The received signal causes distortion in the current flowing through the circuit. So, the received signal is disturbed. This disturbed signal is the indication of the first incident of waves on the object. So, the time taken is recorded in the Arduino. This time is used to calculate the distance using the formula $\text{Distance} = \text{Time} * \text{wavelength of the signal waves}$. This is the time taken for two-way travel so the time taken for one way is half

$$Distance = \frac{Time\ taken \times wavelength}{2}$$

This identifies the signal to stop and start when there is obstacle before them. The data is analysed by the Arduino Yun mini. This data should be transferred to the Arduino Orion. This can be done using the Bluetooth codes. The code Serial. Available () helps to search and identify the already connected devices. If the device is available, it connects to them automatically. serial.Read() helps to read the incoming data. This data is also stored in the database. Based on the code it controls the robot. The infrared sensor data is transferred to the robot through the Bluetooth.

```
void setup ()
{
  Serial.begin(9600);
  pinMode(13, OUTPUT);
}

void loop ()
{
  if(Serial.available() > 0)
  {
    data = Serial.read();          // Read the incoming data & store into data
    Serial.print(data);
    Serial.print("\n");
    if(data == '1')                // Checks the value of data is equal to 1
      digitalWrite(13, HIGH);     // If value is 1 then LED turns ON
    else if(data == '0')          // Checks the value of data is equal to 0
      digitalWrite(13, LOW);     // LED turns OFF
  }
}
```

When these codes are combined, the final code to run the robot is created. The code is included as the attachment in the CD as an Arduino file. The file contains the complete list of codes that is used to run the vehicle.

7 - Vehicle at Work

Once the construction is done, the final code is uploaded to the Arduino Yun Mini. The Arduino Orion comes with predefined codes that help the board to run the robot when the proper code is given to them. Hence the task is to command the Arduino Orion with the help of Arduino Yun Mini through the Bluetooth connection. When all the connection is made as the circuit diagram, the robot needs power to operate. Battery is the powerhouse for the robot. The vehicle is powered by 6 AA lithium ion batteries. When the batteries are inserted into the vehicle the power output is distributed among two elements, the Arduino Yun Mini and the Arduino Orion. The Arduino boards begins to work on the task assigned to them.

7.1 - Following the line

The infrared sensors are responsible for the line following. Basically, the LEDs emit the infrared light. These lights are impossible for human to view them. When these lights hit an object, they get reflected. So, they identify the object. Here they are programmed to follow a black line. The light that fell on the black line are absorbed. So, there will be no reflection of the object. This gives a low signal to the Arduino. This act as the trigger voltage. When there is no object or black object, the Arduino recognize the low current as the indication that vehicle is not moving in the defined path. So, it steers the robot in the way that put the robot is the correct path. For example, when the left sensor detects the black line and sends low signal current to the Arduino, it turns off the left motor and only the power is given to the right motor. If the right sensor detects the black line the same scenario happens. The right motor is out of power while left one moves. When both the sensors recognize the black line, the vehicle stops.

Table 1 - Logic Table for Infrared Sensor inputs and State of motors

Inputs and Reponses	No Input	Left Sensor	Right Sensor	Both Sensor
Left Motor	On	Off	On	Off
Right Motor	On	On	Off	Off

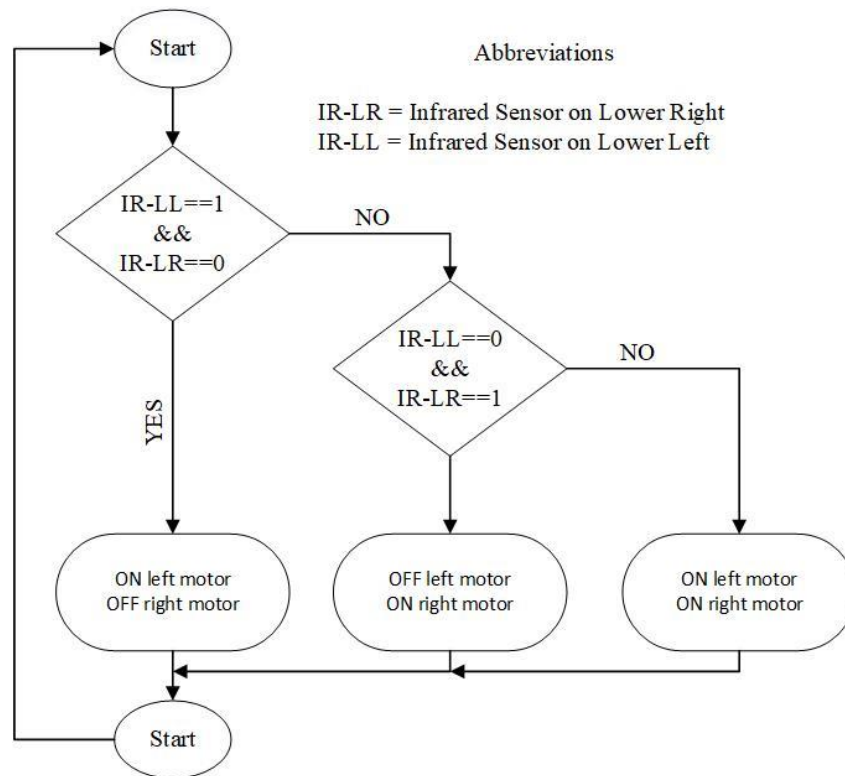


Figure 28 - Flowchart for the IR signals and Arduino Output

In the factories, there will be many vehicle that tries to follow the same line. These scenarios will be handled effectively by the other two sensors at the sides of the robot. There will be digital display with black background which is usually ignored by the sensor. When the vehicle needs to take a curve, the display glows and it gives out white colour, which activates the sensors. This input data is used to disable to the line follow sensor temporarily on that side. This results in no input, so the vehicle follow the line on the other direction. Once the vehicle crosses the display, the line follow sensors will be reactivated, this will bring back the vehicle to normal work. The logical flowchart for the whole process is provided in the appendix.

7.2 - Stabilizing the movement

The compass connected to Arduino gives information about the direction of movement to the robot. It also provides information about the inclination of the robot. This helps the Arduino to provide more traction force and control the speed of the motors. By controlling the speed, the vehicle is regulated to travel at speeds that are suitable for the factory. The compass gives output in three direction. We need each axis to identify

the direction of motion. X axis gives information about the inclination perpendicular to the direction of vehicle while the Y axis gives the information about the inclination parallel to the direction of movement. Z axis provide the information about the magnetic compass.

The deviation of the compass is used to identify the direction of travel. This three information are collected parallelly from the compass. The collected values are mapped in the Arduino in the matrix form. The matrix values are used to optimize the drive. During inclination one of the wheel is provided with more power to drive the vehicle while the Z axis values are used to travel straight. When there is some deviation, the infrared sensor informs the Arduino. Arduino collects the information from the compass also to find the precise direction of motion.

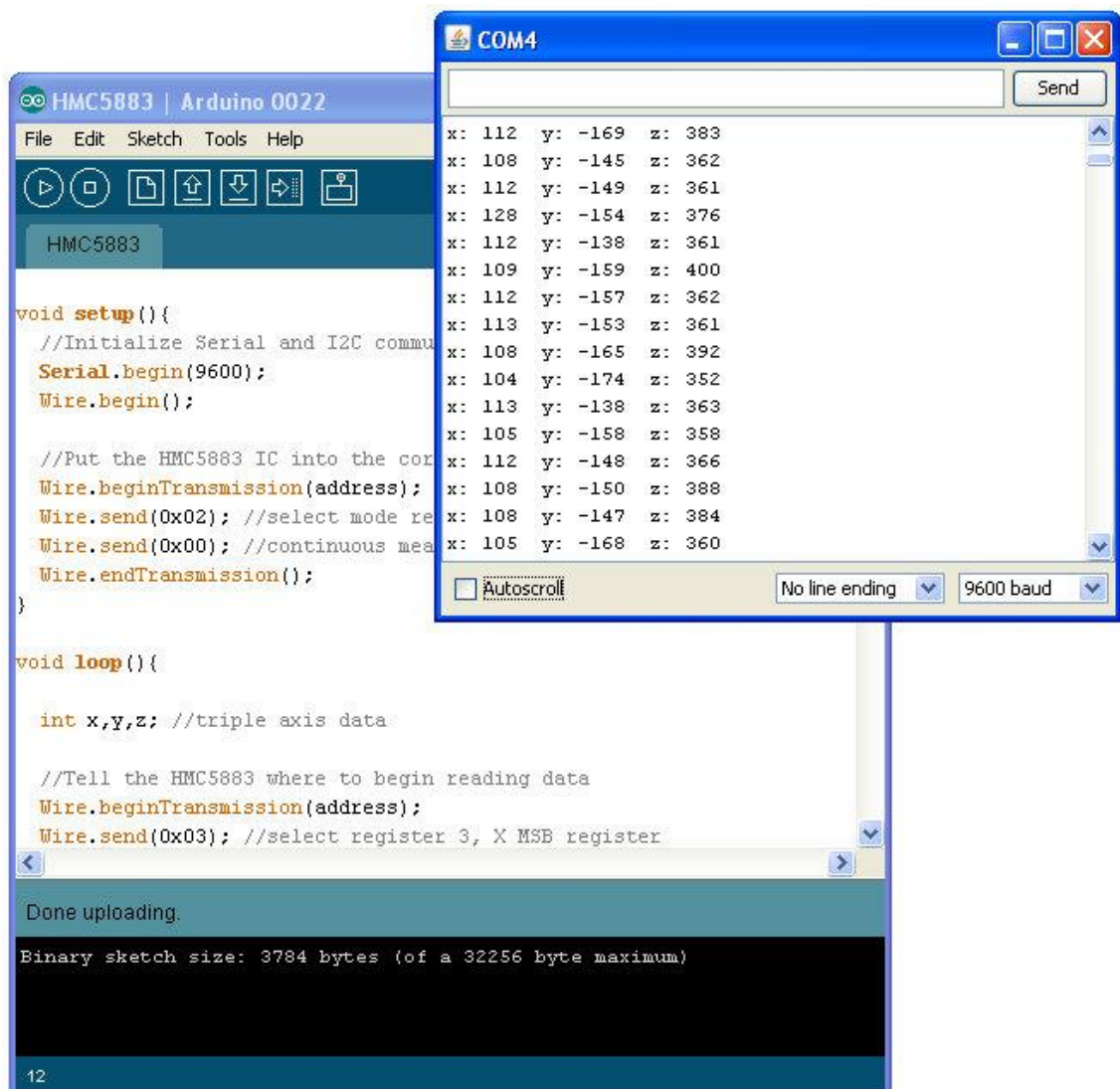


Figure 29 - Display of X, Y, and Z coordinates on the window in Arduino IDE

7.3 – Obstacle detection

Ultrasonic sensors are the front are programmed to identify the object before them. When an object is identified at the distance of 1m, it notifies the Arduino about the incoming disturbance. The robot recognizes the disturbance and then calculates the distance between the object and the vehicle. Based on the distance between them, Arduino decide the steps to be taken. If the object is too long, it rides the vehicle slowly. When the object is less, it stops the vehicle [3].

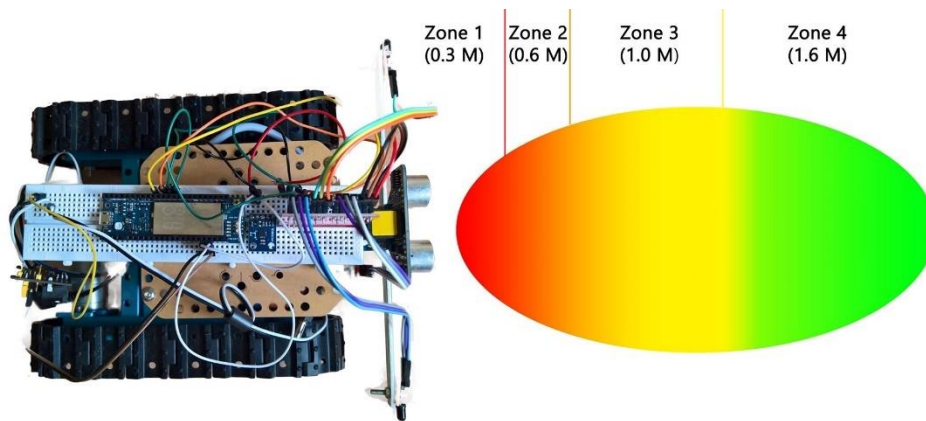


Figure 30 - Separating the distance into zones for better transit

The different zones are explained in the table. The green zone is free to travel and that is the maximum limit set to the Arduino to avoid environment disturbance. The minimum distance is set to 0.3m because the vehicle has to take other measure when the object in the front starts moving [6].

Table 2 - Different zones of obstacle distances and the vehicle response

Zone	Distance	Response
RED (1)	Less than 0.3m	Vehicle moves backward till the distance is in Zone 2
Orange (2)	0.3 to 0.6m	Vehicle stops with in this limit. The vehicle doesn't move until the Zone 3 is active

Yellow (3)	0.6 to 1m	In this Zone, the vehicle moves slowly and carefully. It calculates the distance more frequently than before to avoid collision
Green (4)	More than 1m	The vehicle is driven at high speed. The speed determined by other factors like inclination etc.

7.4 – Driving the vehicle

The Arduinos communicate among themselves to make the vehicle move. The codes are transferred via Bluetooth among themselves. When the robot is switched on, the Bluetooth modules are programmed in such a way that, one identifies the another one with in the limit. Once the devices are paired up. Arduino Yun Mini collects the information from all the sensors and instruct the Arduino Orion to drive the vehicle as per the information. The Bluetooth codes gives as the bit of data. This enables them to follow the commands seamlessly [9].

As I explained earlier that Arduino Orion is preprogrammed with codes that control the motor. The codes from 1 to 9 should be fed to robot to make them travel. For example, codes 1 commands the robot to travel forward and code 2 command the robot to stop. By providing the alternate commands the motion of the robot is controlled.

Table 3 - Bluetooth codes and their effects on the drive

Bluetooth Codes	Action on Robot
1	Drives Both Wheels Forward
2	Drives left Wheel Forward
3	Drives Right Wheel Forward
4	Drives Both Wheels Backward
5	Drives Left Wheel Backward
6	Drives Right Wheel Backward
7	Stops all the Wheels
8	Increases the motor Speed
9	Decreases the motor speed

8 – Conclusion

The content of this diploma thesis was to study about the Industry 4.0 and develop a vehicle for transportation of goods within a factory. The project was divided into many tasks. The results of these tasks are listed below

- 1) Concepts of Industry 4.0 [study] – Many journals and books were studied and the summary of the knowledge is written in the Introductory part (Chapter 1).
- 2) Study about the existing technologies – Most of the market available products and technologies were analyzed. Possible navigation systems are explained in the Chapter 2 – Design Possibilities.
- 3) Designing a vehicle – Based on the information gathered with the resource from the internet, a robot was designed. while designing the robot, all the parameters for the industry 4.0 should be fulfilled. These parameters are explained in the Chapter 3. Based on these principles, this robot was constructed with the help of the professor Ing. Radek Votrubec Ph.D. Construction details are provided in the Chapters 4 and 5.
- 4) Coding and Trail run – The robot was coded in the Arduino IDE which is controlled by various sensors. These data are used to run the robot in the precise path. The coding language and the codes are furnished in the Chapters 6 and 7.
- 5) Future scope for development – Possible improvements for the vehicle are discussed below.

There are certain areas which needs improvement for better handling of vehicles inside the factory. The robot that was constructed is used to transport goods from storehouse to stock unit. The factory needs vehicle to travel each and every corner of the factory. This needs some other navigation system with more carrying capacity. For this purpose, another vehicle is under construction.

It is controlled by Arduino Mega 2560 which is powerful Arduino and capable of doing more task than Arduino Yun Mini. These robots carry the semi processed goods and final products. These products can be heavy and irregular shape. So, the vehicle is designed with better stability and powered by 4 motors to deliver better performance.

This robot also uses the Wi-Fi module to communicate with the server and the proximity sensor at the front helps to identify the distance between them.

Thus, the main goal of constructing a smart factory with modular structured units controlled by cyber-physical systems is developed. After several trials runs with modification in the codes, the final code is created.

9 – Reference

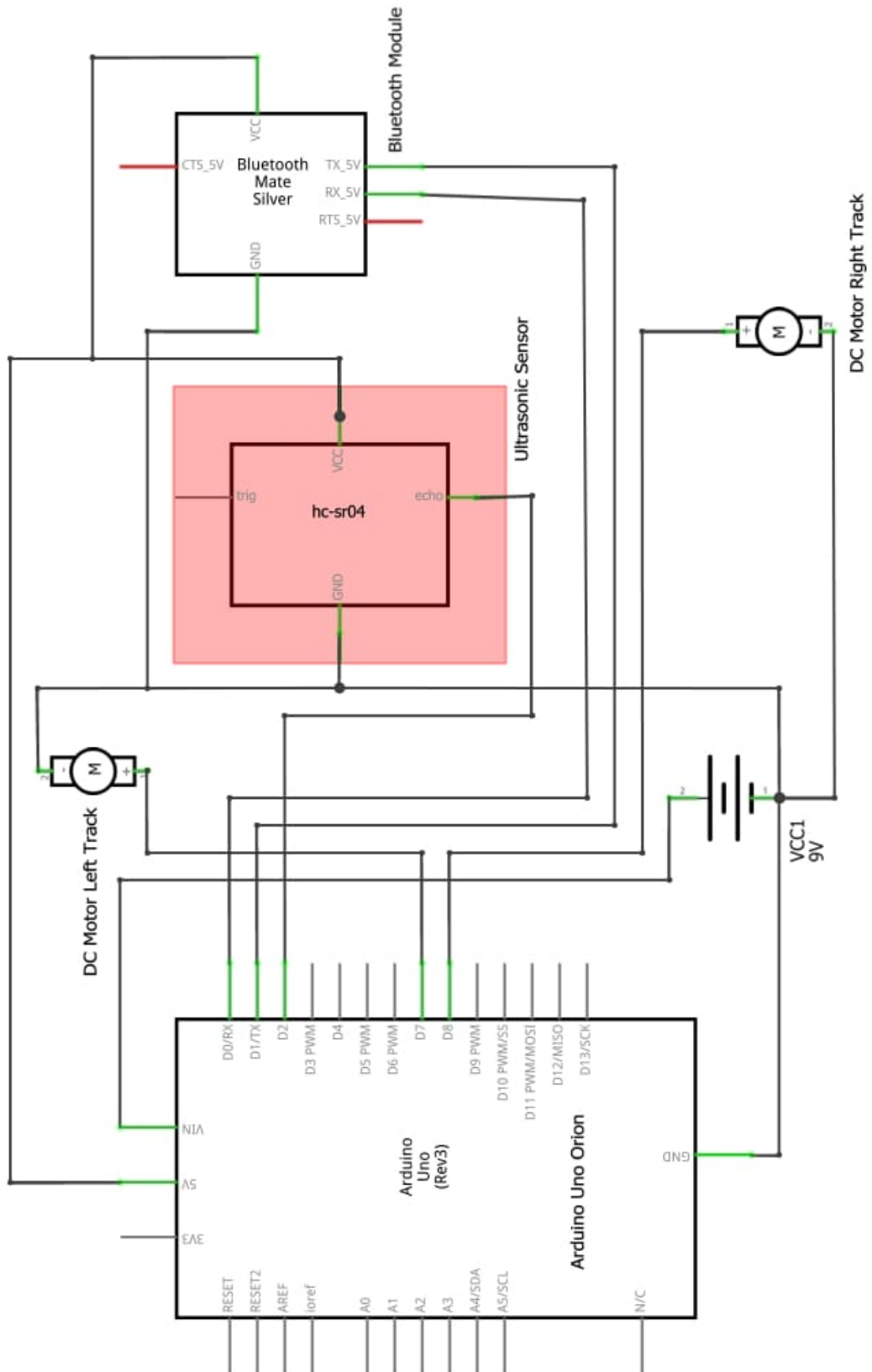
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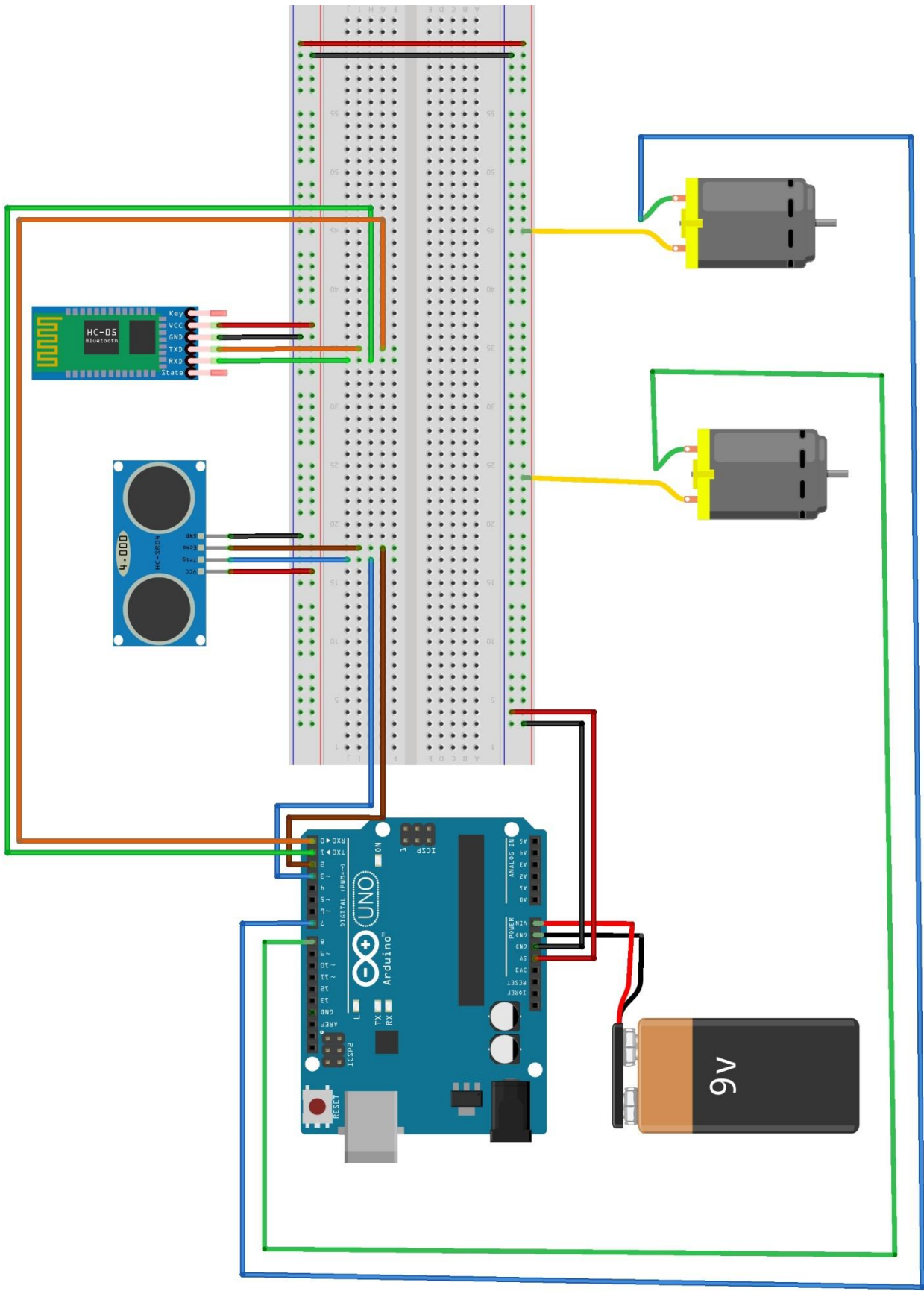
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List of Attachments

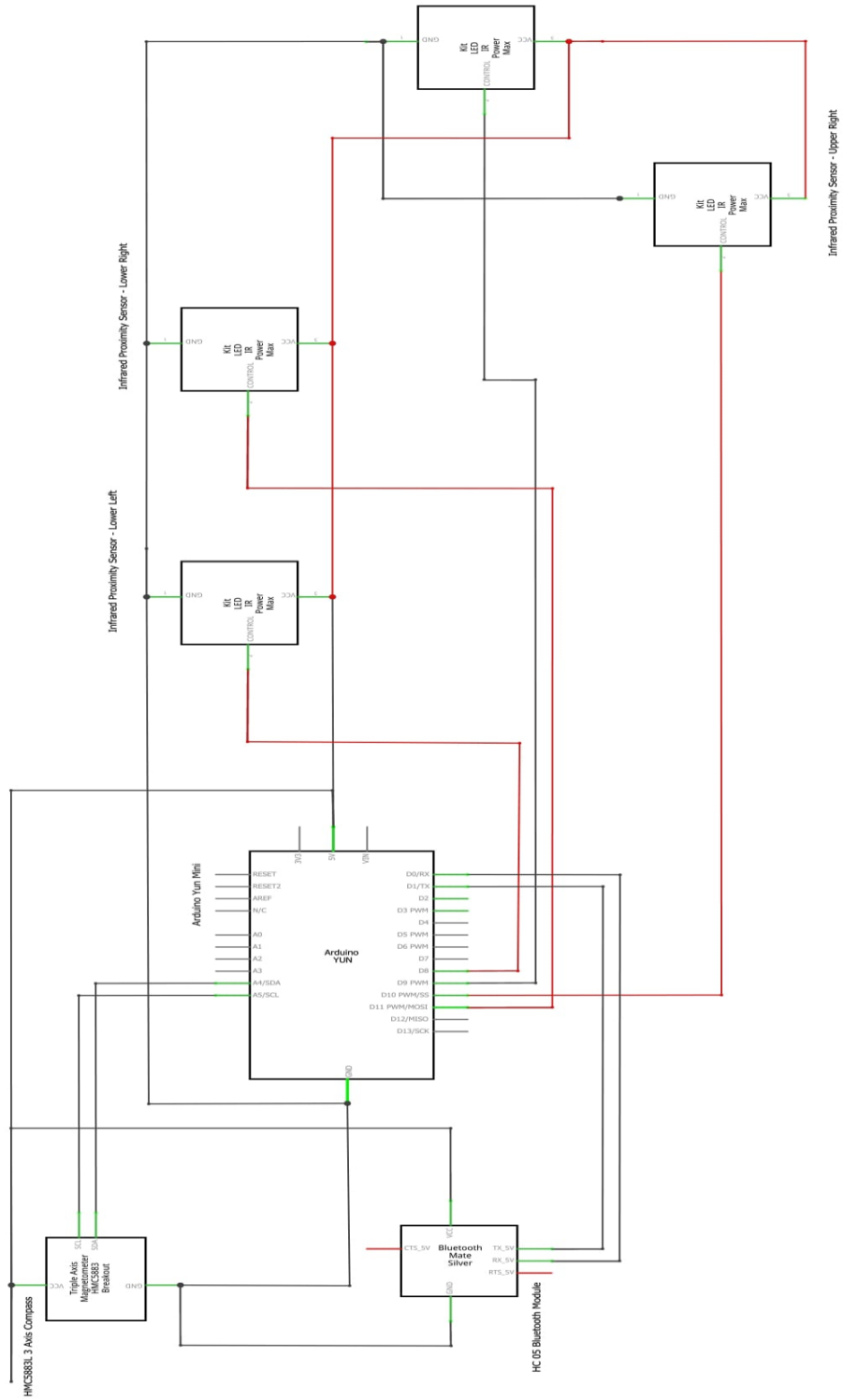
- 1) Compact Disk with Final Thesis Report and drawings
- 2) Schematic Diagrams
 - i. Schematic diagram of Arduino Yun Mini
 - ii. Schematic diagram of Arduino Orion
- 3) Wiring Diagrams
 - i. Wiring connection of Arduino Yun Mini
 - ii. Wiring connection of Arduino Orion
- 4) Logical Flowchart of the Vehicle



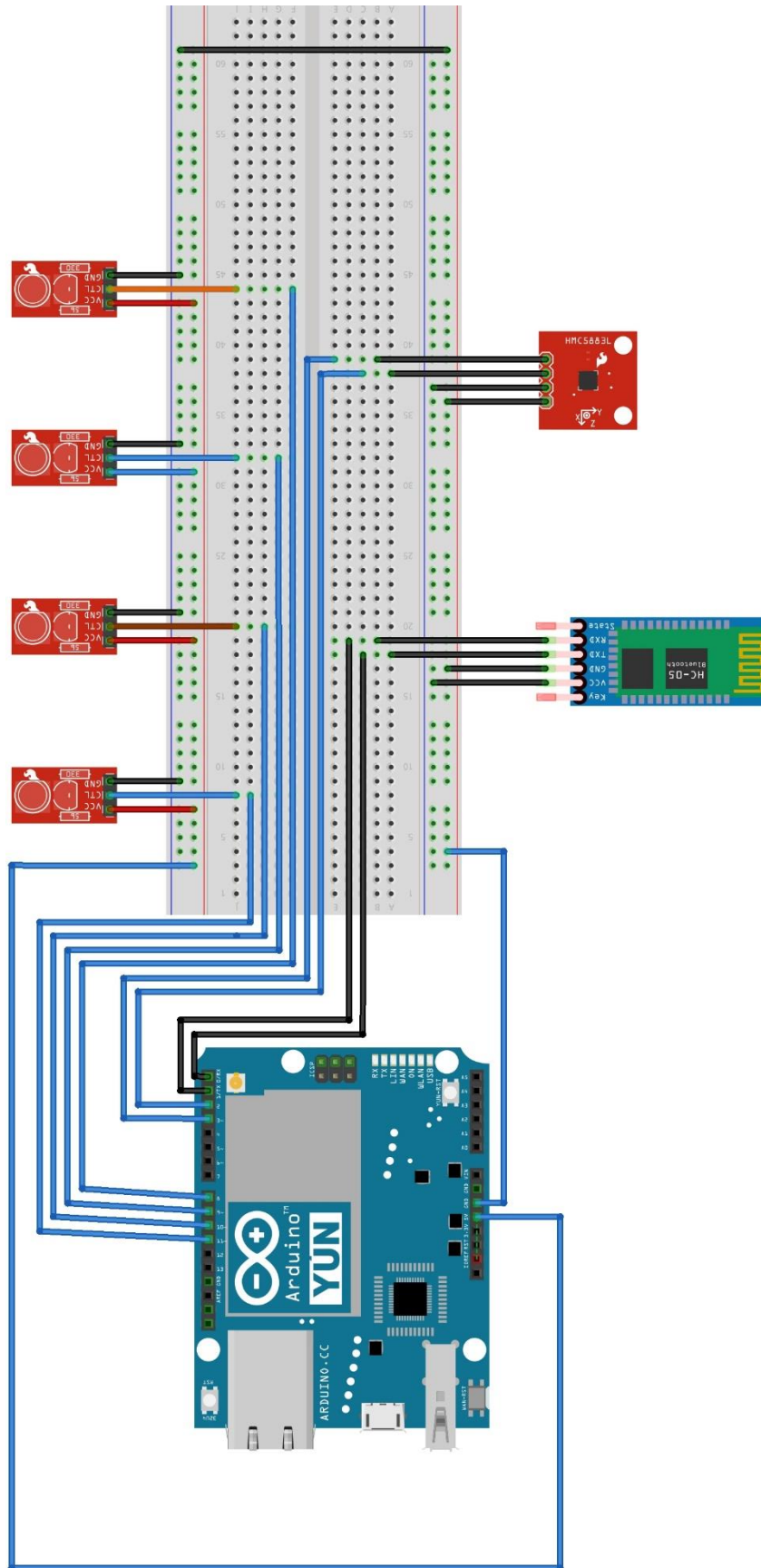
Attachment 2 - Schematic Diagram of Arduino Uno Orion



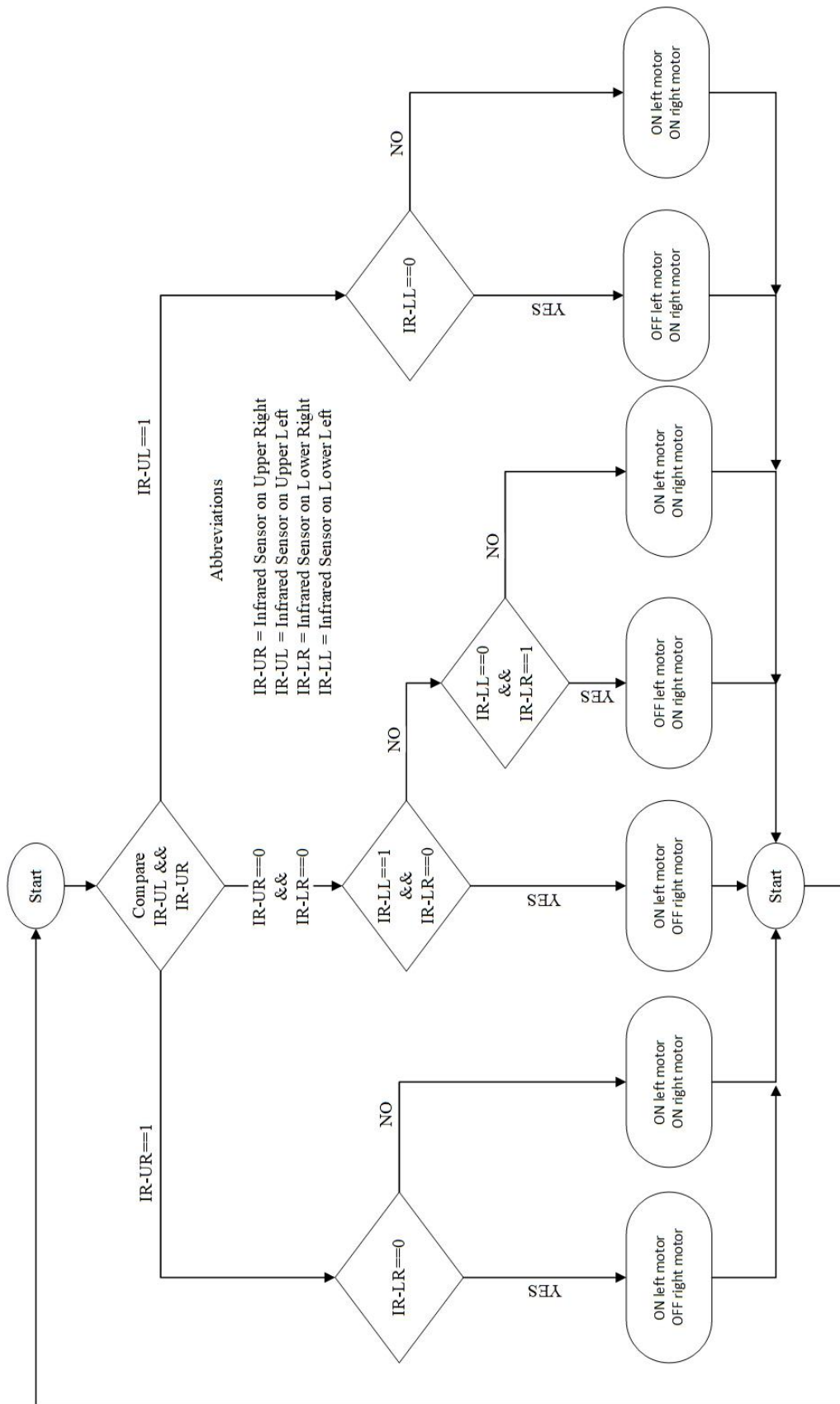
Attachment 4 – Wiring connection of Arduino Orion



Attachment 1 - Schematic Diagram of Arduino Yun Mini



Attachment 3 - Wiring connection of Arduino Yun Mini



Attachment 5 - Logical Flowchart of the vehicle