Resilient Forests Programme

Nursery Automation: Interim update

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Nursery Automation - Interim project update

Background

Production nurseries across New Zealand face labour shortages and pressures to reduce inputs such as pesticides and herbicides. At the same time, nurseries are likely to need to increase total production to meet an expected increase in demand for new plantings.

Scion has invested heavily in a state-of-the-art research nursery with the goal of achieving a high level of automation; however, this investment is focused towards advancing research capabilities and pioneering and demonstrating new methods for adoption in commercial nurseries. Scion's researchers have recognised that there are also substantial opportunities to apply advanced sensors and technologies to automate aspects of production in existing nurseries growing outdoor bare-root or containerised seedlings. The current research aims to address three key objectives of interest to commercial nurseries:

Objective 1: Automate radiata pine seedling counts at scale using computer vision techniques for New Zealand commercial nurseries.

Objective 2: Develop a radiata pine seedling growth/height estimation model using stereo camera imagery.

Objective 3: Write a work plan to extend the trial into a commercial seedling bed within 2020.

These objectives are being addressed through a trial hosted in Scion's nursery to test and develop methods addressing these objectives, with a view to developing technology that is ready for delivery to the industry. This report presents an interim update on the project including the methodology, trial layout, and early testing.

Progress update

Trial location and layout

Scion has established a test crop of cuttings for the purposes of this study. The cuttings were set in the 2019 season and covered in frost cloth until November of the same year. The layout and management regime used on these beds is close to that used in most bare-root production nurseries (Figure 1). The majority of the in-field sensor testing will be carried out within these trial beds. A total of 36 permanent measurement locations have been established at fixed intervals within the beds. Each location is marked and numbered using stakes that will be visible to all the sensors used in the trial. At each measurement location, the eight seedlings within each row have been marked for re-identification. A custom-machined measuring board will be placed behind the seedlings in each row to allow individual seedling heights to be rapidly assessed and recorded. Measurements will be repeated at least monthly until the crop is lifted and these data will form the ground-truth measurements against which the sensor-based measurements will be compared.

Figure 1: Trial beds containing cuttings for sensor testing at Scion’s nursery.

Objective 1

In this objective, we aim to develop a means of rapidly measuring seedling height within an entire bed of seedlings. This will allow growth to be accurately monitored with a view towards removing the need for topping to achieve crop uniformity. In addition, these measurements can be used to assess performance of different crops and regimes within nurseries. Scion has demonstrated that methods based on photogrammetry can be used to assess height, but this approach requires relatively expensive input data (high-resolution, high-overlap UAV orthomosaics). New methods based on advances in sensors and computer vision offer the potential to perform rapid, in-field assessment of crop height.

Scion has purchased two affordable camera systems that offer direct depth estimation alongside traditional imagery capture (RGB+D). The first camera is the Intel RealSense D435i depth camera (Figure 2, A).

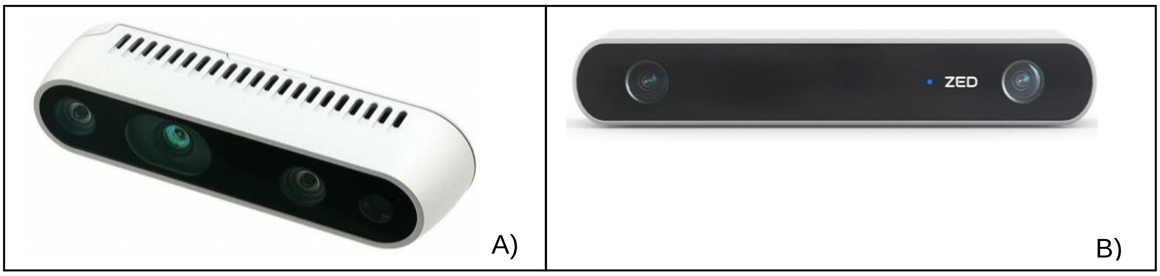

Figure 2: A) Intel RealSense depth camera based on infra-red stereo vision. B) Stereolabs ZED depth camera based on visual-inertial SLAM.

The camera specifications (Table 1) allow high-resolution imagery to be captured alongside accurate depth estimates at up to 10 m using stereo-enabled vision. The second camera is the Stereolabs ZED camera. This system uses a fundamentally different approach based on visual-inertial SLAM (Figure 2, B).

A newly released time-of-flight based sensor (Azure Kinect) is also being considered; however, the device has market-leading performance and its popularity has made it hard to acquire.

Table 1: Summary of depth cameras selected to measure seedling growth.

	Intel RealSense D435i	Stereolabs ZED
Depth range	0.11 – 10 m	0.5 – 20 m
Max resolution	1920x1080	4416x1242
Max frame rate	30 fps	100 fps
Technology	Active IR stereo	Visual Inertial SLAM
Output	RGB+D	RGB+D
Est. Price	NZ$350-400	NZ$800

The cameras have been calibrated and configured and the first set of measurements are due to be taken alongside the ground-truth measurements in late November / early December. The cuttings laid out in the trial beds are currently dormant, as their growth increases over summer we will consider the option of increasing the measurement frequency to increase the resolution of the growth curve and test the sensitivity of the depth cameras to smaller growth increments.

In terms of ground-truth data, the first UAV data capture was performed in late November and the ground-truth measurement board has also been fabricated and is being used to capture ground-truth heights. This work will be completed before the end of November / early December. The slow growth of the seedlings permits some time gap between the different measurements planned, but we will move towards a co-ordinated capture of all data within a few days as the growth rate increases.

Figure 3: Measurement board for rapid, accurate measurement of seedlings in a row.

Objective 2

A previous UAV data capture (funded by Scion's SSIF) on the 2018/2019 seedling crop grown in Scion's nursery has allowed us to begin work on objective 2 before the current crop is ready. The goal is to be able to detect and count seedlings without the need for orthomosaic generation (high-overlap UAV imagery). Instead, we are focusing on counting seedlings from nadir-facing video footage acquired from a low-cost UAV. A workflow has been developed to export imagery from the video and rapidly stitch the images together to cover an entire seedling bed. The images are cropped, matched and mosaiced using the PTGui image stitching software package purchased by Scion for this task.

The proposed approach will use the RCNN-based detection algorithms e.g. Faster / Mask-RCNN. This family of algorithms are based on data-hungry deep learning methods and a major challenge will be to develop a suitable training dataset from such limited data capture. Data annotation consisting of outlining individual seedlings and this task has been carried out on the first batch of test data (Figure 4). This work has generated several hundred training examples, but this is well short of the target of several thousand examples. The next step in the programme will be to explore the use of data augmentation approaches to 'synthesise' additional training data. In addition, we will acquire and annotate new data from the current crop and other beds containing comparable seedlings once the growing season is well underway.

Figure 4: Densely annotated training data from previous data captures used to train seedling detection models.

Objective 3

This objective has not been started yet. Ideally, we would like to test both the automatic counting approach as well as the height assessment methods with a commercial nursery partner. Pending positive outcomes from the early phase of the project, we will select and approach a commercial nursery to develop a plan for future testing and development.

Conclusions

The project is well underway now and the initial datasets are set to be captured by mid-December. There are likely to be some technical challenges to work through before the measurement protocol is finalised. Some of the data processing has already been started using existing data and this work has gone well. The methods developed can be applied to incoming data to rapidly expand our training dataset as the new crop grows. We are on-track to have high-quality data for Objectives 1 -2; however, the final months of the project may be challenging as we will collect the last set of measurements with very little time before project wrap-up. We will re-assess the impact of the condensed timeline once we have interim results (mid-April) and engage with FGR if any changes are needed to the project timeline.