AUTOMATED BROCCOLI HARVESTING PROJECT

PROGRESS REVIEW

AHDB Reference: CP 153/3110153021

14 December 2015

BACKGROUND INFORMATION

The ultimate aim of the project is to replace manual operations in horticulture with automated processes that can replace the hand/eye coordination of a human operator.

The project team is led by Peter Keeling of KMS Projects Ltd and includes partners representing growers, agricultural machinery manufacturers and other equipment suppliers. This collaborative approach has been adopted deliberately in order for the project team to benefit from the input and experience of experts in each area of specialist knowledge.

In choosing to develop a solution for broccoli, the team believe they will be able to create a foundation system that in due course could be further developed to overcome the complexities required to automate the harvesting of other crops such as cauliflower and lettuce.

The project team's ultimate objective is to create a solution that delivers real, quantifiable commercial benefits.

In order to automate the harvesting of broccoli, the system must be able to undertake the following tasks in real time, whilst under continuous motion across the field and in such a way as to deliver measureable benefits to the grower:

1. Accurately identify broccoli plants in the field.
2. Accurately measure the size of each plant and compare it against pre-agreed criteria in order to establish whether or not it is suitable for cutting.
3. Obtain accurate data regarding the position of each harvest-ready broccoli head.
4. Despatch the robotic arm with pinpoint accuracy to the precise location of each harvest-ready broccoli head.
5. Cut each harvest-ready head, leaving the stalk and any immature or unsuitable heads undamaged in the field.
6. Lift each cut head without damage.
7. Enable cut head to be collected without damage for transportation to the processing facility.

It was hoped that by the end of the UK's 2015 broccoli season, the team would have created a prototype solution capable of undertaking tasks 1 – 4.

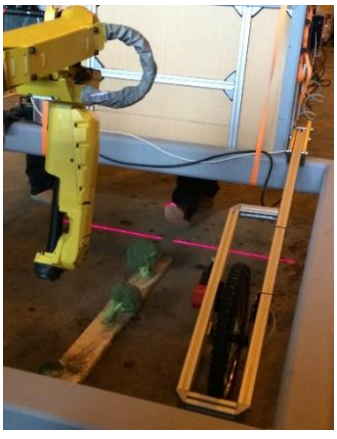
This was successfully achieved and a demonstration of the rig completing tasks 1 – 4 both inside a barn and out in the field was delivered by the team at TH Clements' premises in Lincolnshire on 24 & 25 November 2015.

TASKS PERFORMED BY THE PROTOTYPE RIG

The Prototype rig during field trials at TH Clements on 25th November 2015

Task 1 – Identifying broccoli plants in the field.

As the rig passes over the field, a 3-D imaging camera is used to gather data about the objects within its field of view. This is process uses a red laser beam which can be seen in the photograph below.



The camera operates using red light which means that in order for it to function effectively, the interference caused by light from the rest of the spectrum should be minimised and the light levels

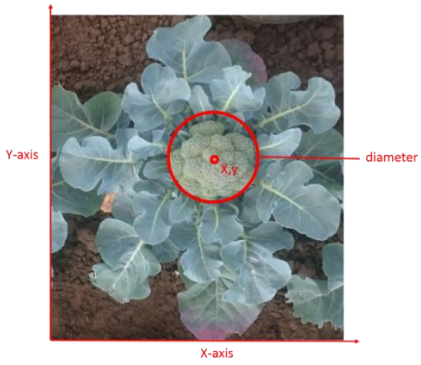
kept as constant as possible. The camera is housed in a protective box on the front of the prototype for this reason.

It is also the reason why this system comes into its own at night and provides the added potential benefit to growers of being able to harvest 24 hours a day.

The data collected by the camera is transmitted to a computer where our specialist software, is used to accurately identify broccoli plants and their heads from other objects such as weeds.

Task 2 - Accurately measure the size of each plant and compare it against pre-agreed criteria in order to establish whether or not it is suitable for cutting.

Data gathered by the imaging camera is used not only to correctly identify broccoli plants from other objects, but also to enable to the system to grade plants according to pre-specified criteria. In the case of broccoli harvesting, this means the size of the head. Information regarding the size of broccoli heads that the grower considers to be the optimum minimum size for cutting is uploaded. This enables our system to accurately identify which broccoli heads need to be cut and which need to be left undamaged to continue to grow.



The centre of the broccoli head can be defined by x and y co-ordinates enabling the approximate diameter of the head to be measured.

Accurate determination of the height (z-axis measurement) above the ground can also be obtained.

Task 3 - Obtain accurate data regarding the position of each harvest-ready broccoli head.

In order for automated harvesting to be commercially viable, it must take place under continuous motion. This introduces a number of challenges when it comes to obtaining the accurate location of the heads selected for cutting.

The imaging equipment gathers information regarding the 3 dimensional co-ordinates of each broccoli head. In other words, its longitudinal (x), latitudinal (y) and height (z) position from a datum point.

The robotic arm which moves the cutting head into the correct position to cut the selected broccoli heads has to be mounted behind the camera equipment with sufficient room to operate within the confines of space and time allowed by the frame of the rig and the speed of travel.

As a result, the location co-ordinates gathered by the camera have to be adjusted to take into account the fact that the robot's datum point is different to its own and that both are moving as the rig travels across the field.

The solution is to introduce an encoder wheel. This equipment combines an electronic pulsar with a wheel that rotates in sync with the rig in order to transmit accurate positioning data to the robot's control system.

Task 4 - Despatch the robotic arm with pinpoint accuracy to the precise location of each harvest-ready broccoli head.

Precise information regarding which heads have been selected for cutting and their location are transmitted to the robot's control system which uses this data to instruct the robotic arm to point to each selected head and to ignore those heads which have not fulfilled the selection criteria.

The robot is designed to work in a wide range of temperatures and can move in six axes of freedom. This means that it can be moved forwards, backwards, sideways, up and down as well rotated around all the directions of movement. In other words, it is highly manoeuvrable and it this dexterity that enables it to mimic human actions.

Robotic arm pointing to correct sized broccoli head during field trials.

TESTING THE PROTOTYPE

The prototype rig was assembled at TH Clements by the project team. The first tests were undertaken indoors in the controlled environment of a barn. Broccoli heads were mounted on spiked boards laid on the ground. The rig was driven over the 'crop' by tractor under slow forwards continuous motion.

The robot successfully pointed to heads of broccoli, even when these were off-set and not uniformly spaced. It also pointed only to heads of the correct size and ignoring ones which were below the designated size.

Following the success of the barn-based tests, the team took the rig into the field. Since the broccoli season was at an end, it was not possible to test the rig on harvest-ready crop. However, TH Clements had left an area of recently harvested broccoli in a field for the team. Fresh broccoli heads were mounted on spikes on the stalks of recently cut plants. This produced a close approximation to the conditions in a harvest ready field of broccoli.

The prototype once again performed well and the team were delighted with the outcome. Please double click on the icon below to watch a video of the prototype in the field.

Stage 4 -
Video.mp4

Video of the prototype rig in action in the Broccoli Field.
Video plays at x 2 real time.

NEXT STEPS

The project team are very clear about the next steps they would like to take with this exciting work. Assuming that sufficient funding can be raised, they intend to build on their work to date to redesign and produce a new prototype rig which also cuts, lifts and collects broccoli heads and to test it rigorously during the 2016 UK broccoli season.