To improve robot performance for agricultural tasks, and decrease its cost, the robot can be optimally designed for a specific task in a specific working environment. However, since the environment defines the robot optimal kinematics, the environment itself should also be optimised for optimal robot performance. The objective of this paper is to present and demonstrate a methodology for simultaneous optimal design of robot kinematic and the working environment. This methodology was demonstrated by an example on a tree orchard design for an apple harvesting robot. First, an optimal robot structure for apple picking task was found for a number of tree architectures (shaped by different training systems): Central Leader, Y-trellis and Tall Spindle. Results indicate that for minimising the average apple picking time, the Tall Spindle architecture is preferable for the robotic harvesting of both a single tree and a tree row. Further, the influence of the robot platform motion time on the chosen robot kinematics and the tree training system was analysed. Results show that for fast platforms, the Tall spindle architecture is advantageous. If the platform movement between positions near the trees is slow, the Central Leader architecture is favourable. Additionally, the tilt angle of the Y-trellis training system was analysed using simulated models created by the L-systems simulations. The optimal tilt angle was found to be nearly horizontal ($85^\circ$), allowing the robot designer to choose the optimal combination of the robot kinematics, number of robot harvesting positions around the tree and the tree training system.

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influence the optimal result, both the robot and the environment must be optimised simultaneously to achieve the optimal robot performance. In this paper, we present and demonstrate a methodology for simultaneous optimisation procedure for kinematic design of a robot as well as modification of the working environment. The methodology consists of the three following parts, each demonstrated by an example.

1. Comparison of the robotic harvesting effectiveness of existing tree shaping methods (training systems). This is shown by comparing the performance of a single robotic arm picking apples from single trees with different training systems: central leader, tall spindle, and Y-trellis.

2. Influence of the robot platform moving time on the robotic harvesting effectiveness for trees shaped by different training systems. This is shown by comparing the performance of a single robotic arm carried by a platform moving along the row with different speeds.

3. Influence of the geometric tree parameters on the robotic harvesting effectiveness. This is shown by comparing the performance of a single robotic arm picking apples from single simulated y-trellis trees with different tilt angles.

The goals of this paper are to demonstrate the methodology for simultaneous optimisation for a robot and its working environment, and to discuss the preliminary results achieved by this methodology.

For agricultural applications, robotic arms are often tailor designed. They strive to be “light, simple and cheap” such as the arm for kiwi harvester of Scarfe, Flemmer, Bakker, and Flemmer (2009), with low number of degrees of freedom (DOF) such as a robot for harvesting lettuce of Cho, Chang, Kim, and An (2002), or low-cost robot for greenhouse applications developed by Belforte, Deboli, Gay, Piccarolo, and Aimonino (2006). Moreover, the robots are optimised for a specific task, such as an optimal robot for cucumber harvesting (Van Henten, Slot, Hol, & Van Willigenburg, 2009), eggplant harvesting (Han, Xueyan, Tiezhong, Bin, & Liming, 2007), melon harvester (Edan & Miles, 1993) or apple harvesting (Bloch, Bechar, & Degani, 2017; Silwal et al., 2017). However, up to now, the optimisation was focused mainly on the robot, assuming that the environment was given and unchangeable. A number of commercial developers (FFRobotics Ltd., Israel; Abundant Robotics Ltd., USA) use modern tree architectures as more convenient environment, nevertheless, systematic environment analysis was not reported.

In the manufacturing domain, the robot environment is defined as a robot cell. Design of robotic cells for throughput optimisation is well studied and helps to solve numerous industrial challenges (Dawande, Geismar, Sethi, & Srisankarasjah, 2007). The main methods of the cell design are effective scheduling, use of multiple gripper, and parallel working robots. Current agricultural environments were designed to meet the agro-technical constraints and to fit manual labour, and do not take into account the suitability for robotic processing.

Simplifying and structuring of the agricultural environment was investigated by Hua and Kang (2013) (optimising...
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