Design and Development of a Farmer Friendly All-Terrain Guided Vehicle

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Abstract. Farming is a labour intensive occupation and there is heavy shortage of agricultural labours due to rapid urbanization. In India agriculture contributes about 15% of the gross domestic product and there is need for mechanizing the agricultural activities to meet the raising demand for food and labour shortage. In this regard, a guided all-terrain vehicle will be designed and developed in this study to help the farm labour in his regular agricultural activities. The all-terrain vehicle has capability to traverse through rough terrains and it will be IoT(Internet of Things) enabled so that it can communicate with the various subsystems in the cloud and can be also monitored and controlled remotely. The vehicle will be guided and controlled by human through a proper interface. It will be designed with farming specific accessories hence it would reduce human efforts during his farming activities. Thus the proposed vehicle will act as farmer’s friend in assisting him to perform his tasks and thereby increasing his productivity.

1. Introduction
Modern farms are trying to produce more quantity with higher quality at lower expenses in a sustainable way which is also not labour intensive. Implementation of digital farming and site-specific precision management are a number of the possible responses to the present expectation, which depends not only on the sensor technology but the continual collection of field data that's only feasible through proper utilization of agricultural robots. Agricultural scientists and farmers, are also facing the challenge of manufacturing more food from less land under a sustainable method to meet the needs of the anticipated 9.8 billion populations in 2050. Integration of digital tools and control technologies have accelerated design developments of agricultural robotics, demonstrating significant potentials and benefits in modern farming. These evolutions range from digitizing plants and fields by collecting accurate and detailed temporal and spatial information in a timely manner, to accomplishing complicated nonlinear control tasks for robot navigation.

Agricultural field robots and manipulators became a crucial part in several aspects of digital farming and precision agriculture. These robots are now capable of performing various farming operations, including crop scouting, pest and weed control, harvesting, targeted spraying, pruning, milking, and sorting and these are often extremely challenging to be fully automated. An agricultural robot is subjected to an extremely dynamic environment, and yet expected to touch, sense or manipulate the crop and the surroundings in a precise manner which makes it...
necessary to have robust structure and control system while also increasing its efficiency. Although industrial robotic platform with precision accuracy and speed are available, their application in agriculture is restricted thanks to unstructured environments and unsure tasks which impose greater challenges.

In this regard a human guided all-terrain vehicle is designed and developed in this study to traverse through rough terrains of farming land. The proposed vehicle can be utilized by the farmers to help them in their regular activities like carrying agriculture or poultry farm tools, transporting the harvested crop or eggs from the farm fields to the plains, provision for a camera to regularly monitor the environment, load weighing option to measure the harvested crop and provision for attaching a setup to plough the agricultural land or rake the floor of poultry farms. The proposed vehicle will have an IoT capability so that it can be controlled and monitored remotely. Due to this capability the information can be shared among the sub systems in the network and field experts can provide their advice to the farmers. Thus the proposed vehicle helps in reducing the manual agricultural labour and thereby increases the productivity.

The motion control of the developed vehicle would be carried out through a mobile application in Android platform. In this regard a GUI (Graphical user interface) is developed which would be interfaced with the vehicle for continuous communication and monitoring a part of the present work explains in detail the remote control strategy using a mobile application [1]. Large-scale technology implementation into agriculture will help the farmer and reduce man power. The use of path following robots in agriculture is increasing day by day for different applications as per the requirements of the farmers. The use of robots in agriculture decreasing the burden and crop cultivation cost but they lack in efficiency in compared to manual labour in activities like seed planting as required by the farmer [2]. Our proposed vehicle provides a greater flexibility which helps the farmer to adjust its motion according to his requirements. Robots with computer and artificial intelligence capability that make decisions customized to each plant or area have been reported in literature [3]. Depending on the application, it may require more than one Sensing technology operating together for acceptable field performance.

An engine powered vehicle which move autonomously using the machine vision technology has been designed and fabricated with the help of mechanical, electrical and software systems [4]. A Hybrid controller helps to control the vehicle in more than one way by using either autonomous or manual control [5, 6] thereby helping the farmer in customized ploughing and seeding of the agriculture field. Bluetooth technology has been increasingly adopted to operate the and control the vehicle through mobile phones [7], which helps the farmer to interact with the machine at the time of seeding and ploughing. The autonomous agribots are available utilizing infrared technology to detect the obstacles and for providing a collision-free path [8] during any agricultural activities.

Environmental condition monitoring very important activity in agriculture. IoT technology leverages farmers the capability to monitor and control his farm anytime from anywhere. Wireless sensor networks are utilized for monitoring the farm conditions while the microcontrollers control and automate the farm process according to inputs from the sensors. IoT technology can reduce the cost and enhance the productivity of traditional farming [9, 10, 11]. The implementation of wireless communication or wireless control in agriculture equipment’s are done through technologies like Radio Frequency (RF) signals, GUI interfaced with WIFI or Bluetooth technology or communication using GSM module [12, 13].

Quacopters are finding more agricultural applications and they have a capability to quickly obtain information through multispectral images of higher resolution obtained through advanced cameras in accordance with the software found in the ground station allowing the decision algorithm to identify the optimal moments to spray the pesticides during the harvesting periods. It can be controlled by using wireless communication [14][15] through a 3G mobile network by utilizing a GUI in a personal computer or mobile.

The farming activities require mobile autonomous vehicles which could traverse through different terrains like muddy track, wet land, rocky and uneven fields with bumps and droops and plain
situations. The technological gap in the existing service robots implemented in agriculture lacks IoT capabilities and there is no flexibility and provisions for attaching multiple agricultural accessories for carrying out various farming activities. In this regard a problem statement has been defined to design and develop an all-terrain farmer friendly guided vehicle which can help the farmers in carrying out their regular agricultural activities. The proposed vehicle will have the following provisions and functionalities,

- Provision for fixing a camera to monitor the environment
- Provision to weigh the harvested crop or poultry goods
- Transportation of poultry items or harvested crop
- Provision to fix a ploughing tool or raking tool for poultry farm.
- Remote monitoring and control through a mobile application.
- Implementation of IoT for remote control and monitoring through a GUI.

2. System Structure
The wireless communication between the vehicle and operator or controller is done through a graphical user interface (GUI) provided in the mobile application. The operator controls the vehicle through the GUI for maintaining its movement within the range. Both the operator and vehicle system will be connected through mobile network like 4G and the operator sends the signal using a GUI in the mobile and controls the vehicle in the field for monitoring purpose. We can also attach different functionality kits for any specific agriculture applications and control the vehicle movement accordingly by sending the signal to the controller through ESP32 which receives the signal from the operator as mentioned in the Figure 1.

Making a ESP – Mesh Network in which the main ESP32 acts as the Wi-Fi Access point and also the receiver and sends the signal to the respective ESP module connected to it in the network as per the user signal. This network is connected to cloud and hence provide the IoT capability which would help to communicate any amount of data collected from the vehicle to any subsystems or people in the cloud. An ESP-Cam is also connected in the network which will be mounted on the vehicle for surveillance of the environment.
Figure 1: Signal Flow between the transducers, cloud and GUI to control and monitor the vehicle.

3. Vehicle Overview

3.1 Vehicle Modeling & Design Considerations

The proposed vehicle is to help the farmer with various agricultural functionalities. It is an all-terrain vehicle with the track-belt type of wheels which helps to move the vehicle in different types of terrain’s like muddy track, wet land, rocky fields, uneven fields with bumps and droops and on plain surfaces. Provisions for various functionalities are given on the vehicle chassis and body. The frame of the vehicle is made flexible such that it is suitable to fix kits for which the provisions were given depending on the application. This would help the farmer to retrofit the vehicle with necessary farming accessory to increase the productivity and for decreasing the manual or labor involvement in farming. It is electrically driven with motors which are powered by a battery. By implementing IoT in the vehicle functionality the operator or the landlord can monitor the crop quantity using the cloud. The specifications of the vehicle are as follows:

- Vehicle is Track belt enabled.
- Wheel base of the vehicle is 30inches as per the designed model.
- Track width of the vehicle is 28inches as per the designed model.
- Ground clearance of the vehicle is 4inches as per the designed model.
- Overall dimensions of the vehicle are 50x35x15inches (Length x Width x Height).

The vehicle is designed in a flexible way such that, assembly of the farming kit or Agriculture tool kit can be achieved by temporary assembly process i.e. by using fasteners like nuts, bolts and locking mechanisms. The computer aided design model of the proposed vehicle is shown in figure 1. Depending on the application farmers can assemble the required kit on the chassis and provisions are provided for the same. The ploughing kit which can be used for ploughing the farm field can be assembled to the front part of the chassis and will be locked to restrict the vertical movement of the kit due to the obstacles in the field at the time of ploughing. In a similar manner the harvesting equipment can also be fitted to the vehicle to harvest the paddy crop. The vehicle can also be used for the transportation purpose by attaching the storage container or box on the top of the frame or vehicle as shown in figure 2. This can be used to transport the harvested crop from the field which may be muddy terrain to the required place. The vehicle is fitted with a load sensor which would also help to weigh the crop loaded in the container or the carrier box can be measured for monitoring.
3.2 Vehicle Components

3.2.1 Drive Terrain. Track belt or the RC-belt is used for this vehicle instead of wheels as observed in the existing models which are used for both on and off-road applications. The track belt helps to provide the flexible movement of the vehicle in all type of terrains. The track belt rotates with the help of the wheels or pulleys. These pulleys are driven with the help of Motors (Dc-Motors were used for the prototype) which are mounted on the base of the chassis individually each for their respective side of the vehicle which can be called as semi-independent transmission. These motors which drive the vehicle are controlled by using a Controller (driver). The vehicle/motor speed and the required torque for the vehicle in the required direction is controlled by communicating with the controller. Individual motors are mounted to drive the vehicle which is powered by a battery as per the requirement. The maximum speed of the vehicle is 20KMPH. A L298N motor driver is used for controlling the dc motors which are used for the prototype to drive it. The L298N Motor Driver Module is a high power motor driver module for driving DC and Stepper Motors and its pin configuration is shown in Table 1. This module consists of an L298 motor driver IC and a 78M05 5V regulator. L298N Module can control up to 4 DC motors, or 2 DC motors with directional and speed control. In this work 2 motors are used each on their respective sides. The continuous contact of the belt to the ground the bumps and drops prevents the vehicle from getting stuck in the field.

Table 1: Pin configuration of the motor Driver used in the proposed vehicle prototype.

| Pin Name           | Description                                      |
|--------------------|--------------------------------------------------|
| IN1 & IN2          | Motor A input pins. Used to Control the spinning direction of Motor A |
| IN3 & IN4          | Motor B input pins. Used to Control the spinning direction of Motor B |
| ENA                | Enables PWM signal for Motor A                  |
| ENB                | Enables PWM signal for Motor B                  |
| OUT1 & OUT2        | Output pins of Motor A                          |
| OUT3 & OUT4        | Output pins of Motor B                          |
| 12V                | 12V input from DC Source                        |
5V Supplies power for the Switching logic circuitry inside L298 IC
GND Ground Pin

3.2.2 Wireless Communication and MCU. The ESP32-CAM is a very small camera module with the ESP32-S chip. Besides the OV2640 camera, and several GPIOs to connect peripherals, it also features a microSD card slot that can be useful to store images taken with the camera or to store files to serve to clients. It is Wi-Fi enabled. It can also act as an MCU to control the motors by sending the signal to the drivers. It has GP pins which are connected to the driver to control the motors. It operates with 5v as power supply. The ESP board not only has the feature of Wi-Fi but also has the Bluetooth capability. It is the preferable transducer for wireless communication. By using the unique IP address of ESP a GUI can be used to log in to operate the motors and can control the vehicle moment. With this ESP camera we can monitor the environment of the vehicle within its range. With the help of wireless communication the environmental conditions can be monitored by using the mobile application through the camera fitted in the vehicle. The vehicle also helps to monitor the places where it is unsafe for a human to be physically present. By using this vehicle the farmers can monitor the field regularly without visiting the field and for example they would be able to inspect any leakage pipe lines supplying water to the crop.

3.2.3 Load Cell with ADC. A LOAD CELL is a force transducer. It converts a force such as tension, compression, pressure or torque into an electrical signal that can be measured and standardized. As the force applied to the load cell increases, the electrical signal changes proportionally. The most common types of load cell used are strain gauges, pneumatic and hydraulic. In this work we used strain gauge type of load cell. Strain gauge load cells are the type most frequently found in industrial settings. Structurally, a load cell features a metal body to which strain gauges are secured. When force is exerted on the load cell, the spring element is slightly deformed, and unless overloaded, always returns to its original shape. As the spring element deforms, the strain gauges also change form. The resulting alteration to the resistance in the strain gauges can be measured as voltage. The change in voltage is proportional to the quantity of force applied to the cell, thus the quantity of force are often calculated from the load cell’s output.

HX711 module is a Load Cell Amplifier breakout board for the HX711 IC that allows you to easily read load cells to measure weight. This module uses 24 high precision A/D converter chip HX711. HX711 is an IC that allows you to easily integrate load cell. The HX711 uses a two wire interface (Clock and Data) for communication. Compared with other chips, HX711 has added advantages such as high integration, fast response, immunity, and other features improving the total performance and reliability. Weighing of the harvested crop or the objects placed inside the storage area of the vehicle is the one of the provision given in the vehicle. The crop or the things placed will be measured by the load cell which is placed under the storage area. Its capacity is upto 40kgs. The data acquired from the sensor is in analog form and HX711 a modulator converts the Analog reading from the sensor into the digital output. The functionality of measuring the harvested crop helps the land owner to check quantity of the crop which was harvested from the field.

3.2.4 Wi-Fi and IoT accessibility. ESP32 is a low-cost, low-power system on a chip (SOC) series with Wi-Fi & dual-mode Bluetooth capabilities. There is a dual-core or single-core Tensilica Xtensa LX6 microprocessor with a clock rate of up to 240 MHz ESP32 is highly integrated with built-in antenna switches, RF balun power amplifier, low-noise receive amplifier, filters and power management modules. Engineered for mobile devices, wearable electronics and IoT applications, ESP32 achieves ultra-low power consumption through power saving features including fine resolution clock gating, multiple power modes and dynamic power scaling. This Wi-Fi module acts as Access point and also
as receiver point. In this work the ESP32 module acts as Wi-Fi Access Point (WAP). It acts as a Wi-Fi network station to which the farmer can be connected or it provides the network to ESP8266 to transfer the data to the cloud which is acquired by the sensor. IoT plays an important role in this work. Even by connecting to the network provided by the ESP module the operator or the farmer who is going to control the vehicle can connect to this same network which solves the issue of inaccessibility of the vehicle in the remote areas or areas where network is not stable or no network areas. The data stored in the cloud can be both publicly or privately viewed which depends on the priority of the owner or the farmer. By uploading the data into the cloud the owner or the farmer can monitor the quantity, status etc. of the crop regularly even by staying far from the field.

The Internet of Things (IoT) is a reference to a collection of devices or objects that are linked together using an Internet connection. The data acquired by HX711 is stored in the cloud thingSpeak at regular intervals of the time. ThingSpeak is an IoT analytics platform service that allows you to aggregate, visualize and analyze live data streams in the cloud. ThingSpeak provides instant visualizations of data posted by your devices to ThingSpeak. It is often used for prototyping and proof of concept IoT systems that require analytics. By logging into the provided IP address and channel the user or owner can easily monitor the crop quantity using the ThingSpeak with IoT. ThingSpeak allows you to aggregate, visualize and analyze live data streams in the cloud. Some of the key capabilities of ThingSpeak include the ability to:

- It is easy to configure devices to send data to ThingSpeak using popular IoT protocols.
- Visualize your sensor data in real-time.
- Run your IoT analytics automatically based on schedules or events.
- Prototype and build IoT systems without setting up servers or developing web software.
- Automatically act on your data and communicate using third-party services like Twitter.

### 3.2.5 Networking

Internet of Things (IoT) has seen exponential growth over the past couple of years. As the number of IoT devices grows; the amount of data grows, along with that, grows the need for superior network instruments; which can support this load. However, if we consider a common host (like a generic router), it can connect to a limited number of nodes, less than 32 to be exact. And with an increasing number of IoT devices that could be in our home or industry, this is not sufficient. Currently, there are two solutions to this problem: The first one is to use a mesh router that can handle a lot more connections compared to a generic one, or we can use a network protocol known as mesh network. According to the official documentation of ESP-MESH, it is a self-organizing and self-healing network meaning the network can be built and maintained autonomously. A mesh network is a group of connected devices on a network that is acting as a single network. **ESP-Mesh** is quite different from a traditional mesh setup. In an ESP-Mesh, the node or a single device can connect to its neighbour simultaneously. One single node can connect to multiple nodes and they can relay data from one node to another. This process is not only efficient but it’s also redundant. If one of any nodes fails; the data from other nodes can reach its destination without a problem. This also opens possibilities of achieving interconnection without needing a central node, which significantly extends the coverage area of the mesh-network. With these features, this network is less prone to conjunction because the total number of nodes in the network is not limited by a single central node. In a general networking the Wi-Fi router will act as the root node which will provide the connectivity to the different stations which will be controlling the respective sensors or functionalities. In this general networking the router acts as the access point by getting the data from the server and the stations will be connected to the router. When the operator or the controller is connected to the same network each station can be controlled individually without depending on other completely. Each station will again connect to a transducer which is being used for a specific application. Hence by connecting to the same network we can control the station but this LAN or server cannot be moved to the area of application and the range of the network will be less which does not help the vehicle or the system to work without the network to control the vehicle, monitor the environment and transfer the data using IOT to the cloud. This
router to which the stations are connected to receive the internet which they work with respect to the
signal or command they receive from the source or operator should be connected to the server which
creates the data network, where server will act as Wi-Fi access point and the router which receives the
data from the server and sends to the stations will act as the serving point between the access point and
the stations, the operator or the controller must be connected to the same server point to send the
signal to the stations which are connected to the same sever point for the respective applications. The
general network architecture is represented in the Figure 3.

![Figure 3](image)

**Figure 3:** The general network which is being used at all the areas where the stations are directly run
using the network provided by the router.

In this work to make the IOT connectivity to be connected to the network a new network called ESP-
Mesh network has been created. As mentioned in the previous statements that ESP has a capability to
provide its own network for internet. It can act as a server as well as access point for the network or
the system. In this work it acts as the access point which is directly connected to the stations. These
stations are ESP board enabled, these ESP stations are connected wirelessly to the neighbouring ESP
access point or ESP Wi-Fi access point, by this all the ESP stations are connected to the same Wi-Fi
access point and can be controlled easily when the operator or the controller is connected to the same
WAP. This network which is connected to the system is flexible with wireless communication
between them and is not dependent or any external server. It has a wide range of connectivity with the
system. The network used for the system is as following **Figure 4.**

![Figure 4](image)
Figure 4: The network which is used for this system in which A is the WAP where the stations are directly run using the network provided by the WAP.

4. Hardware Setup
The prototype has been modelled and designed with the mentioned components. 100RPM DC-motors are used to run the vehicle wheels connected to the track belt which is in contact to the ground as shown in the figure 5. L298N motor driver has been used as mentioned to run the motors and for controlling the speed, direction of the motors which directly controls the vehicle moment in the prototype. 40 kg capacity load cell connected to the ADC HX711 is fitted for the weighing functionality as shown in figure 6.

Figure 5: Proposed vehicle prototype

Figure 6: Load cell sensor with its associated circuit

5. Result
The proposed vehicle prototype has been made with following functionalities:

➢ The prototype of the vehicle model as shown in Figure 7 with track belt is made and tested by driving on the wet, muddy, grass terrain without any functionality kit fixed to it and was controlled by wireless communication through GUI as shown in Figure 8.

➢ The scaled down prototype has following dimensions:
  ▪ Vehicle is Track belt enabled with center to center distance of 6inches.
  ▪ Wheel base of the vehicle is 6inches.
  ▪ Track width of the vehicle is 6 inches.
  ▪ Ground clearance of the vehicle is 2inches.
  ▪ Overall dimensions of the vehicle prototype are 12x10x3inches (length x width x height).

➢ Monitoring of the environment using the camera module through IP Address is fixed to the vehicle body as shown in Figure 9.

➢ Wireless Controlling of the vehicle using Bluetooth and WIFI.

➢ Weighing the crop or the load placed on the vehicle using weighing functionality kit fixed on the vehicle at its respective place as shown in Figure 10.

➢ Enabling self WIFI network for the transferring of data.

➢ Enabling the IoT and interfacing with cloud to store the data and monitor regularly as shown in Figure 11.

➢ Flexibility to attach various functionality kits for which provision has been given in the proposed design of the vehicle.
Figure 7: Manoeuvre of the prototype vehicle

Figure 8: GUI to Control the speed and direction of the Vehicle using wireless Bluetooth communication.

Figure 9: Vehicle with Camera Module for monitoring the environment using WIFI.

Figure 10: Vehicle prototype with weighing functionality kit to weigh the harvested crop.
6. Conclusion
Implementations of technological devices in agriculture are of greater demand in these modern times. There are many issues being faced by farmers regularly in the field. To overcome these issues faced by the farmers and also to increase the productivity an all-terrain vehicle is proposed in this work. By developing this kind of vehicle the farmer is benefited because of the flexibility of the vehicle since single machinery can be utilized for performing various agricultural related activities with less investment and man power. As the agricultural labours are of greater demand the development of these types of vehicles or robots would help the farmers in their farming activities. By implementing IoT in these vehicles it would enable the landlords to monitor crop and farming activities remotely without the need for their physical presence. The proposed vehicle with its provisions for attaching various farm specific accessories would be of great help to the farming community.
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