Deliverable for experiment GAROTICS

D 1.1: Implementation report

Green asparagus harvesting robotic system

STRAUSS
UNIHB
CWS

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INDEX

1 Introduction

The earlier project AmLight concluded in a pre-competitive prototype, which need further developments to increase the precision and reliability of the asparagus detection system and to improve the harvesting tool with respect to higher harvesting speeds and improved asparagus gripping.

The GAROTICS experiment thus had the objective of developing and integrating innovative technological solutions.

Based on field experiments performed during summer 2015 and the advice of RIF-experts (RIF visit in September 2015) the following sub-components have developed:

a) An asparagus detection system, which is a combination of a 3D Kinect camera and an IPP (Image Processing Program);
b) A pneumatically based active harvesting tool; and
c) A PLC program;

The carrier unit (vehicle) of the harvesting machine also was mechanically adapted in order to carry the new/additional sub-components.

This report is summarising (i) the development of named sub-components, (ii) their integration into the carrier unit and (iii) the results of functional testing after integration.

2 Development of the asparagus detection

Chosen as best camera system for the asparagus detection was the ‘Microsoft Kinect v2’ with a USB 3.0 cable as connection for the requested data transfer. The procedure for IPP programming was as follows:

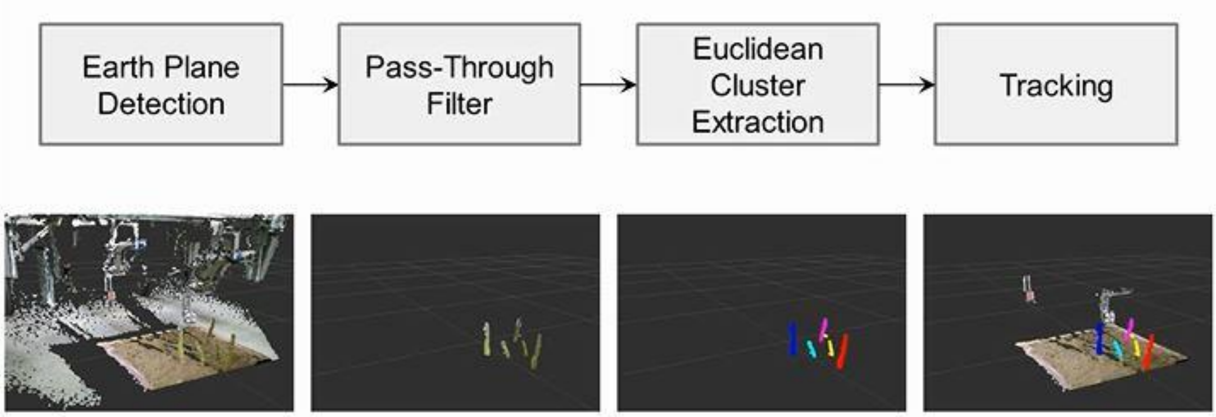


Figure 1 Detection and tracking of asparagus

Figure 1 shows the four steps of the IPP program. The initial 3D image will be sent through filters which eliminate the earth plane and the rest of the background and only leave the detected asparagus stalks. Each stalk is assigned a unique ID, which is also illustrated by the different colors in Figure 1. In subsequent frames, the new position of each stalk is detected and sent to the PLC together with the stalk ID. In this way, eventual lateral drifts of the harvesting machine are continuously compensated, so that the harvesting tool can properly grasp the asparagus.

Another aspect of the asparagus detection was to ensure communication between the IPP and the existing PLC program, which controls the movement of the machine (carrier unit and harvesting tools). Once the communication was established the tracking of asparagus positions (see picture 4 of figure 1) needed to be programmed to the PLC (see also chapter 4).

Achievements:

- ✓ GARotics IPP completed
- ✓ Communication protocol between IPP and PLC established

3 Development of asparagus harvesting tool

The development of the new harvesting tool was done in three steps:

a) <u>Analysis of existing tool</u>

The AmLight prototype harvesting tool was taken of the machine for an in depth analysis with respect to the cutting and gripping performance. For this the following parameter were taken into consideration:

- Number and position of rubber grippers c_1 , c_2 , c_3 and c_4; see figure 2.

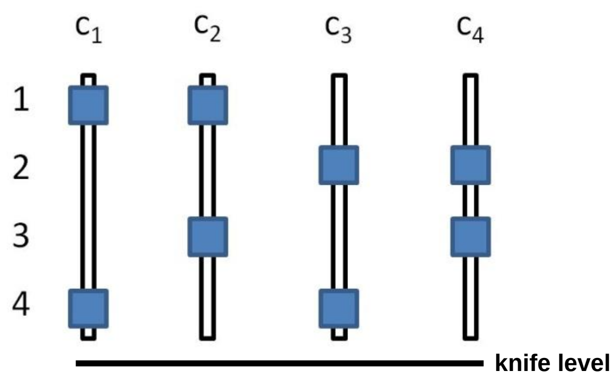


Figure 2 Rubber gripper arrangement

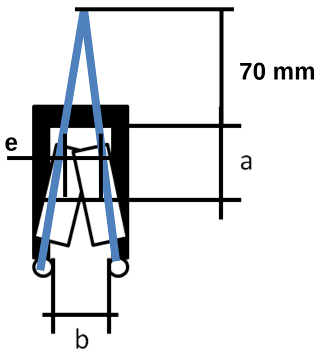


Figure 3 Harvesting tool settings

- Width of opening (a, b and e); see figure 3.
- Diameter of asparagus stalk (from 12 to 20 mm)

Experiment set-up and execution

Figure 3 shows the set-up for cutting and gripping experiments. An asparagus stalk is being mounted into a stationary holder (1). The harvesting tool (2) which consists of a two knives and grippers is fitted ball screw which is driven by a servo motor (3) at a constant speed of 0.5 m/s across the asparagus stalk. This movement is simulating the harvesting process of the AmLight prototype while the harvesting tool is in its lowered position.

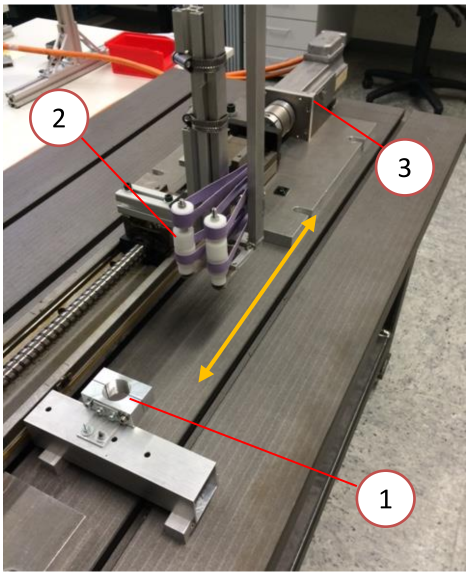


Figure 4 Experiment set-up

The settings as shown in figure 1 and 2 have been combined and varied by changing the opening of the harvesting tool and by moving the cutting point forwards and backwards. The gripping point is where the stalk is cut completely and cannot move any further relatively to the gripper bands. At this point the asparagus has to be gripped. Real green asparagus of different diameters were used for the tests.

'b' and 'd' are measured at rubber position 4. The distance between the other band positions are 5 mm lower, because the asparagus is thinning from the bottom to the top.

Under observation and of interest during tests have been

- ✓ The cutting effectiveness
- ✓ The gripping effectiveness while cutting and
- ✓ The gripping effectiveness in reverse acceleration

In total number of 48 testes, each one always having one parameter changed, we done and results listed in tables. The observations have been as following:

Observation

i. The diameters of asparagus varied between 12 - 20 mm.
ii. The diameter varied in cross section (oval 10 - 16 mm) and it can be curved in length direction.
iii. The cutting of an asparagus stalk was always successful, independent on the position of the knife and the diameter of the stalk.
iv. The position of the knife has an influence on the gripping success.
v. Gripping of stalk appears to be the major problem.
vi. In all cases of successful cutting and gripping with rubber position 'c_1' was the opening 4-8 mm larger than the diameter of the asparagus stalk – in other words: with a 22 mm opening all stalk with a diameter of 14-18 mm were processed successfully.
vii. When the space between mounting and cutting point gets to small (a < 15 mm), the asparagus can collide with the rack.
viii. When 'b' gets to small (b < 20 mm), the asparagus can collide with the outside edge of the gripper. Furthermore it influences the transferred gripping force.

ix. Positions ‘c_2’, ‘c_3’ and ‘c_4’ as well as a layering of rubber bands have no significant influence on a gripping.

x. **High speed camera videos** (available on request) have revealed that the upper rubber band causes a higher momentum with a result of wider stalk getting pushed out.

All tables, results, observations and conclusions made are available in the technical report of period 4.

b) <u>Concluding and brain-storming for innovative ideas</u>

Based on the results and observations from above mentioned tests, the main conclusion of GARotics partners was that:

Harvesting with a stationary fitted knife and stationary fitted grippers will under no circumstance be reliable enough for automated harvesting!

Thus a new thoughts shower was required with the aim to create innovative ideas of how to trap an asparagus stalk once it has been cut; and how to integrate an intelligent solutions for activate cutting and gripping to the existing harvesting mechanism.

c) <u>Design and manufacturing of new harvesting tool</u>

With innovative ideas in mind it was the responsibility of UNIHB to design and develop a new harvesting tool. Figure 5 on the right shows the principle design of the new harvesting tool. It consists of a modified aluminium frame, which allows for enough space to fit a pneumatically cylinder to it. This cylinder (activated by the PLC) would close at the same time both the two angled cutting knifed and rubber bands. The new harvesting tool was manufactured in cooperation between STRAUSS and UNIHB and the functionality of the pneumatically active cutting and gripping was tested in the labs of UNIHB (see figure 6). A video of these tests can be provided on request. The active harvesting tool was re-integrated to the ‘AmLight’ carrier unit in the week of May 2016.

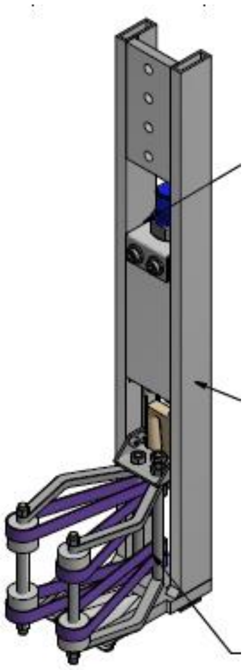


Figure 5 3D design of new harvesting tool

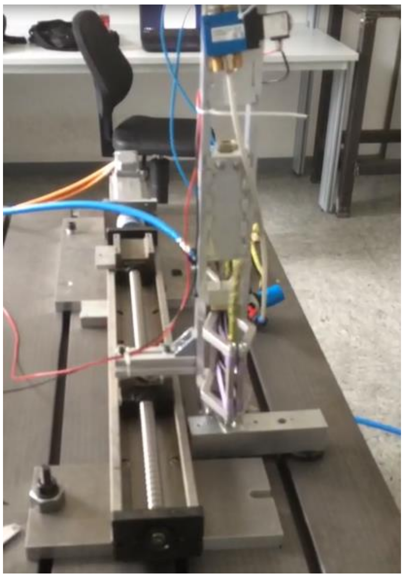


Figure 6 Manufactured harvesting tool tested at UNIHB

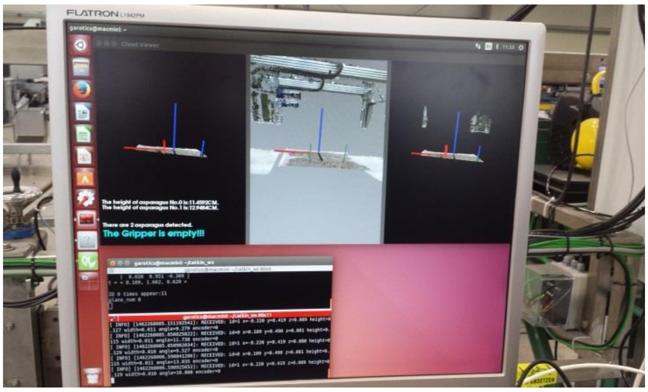
4 System integration and functional tests

System integration

The developed components were all shipped to STRAUSS and re-integrated to the AmLight carrier unit.

Figure 6 Integrated items to the AmLight carrier unit

Due to new items and functions that have been integrated to the harvesting machine (new camera, asparagus tracking, pneumatically activated cutting and gripping and in consequence a compressor for pressed air supply), the PLC program needed to adapted accordingly. The changes were done by STRAUSS in parallel to the above explained mechanical developments. However the testing of the PLC changes took place during functional tests at the beginning of May in the facilities of STRAUSS.



Functional tests

Functional tests of integrated technological solutions took place at the premises of STRAUSS during in total three sessions. Part of these tests was:

a) To check the communication between PLC;
b) To determine that the PLC would control all components of the machine as requested;
c) To make sure that the movement and activation of blades and grippers is functional;
d) To chick if a position of an asparagus stalk can be tracked.

Once all functions were given, short videos were taken which show the functions teste. These videos are available on request.