Swarm Robotics: A Resilient Infrastructure for Sustainable Agricultural Growth.

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ABSTRACT

Farming had gone beyond the use of hoes and cutlasses to achieve sustainability in agriculture. Technology has brought about Precision Agriculture in which technological tools and infrastructures are used to plant and monitor crop yields for optimum growth. However, when the farmland becomes very large the amount of technology that needs to be deployed will increase for proper monitoring. In the light of this, this paper tends to x-ray swarm robotics in agriculture as a resilient technology for sustainable growth in very large farming system. Swarm robotics is the use of autonomous robots composed of many individuals that co-ordinate using decentralized control to perform a certain task or work towards a common goal. At the end, this paper tends to propose a swarm robotics architecture that can be used to build a resilient infrastructure that can be deployed by farmers of large farmland to monitor growth of crops for optimum yield.

Keywords: Precision Agriculture, Swarm Robotics, Resilient Technology, Resilient Infrastructure.

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1. INTRODUCTION

Agriculture plays a major role in the economy of a country. For this sector to boom and add significantly to the economy there should be frequent monitoring of the farm environment and the plants itself for optimum output and less wastage. To achieve this using human power and knowledge will be difficult, costly and filled with error. With the advancements in every field of our daily life, people are advancing towards new trends in the Agricultural technology (Anil H et al, 2015). One of the emerging trends in agricultural technology is the usage of a robot in farming. According to the World Robotic Report 2016 of the International Federation of Robotics as identified by F. A. Auat Cheein and R. Carelli (2013), agriculture represents a very challenging and increasingly important domain, and constitutes the second highest impact market (after defense) for mobile service robot applications. A robot is a machine that can be programmed and reprogrammed to do certain tasks and usually consists of a manipulator such as a claw, hand, or tool attached to a mobile body or a stationary platform (Sajjad et al, 2013). There has been an increase in the use of robots for farming, but its use in farming has proven to be very costly due to its complex parts, not very effective in navigating the farmland due to the rough terrain and a breakdown of the robot will result in the stoppage of farm work until when it is repaired. The ability to use cooperative miniature simple machine (swarm robots) has been of interest in many applications ranging from material transportation to farming operations.

These set of small machines achieve small tasks, but are able to work together in a coordinated and decentralized manner to complete larger tasks (Audrey Guillet et al, 2014). By collecting and analyzing data from a particular farm area, swarm robot can make decision based on information from just that area, which might not be suitable for other areas of the farm. Agricultural processes like weeding, field watering, fertilization needs frequent updates in data. Sensors and continuous data acquiring plays an important role in preserving environment by reducing pesticide usage and maximizing quality (Agris Pentjuss et al, 2011). Swarm robotics is a field inspired by swarm intelligence and among other things, the emergent behavior observed in social insects such as ants, bees, wasps, and termites (Madhav Patil et al, 2013). In swarm robotics, a group of mainly independent homogenous robots work together through a decentralized control mechanism to accomplish a given task.

2. LITERATURE REVIEW

Garzn et al (2013) used a simple heterogeneous architecture in their design. A single UAV was used to navigate a UGV around an area. The UAV maps and detect obstacles which it communicates wirelessly to the UGV to navigate it perfectly around the area. Tanner et. al. (2004) used a group of UAV and UGV in their proposal. These two operate in a decentralized manner and the UGV navigate an area through data given in real time by UAVs.

2.1 Applications in farming

Swarm robots are used in mapping and detection of weeds in farming. (Dario Albani et al, 2017) designed a swarm UAV based on the SAGA (Swarm Robotics for Agricultural Applications) project Concept which is used in sugar beets field to detect the presence of volunteer potatoes (weeds) and assign recourses (land robots) to the infected area to clear the weed. An existing swarm of autonomous micro planters "Prospero" was identified by Anil H et al (2015).These micro planters determine where and how to plant each seed; apply any necessary fertilizers, herbicides and insecticides to increase the productivity of the field. An agent communicates with the rest of the swarm to optimize the swarm's planting efficiency, letting nearby robots know if it needs help planting in that area. They also went ahead to design a swarm of robot that can scout, plough, and sow seeds, apply fertilizer and insecticides and water the entire cropping area.

2.3 Advantages of swarm robotics in farming

Plants treated can be treated on a single basis (targeted spraying) with robots reducing the cost of wasting chemicals (herbicide) to as little as 5%-10% compared to blanket spraying (Redmond Ramin, 2018).These mobile agricultural robot swarms are miniaturized with a stream-lined body that have minimum soil compaction and energy consumption and aim at optimizing plant specific precision agriculture (Redmond Ramin et al, 2018).It drastically reduces the manpower thereby eliminating human error, thereby achieving maximum efficiency (Anil H et al, 2015).
Using swarm robots rather than a single robot can have several advantages and leads to a variety of design tradeoffs. Therefore it is more economical, more scalable and less sensitive to overall failure. Destruction of a single member of a large swarm may not be catastrophic while the failure of a single subsystem of a conventional robot is usually disastrous. Swarms offer the possibility of enhanced task performance, task reliability and decreased cost over more traditional robotic systems (G. Dudek et el, 1993).

3. PROPOSED ARCHITECTURE AND FARM LAYOUT DESIGN.

The system will compose of two homogenous groups of swarm robots – the UAV (unmanned Aerial Vehicle) robots and the UGV (unmanned Ground Vehicle) robots which will be used to monitor the farm. A large farm will be divided into a number of equal areas and batches of UGV will man each segmented area.

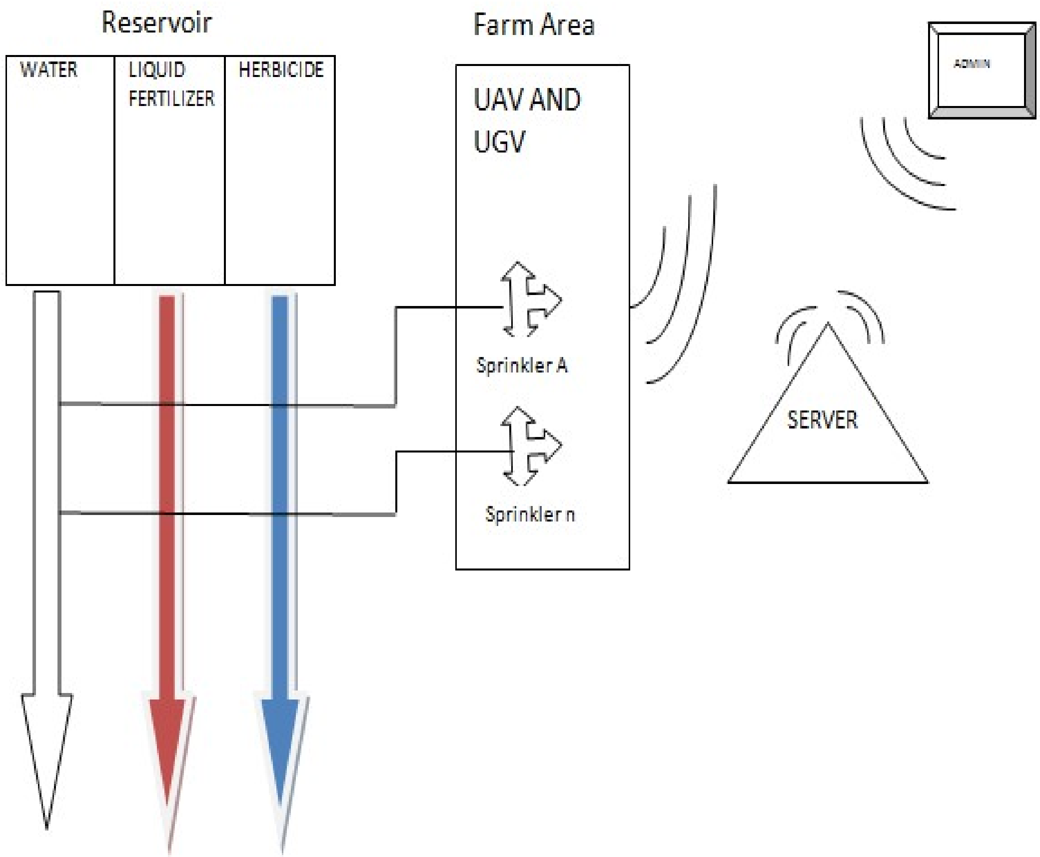

Figure 1: The diagram of the system.

The swarm robots design and architecture will follow (G. Dudek et el, 1993) taxonomy. The taxonomy recommends that for robots to be taken as swarm, it must align with the following conditions:

- By swarm size: The number of robots (n) in the environment where n>1
- By communication range
- By communication topology
- By communication bandwidth
- By swarm composition (Homogenous)
- By swarm unit processing ability

UGV (unmanned ground vehicle**)**

Figure 2: A PICTURE OF A UGV (source: Emmanouil G. F., 2017)

Work: weed detection, soil condition monitoring, alarm sounding.
Sensors: GPS, IR, Ultrasonic sensor, Ground Penetrating Radar (GPR), sound detector
Actuators: Tires, digger (coupled with soil sensor), alarm
Inter robot communication: infra red
Robot-server communication: RF, WI-FI Module

UAV (Unmanned aerial vehicle)

Figure 3: A PICTURE OF A UAV (source: Emmanouil G. F., 2017)

Work: image capturing.
Sensors: IR, Ultrasonic sensor, GPS, Camera.
Inter robot Communication: infra red
Robot-server communication: RF, WI-FI Module

4. WORKING OF THE SYSTEM

The swarm of robots at each particular area of a farm is used to monitor the growing environment of the plant (data collection). The UGV moves around at predetermined interval around the farm area to check for the soil and plant conditions through its sensors. When any agent senses weeds, drop in soil moisture or nutrient it sends a signal count to a controller (microcontroller) controlling the sprinkler of that particular region and at the same time signals a nearby agent to come and inspect the particular region of the area for confirmation. When the signal count (c) is >1, the sprinkler fixed with the pipes from the reservoir is triggered and the necessary recourses sprayed in the region. Also the UGV are equipped with sound detectors which will trigger off an alarm to scare off pests. After the patrol (monitoring), the swarms congregate at a particular section of the farm area where there is a wireless charger to charge them wirelessly and also with the solar panel mounted on them.

The UAV also flies at the same time the UGV are making patrol. Its work is mainly to monitor the health of the crops by taking aerial pictures which will be sent to a server for processing and storage. At anytime the UGV and UAV makes a patrol, it collects data (soil nutrient, soil moisture content, weed presence and aerial crop pictures) and sends it to a database which can be assessed by an Administrator for making informed decision.

The overall phases of the system are as below:
Data collection
Data analysis
Data utilization (application)

5. CONCLUSION

With the working architectures of swarm robots and identified swarm robots already tested as identified by the literatures reviewed, this proposed Architecture will be feasible. The Advantage of this architecture is a prolonged battery life of the robots due to the onboard solar panels charging the battery and decreased load due to the fact that chemicals are stored in a reservoir and not carried by the robots. This system if implemented will drastically reduce the cost of farming as the use of herbicides, fertilizers will be conserved and wastage reduced or totally avoided.

REFERENCES

1. Agris Pentjuss, Aleksejs Zacepins, Aleksandrs Gailums. (2011). Improving Precisio Agriculture Methods With Multiagent Systems In Latvian Agricultural Field
2. Anil H, Nikhil K.S , Chaitra V, Gurusharan B.S. (2015) Revolutionizing Farming Using Swarm Robotics: *6th International Conference on Intelligent Systems, Modelling and Simulation.*
3. Audrey Guillet, Roland Lenain, Benoit Thuilot, and Philippe Martinet. (2014). IEEE Robotics &Automation Magazine. DOI: 10.1109/MRA.2013.2295946.
4. Dario Albani, Joris IJsselmuiden, Ramon Haken.(2017).Monitoring and Mapping with Robot Swarms for Agricultural Applications
5. Emmanouil G. Fragkoulopoulos. (2017), Agricultural Robotics and Automation Robot Collaboration for Precision Agriculture.(PhD Thesis) University of thessaly, Essex, UK.
6. F. A. Auat Cheein and R. Carelli. (2013). Agricultural Robotics: Unmanned Robotic Service Units in Agricultural Tasks. *IEEE Industrial Electronics Magazine, 7(3),*48–58.
7. G. Dudek, M. Jenkinj, E. Milios and D. Wilkest. (1993). A Taxonomy for Swarm Robots: *international Conference on Intelligent Robots and Systems Yokohama, Japan.*
8. L. Chaimowicz, B. Grocholsky, J. F. Keller, R. V. Kumar, and C. J. Taylor. (2004). Experiments in multirobot air-ground coordinatio: *IEEE International Conference on Robotics and Automation, 4:4053–4058*.
9. Madhav Patil, Tamer Abukhalil, and Tarek Sobh. (2013).Hardware Architecture Review of Swarm Robotics System: Self-Reconfigurability, Self-Reassembly, and Self Replication: ISRN Robotics.
10. M. Garzn, J. Valente, D. Zapata, and A. Barrientos. (2013). An aerial-ground robotic system For navigation and obstacle mapping in large outdoor areas: Sensors, 13:1247-1267.
11. Redmond Ramin Shamshiri , Cornelia Weltzien , Ibrahim A. Hameed , Ian J. Yule , Tony E. Grift , Siva K. Balasundram , Lenka Pitonakova , Desa Ahmad , Girish Chowdhary.(2018).
12. Research and development in agricultural robotics: A perspective of digital farming: *Int J Agric & Biol Eng. 11(4): 1–14* .
13. Sajjad Yaghoubi, Negar Ali Akbarzadeh, Shadi Sadeghi Bazargani, Sama Sadeghi Bazargani, Marjan Bamizan, Maryam Irani Asl.(2013). Autonomous Robots for Agricultural Tasks and Farm Assignment and Future Trends in Agro Robots: *International Journal ofMechanical & Mechatronics Engineering IJMME-IJENS Vol:13* .