The SOUP project: current state and future activities

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Abstract. Greenhouse cultivation represents one of the most significant production sectors of Greece, however it remains a labour-intensive activity and requires large amounts of pesticides. The SOUP project (SOilless culture UPgrade) aims to automate the monitoring of plant growth through sensor networks, and to introduce robotic technology for the labour-intensive tasks such as pest management and harvesting. The project investigates the cultivation of tomatoes, which is of high financial importance for Greece due to its size.

Keywords: greenhouse · tomatos · visual disease detection · visual servoing

1 Introduction

Greenhouse cultivations represent one of the most significant production sectors of Greece, with an estimated annual turnover of 900MEuros. Despite their economic importance, greenhouse cultivations are still a labour-intensive activity, with workforce and pest-management expenses making up a large percentage of the production costs. Additional problems associated with greenhouse cultivations relate to personnel health and safety issues, as well as increased environmental footprint, both arising from the use of chemical pesticides and fertilizers, and the need for product quality assurance.

In this context, project SOUP is a three -years project aiming to modernize Greek greenhouse cultivations, by reducing their dependence on manual labour and agrochemicals, through the following technologies:

- Automated monitoring systems that analyze the plants' growth through the use of sensor networks, advanced image processing and state-of-the-art deep learning techniques.
- Robotic mechanisms to automate labor-intensive tasks such as pest management and harvesting.

The above technologies can potentially allow the individualized management of the plants, as opposed to the current practice of indiscriminate plantation-wide interventions, which leads to resource wastage and often excessive use of agrochemicals. In addition, robotics can reduce the need for human presence and manual interventions, and allow for round-the-clock operation of the greenhouse.

Hydroponic tomato production, representing one of the country's main exported greenhouse products, has been selected as the pilot cultivation to develop these technologies within SOUP. Initially, a series of independent hydroponic chambers will be set up, containing tomato plants of different growth stages, and with the ability to inflict insect pest infestations. This facility will be the main testing ground in the development of a plant monitoring system, based on a sensor network and advanced algorithms employing neural networks and deep learning techniques, which will allow identification of pest inflictions and assessment of fruit ripeness. In parallel, a series of robotic mechanisms will be developed, which will be capable of carrying out tasks such as targeted pesticide application and automated harvesting of ripe fruits. These two core technologies will subsequently be combined with conventional automation systems, to form an innovative and eco-efficient greenhouse unit, operating under an intelligent management system. Data from this pilot unit, collected over a period of one year, will be analyzed to asses the economic and environmental impact of the proposed cultivation method, in comparison to the current paradigm, and to draw up a comprehensive results' commercialization plan.

The SOUP consortium is formed by Glafcos Marine Ltd, the Signal Processing and Communications Laboratory of the University of Patras, the Laboratories of Agricultural Production and the Control Systems and Robotics of the Hellenic Mediterranean University, and Up2Metric P.C.

2 Project Description

The project workpackages aim to develop the system presented in fig. 1. These are briefly described in the following:

Hydroponic cultivations We will develop in separate and insect-proof chambers independent hydroponic systems and tomato crops at different ages and with possibility of separating diseases and insect attacks. This infrastructure will be used both to develop the necessary database for the System that will manage the cultivation as a whole, as well as for the experimental evaluation and development of different robotic systems.

Systems for Monitoring, Recording and Analysis of Plant Growth We will use visual sensors (RGB and multispectral), giving input to specifically developed software to monitor the separated hydroponic tomato crops for the development of both the plant growth monitoring system. Image processing and learning techniques will be used. The Intelligent Management System will enable automatic decision-making and corrective interventions. A database with color and multispectral images covering all crops will be developed.

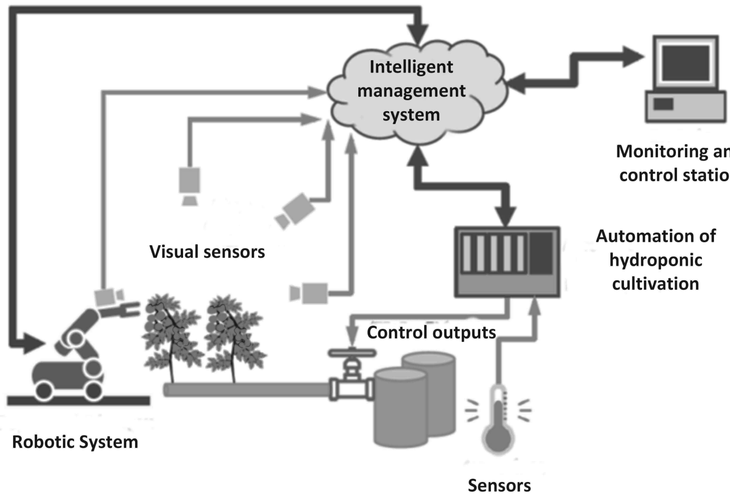

Fig. 1. Overview of the SOUP system and its subsystems

Robotic Systems for the automation of manual tasks A series of end-effectors will be developed which will be attached to a robotic arm and through appropriate control algorithms, will enable the automated execution of various tasks. Such tasks include the targeted spraying of affected areas of plants with protection agents, as well as the fruits harvesting. Due to the complex nature of all the aforementioned operations, it is envisaged to incorporate a visual servoing system for feedback of visual information to the controller, which will guide the end effector to the desired element (stem, stalk, foliage, fruit) of the plant.

3 Current Status

As regards the greenhouse, we have transplanted tomato seedlings ("Elpida" hybrid) within a four weeks interval in order to attain a continuous hydroponic cultivation in different vegetative stages. Phytopathological diseases and phytoparasitic species will be kept active in twelve controlled environment greenhouse compartiments. Three compartments will be used for phytopathological diseases Alternaria solani (Pleosporaceae), Phytophthora infestans (Peronosporaceae) and Leveillula taurica (Erysiphaceae). Three compartments are used for tomato-phytoparasitic pests (see fig. 2): Aphis gossypii (Aphididae), Tetranychus urticae (Tetranychidae) and Tuta absoluta (Gelechiidae). Six compartments will be used to monitor normal morphological growth of tomatoes plants at all vegetative growth stages. Cultivation is designed to take place all year long.

As regards the robotic system, we have completed the design of the robotic platform, the end-effector for fruit collection and its motion on tracks in the greenhouse (see fig. 3).

Fig. 2. The entomological pests we used so far: Tuta absoluta (Glechiidae), Aphis gossypii (Aphididae) and Tetranychus urticae (Tetranychidae)

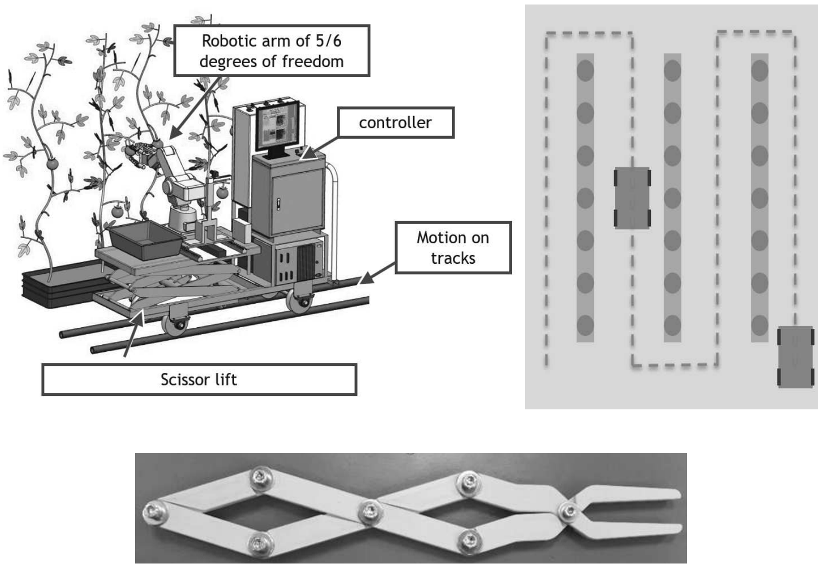

Fig. 3. The design of the robotic platform, its motion on tracks in the greenhouse and the robotic end-effector.

For the computer vision system we have acquired a custom-design multispectral camera, which is going to be used for data acquisition. A static automated system is currently used until the robotic end-effector becomes available. To maximize the amount of images in the database we acquire several images per plant from different viewpoints (see fig 4, 5). Furthermore we have acquired some hundreds of multispectral images, which are now being annotated to mark the different diseases and pests. We have customized and run initial classification experiments using deep learning methods.

Fig. 4. The multispectral images.

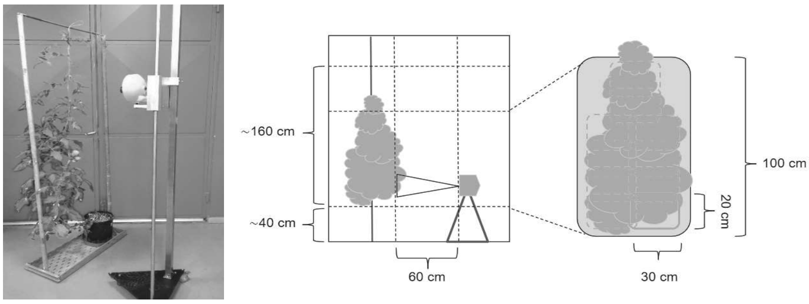

Fig. 5. The multispectral acquisition camera setup and the acquisition of multiple images from a single plant.

4 Conclusions and future work

The SOUP project has successfully completed its first year. The system design has been completed, the first greenhouse prototype has been implemented and the initial visual experiments are running. In the next phases we plan to (a) install more greenhouse compartments to monitor more diseases (b) acquire more images to develop a full database with multispectral images (c) implement a new greenhouse customized to the needs of the robotic system (d) develop the robot controller (e) develop the visual servoing system (f) deploy the robotic system in the green house for disease/pest detection and spraying/harvesting.

The interested reader can be informed about new developments via the dedicated project web-page (https://soup-project.gr/).

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