DEVELOPMENT & DEMONSTRATION OF AN AUTOMATED, SELECTIVE BROCCOLI HARVESTER

CP 153a

KMS Projects Limited

Project Summary

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Broccoli is an important vegetable crop for UK growers who produce about 75,000 tonnes each year. Labour is a significant cost for growers as broccoli is harvested manually, typically by a team of 7. Between 2016 and 2021 the cost of these workers will have increased by 35% due to increases in the National Living Wage. The NFU believes that this is likely to make many growers uncompetitive and drive crop production to low cost countries. They are also concerned that it may not possible to maintain a supply of suitable workers from the EU given unhelpful currency exchange rates and Brexit uncertainties.

The development of a fully automated harvesting system is therefore crucial for growers. Since a field of broccoli plants becomes harvest-ready at different times, a slaughter approach to cropping the field is not ideal. This is because the cut heads would have to be size-graded in a processing plant, to separate those that meet customer specifications from others which are either too small or too large.

The ideal solution is therefore a fully automated, selective harvester that can be programmed to crop heads which meet customers' predetermined criteria.

Designing a selective, automated harvester to replace the manual system is no easy task. It must accurately identify and measure the size of the broccoli heads and select only those which fit the grower's pre-determined profile for picking. Each selected head must be cut and collected without damaging the uncut crop. And all this must be achieved in real time whilst the rig is under continuous motion.

The auto harvester developed by KMS Projects has been designed as a stand-alone rig. It is powered by and mounted on the front of a standard tractor. The harvester uses sophisticated imaging and data analysis techniques to identify the broccoli curds and to select those of the required size for cutting. The cutting mechanism is moved swiftly into position by a 6-axis robotic arm and the selected heads cut and lifted leaving the rest of the crop undamaged in the field.

In 2015, with financial support from the AHDB and encouragement from the Brassica Growers Association, KMS Projects set out to prove that their idea of marrying imaging and robotics together could work (AHDB project CP 153). Initial tests using a conveyor belt and cardboard boxes to mimic the rig moving over plants in the field were designed to ensure that the

imaging and robotics systems would operate seamlessly together. Having succeeded in proving that the concept was viable, the team designed and developed their first full size prototype.

At this stage, the prototype rig was able to identify and measure the size of broccoli heads (with leaf cover removed) as well as to obtain the location coordinates of each one it passed over.

In November KMS Projects had made sufficient progress to demonstrate it in action in a controlled environment. Those present could see the red light of the camera's laser beam sweeping over the broccoli heads as the rig passed over them and the harvester's systems instructing the robot to travel to the location of each head within a pre-determined size range.

The success of project CP153a led to a further, larger funding grant from the AHDB and in June 2016, the team began work on a second project (AHDB CP153a) to further develop the selective automated broccoli harvester.

The team constructed a new prototype which incorporated learnings from 2015 together with many refinements and developments. This rig was equipped with a larger, more robust dust and weather proof robot and for the first time, it was also fitted with a rudimentary cutting hand.

One of the most difficult issues facing KMS Projects at this time was designing an encoding system which would reliably and accurately account for the forward motion of the rig over a field. Progress in devising a solution that would reliably deliver the desired results was made and by November 2016 the team were able to demonstrate the rig successfully cutting heads of a pre-determined size in a field of commercially grown broccoli.

This was an important milestone for the project team. However, up until this point, the prototype could only find and cut broccoli heads that had been stripped of leaf cover. To be useful to growers, the harvester must be capable of correctly locating broccoli heads that are partially covered by leaves.

The team worked on this tough challenge during the winter of 2016 and the early months of 2017. They also used this time to refine and improve many aspects of the harvester. For example, key enhancements to the imaging system significantly improved the quality of the imaging data gathered.

To solve the problem of leaf cover, the team devised a new and genuinely ground-breaking method of detection; one built on deep learning techniques. This new approach means that the harvester is now able to correctly identify broccoli heads that are partially obscured by

leaves. The vision system's deep learning capabilities have also been used to train the rig to classify different sizes of broccoli head with impressive accuracy. One of the key advantages of AI (artificial intelligence) is that the imaging system is continually learning from the data it collects.

The HMI (human machine interface) was designed and work has begun to develop it so that it will integrate with ISOBUS, taking the concept closer to a turn-key solution.

The rig has been equipped with CCTV cameras allowing the Tractor Driver to directly monitor the harvester from inside the cab. Real time updates can be accessed via the harvester's communications' hub using a user-friendly website interface designed by KMS Projects. This provides access to performance analytics direct from the harvester to both to the Tractor Driver and remotely sited farm managers.

The rig's imaging system is perfectly suited to low light levels. Night trials were conducted which endorsed the team's belief that the prototype would perform well in the dark. This is good news for growers as it proves that the auto harvester can work round the clock without a drop in performance or efficiency. What's more, harvesting at night when ambient temperatures are lower improves both shelf life and product quality and could also reduce refrigeration costs.

Thanks to TH Clements & Sons who provided the project team with limitless access to commercially grown crop, the rig was thoroughly tested throughout the UK season. This enabled KMS Projects to assess how well the harvester performed at different speeds and in a range of weather conditions. It was also successfully tested on several varieties of commercially grown broccoli.

These trials provided invaluable insight which is being used to further refine and develop the rig. For example, a blown air system to remove the cut heads is in development as are live yield mapping functions using the real time data gathered by the harvester.

In November 2017, at the end of both the broccoli harvesting season and project CP153a, KMS Projects demonstrated their harvester successfully cropping commercially grown broccoli heads of a predetermined size at twice the speed of a manual cutter.

KMS Projects' goal is to see their harvester as a commercially available machine cutting broccoli heads which exactly match customers' specifications; operating round the clock without tiring; reducing growers' reliance on manual labour and cutting harvesting costs significantly.