Studentship Project: Annual Progress Report Oct/2021 to Sept/2022

Student Name:	**Katherine James**	**AHDB Project Number:**	**SF/TF 170/a**
Project Title:	**High-throughput phenotyping of fruit traits for automatic strawberry harvesting**		
Lead Partner:	Berry Gardens		
Supervisor:	Grzegorz Cielniak		
Start Date:	01/10/2021	**End Date:**	30/09/2025

1. Project aims and objectives

Strawberries are a berry crop of major economic importance, grown commercially throughout the temperate and subtropical zones of the world. Labour, or rather the lack of it, poses a huge challenge to the soft fruit industry. In a survey conducted by British Summer Fruits, the industry body representing 95% of all British grown soft fruits), a loss of £36.5 million was reported in 2021, equating to 7709 tonnes of fruit, solely due to berry waste from lack of labour (British Summer Fruits Members' Survey, 2021).

A promising technological solution to these labour problems is the introduction of fruit-picking robots (Ducket et al, 2018). Considering the strawberry industry alone, a substantial amount of research has been conducted towards developing strawberry harvesters, spanning both academic institutions and commercial start-ups around the world (Kondratieva et al, 2022).

An obstacle to increased success in robotic picking operations is a lack of general understanding of which fruit variety is the most suitable for the task. As robotic harvesters differ in their methods for fruit detachment (stem cut, fruit twist and fruit pull), it is possible that although some generic traits may be beneficial across all harvesting technologies, there may also be particular traits of special importance to each. There is potential for the development of new varieties of fruit crops that are more suited to robotic harvest, for example, adjustment of the fruit clusters to reduce occlusion.

High-throughput phenotyping using computer vision-based methods has the potential to transform the phenomics bottleneck in strawberry breeding Zheng et al (2021). However, as things stand, not only has minimal research been done for automating phenotyping beyond traits relating to fruit and phenology, but there also exists a gap in the high-throughput strawberry phenotyping knowledge base for how to translate complex, subjective measures such as display into something measurable using high-throughput technologies.

This project aims to address the task of identifying which phenotypic traits are relevant to the robotic harvest of strawberry, through the use of 3D-perception to achieve high-throughput phenotyping. This will be approached through four objectives, as follows:

O1. Determine the current status of automation of relevant phenotypic traits and the potential for automation of unautomated traits

O2. Investigate and implement algorithms necessary to conduct standard holistic and component phenotyping tasks

O3. Develop algorithms that will compute new traits relevant to a bespoke breeding target

O4. Select appropriate measures to assess the success of robotic harvest of strawberries, validate the developed models and system and isolate traits common amongst varieties that have the best harvest success

References:

British Summer Fruits (2021). British Summer Fruits members' labour survey. https://committees.parliament.uk/writtenevidence/42845/default/.

Duckett, T., Pearson, S., Blackmore, S., & Grieve, B. (2018). Agricultural robotics: The future of robotic agriculture. Technical report. doi:10.31256/WP2018.2

Kondratieva, O., Fedorov, A., Slinko, O., Voytyuk, V., & Alekseeva, S. (2022). New solutions in the horticultural industry. IOP Conference Series: Earth and Environmental Science, 1010 (1), 012103. doi:10.1088/1755-1315/1010/1/012103.

Zheng, C., Abd-Elrahman, A., & Whitaker, V. (2021). Remote sensing and machine learning in crop phenotyping and management, with an emphasis on applications in strawberry farming. Remote Sensing, 13 (3), 531. doi:10.3390/rs13030531.

Zhou, H., Wang, X., Au, W., Kang, H., & Chen, C. (2022). Intelligent robots for fruit harvesting: recent developments and future challenges. Precision Agriculture, (23), 1856–1907. doi:10.1007/s11119-022-09913-3.
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2. Key messages emerging from the project

Determination of which traits of strawberry plants make a variety more suited to robotic harvest. This impacts future strawberry breeding and robotic harvester design.

3. Summary of results from the reporting year

Objective 1 has been achieved, and I am part-way through Objective 2.

Project progress:

1. **Reviewed the current status of automated phenotyping for strawberry:** James, K., Sargent, D., Whitehouse, A., & Cielniak, G. (2022). High-throughput phenotyping for breeding targets – current status and future directions of strawberry trait automation. Plants, People, Planet, 4 (5), 432–443. doi:10.1002/ppp3.10275. **(Objective 1)**
2. **Dataset collection:** A dataset consisting of 84 scans of strawberry plants was collected for developing and validating automated phenotyping algorithms. **(Objective 2)**
3. **Basic phenotyping:** I have been working towards building a minimal representation of a strawberry plant in the 3D space so that I can extract this representation from scans of different strawberry plants and compute comparable phenotypes from each of these. This is the first step towards Objective 3, where I will begin to deduce phenotypes relevant to robotic harvest. **(Objective 2)**

4. Key issues to be addressed in the next year

In the coming year I will be focussing on defining a complexity index which will indicate how plant structure impact the ease of robotic harvest. Using this index, I intend to begin to unravel which traits are linked to robotic harvest and to potentially define new phenotypes related to this.

5. Outputs relating to the project
(events, press articles, conference posters or presentations, scientific papers):

Output	**Detail**
Review paper in New Phytologist Foundation Journal	James, K., Sargent, D., Whitehouse, A., & Cielniak, G. (2022). High-throughput phenotyping for breeding targets – current status and future directions of strawberry trait automation. Plants, People, Planet, 4 (5), 432–443. doi:10.1002/ppp3.10275.
TedXBrayfordPool Talk	"How agri-robotics will change the food you eat" A TedX talk presented on 3 September 2022 at TedXBrayfordPool. Abstract: Agricultural robotics and artificial intelligence are changing how we farm, from day-to-day practices to selecting new crop varieties. In this talk, Katherine James gives an overview of how agri-robotics is changing the way we interact with crops, how this will change the crops themselves and, ultimately, how this will allow humans to focus more on things which require the 'art-of-being-human'.
CTP Autumn Event	5-minute presentation covering personal background and interest in the project, the motivation for the project topic and an introduction to the project
CTP Summer Event	5-minute presentation giving a broad overview of the project and progress made so far.
LAR research seminar	20-minute presentation within the broader University of Lincoln research group to disseminate the content of the review article.

6. Partners (if applicable)

Scientific partners	
Industry partners	Berry Gardens (Richard Harnden)
Government sponsor	