

ECE 480- Proposal

Team 8- agBOT competition

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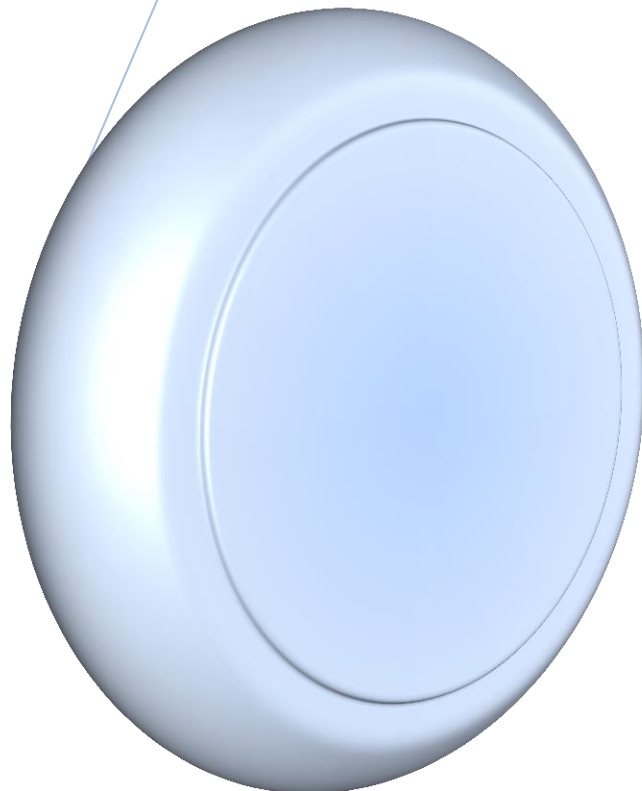


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Introduction:

The 21st century is the century of technological advancement and with over 2.11 million farmers, with an average of 434 acre of farming land, only in USA; Farmers should be provided with the best equipment to produce the total yield of around 10 billion ton of crops. AgBOT competition is the fusing point between agriculture and technology. AgBOT is the abbreviation for Agricultural Robot that is designed to perform agricultural field task with minimal human intervention. With the development of the agBOT, not only will it make the agricultural tasks easy but will do it with the speed. In terms of work force, as you can see in fig 1, in USA there is a decaying trend in employment rate versus increase in the demand in terms of GDP. Agricultural robot will help in filling some of those gaps that is hurting farming process due to under employment. AgBOT will then make farming faster and will eventually help in increasing the quality of the crops along with solving the problem of employment in agriculture area.

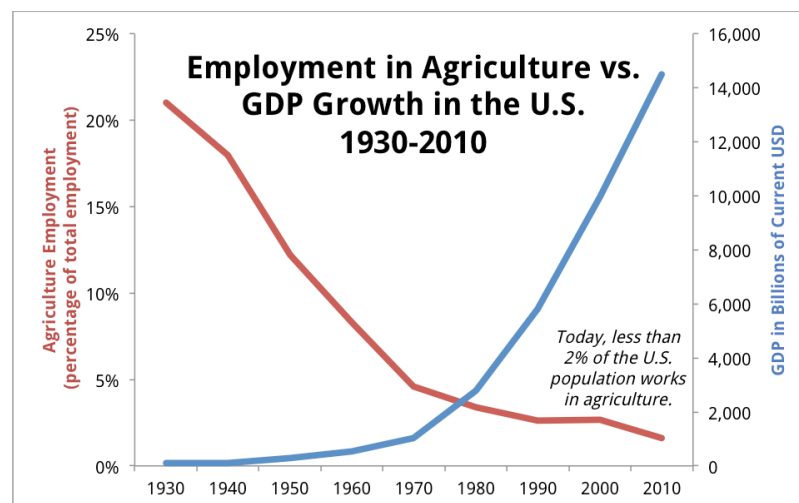


Figure 1 - Employment vs. GDP in USA from 1930 to 2010

Background

The goal of the project is to build an agBOT for the agBOT competition. The competition's main sponsors are airBridge. AirBridge designs and provides ultra-high speed internet communication infrastructure for mobile and static environments. The task at hand was to create an unmanned robot that can plant seeds and fertilizer on the field. The task is to plant an assigned set of GPS coordinates in two 30-inch rows. There would be a total of 12 rows, each of which would be half a mile long. The agBOT should also be able to operate within speeds ranging between 3.5-10 miles per hour. Moreover, the agBOT should be capable of docking and loading two separate varieties of seed while weighing the intake of seed and sending that data back to the user. On the field, the agBOT is expected to capture and send real time video back to the user base station. The video needs to be front and back which would give the user a rough idea if or not the robot is performing as expected or having some difficulties. Therefore, there is a need for the user to be able to intervene whenever they desire. Thus, the robot should also have the ability to perform the orders received from the base station. According to the specifications, the user of the agBOT should be able to control/intervene with the following:

- seed rate
- fertilizer rate
- the speed of the agBOT
- down pressure of press wheel
- data migration from agBOT to network host/operator
- Use BATS mobile antenna for communication

One of the requirements of the competition was the use of the BATS wireless system. A BAT is a fully developed multipurpose transmission system. It helps in the transmission of data between the robot and the base station for long distances. It supports major parts of the capabilities this challenge is asking for. This antenna is built with military technology and can track up the object up to 50 miles. It also provide high capacity data transmission rate, which is perfect for our GPS navigation and video streaming purpose.

To meet the requirements, sensors needed to be implemented into the agBOT. Sensors should also be implemented on the robot for various purposes. Some of the sensors required would be for the seed rate (how much seed is left/lost), fertilizer rate (how much fertilizer is left) and also for the down pressure of the wheels (how much pressure is exerted on the wheel when the robot is completely loaded). The robot should also be able to make real time decisions by itself; for example, it should be able to realign itself if it goes off the path or does not move in a straight line. Thus, a vision based control was required for the agBOT to be able to achieve the desired outcome.

Problem Statement

The agBOT competition is a challenge solving event where different group of people with the background in different arears of engineering and agriculture come together and try to solve problems related to agriculture. The theme for the 2016 agBOT competition is to make an autonomous vehicle that can do the planting process with minimal human intervention.

The team has five months and \$500 budget to work on the project. Given the size of the competition and time, it would be impossible to make a full scale autonomous vehicle. Although the competition requires that the competing teams implement the BATS wireless system into their model, it was not a feasible option for this project. The main reason is the size of the BATS, which needs to be mounted on the full scale large vehicle that has capability of carrying substantial amount of equipment's. Therefore, long range wireless communication was not possible for this project as there is no other system that can help with long range wireless data transfer.

Voice of Customer

Under the provided time and budget, it is impossible to produce the full scale autonomous vehicle. Therefore, the team agreed to build a scaled down version of the real agBOT, which the sponsor concurred to. The proposed prototype only focuses on the electronics part of the competition built on a scaled down version. There will be three main areas that the team will be concentrating upon and those areas are:

- Communications
- Navigation
- Data processing

Thus, the final model that will be built will be a scaled down version of the final agBOT that will compete in the competition; performing most, but not all, of the functions that the competition requires. But, it will serve as a stepping stone for the future teams to build on and complete the agBOT.

Exploring the solution

Communication is an important part of this project. In order to navigate and to carry out any data transfer, the communication between the robot and the based station is very important. Thus the main topic of discussion for the team was to find a liable communication system that is capable of transmitting and receiving large amount of data and controls.

The group has three proposed design solutions, which are primarily determined by the means of communication. Since the data and video streaming between the car module and the base station has to be done wirelessly and over a substantial range, we had to explore options other than Wifi itself; although Wifi was one of the solutions that the team looked at. Some of the explored solutions were:

	ZigBee	WAN	LAN
Application	Monitoring and Control	Email, Web, Video	Local Network
Data Rate	1 Mbits/s	150 Mbits/sec	1000 Mbits/s
Range	10-100 meters	Worldwide	100-200 meters
Power Consumption	Low	High	High

Table 1 - Comparison between ZigBee, WAN and LAN

1. Using ZigBee for communication

ZigBee is one of the most popular communication strategies used by contemporary remote control systems. The reason for considering this approach in this project is because ZigBee has a LR-WPANs (low-rate wireless personal area networks) MAC layer with Mesh networking topology, which the coordinator is able to initiate and sustain the network at any locations. Although the range of data transmission between two nodes is not as close as we expect, ZigBee allows other devices to be setup as routers to bypass the data in a mesh environment, which made an infinite range of extension possible. The vital problem of this approach comes when considering the data transmission rate of the ZigBee module. Even though 250 kbits/s is more than enough to perform normal data monitoring and control, video streaming requires a transmission rate substantially larger than that value. Moreover, a practical problem comes: How to crack the ZigBee protocol and utilize it into Raspberry Pi programming? ZigBee has a predefined X-CTU user interface which was maintained by certain certified product member, such as, the selling company. It was not supported by open

source organizations due to the contradiction in GPL protocol. It will take substantial amount of time to merge all the information into a customized user interface.

2. Using Wide Area Network (WAN) for communication

Wide area network is the primary choice for most indoor communication system, but it is also a pain for outdoor communication system. It is user friendly, WiFi USB adapters are able to work fluently with any real-time operating system by simply plug into a usb port of a microcontroller or a microprocessor. It is able to provide sufficient data capacity approximately 50 Mbits/s which is more than enough to satisfy the data transmission requirement for most of the university applications. However, a central server is required for constructing this type of network. That's the reason why people can get access to their home facilities even they are in another corner of this planet. While favorite by most of people, this point-to-hub networking topology can be detrimental to the group's project. The hub is often wired in fixed infrastructure which means it cannot move with our base station and require additional routers to enhance signal range. In this project, to receive GPS signals, the robot has to operate in an open environment such that the signal is not going to be blocked by the walls of building. Although the robot and the PC base station are close to each other, connectivity might be zero if they were beyond covering range. Therefore, a WiFi range extender is considered, in order to boost the signal out of the building.

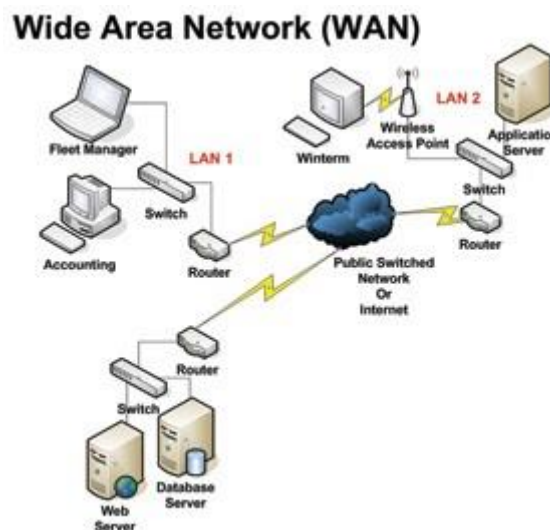


Figure 2 - Wide Area Network connection diagram

The setup of WAN, as shown in figure 2, is advantageous if we need to connect two devices that are great distances apart. But in order to use WAN a network server needs to be made and it costs money.

3. Using Local Area Network (LAN) for communication

The third communication option is proposed based on the idea of using LAN. The only difference is that a local area network does not require a valid internet access and is infrastructure less. As commonly known by people, a WAN (wide area network) generally requires a valid internet access and wired hub to setup. However, for some special circumstances, a preexisting infrastructure might not be competent. The project described in this proposal is a good example. A farmland might be located hundreds of miles away from an internet infrastructure or base station, thus it is not possible to rely on any of them. The team needs a extemporaneous mobile network that can be setup quickly and dynamically with self-configuring manner. If the internet access is not a necessary requirement, then a local area network could satisfy all these features. Basically, any laptop or computers, which can connect to internet wirelessly, is able to create and join a LAN anywhere.

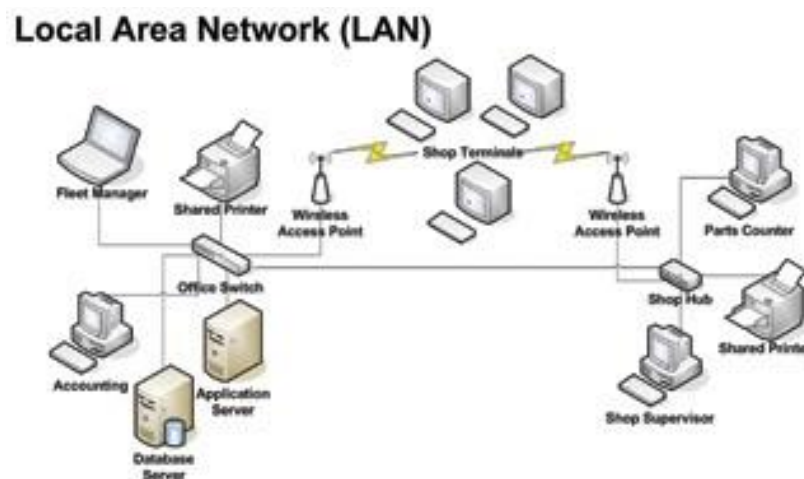


Figure 3 - Local Area Network setup

As we can see in figure 3, LAN does not need any access to any internet services and multiple devices can be connected wirelessly but it has to be in closed proximity.

Selecting the approach

The group has carefully evaluated all three options in different aspects. The first option was excluded at the earliest stage. But the means of sending and receiving data from ZigBee to other devices might need extra measures, such as, encoder and decoder. Recently the team found that the second and the third options are not mutually exclusive. They have a similar networking configuration and the major difference is whether it has the access to the internet. WAN can be used in programming phase, while LAN can be used in testing phase. In the programming phase, a strong gps signal is not necessary. The team should be able to download and edit open source codes directly on the Raspberry Pi from internet server. Sometimes a virtual raspberry pi desktop access can be used for ease of programming, that the programmer can use his own computer to access the raspberry Pi's desktop. Since programming on Raspberry Pi need to attach external devices, such as, monitor, mouse and keyboard, a common internet server could allow the computer as a client to control the raspberry pi remotely. In the testing phase, the code should already been uploaded to the microprocessor. Point-to-point local area network allows data to be transmitted between the base and the robot even without internet connection. The connecting procedure is that after the raspberry pi is booted up, the WiFi dongle will automatically enable the raspberry Pi to host a webpage that can be viewed wirelessly on a laptop or any mobile device by entering the local IP address of the raspberry Pi.

Selection Matrix

Communication Criteria		Importance	Possible Solutions		
			ZigBee	WAN	LAN
Data Capacity	Streaming Video Quality	4	3	7	8
	Network Latency	4	9	6	8
Range	How far the signal can reach	3	4	9	6
	Trans. Distance between PC and Car	5	4	5	9
Protocol	Communication Stability	5	9	6	7
	Networking Security	3	9	7	8
Compatibility	working with current system	5	1	9	9
	User Friendly	3	3	9	8
Cost	No Additional Parts Needed	2	3	7	7
	Low Power Consumption	3	9	5	5
Totals			5.4	7.0	7.7

Table 2 - Selection Matrix for communication option

The selection matrix, which is represented in table 2, shows the most viable option for communication is Local Area Network.

Hardware

Scaled-down car Module

The team will be using a scaled down vehicle for this project. The total length of the row is also been scaled down to 100 meters which is the maximum effective range of the wifi network. The group chose an RC model car in size of 12.5 inches long, 7 inches wide to fit in this 100-meter-field. One of the models for the RC car is shown in figure 4. The motors of the car need to be connected with motor drivers and an IC in order to run properly. At the same time, a microprocessor's output pins which are controlled by the inputs will also be connected with the IC circuit. By doing this the group is able to control power that is supplied to the motors. The car's speed and direction then can also be controlled.



Figure 4 - RC modeled car

Microprocessor

To achieve the required functions, the design team has to connect several separate hardware devices and the module car together to build the prototype. First of all, a Microprocessor is needed in order to connect the car with each device as well as to process all the information and data. A microprocessor is a computer central processor unit on a small IC board. The group chose to use the raspberry pi which has a cpu quad-core ARM Cortex-A7 working at maximum of 900MHz. This processor has a independent linux operating system so it is powerful enough to process different software's and devices at the same time. There are 40 GPIO pins on the board which can be set to both input and output pin by simple commands. The Raspberry pi as a microprocessor accepts digital data as inputs. These inputs could be both from a software code or from an outside circuit's output. The Raspberry pi is able to process these inputs according to commands or pre-programmed software and will output results as voltages to the pins which are set to be output. The output pins will be connected with further specific devices and serve as inputs in order to make the devices programmable.

Raspberry pi Camera

A major function of the car is to do the live video streaming. The group decided to use the raspberry pi compatible camera. The most advantage of using this camera is that it can be simply plugged into a specific interface on the raspberry pi. The raspberry pi camera is also fully programmable. Parameters like brightness, resolution and video length can all be

adjustable if necessary. The video will be stored in the micro SD card on the microprocessor. By using proper software, the video can be remotely displayed on a website with a specific IP address.

GPS Module: Adafruit Ultimate GPS Breakout

Navigation is another basic requirement of the project. The car should be able to receive location information (GPS coordinate) from the base station and head to that location by itself. A GPS module needs to be connected with the car and navigate the route for it. The group researched and found that the Adafruit Ultimate GPS Breakout could accomplish this function properly along with the microprocessor. The Adafruit Ultimate GPS Breakout is a GPS device supplied by 22 satellites and has an accuracy within 3 meters which is pretty fine for the design. This device could use UART ports or USB to TTL Serial Cable to connect with raspberry pi. The raspberry pi has built in UART ports (pin8 and pin10) as well as on board usb ports so this GPS Module would be fine for the project. After connection, the next step will be getting software loaded to the raspberry pi which understands the serial data the GPS module provides. There are already this kind of open source software existing, one of them is called the GPS Daemon, as well as gpsd. It acts as a layer between the microprocessor and the GPS hardware so the microprocessor can “understand” what the GPS Module “means”. The design team will also need to build a circuit to connect the output ports of GPS information to the motor drivers on the module car. Finally the car will be able to be navigated by a given GPS coordinate input. The GPS Module is also able to collect the data such as speed, direction of the movement.

Power Distribution Module

The RC model car is equipped with three motors. Two of them are used for driving the wheels and one of them are used for steering the car. These motors consume 9V power and all the power will be supplied by a 11.1 V Lithium-Polymer battery. In order to regulate the power, a power distribution module will be used. The power distribution module will also provide power to raspberry Pi and all other sensors.

The power distribution module will also have an output pin which will be connected to raspberry Pi that will monitor the battery life. The raspberry Pi will also transmit the battery life data to the base station for monitoring purposes.

Kill Switch

There will be a kill switch integrated into the system that will shut off all the power on the robot. This is for safety purposes. If the robot goes rough or out of control, the operator can use this kill switch to shut off the robot.

Software

Autonomous drive programming

To let the robot move autonomously in a predetermined path, specific GPS locations will be assigned and defined in a program that outputting the voltage pulses to directly control the motor behaviors and integrating the sensor measured data to yield next stage movement. The software needs to interact with both a gps receiver module and a gyroscope in inertia measurement unit (IMU) to retrieve its current position and direction of travel. That implies, when a valid GPS signal is acquired, the robot will determine its present location first and then compared to the destination waypoint. By calculating the difference between its current bearing angle and the correct orientation to the destination using a gyroscope, the robot is going to adjust its heading destination and repeats this process during the movement towards destination. The major difference between this project and other GPS guided obstacle avoidance project is that there are almost no interruptions during the destination approaching process. A straight line alignment algorithm can be used after the bearing angle is fixed. The robot will heading towards the calculated direction until the waypoint is reached. However, in a situation that the second path is parallel to the first path, some specific task should be done prior to the beginning of second approaching process. A pre-programmed action will ask the robot to turn 180 degree from the original direction and then do the measurements again. The robot will drive back to the base workstation after finishing all locations.

Base workstation

Data Subscription

The project has an external workstation at the base for easy monitoring and controlling. The base will be equipped with a router and a laptop. It creates a local network to achieve data communication and a platform to connect user and the robot.

The base workstation will use router for Local Internet Environment. The router provides a 100 meters range monitoring and controlling availability for user. The WiFi 802.11/n/g/b/ac protocol provides the network capability to transfer heavy data like video files. The WiFi environment extends the range of uses and increases the signal stability comparing with bluetooth or ZigBee.

User Interface

The User Interface at base workstation is installed on a laptop. To control the Raspberry Pi GPIO remotely, the team will need a user interface, which the user can use to send the command to the web server, and then the web server will send the command to control the GPIO of the Raspberry Pi.

The Video Streaming Monitor Block contains a video player. It receives live video data by wifi connection with Raspberry PI on robot. The video performs in real time at certain frame rate and save video files on the disk of base workstation at the same time.

The Sensor Data Display Block contains the vehicle sensor information and status. The panel includes: speed, direction, light condition, location and other data acquired. The readings are shown on the panel, also in real time.

The Robot Control Console Block has buttons for the On/Off switch, vehicle moving control (moving forward/back/turns) and action control (plant seeds/fertilizer). As well as, the Active GPS Positioning Block contains a map view that user can zoom, drag and tap on it. Once the tap gesture triggered, the system will return a GPS coordinate to user and also send moving command to robot.

For summary, the Base station works as an external part of the agBot project, performs as an extender of the robot core, which is also important for the project. The robot's video streaming, speed as well as other sensors' data will be the expected output being viewed at the base station.

Integration of all the components

After deciding the correct components for the robot, the assembly procedure will begin. Raspberry Pi will be mounted on car along with the GPS and Accelerometer and Gyroscope modules. The passive sensor, used to collect data, will also be mounted on the car. The two raspberry Pi cameras will be attached to front and back of the car; that will be used for front and rear view for the operator. The battery with the power distribution module and motor drive will be attached under the car. The connections between the components are represented in the block diagram in figure 5 below.

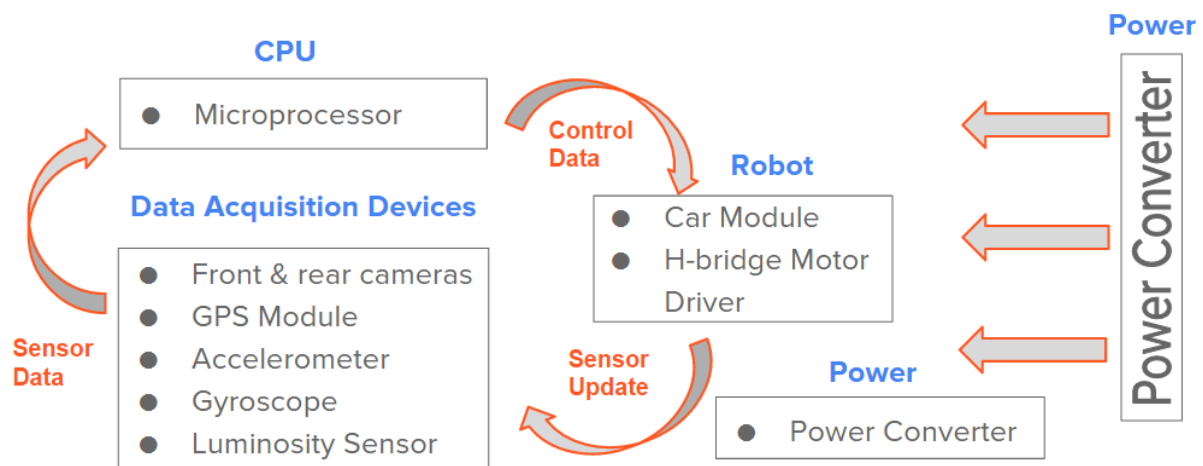


Figure 5 - Connection Block Diagram

From figure 5, the robot can be segregated into four different modules- CPU, Data Acquisition Devices, car module and the power module.

Fast Diagram

The final path that will be taken by the team and its due course can be represented in the form of the fast diagram. The critical paths for this project are shown in figure 6.

FAST Diagram

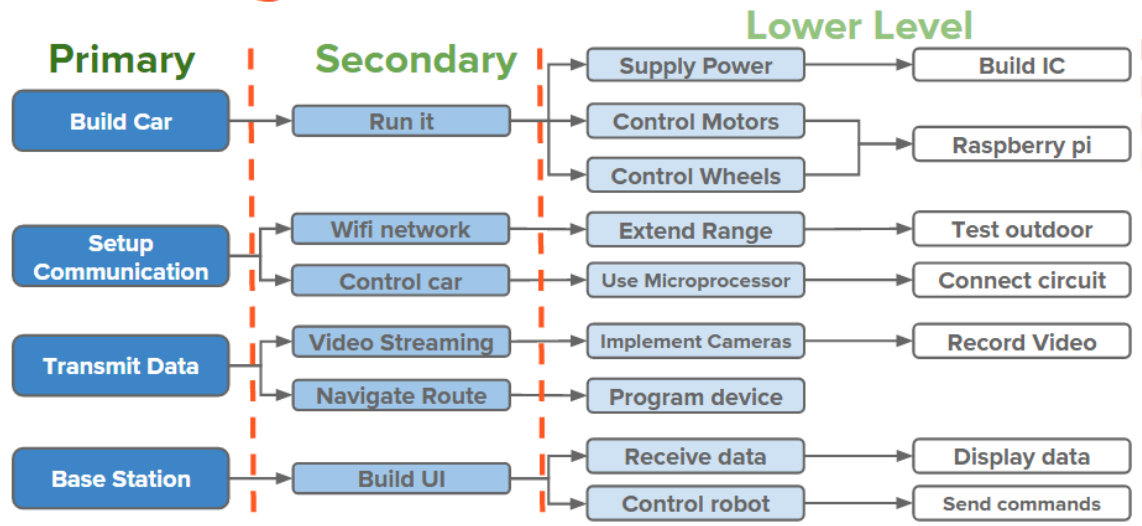


Figure 6 - Fast Diagram

COST

Considering all the option mention above, the budget spending can be explained based on table 3.

● 2 x Raspberry Pi Model 2 Kit (with Cams)	\$150
● Adafruit Ultimate GPS Breakout	\$40
● Maisto R/C Rock Crawler	\$40
● MPU9150 Gyroscope and Accelerometer	\$35
● Dual H-Bridge Motor Driver	\$35
● 2 x Li-Po Battery Pack	\$40
TOTAL	\$340

Table 3 - Cost for all the parts

The team will be left with \$160 that can be spent on upgrades of the parts and/or addition of other components.

Future use and consideration

Unmanned seeding device will be the next potential step that is to be used on future farms. It could be more accurate and efficiency than a truck driven by human. However, the cost will be a main factor to be considered. Since a human-drive seeding truck does not cost too much, besides the man power, unmanned seeding process is a viable option for the future. Over time, the field of autonomous systems will be much more sophisticated that it is today, and that might bring better options for the future generation of farmers.

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LAN and WAN figure web page

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