COMPLEMENTARY MANIPULATOR TOOL DEVELOPMENT FOR SAFE COBOT-ASSISTED HYDROPONICS

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Human–robot collaboration is gaining ground in Manufacturing, Healthcare and Logistics but also in Agriculture. Different types of applications in the latter field are becoming more common. However, in all scenarios, safety assessment and verification are crucial to cope with the related standards and specifications. In this paper, the development and safety testing of a complementary manipulator tool (Clip) is presented which can by design limit the physical interaction energy in a hazardous collaborative robot (cobot) scenario, namely when loading the plant of a Hydroponic System.

Keywords: hydroponics, human-robot collaboration, safety

1. Introduction

Using robots in agriculture is a rather old field of interest with many difficult automation problems. Incorporating automation can help hydroponic systems become more efficient and productive because - according to Ref. [1] - labor is the biggest cost in this domain. In a review [2] about smart hydroponic systems, some robotic applications were mentioned, e.g. harvesting strawberries and cleaning greenhouses. In the real business world, some companies offer completely robot-based hydroponic environments, e.g. a start-up called Iron Ox has just received a big investment [3] for their complete hydroponic farming solution. The safety aspects in indoor farming environments were also investigated [4]. In this paper, the technical criteria of a cobotised Hydroponic System are presented alongside the development of a complementary manipulator tool which is finally tested against a safety protocol.

2. Technical criteria


Furthermore, although a large number of initially considered harmonized standards are present, the main relevant ones are the following:


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Figure 1: Set-up of the Cobotised Hydroponic System with 3 Zones.

Figure 2: Hydro pot.


The technical specification, ISO/TS 15066:2016 [18] - Robots and robotic devices - Collaborative robots, should also be taken into consideration.

These directives and standards were necessary because the cobotised Hydroponic System consists of an UR5 cobot arm mounted on an Automated Ground Vehicle (AGV) which is docked to the hydroponic growing tower with an electric pump (see Fig. 1).

Based on the set-up, 3 hazard zones were defined:
• Zone 1: Primary process area
• Zone 2: Secondary process area
• Zone 3: Surrounding equipment

3. Risk assessment

The risk analysis was carried out for Zone 1 according to a normal methodology, following the steps of the ISO 12100:2010 standard [19]. After recognizing the hazards and the injuries, a risk graph had to be categorized based on ISO 13849-1:2015 [20]. As a result of the categorization, the risk level of each hazard could be calculated. The risk level of each hazard was calculated using the worst result.

As the cobot arm is equipped with a two-finger gripper and is responsible for loading the seedlings, this is one of the crucial elements of the system in terms of safety. Special care needs to be taken when manipulating the plants as on the one hand, damage to the crops, leaves and roots should be avoided, but on the other hand an unintended collision with a plant carrier should not exceed the biomechanical threshold values defined in Ref. [18].

4. Clip development

Green Drops Farm Kft. developed its hydroponic system using a commercially available product called a hydro pot (see Fig. 2) with a diameter of 50 mm for creating holes to plant plants by following the same practices adopted by similar pieces of equipment.

During the development of automation and robotization, a problem occurred, namely that as the crops grow their roots overgrow the hydro pot so the plant becomes stuck where it is (see Fig. 3). As a result, the arm of the cobot is unable to handle the pots, which cannot be used again.

In order to be sustainable and recycle, several versions of clips have been designed and commercially available rockwool cubes used.
As the cobot arm could not handle the clips because the part (a flag-like handle) it would grab (see Fig. 4) had become overgrown by the plant, that part had to be redesigned.

In the first versions of the design, the spike on the clips was vertical, but during testing it was demonstrated that it could cause serious injuries to people (see Fig. 5), despite the fact that the clips had been created using 3D printing.

The end of the spike needed to be blunted and placed horizontally in order to avoid causing potential injuries (see Fig. 6). Even though horizontal rockwool cubes were produced to facilitate its installation, the plants could still fall off.

In the final version, nooks were placed on the clips on which semicircular plant holder rings can be placed at different heights. This prevents plants from falling off and it is safer moving them using the cobot arm (see Fig. 7).

5. Collision tests

Tests were carried out on the clips according to a testing protocol entitled “Test robot arm for collision with movable object (Impact)” from the COVR Toolkit [21], which functions also as a library for protocol testing of cobot applications. These tests are in harmony with the standards within the frame of cobot usage as described in Ref. [22]. Force measurements were recorded with a GTE KMG 500-75 force cell (Spring rate: 75 N/mm with the damping material SH70) while pressure values were measured with Fuji Prescale LLW-type Films (see Fig. 8).

The results of 3 experiments at a cobot speed of 0.1 m/s showed that for a human hand only a transient collision can occur with a maximum force of 47 N (see Fig.
9) as in all cases the 3D-printed clip breaks at the same position.

The maximum pressure was 300 N/cm² (see Fig. 10).

As in some cases the pressure can be close to the threshold, the use of gloves while carrying out clip-assisted plant loading is highly recommended.

6. Conclusion

Hydroponics is a subset of hydroculture, which is an environmentally friendly technology for growing plants in the absence of soil by using mineral nutrient solutions dissolved in water. Many tasks in the Hydroponic production process cannot be fully automated and require safe human-robot collaboration, moreover, cobotised tasks like the loading of plants must be tested with a safety protocol similar to the one followed in this paper. The proposed 3D-printed complementary manipulator tool (clip) was tested by following the protocol “Test robot arm for collision with movable object (Impact).” Test results showed that only transient collisions can occur and force as well as pressure values are below the threshold in the case of a collision with a human hand. However, to maximize safety, it is recommended that gloves are worn.

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