Assignment title	**End of Module Assignment**
Discussion	Aerial Intelligence in Agriculture: Hybrid P2P IoT and AI
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INTRODUCTION

Robots are the intersection between mechanical design and computer science. These provide support in tasks where human intervention can be greatly reduced or in some cases, even completely replaced. The focus of my research concatenates an Internet of Things (IoT) with small intelligent robot systems. These can either be terrestrial or aerial. When combined, companies and businesses can benefit from their powerful applications, and the one that I decided to explore is Precision Agriculture in the open air. According to EUSPA (2015), the European Union foresee an increase in the world population of 2 billion people by 2050, meaning the same amount of available land that feeds us nowadays needs to be maximised to meet the future demand. Here is where Precision Agriculture steps in.

BACKGROUND OF THE ORGANIZATION

Here is the case scenario for the banana farmer Plátano de Canarias: Canary Islands (Spain) are famous among other things for the banana production. This organization comprises more than 8000 farmers, a crop area of more than 8600 hectares and an annual production of 438,000 tonnes (Plátano de Canarias, 2018). Banana production is carried out in seven islands, and it accounts for 52% of the European Banana Production.

RATIONALE OF CHOSEN ORGANISATION

Banana farming was chosen as the industrial application for this solution due to the popularity of the crop globally. It also opens possibilities to a broad market, as this fruit is grown in many regions. Despite many countries growing their banana crops, Plátano de Canarias was chosen due to being the European Standard and one of the most biologically safe productions. Not having many pesticide by-products simplify the algorithm design. They display the different pesticide by-products in this chart:

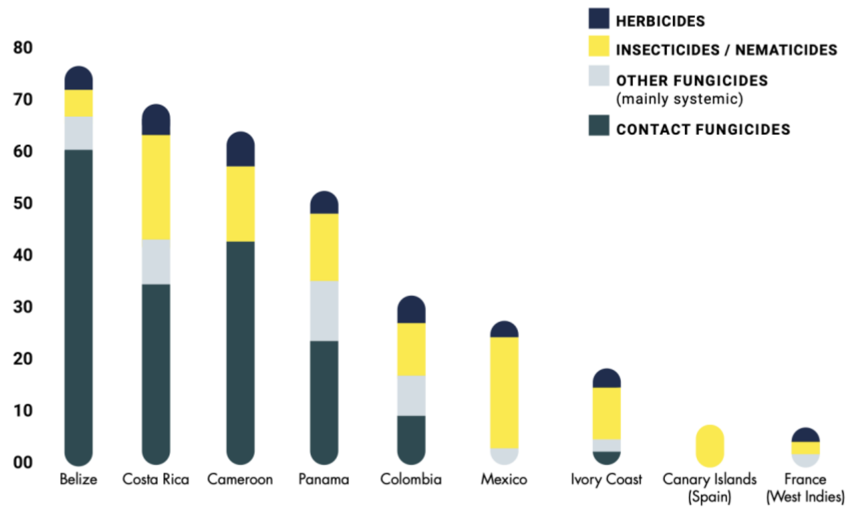

Figure 1: Use of pesticides for banana production globally (Plátano de Canarias, 2018)

Moreover, crop plots are less than one hectare (Plátano de Canarias, 2018) and are step like plots with difficult access for traditional ploughing machinery making this region ideal to implement the precision farming case study.

According to a study in the region, these islands are at the top of the European list when it comes to agricultural toxic chemicals (Rodriguez, 2018). Moreover, the locals are feeling the impact in the form of health issues. One of these dangerous products are the nitrogen fertilisers, which make up to 17.5% of the carbon footprint of the product (Cartaya & Buena, 2018). These fertilisers have boosted our agricultural expansion making possible to feed millions of people during the green revolution. Gates (2013) said that "two out of every five people on Earth today owe their lives to the higher crop outputs that fertilizer has made possible.", so the use of this chemical is not bad in every aspect. However, action must be taken to reduce it.

RESEARCH CONTEXT

The system network proposed architecture would be a Hybrid P2P Internet of Things (IoT), where an AI cloud platform is deployed. This ensures direct communication between the devices and a cloud private server for monitoring and storage. Machine learning (ML) will be used to predict and deploy storm preparedness (Casto, 2021) and allocate resources intelligently based on its predictions. Similarly, the robot will be equipped with camera and sensor systems, allowing for machine vision (MV) to also take part into this complex infrastructure, so the ML algorithm has a wider input range.

The IoT will be a network of devices that comprise, aerial and/or terrestrial robots, valves, sensors and irrigation systems. The proposed system is represented with three fundamental levels from most fundamental to more complex structures (bottom-up):

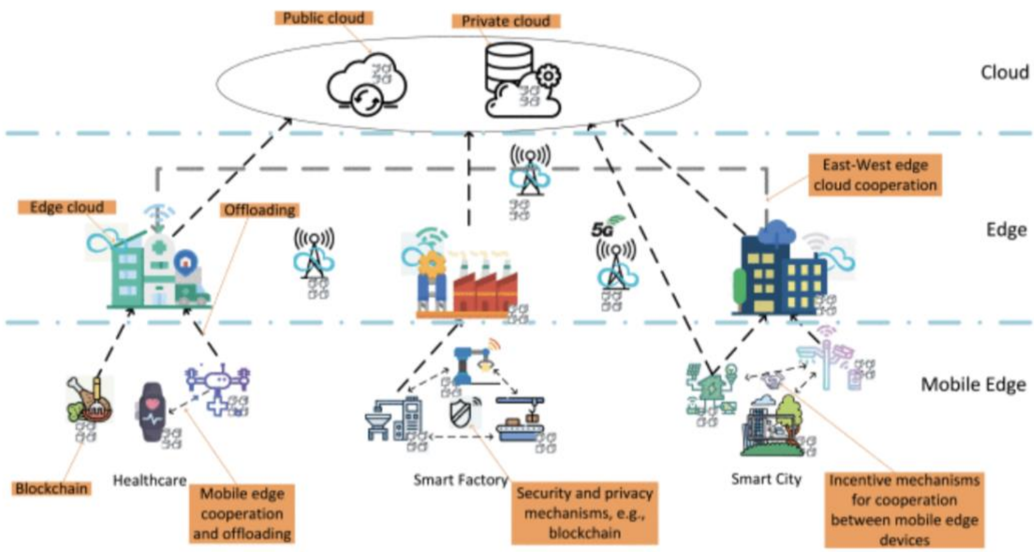

Figure 2: IoT infrastructure (Wu, 2020)

All the storage happens in the private cloud server from which the ML algorithm is fed bulk data to perform analysis. These are k-means clustering and particle swarm organization (PSO).

K-means is an algorithm that can be comprehensively implemented with Python. Moreover, it has already been used for weather prediction accurately (John, 2021). To build this model, the more weather data obtained the better for its accuracy in prediction. Having an IoT where robots are integrated opens great possibilities for the PSO. In a PSO, knowing the node position is key to coordinate the network.

Oliveira de Sá, Nedjah and Mourelle (2016) propose several options to locate robots without the need of an external positioning system like GPS (Global Positioning System). Out of all the options outlined in this paper, the anchor approach is deemed as the most accurate one. Anchors are reference nodes that can be placed in the plot bounds. Three of these anchors create a bounding box or node area of high probability and this box is later refined by the relative position of this node to another network node. This is done through the received signal strength. In fact, this is the same concept as antenna triangulation.

With PSO, a swarm can for instance evaluate by trial error which are the best paths to cover the greatest length or crop area to apply pesticide and scan the crops. To communicate with the positioning mechanism and perform the required scans to apply machine vision, the robots must be equipped with a set of cameras, lidar (depth measurements) and radio receiver.

Simply put, the "smart" farming process would go as follows (DK London, 2023, p.107):

1. Prepare the plots with intelligent irrigation systems (intelligent valves and sensors), anchors and/or QR posts for swarm positioning.
2. Enter crop input parameters into the AI hybrid IoT. These can include optimal soil conditions, estimate growth period or crop desired volume. TNAU (2011), makes a comprehensive review of the different points to be considered when dealing with banana precision farming. These are pesticides, fertilizer and greenhouse harvesting being actually very important for setting up the inputs of an AI model.
3. Use of “crop scanners” in the form of terrestrial and/or aerial robots to scan the field and store the data in the AI cloud. Data like vigour, crop volume, soil samples…
4. The trained AI will gather this data and act upon the crops needs. For instance, if the soil is dry, it will trigger the valve irrigation mechanism.
5. With minimal human intervention, the system can very efficiently work on its own.
6. Improvement of the system like solar panel implementation for a greener operation can be deployed.

In a practical example, Plátano de Canarias farms can prevent the product from being wasted and fertilisers applied upon the individual plant needs. In a storm event, let’s say a section of the crop is scanned and deemed mature enough by a swarm of robots. The ML algorithm, who based on data (weather, product-cleaned crops, location…), builds an accurate prediction of which crops must be gathered before the storm takes place and AI allocates resources accordingly to minimise waste.

CRITICAL ANALYSIS

The main reasons for choosing a hybrid approach to a P2P IoT are scalability, resource efficiency, decentralisation and increased privacy and security. Furthermore, P2P IoT platforms are developer friendly as to having many available libraries opening a wide range of possibilities (Team Bytebeam, 2023).

Nevertheless, on the one hand some challenges need to be accounted when providing a solution for a mass production crop. Wu (2020) explains that security and privacy need to be put in place when transmitting data to comply with the data protection laws. Furthermore, IoT infrastructure needs good infrastructure planning not to overload the network and processing facilities. However, these can be tackled using edge servers or sometimes called fog-computing. Koketsu Rodrigues, Suto and Kato (2019) propose an edge server deployment close to the network to improve latency. In fact, the IoT devices transfer a pre-processed query to the edge server to make the system decision even faster. Furthermore, edge computing can be used as a solid blocker for cyberattacks. Abeshu and Chilamkurti (2018), state fog-nodes provide distributed intelligence and responsiveness to hosting security services more reliably than the cloud. Hence why they propose a deep learning model (unsupervised) for cyberattack detection in this level on top of top-notch encryption.

On the other hand, training the swarm and AI model on what to do is not a simple endeavour. Massive companies like Amazon (2023) or Nike are already using this robot swarm technology primarily for warehouse logistics. To tackle the model training, crops can be cultivated in their early stages inside a greenhouse. The model will be fed different parameters like crop diseases, health conditions and basic needs, for instance watering frequency. With a set of strategically placed QR codes, robots (either drones or terrestrial) can decode the QR information like path planning, guidance, and 3D coordinates (Bach, Khoi and Yi, 2023). Ultimately, the system will get very efficient on its tasks as the longer it runs, the better its decisions. When good efficiency is achieved, the QR posts can be replaced by the proposed outdoors solution, anchors.
To ensure the technology is well adopted, a simple TAM (Technology Acceptance Model) study was put in place:

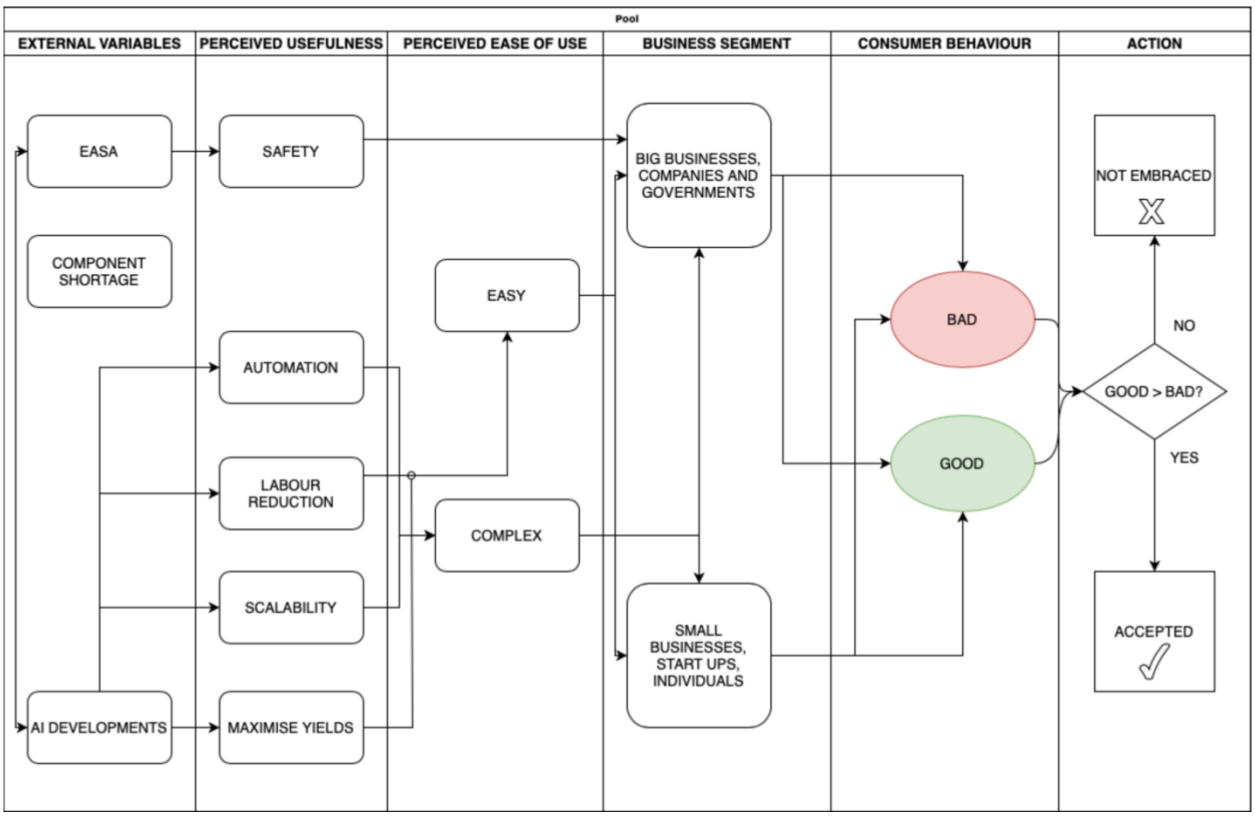

Figure 3: Simplified Technology Acceptance Model (TAM)

This technology according to the National Institute of Food and Agriculture (n.d), will be adopted following the diffusion adoption model. Eventually, it will be gradually embraced by big agricultural companies and followed by smaller landowners. Although the former are more technologically aware to take advantage of the technology, more affordable, and adaptable options are foreseen to emerge in the market. The aim of this technology is to produce a model that is pre-trained to broaden the acceptance of the public. A model that can be up-and-running by just booting it up.

SCHOLARLY REVIEW

The World Health Organisation has raised its concerns about the global food supply. Adult obesity and child malnutrition being at the forefront of the concerns (World Health Organization, 2021). In addition to that, global conflicts further strain the global food supply. The US Government has put 100 million USD to an action plan (VACS) to tackle these issues focusing on boosting nutrition and agricultural productivity (U.S Department of State, 2023).

Fruit and vegetable production are key to ensure a balanced global supply, to provide a healthy and fresh option to everyone globally. Banana is a very versatile fruit, and Plátano de Canarias (2018) states its many benefits including improving the cardiovascular system or being antioxidant and vitamin rich.

At a global scale, banana is mainly produced in tropical and rainforest regions, one of them being the Canary Islands.

Figure 4: Canarias Banana Crop Plots (Redacción, 2020)

IoT's are now an emerging trend of study in Computer Science. These systems are now being implemented with an intelligent agent that coordinates the actions of the devices in the network. In many cases, this agent is a trained artificial intelligence. Proof of this is the launch of Microsoft Azure Open AI in 2021 (Microsoft, 2019). Moreover, they successfully proved the Azure technology using drones with a real-time IoT Microsoft (2023).

Other companies take the precision farming approach slightly differently but with the same solid foundation. Tevel (2022) is an Israel based company that has produced a working IoT with fruit-picking drones. By efficiently monitoring the amount of crop collected and harvested area, the company ensures maximum yield with predictive analysis. The approach is the same as well, by ensuring stable positioning of the nodes in the system with QR codes and a central hub where the drones are hard-wired to.

There are companies which already provide similar off the shelf drone solutions (Agriculture Intelligence, 2020). Other bigger companies, like the agricultural manufacturer John Deere has taken some steps in process automation and crop mapping, but only using their heavy machinery. The technology used is GPS + cellular with a device called JDlink (John Deere, 2013). IoT with AI are game changers with more accessible technologies and compact robot format.

CONCLUSION

These systems, compared to the traditional ploughing and irrigation techniques, are more affordable and scalable in uneven terrain, yet allow for better automation and visualization of the crop growing process. Ultimately, these benefits are expected to yield higher returns (Addicott, 2019). Despite these benefits, farmers have not opted to build their infrastructure around this technology yet due to transition costs and an increased system complexity like EASA regulations for drones, server deployment and stable interconnection. Several companies are pushing for this technology to spearhead the market with their robotic solutions, being IoT the chosen approach. Having a pre-trained system that can be deployed in any terrain would benefit labour shortage mitigation in agriculture. Furthermore, it promotes sustainable food production with renewable energy networks, making precision agriculture a complex yet efficient method to tackle one of the world's greatest problems.

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