Proposed Design for Automated Agro-Quadcopter "Agro-ropter"

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Abstract

Since 1930s automation has always been a dream in every sector and in every field. The biggest benefit of automation is that - it saves labour, energy, materials and also improves efficiency with better accuracy and precision. The purpose of this research paper is to introduce the design of a low cost "agro-quadcopter" module - that will be able to send feedback and receive command, reacting spontaneously to administer various control systems while operating in real-time. It will be able to perform the analysis on daily weather, record daily temperature, find infected crops, keep pests away, aid in artificial pollination, spraying and seeding; hence reducing farmer's workload and increasing the productivity of a farmer. The set up depends upon an interface between android, Arduino and MATLAB. The module developed can run through a computer. The quad-copter is mounted with an android smart-phone having sensors along with an Arduino. The module receives real-time data from the quad-copter and analyses, then send feedback or command to the quad-copter in real time. This module can further be developed for usage on an aircraft, allowing us to sway an aircraft from ground – initiating a new era of completely automated civil flight.

Introduction

When we look into the matter that what causes loss in farming some of the major problems that we encounter is: wrong prediction of environmental condition, use of correct labour, correct investment and identifying the infected crops. Keeping that in mind we are building a quadcopter naming it "Agro-ropter" which will assist in mitigating all the problems with more precession and accuracy being small in size and lower in cost. Our newly designed system will combine the strength of ground and aerial robots for sensing, analyzing and publishing command required to perform the necessary operation. In short, it will be capable of performing the analysis on daily weather, temperature, spotting infected crops, chasing pest away, spraying insecticides, seeding and also help as an aid for artificial pollination. As a result reducing farmer's workload and also increasing the productivity and efficiency of an individual farmer. The quad-copter is mounted with an android smart-phone having sensors and Arduino. The Pc or laptop on ground receives real-time data from the quad-copter and analyzes it, makes decision and then send feedback or command to the quad-copter in real time.

Literature Review

Men has always tried making life easy - automation has opened a new window to increasing accuracy, efficiency and reducing cost of production by dramatically lessening the human stress and effort. Agricultural sector has also encountered a vast amount of automation in the last decade. The introduction of UAV has changed the total scenario of farming, however there remained certain limitation which are being developed in the course of continual research. Some of them are the adoption of precision agriculture and reduced-input farming technics which entails higher level of input data, with enhanced spatial and spectral resolution, and increased frequency of information delivery. It has been concluded that the earlier developed system addresses the need and challenge identified for the incorporation of UAV sensing technology into reduced-input precision agriculture application.[21]

Agro Quadcopter

Farmers can grow better crops using aerial pictures, sensors and robotics to acquire data for precision. This method was once used as military aviation technology. Major problems that contribute to low agricultural yield are damage caused by birds and lack of proper farm monitoring techniques. Though the exact cost of loss associated with birds is undocumented, generations of farmers have been performing a number of traditional and conventional techniques to prevent birds from damaging the agricultural area. This not only requires a massive hours and manpower but also farmers' unaccountable loss of opportunities. Moreover, it is shown that the agricultural yield can be considerably increased by adopting Information technology to the agricultural area. The core contributions of our work can be summarized as follows:

• A self-sustaining agricultural monitoring platform has been designed that comprises of a quadcopter with wireless power control capability by MATLAB – Arduino interface.

• The proposal consists of a "Turtle bot" routing approaches to facilitate the self-sustaining agricultural monitoring platform and demonstrate improvement in crucial metrics over existing routing approach.

The following sectors show a phenomenal development:

- Increase Yield.
- Save Time
- Return on Investment
- Ease of use
- Integrated GIS mapping
- Crop Health Imaging
- Failsafe - The Drone Flies Home

Proposed Concept

It is shown that the agricultural yield can be considerably increased by adopting Information technology to the agricultural area. Gran Monte vineyard is one of the examples that obtains a higher crop yield after implementing environmental monitoring stations throughout the agricultural area.

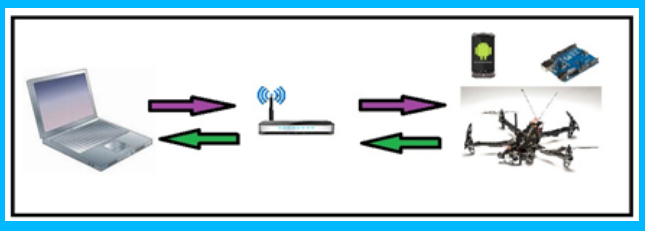

Figure 8. Schematic diagram of system linkage

We design a self-sustaining agricultural monitoring platform, comprises of Unmanned Aerial Vehicle (UAV) with wireless power control capability by MATLAB – Arduino interface.

It can also provide up-to-date environmental data monitoring, it enables farmers a prompt response to mitigate fluctuation of important variables, i.e., humidity, temperature, that affect the crop yield.

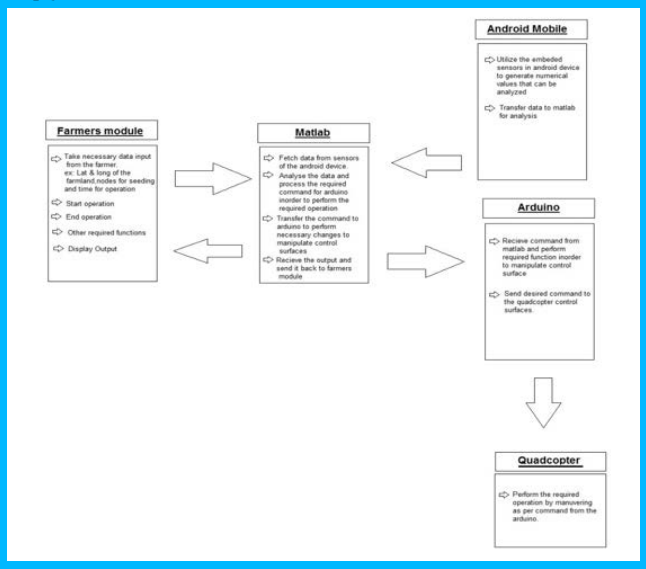

Figure 2. Flow chart of the function performed by different systems

MATLAB Requirement

The purpose of using matlab is that it is such a coding platform in which we can communicate simultaneously with android and Arduino system simultaneously without any interruption. In that case we just have to add "add-ons" to our matlab system. In order to do this no extra charge or coding is required.

The function of matlab is basically to acquire data from the android mobile, provided by the sensors inbuilt. Those data will be analyzed by matlab and the required command for maintaining correct function will be issued. This command will then be sent to the Arduino for making necessary changes in the control surface.

Arduino Requirement

The purpose of Arduino is to receive signal from matlab and to the corresponding action by making corresponding changes in the control surfaces.

Android Phone Requirement

The sensors that can be accessed by an android mobile are GPS, Wi-Fi, accelerometer, proximity, and light Gyroscope, Magnetic, Rotation Vector, linear Acceleration and Orientation. These sensors are usually built-in in any smart android mobile phone. The compactness of the sensors in one device and less weight makes it a better option for replacing bulk individual sensors.

Wi-fi Requirment

The purpose of setting Wi-Fi is to make the system connected over internet. This is done to make a farmer capable of operating from any distance. As it is connected over internet there will be good track of any update in the system and anything wrong can be easily identified with proper invigilation.

Farmers Operating Module

Farmers operating module is to help the farmer to communicate with the quadcopter. It will take and provide the output in real time. The actions made will also be visible to the farmer in the section: "Actions Taken". This module is to reduce the complexity of the coding and make it user friendly.

Figure 3. Farmers operating module

Operational Compatibility of "AGRO-ROPTER"

Drone technology will give the agriculture industry a high-technology makeover, with planning and strategy based on real-time data gathering and processing. PwC estimates the market for drone-powered solutions in agriculture at $32.4 billion. Following are ways in which aerial and ground-based drones "Agro-ropter" will be used throughout the crop cycle:

i. **Soil and field analysis:** Agro-ropter can be programmed to produce precise 3-D maps from early soil analysis which will be useful in planning seed planting patterns. Even after planting a drone-driven soil analysis will help to provide data for irrigation benefits and also make the farmer aware of nitrogen-level management.

ii. **Planting:** The new planting system will increase the precission of planting and decrease planting costs to almost zero. This is because now a single farmer can plant land after land by just recharging and making the Agro-ropter do the work. The Agro-ropter can also be programmed to shoot pods with seeds or directly inject seeds and plant nutrients into the soil; providing optimum condition for the crops.

iii. **Crop spraying:** Since the beginning of the history of farming the process of keeping pests away from crops had been a too tough job. However with Agro-ropter detecting and spraying on the infected crops has become too accurate and less time consuming. The result: increased efficiency with a reduction of in the amount of chemicals penetrating into groundwater. In fact, experts estimate that aerial spraying can be completed up to five times faster with drones than with traditional machinery.

iv. **Crop monitoring:** The process of crop monitoring becomes too hectic for a farmer. The time consumed for doing so can be utilized for some other jobs and increase the productivity of a farmer. With Agro-ropter a farmer can sit in his room doing some other job and ask the UAV to do the monitoring for him at any time regardless of the situation or the time of the day.

These above mentioned ways are not just it's limit. By making it an open end programming system anyone with the knowledge of Matlab, Arduino and Android can Agro-ropter to any operation in the field of agriculture. All that is needed is a bit of modification.

Issuing Control Command of Turtle Bot

The Hardware Support Package is a built in robotics Add-ons command known in Matlab as "TurtleBot-Based Robots". The function instructs about how to set up the object and how to

initiate the keyboard control. It gives the instruction on how to use keyboard control when the function is executed. In order to change the control of the parameters of the function we just have to edit the ExampleHelperTurtleBotKeyboardControl function or the ExampleHelperTurtleBotKeyInput class. The example describes about how to work with a TurtleBot using its native ROS interface. The Robotics System Toolbox™ Support Package for TurtleBot® [2] provides a more streamlined interface to TurtleBot. The capability of it are:

i. Acquire sensor data
ii. Send control commands - without explicitly calling ROS commands
iii. Communicate transparently with a simulated robot

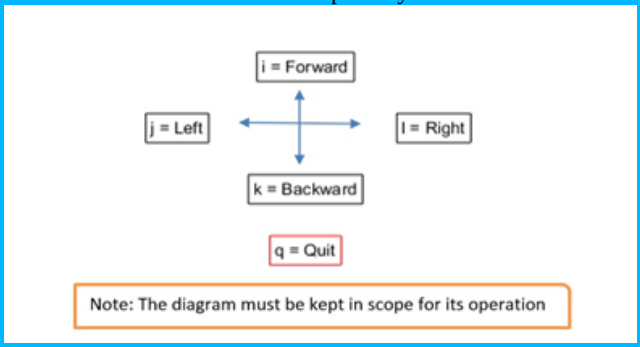

Figure 4. Setting of keyboard control

Avoiding Obstacle

It is also a built in example in Matlab that demonstrates an implementation of the VFH+ obstacle avoidance algorithm with the TurtleBot®. The VFH+ algorithm is a local and simple method built for a robot in order to help it navigate through a space without hitting obstacles.[1][2] In case of our quadcopter this function is used in order to avoid bird hits or any other foreign object and thus make it more sustainable and smooth going.

However, the performance of the VFH+ algorithm is subject to the limitations of the Kinect sensor. These are namely its minimum range and its limited field-of-view.

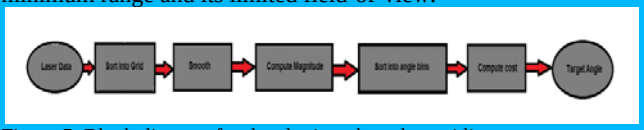

Figure 5. Block diagram for developing obstacle avoiding system

Acquisition and data analysis from android sensors

As we are replacing all the bulky sensors previously used with the sensors now found in our android phone so now acquiring the data becomes an issue. It must also be added that the data analysis is also needed. So to receive data from an Android device mounted in the quadcopter to MATLAB® in our laptop or PC we will need the MATLAB Mobile™ app (version 2.0) which is available in Google® Play™.[2]

At first we have turn on the connector in MATLAB and further allow the connector to allow connection between our desktop MATLAB session and MATLAB Mobile on our Android device. Both the devices must either by being on the same network, using a VPN, or through a similar configuration. Then using the command functions as defined in Matlab examples we can acquire the data from the mobile in less than 1ms (though the strength of connecting signal does matters).

After the data is acquired, they are analyzed and graphs are plotted. Any discrepancy observed will be detected and the consecutive command to nullify the discrepancy will be issued. This all is done autonomously with the help of nested and for loops and conditions pre fed during coding.

Acquire GPS data from android device and plot location on map with mesh nodes

The data acquired will also contain the longitude and latitude information of the quadcopter. A farmer has to first identify the latitude and longitude of the corners of the field. Depending on the points found straight lines will be drawn. This will identify the area of operation. For better output Matlab takes access to Google map and shows the region. On it meshing is done as per farmer's requirement and at the nodes seeding will be done by lowering the quadcopter 'Seed Injector' into the ground at that point.

Figure 6. Identifying operating farmland and performing mesh

Counting Steps

This example in Matlab is used for making it more user friendly. This process shows how to collect acceleration data from an Android device and use it to count the number of steps taken. This is needed to match the work guidance from the farmer and also further helps the farmer to operate easily.

Track and follow an aerial object

As mentioned earlier birds are the greatest threats to the crops so we allow the quadcopter to act as a flying scarecrow. In order to that we use the concept of 'Track and Follow an Object' in Matlab. In this example, we explore the autonomous behavior that incorporates the Kinect® camera. This algorithm involves the TurtleBot® looking for any ariel object and then staying at a fixed distance from it; however the robot will come back as it crosses few steps from the operating area.

Detection of infected crops by image processing and detecting unwanted vegetation

It has already been developed in various studies on how to detect infected crops by image processing.[3] There are works that presents initial approach to remote sensing and precision agriculture for monitoring crop fields in Colombia.[4,19-20] Using an autonomous quadcopter UAV (unmanned aerial vehicle) equipped with a multispectral camera onboard. The aim is to provide farmers with an integrated tool for measuring and assessing live green vegetation by assembling a terrain image mosaic based on capturing multispectral images of the terrain.[5-12] There are research paper presents how to integrate an UAV- based solution for capturing geo-tagged multispectral imagery and the methods to compute multispectral image mosaics. [3, 13-18]

Design of the quadcopter

The picture bellow shows a generic design of the agro ropter. In this case the portion at the center which seems like a box will hold the android mobile and the Arduino. The hole at the bottom will be the space for placing a camera such that the crops become visible. The pointed portion is the 'seed injector' the tube will contain the seeds, as it passes over the nodes it will release a seed into the ground and again move to the next node. The injector portion will be removable such that it may be set with various accessories based on requirement.

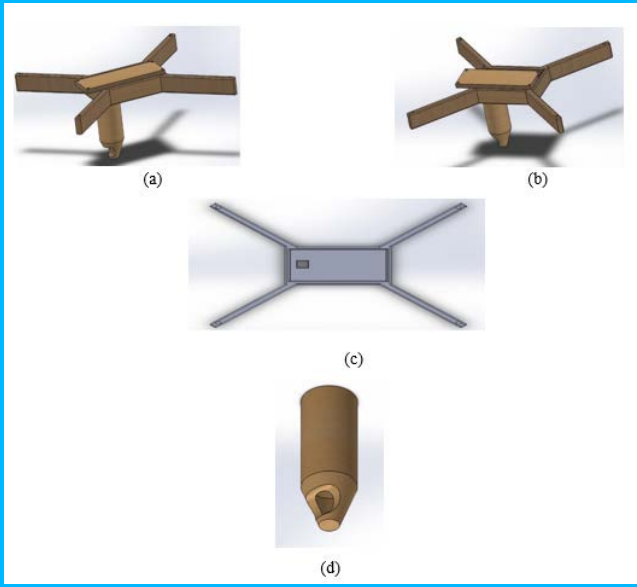

Figure 7. Design of the frame of Agro-ropter (a)&(b) total frame of the Agro-ropter (c) top view of the base frame (d) seed injector

Generic Algorithm of Agro-ropter in Matlab

Survey:

Aquire data from the android sensors and camera

- Select the datas required for operation
- Plan flight using ground station software
    - Highlight field/region on base map
    - Define landing and take-off area
    - Set required image resolution & photo overlap
- Optional: define elevation
    - Capture Ground Control Points (GCPs)
- Fly
    - Maintain orientation
    - Fully automated flight & landing
    - Monitor flight / live update of flight plan possible
- Process (field/office)
    - Perform initial processing
    - Make graphical presentations

2. Analysis & inquiry:

Options:

- Local analysis (data not shared)
- Use supplied post-flight conditions
- See compatibility
- Collaborative analysis
- Detect structural, chlorophyll & water stresses
- Elevation data/topography
- Detect patterns
- Inquire machine issues
- Detect weeds, plant stand, erosion etc.
- Plant counting & statistics
- Soil moisture & temperature
- Evaluate drainage systems, disease & plant mortality
- Inquire
    - Index variations
    - Patterns in canopy height, vigour, colour, density
    - Developing erosion channels
    - Damage observations
    - Plant statistical variations & comparisons to other data (e.g. planter data)
    - Patterns in dry soil vs. wet soil
    - Determine relative location of drainage tile & whether functioning/broken
    - Identify pests, disease, weeds
    - Collect soil samples for soil, fertility, pH & pest issues
    - Dig plants, inspect root structure for signs of compaction, depth, disease, pests
    - Count plants & determine population / spacing issues
    - Identify deficiency in fertility, water or other
    - Verify survey data
    - Drainage tile, terrace & waterway condition/functionality

5. Compile & plan:

- Compile
    - Match observations & assessments with survey data
- Plan
    - Depending on defined conditions

6. Execute:

- Carry out plan – avert risk, economical
- Don't carry out plan – no risk, not economical

Discussion

The use of UAV for agricultural purposes is recently proposed by Kasetsart university researchers. The research project is a collaboration between the faculty of engineering, Kasetsart University and the Yamaha motors (Thailand) and aims to effectively plant, deliver fertilizer, and spray pesticide to the cultivation area. The prototype is expected to weight 70 kilograms and able to carry the payload of 29 kilograms. The source of power is fossil fuel with the consumption of 8 liters per 2 hours flight. However, the project has several challenges and issues to be addressed. First, the project relies on a single objective UAV that is designed to only deliver payload. It does not employ agricultural monitoring or responsive system that reacts to stimuli. Second, the UAV needs to be manually filled once its fuel is exhausted. This incurs not only budget allocation for fuel cost but also time consumed in maintenance of internal combustion engine. Third, environmental impact is a major concern since the UAV employs engine powered by fossil fuel. Not only is noise pollution expected from an internal combustion engine but also the air pollution from its exhaust.

Conclusion

The Agro-ropter is a design with open end to its function ability. The design gives full freedom to its operator to function as per requirement of the operator i.e. as programmed. However the precision and sustainability of the robot will develop with the development of its coding. The cost of developing such a system will be at the cost of USD 479 (Laptop at USD 200, Smartphone at USD 115, Arduino at USD 14 and Quadcopter at USD 150); which is 70 times less than the loss that single farmer incurs during the production process. However research work is being carried out for the development of system to be more accurate and function able.

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