OPTITHIN - PRECISION FRUITICULTURE BY TREE-SPECIFIC MECHANICAL THINNING

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ABSTRACT

Apples show biennial fluctuations in yields (alternate bearing). The alternate bearing cycle can be broken by reducing excessive flowers using either chemical or mechanical means. Currently, automatic thinning systems are treating the trees uniformly despite the fact that neighboring trees can have a very different numbers of flowers resulting in different thinning requirements. In order to solve this problem the joint project OptiThin has been started. The aim of OptiThin was to develop a system that adapts thinning intensity individually to each tree and that reduces the flowers efficiently and environmentally sound. In the result, OptiThin comprises a set of new technologies including: a) a stereo camera with software for real-time determination of flower density per tree; b) a shock absorbing camera platform; c) a mobile geographic information system with a decision support tool to calculated optimum thinning intensity based on current flower density and ancillary data (e.g. yield, soil); d) a mechanical thinning unit

which is controlled in real-time. It was shown that adaptive management of excessive flowers could improve yield of marketable fruits and that environmental friendly mechanical thinning – without chemicals – is feasible.

Keywords: Precision horticulture, Thinning, Flowers, Apples

INTRODUCTION

Apple cultivars like ‘Elstar’ show strong temporal fluctuations in yields (alternate bearing). This is due to natural tendency of individual trees to produce many flowers which eventually leads to a high number of small fruits of poor quality. In the successive low-yield year, the number of flowers and fruits will be less. The phenomenon is induced by reduced yields in one year due to freeze damage, low pollination rate or other reasons. Consequently, trees develop many flower buds that blossom in the following year. The many flowers lead to a high number of small fruits that won’t be accepted on the market. Endogenous factors (phytohormones and carbohydrate allocation) subsequently suppress the development flower buds which finally establishes the biennial cycle. The alternate bearing cycle can be managed by reducing excessive flowers. In early days, this was done manually. In today’s commercial apple production famers are using either chemicals or mechanical actuators.

The first commercial mechanical thinning system DARWIN® by Fruit-Tec has been available since 2007. It is composed of a vertical rotating spindle and 60 cm strings attached to it. Mounted on a tractor the unit is driven along the tree rows and a proportion of flowers is pruned by the strings. Working with velocity of up to 15 km/h commercial growers can manage several hectares per day. The system has been sold worldwide. However, handling of the system requires an experienced driver. In addition, it is not possible to consider the individual flower density of a tree and its last year’s yield.

It was the intention of the OptiThin project, which has started in 2009, to tackle these issues in order to promote mechanical thinning. The idea was, to achieve optimum thinning intensity by controlling the rotation speed of the actuator using sensors and an on-board decision support system. At the same time, the spacing between the trees and the mechanical thinning device should be automatically adjusted in order to relieve the operator (Fig. 1).

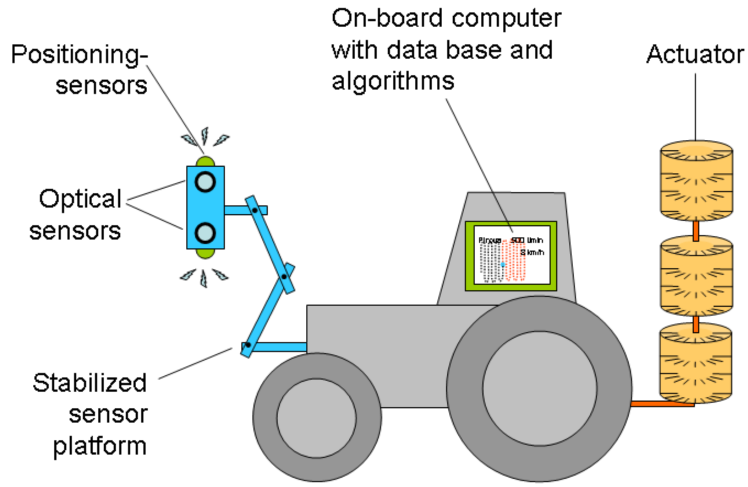

Fig. 1. Sketch of the OptiThin system for tree-specific mechanical thinning of apple trees

SYSTEMS DESIGN

Estimation of flower density by a 3D camera

Within the framework of the OptiThin project a stereo camera and software was developed for counting flowers several times a second while driving along the tree rows. The stereo information from the 3D-camera is required to separate flowers on the trees in the foreground from flowers on trees in the background. With GPS coordinates collected at the same time the estimated flower density can be attributed to every tree.

Shock absorption for better imagery

While the 3D-camera is placed at the front of a tractor, it is exposed to severe vibrations and shocks. A dedicated active camera mount was designed to absorb most of these disturbances. This could substantially improve the quality of the 3D images and the performance of the flower counting algorithm.

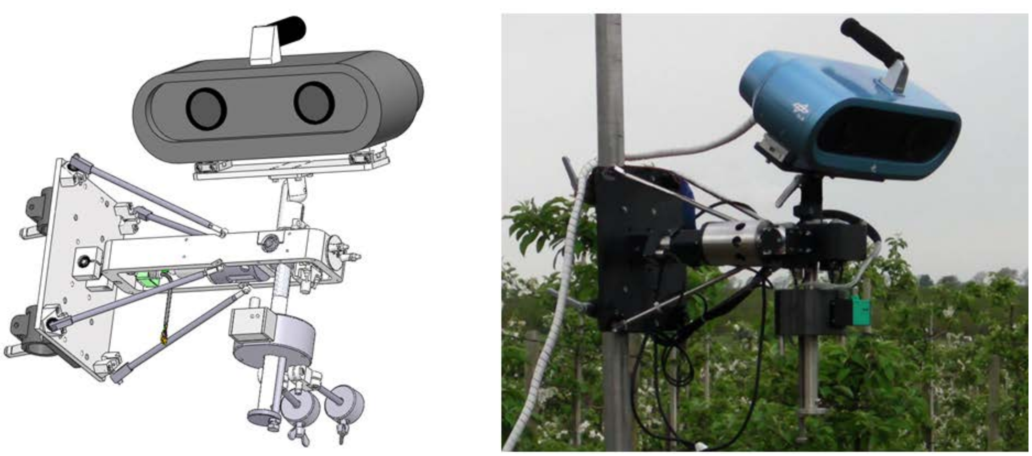

Fig. 2. 3D-camera and mount with shock absorbers

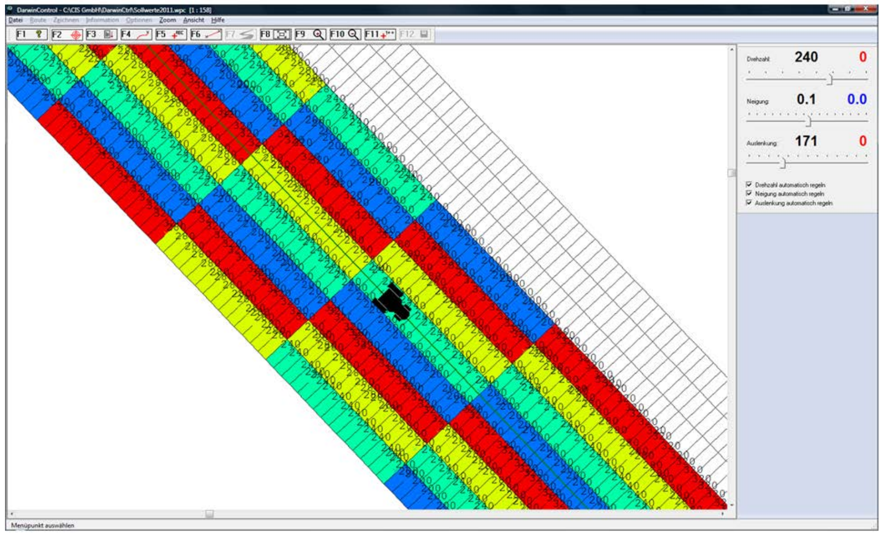

Fig. 4. Prescriptive thinning intensity specified for each tree. Screen shot of the on-board software DarwinControl (CiS Inc.)

Mobile tree-related data management and thinning control

Flower densities, as estimated by the 3D camera, need to be transformed into control commands. This task is accomplished by a mobile geographic information system (GIS) in the drivers cab (Fig. 4) called DarwinControl. The GIS also provides ancillary data such as previous yields and soil fertility indices.

Decision on optimum thinning intensity

Decision rules on thinning intensity were developed by means of three years on-farm experimentation in the growing region of Werder near Berlin, Germany. Apple cultivars under consideration were ‘Elstar’ and ‘Pinova’. Both cultivars are important for the European market. ‘Elstar’ is well known for strong alternate bearing. For determining the optimum thinning intensity current flower density, soil fertility, and last year’s yields have to be regarded as inputs (Fig. 5).

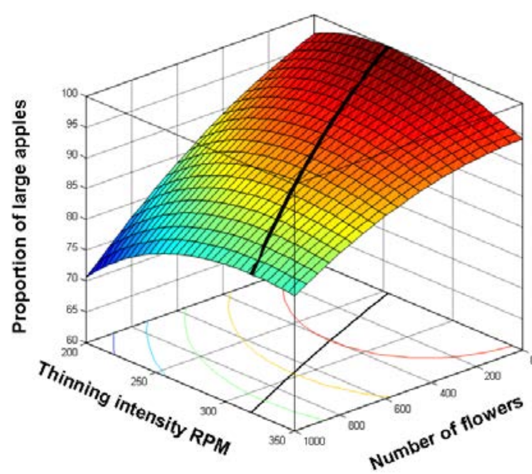

Fig. 5. Model of the proportion of large apples (‘Elstar’) depending on the number of flowers per tree and thinning intensity. The black line prescribes the optimum thinning intensity depending on the number of flowers

Fig. 6. Adaptive mechanical thinning unit; a) tilted and b) upright position

Adaptive mechanical thinning

The mechanical thinning unit DARWIN® was further developed by Fruit-Tec. The enhanced unit provides permanent control of thinning intensity and dynamic adaptation to the shape of the trees. The latter is achieved by changing the unit’s tilt and lateral shift (Fig. 6).

RESULTS

The OptiThin system reduces flowers efficiently while the trees are left unharmed (Fig. 7). In spring 2011, a first prototype system, which includes all components, was assembled. Due to limitations in data processing speed at that time, the camera system was not able to provide estimates of blossoms in real-time. Nevertheless, results from post-processing the data were promising. Later, in fall 2011, we were able to accomplish stereo image analysis in real time in laboratory experiments.

Fig. 7. Apple flowers before (a) and after (b) mechanical thinning by the OptiThin system

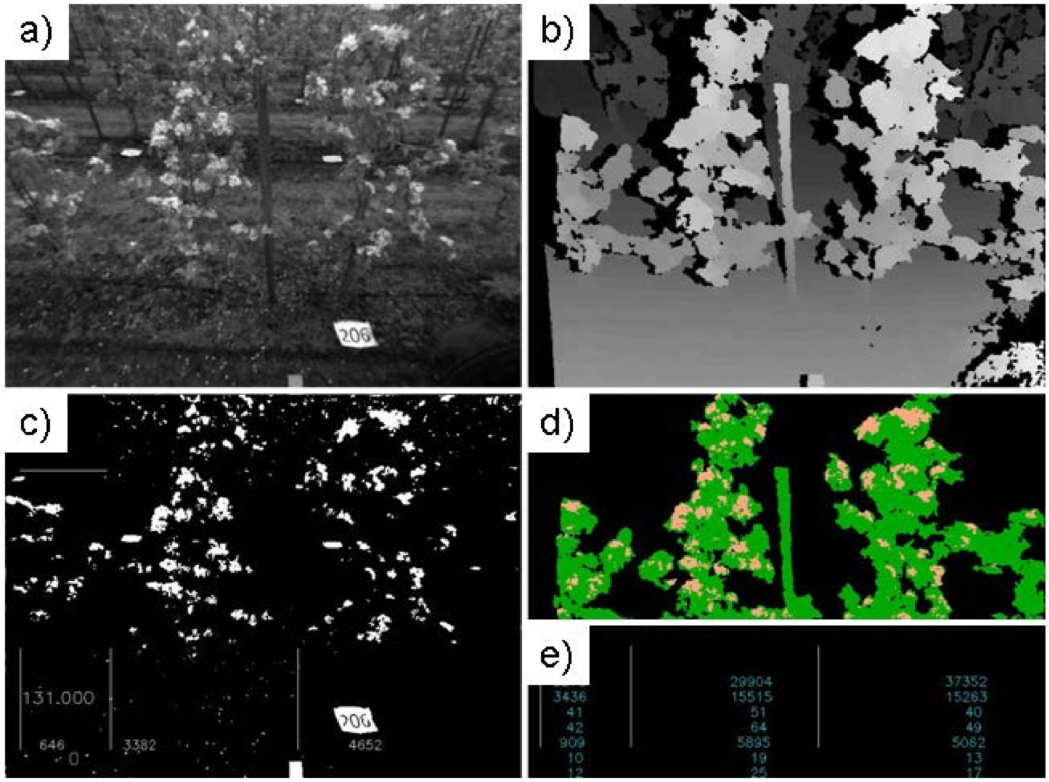

Fig. 8. Image data generated by the 3D-camera (DLR) for assessing tree-specific flower density: a) original image, b) calculated distances, c) extraction of white objects, d) assignment of objects and position e) numerical output

During the experimentation in spring 2011, the actuator was controlled by a prescriptive map which was stored and evaluated by the on-board software DarwinControl (Fig. 4). This was working very well. The average apple weight and the average apple diameter were influenced by the thinning intensity. The overall optimum was about 280 rpm for ‘Elstar’ and a little bit higher for ‘Pinova’ (Fig. 9). Looking specifically at each tree, it was demonstrated that adaptive thinning – according to the number of flowers – improved the yield (Fig. 5).

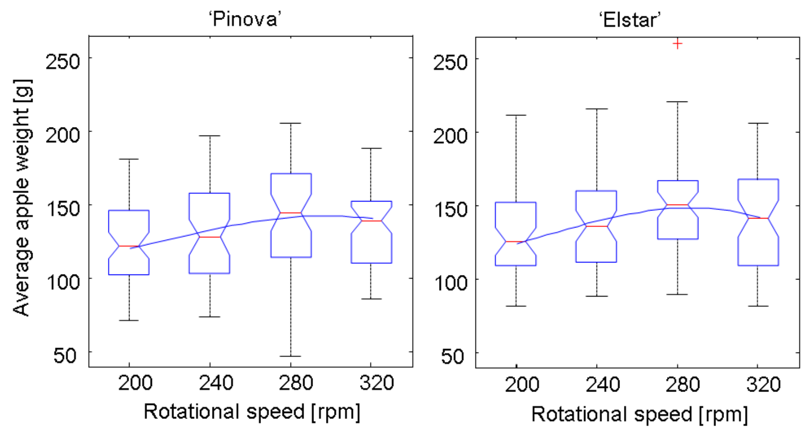

Fig. 9. Influence of thinning intensity (rotational speed) on the average apple weight

CONCLUSIONS

OptiThin takes a promising approach to improve apple yield and quality in an eco-friendly way. This camera based system allows – for the first time – automated tree-specific thinning of flowers in commercial fruiticulture. It achieves a thinning quality that is comparable to manual thinning. Consequently, yield variability is minimised while the proportion of marketable fruits is increased.

The next steps will be to test and further develop the sensor based estimation of flower densities. In particular, this will include FPGA programming in order to increase the speed. Tests have to be carried out with other apple cultivars and under different environmental conditions.

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