Grower Summary

SF/TF 170

Design and Accurate Control of a Novel Low-Cost Soft Robotic Arm for Soft Fruit Harvesting

Annual report 2021

Project title:	Design and Accurate Control of a Novel Low-Cost Soft Robotic Arm for Soft Fruit Harvesting
Project number:	N/A
Project leader:	Philip Johnson, University of Lincoln
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AUTHENTICATION

We declare that this work was done under our supervision according to the procedures described herein and that the report represents a true and accurate record of the results obtained.

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GROWER SUMMARY

Headline

A soft robotic harvester for strawberry picking could address the growing UK labour shortages while protecting the delicate handling of produce.

Background

The UK soft fruit sector is a substantial and growing industry under significant threat from a lack of seasonal labour. The majority of labour for the industry is comprised of seasonal workers with only a tiny fraction of the 29000 workers being UK nationals [1]. The availability of EU labour is decreasing rapidly due to restriction of 'free movement' following Brexit and the decreasing unemployment in eastern European countries which traditionally provided seasonal labourers e.g., Romania [1]. Labour costs already comprise around 50% of the cost of production, which is increasing due to inflation while the value of produce has remained relatively static [1]. More than half of this labour is used for the harvesting of fruit, additionally, jobs in soft fruit harvesting can be 'physically demanding, repetitive in nature, conducted in adverse environments and relatively unrewarding' [1][6].

Labour Category	% Expenditure
▸ Crop establishment ▸ Crop husbandry ▸ Management of crop coverings ▸ Grading and packing	40-50
Harvesting	50-60

Figure 1: Breakdown of labour involved in soft fruit industry [1]

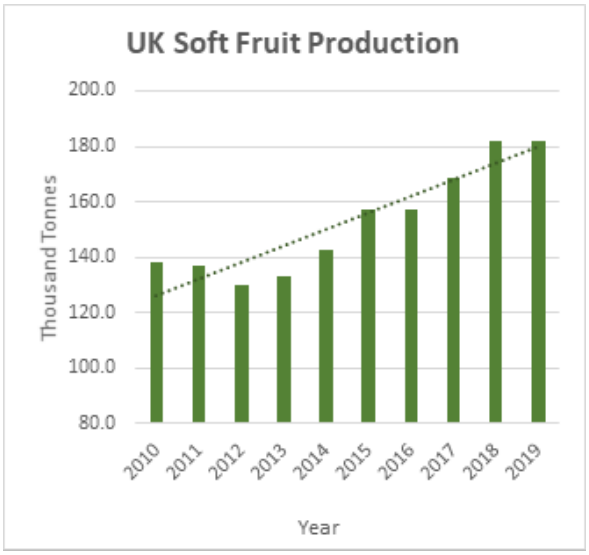

Figure 2: UK Soft Fruit production statistics. DEFRA Horticulture Statistics 2020.

Given these circumstances, there is a huge opportunity for developing robotics and automated systems to meet the needs of the soft fruit industry and wider agri-food sector. Selective harvesting as a research area has seen a huge increase amount of interest and funding in recent years, especially in the UK, resulting in the development of many

associated technologies, however at the time of writing there aren't any commercially successful/viable solutions.

Automated manipulation and grasping of food items present a series of unique challenges compared to other sectors [6]. Firstly discrete, fragile items must be harvested individually without damaging or disturbing those around them in unknown/unstructured environments. Additionally, due to the high level of dexterity needed for picking, control systems are often required to be highly complex. There also exists a high likelihood of human-robot interaction and a resulting necessity for safety.

Summary

To build a suitable robotic harvester for picking soft fruits, we must understand the design challenge, and the necessary characteristics for producing a successful mechanism. Currently the favoured method in literature for robotic picking strawberries is to use a small pair of blades/pincers as part of the mechanism to cut the stem of a strawberry and carry the strawberry back to the punnet. This method is limited in its ability to interact with clusters of fruit and densely packed ripe strawberries hidden behind leaves and unripe fruit. The reasons for this limitation are first, that highly complex and precise motion planning is needed to position the cutting blades on the correct stem amongst a tangled web of similar stems. Secondly, moving any occluding unripe strawberries and generally interacting with the cluster is very risky with rigid manipulators, as the strawberries are very delicate and easily bruised. Any errors or inaccuracies hold potential for damage to the crop.

'Snap-picking' the fruit rather than cutting the stem could hold the key to addressing these limitations. The snap-picking method of picking strawberries is favoured by leading strawberry producers Berry Gardens Ltd, one of the UKs largest soft fruit growers. This picking method involves the human picker directly handling the fruit and rotating it to a 90° angle before pressing their thumb on the stem/calyx and pulling it away from the plant. The stem snaps with an audible 'pop' leaving little to no stem length above the leafy calyx.

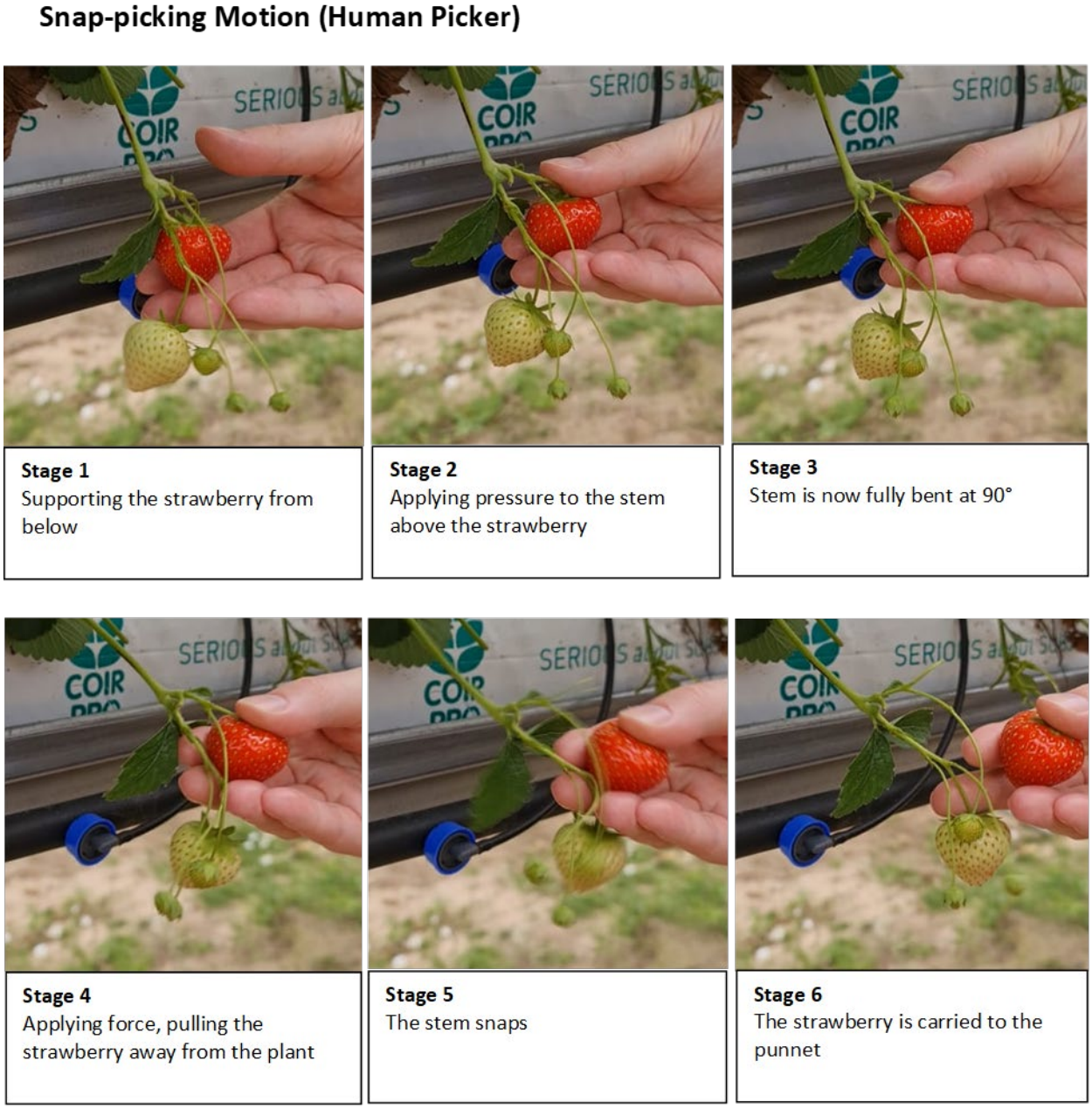

Figure 3: The process of snap picking a strawberry

Simplifying the picking motion into these six stages highlights the desired three functions of the end-effector (Engulfing/grasping, applying pressure to bend stem, and pulling the fruit away from the plant). These three motions are listed in the next section in a table to map desired motions to necessary gripper characteristics.

The snap-picking technique could be replicated with soft robotic actuation, and this challenge forms the first research objective for this project. Rotating the fruit by 90° and applying pressure on the top of the stem could be achieved using custom shaped pneumatic channels

which actuate the manipulator. The pulling of the strawberry while retaining soft material properties could be achieved with the assistance of variable stiffness methods, this will be further explored in year two of the project.

Using soft materials and soft actuators could also address the limitations of current robotic approaches, firstly because using soft compliant materials reduces the need for highly accurate motion planning, since these systems can passively adapt to unknown environments and any errors or inaccurate motions are less likely to cause damage to plant/other fruit. Additionally, using soft materials make interacting with clusters viable and brushing against/moving other unripe fruit is possible because the soft materials are inherently safer.

The major motion challenges to address for achieving this research objective are tilting the stem 90°, increasing the speed of actuation and applying a force to the top of the strawberry to snap the stem.

