Structurized Ecological CULtivation with Autonomous Robots in Indoor Agriculture

SpECULARIA

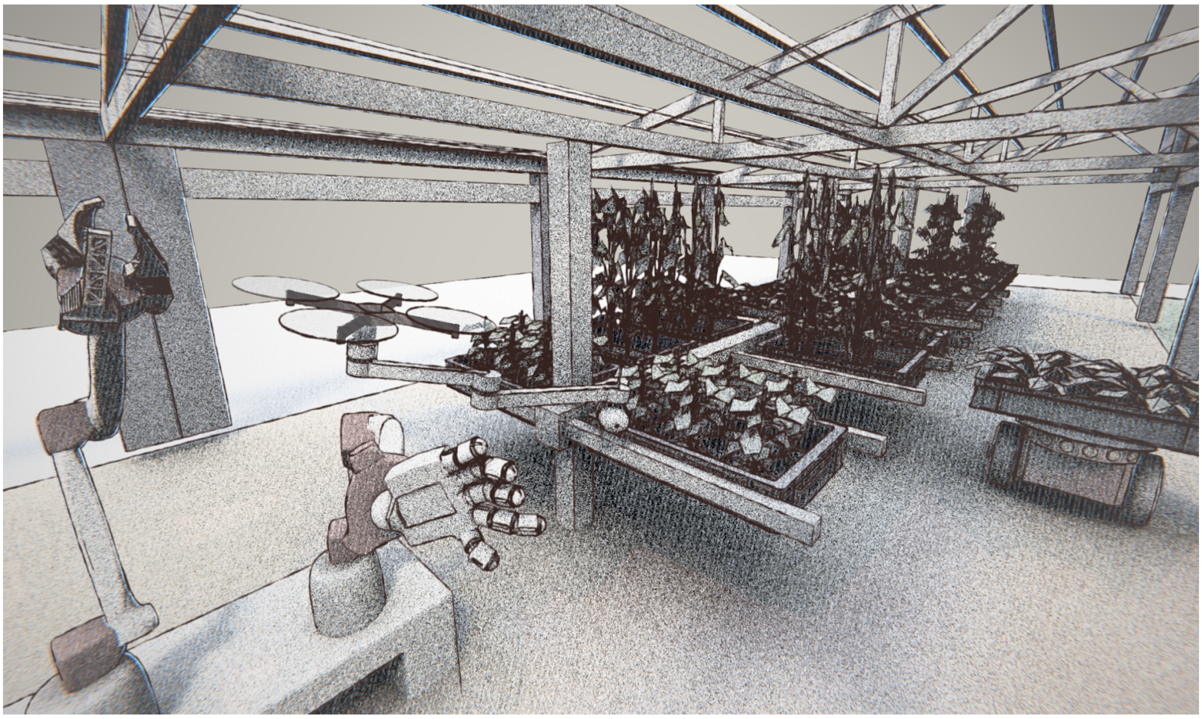

Fig 1. In the first century CE, two Roman agricultural writers, Lucius Junius Moderatus Columella and Gaius Plinius Secundus (Pliny the Elder), referred to proto-greenhouses (specularia) constructed for the Emperor Tiberius (42 BCE–37 CE), presumably adjacent to his palace, the Villa Jovis on the Isle of Capri. Pliny wrote (Book 19, 23: 64) that the specularia consisted of beds mounted on wheels which they moved out into the sun and then on wintry days withdrew under the cover of frames glazed with transparent stone (Loudon 1850). This image shows a Specularia of 21st century, built around the heterogeneous robotic system that is proposed through this project proposal.

The main goal of this proposal is to deal with concepts of compliant robot control, soft robotics and heterogeneous robotic system in general, within the University of Zagreb Faculty of Electrical engineering and computing. To demonstrate the effectiveness of these robotics research topics, we have envisioned a scenario involving a heterogeneous robotics system utilized to help farmers in indoor organic agriculture.

The proposed heterogeneous robotic system is comprised of the following agents:

1. **Unmanned aerial robot (UAV)** - This robot is equipped with a multi degree of freedom manipulator carrying sensors for plant surveillance. The multi degree of freedom manipulator enables the robot to fly outside the danger area, where its prop wash wind gust can damage the plant.
2. **Unmanned ground robot (UGV)** - This agent is equipped with a mechanism allowing it to transport growth unit containers. These containers, are the smallest organization unit within the farm consisting of a single or variety of plants, that are used in the structured greenhouse environment, designed to suit the robot aided farming paradigm.
3. **Compliant multi degree of freedom manipulator** - This robot is utilized to perform delicate handling of plants. This could include, but is not limited to operations like: physical flower and fruit manipulation, plant pruning, and other plant hygiene operations as well as other mechanical interventions at the plant's structure.

Each robot has specific abilities, but when put to work together they can be applied to achieve versatile goals in an unstructured environment, which an indoor organic farm most certainly is.

We aim to use Functional–structural plant models (FSPM) as a tool to plan plant treatment (Vos et al. 2010). The goal of this treatment is to optimize light distribution for photosynthesis, gas exchange, carbon allocation and ideally bring the fruit to the exact position for the harvest. One example scenario planned and executed completely autonomously would include the following steps: ***STEP 1*** UAV flies and executes surveillance, only to find that a part of the system is not receiving a proper amount of light; ***STEP 2*** UGVs are commanded to reorganize container units; ***STEP 3*** Within this new farm organization, some plants need to be pruned in order to receive optimal amount of light, and UGVs are commanded to deliver those units to the manipulator; ***STEP 4*** Finally, manipulator executes the trajectories to shape the plants so that they receive an ideal amount of light and the UGVs distribute the units back to their position.

Deploying robots on big farms is not a new concept. It is rather a fast growing industry, that focuses on big machines applied for specific crops and use cases. The proposed system goes beyond current state of the art, in sense that it proposes a system comprised of small robots with specific abilities that can execute certain tasks only when they are introduced to work together. Such a system surpasses current farming robots in its scalability and versatility, which makes them ideal for small family run organic farms.

In the world that is suffering for ever more obvious pollution consequences, organic farming represents a step towards reducing the pollution with an environment friendly solution. Unfortunately, in order to reduce the use of pesticides and GMO cultures, organic agriculture becomes ever more labour intensive, with a comparably smaller agricultural output. The obvious economical consequence of such a production system is a higher cost of organic food. The labor input in organic agriculture fits the description of dull and dangerous jobs, and therefore ideally fits the use of robots. By aiding farmers in their daily chores, a proposed heterogeneous robotic system has the potential to make the products of organic agriculture less expensive, and in turn more accessible to wider population.

The key issue in dealing with sensitive plants is to ensure the necessary compliance from the manipulator motion. This will ensure the robot can execute certain tasks, and at the same time make sure that the plant is not harmed. This requirement also fits within the Soft robotics paradigm, that focuses researchers to build better sensing machines, capable of dexterous human like motion. Testing the robots on such a challenging application, represents an interesting research opportunity that will certainly lead to new results in a rapidly expanding field of research.