UNIVERSITY OF CAMBRIDGE
DEPARTMENT OF ENGINEERING

Agri FoRwArdS
EPSRC Centre for Doctoral Training in Agri-Food Robotics

Making MACARONS

Vijja Wichitwechkarn (Agriforwards CDT PhD Student)
Ruchi Choudhary (Dept. Engineering, Cambridge), Charles Fox (Dept. Computer Science, Lincoln)

Introduction

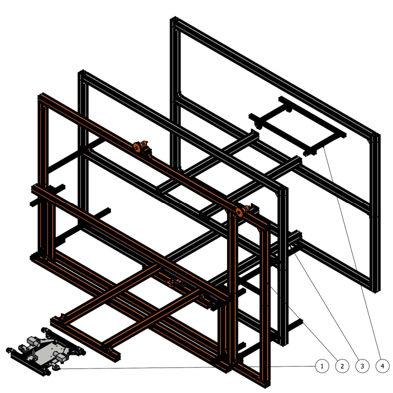
Global population is expected to reach 9.7 billion by 2050, with 70% expected in urban areas[1]. The global amount of food produced must thus increase by more than 50%[2]. Loss of agricultural land to urban and infrastructure expansion puts further pressure on agriculture[3], which is exacerbated by degradation of soil and contamination of water due to uncontrolled use of chemicals, pesticides and herbicides[4,5]. Climate change is expected to increase the unpredictability of the weather and increase the magnitude and frequency of natural disasters, which will drastically impact produce from traditional agriculture[6]. The agriculture sector will have to increase its production capacity despite these factors. There is therefore a need for research into more efficient and resilient means of food production[7]. Controlled environment agriculture such as vertical farming offers a solution.

Summary

This project aims to develop open-source hardware, software and methods that facilitate and accelerate the optimisation of controlled environment agriculture systems such as vertical farms. The first phase of the project involves the design, construction and testing of the Modular Automated Crop Array Online System (MACARONS). The system can be scaled and extended to fit a wide variety of space and purposes and aims to be a cost-effective and easy to build platform. Both software and hardware will be designed to be highly customisable, allowing users to adapt it to specific requirements. The project will then expand towards data analysis methods and specific optimisation procedures.

Sequential Access

The sequential access system is designed to be scaled by tessellation vertically and horizontally. A pilot version with 2 vertical and 1 horizontal units was built and tested in Lincoln. The system comprises a mobile robot (1) that moves under and interact with carriages (4) intended to hold plant trays. This allow trays to be moved horizontally. The elevator (2) allows for vertical movement.

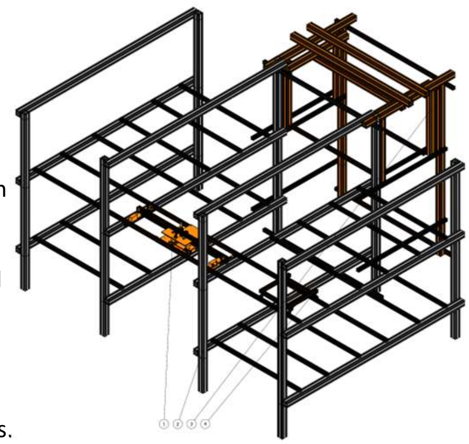


References

[1] United Nations Department of Economic and Social Affairs (2015)
[2] Durham, USA: Duke University, (2020).
[3] Lotze-Campen *et al., Agricultural Economics*, 39(3): 325–338(2008).
[4] Corvalan *et al.,* World Health Organization (2005).
[5] Thomaier *et al., Renewable Agriculture and Food Systems*, 30(1): 43–54 (2015)
[6] Mir *et al., Pharma Innov. J*, *11*, pp.1175-1195. (2022)
[7] Beacham *et al., The Journal of Horticultural Science and Biotechnology*, 94(3): 277–283 (2019)

Random Access

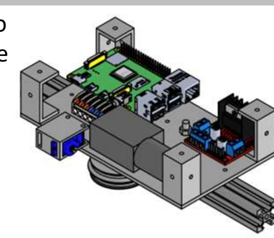
The previous design only allow each plant tray to be accessed sequentially. This improves space efficiency but is not always desirable. The new design addresses this limitation allowing each plant tray to be accessed at all times. The system is currently being constructed with integrated lighting, irrigation and monitoring systems. Once completed the system will be used to run automated experiments.



This will build up a timeseries dataset of growth conditions and images. The system comprises a mobile robot (1), shelves (2), elevator (3) and carriages (4).

ZCF Data Collection

A data collection system will be retrofitted to a section of Zero Carbon Farms. Similarly, the system is designed to be scaled by tessellation. The system will generate a timeseries dataset of temperature, relative humidity, images and metrics such as plant height. The dataset will be analysed using time series forecasting.



Epsilon

Epsilon is the backend that powers all the systems built. Epsilon is a locally hosted webserver that allow ESP32 micro-controllers to be controlled and programmed in MicroPython over Wi-Fi via any device that supports a web-browser. The data read from all the devices can be logged and used to trigger programmed behaviours in other devices. Epsilon also lets each device to be coordinated and controlled together to perform complex tasks.

Outlook

Future work involves automated experiments using the random-access system and retrofitting Zero Carbon Farms with the data collection system. A timeseries dataset will then be collected and analysed to identify avenues for efficiency improvements. Time-series forecasting methods will also be developed and implemented to create a pipeline for data generation, ingestion and prediction. Simulations and economic analyses will be conducted to investigate the impact of the implemented technologies and methods. Upgrades to the performance and user-friendliness of epsilon will be made for potential collaborations that may use epsilon as the backend.

Collaborators

Will Rohde*, Fulvio Forni*
*Agriforwards CDT, Department of Engineering (University of Cambridge)

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