A preliminary field evaluation of an automated vision-based plant geometry measurement system

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Introduction

Machine vision is commonly reported for use in automated plant-based applications such as growth monitoring, stress detection, species identification and fruit harvesting. Geometric measurement of living plants using machine vision commonly requires depth perception, which typically entails establishing correspondence between multiple images. The complexity of such a task in an unstructured environment, such as foliage, often restricts automation of the process.

Automated measurement of the geometry of young plants has been reported using laser range finding and image processing (Kaminuma et al. 2004) or multiple camera views (Lin et al. 2001). Noordam et al. (2005) compared automated methods of locating the main stem of a rose plant using methods including stereo imaging, structured lighting and X-ray imaging, while Ivanov et al. (1995) reported using stereovision and a manually-operated 2D digitiser to model a maize canopy. However an automated vision system for measuring geometry of complex plants in the field is yet to be reported.

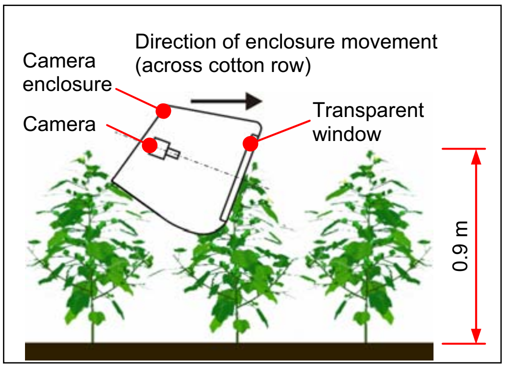
Plant geometry is a significant factor for irrigation purposes in cotton because the distance between main stem nodes indicates water stress in a growing cotton plant. However, manual measurement of internode length is a tedious task for even a small number of plants. An automated method for large scale measurement of plant geometry in the field would provide information about crop irrigation requirement as well as spatial and temporal variability in crop stress and growth.

This research aims to develop a real-time and automatic machine vision sensor for measuring structural parameters such as internode length for plants in a growing cotton crop.

Field measurement apparatus

A camera enclosure which continuously traverses the crop canopy was designed and constructed for field measurement of plant geometric parameters (Fig. 1a). A camcorder mounted within the enclosure was positioned such that the camera's image capture area corresponded to a transparent panel at the front of the enclosure. The camera enclosure makes use of the flexible upper main stem of the growing cotton plants to firstly contact the plant against the transparent panel, and then smoothly and non-destructively guide the plant under the curved bottom surface of the enclosure. When the plant's main stem contacts the transparent panel, the transparent panel becomes a fixed object plane from which reliable 2D geometric data can be derived. Fig. 1b contains a stylised sample image captured from the enclosure.

In the field the camera enclosure was suspended from a gantry above the cotton rows. Two different prototypes of camera enclosure conveyance gantry were used, featuring manual and automatic conveyance of the camera enclosure.



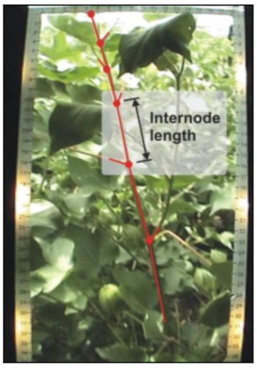


Fig. 1. (a) Image capture apparatus; and (b) stylised sample image from camera enclosure.

Collected datasets

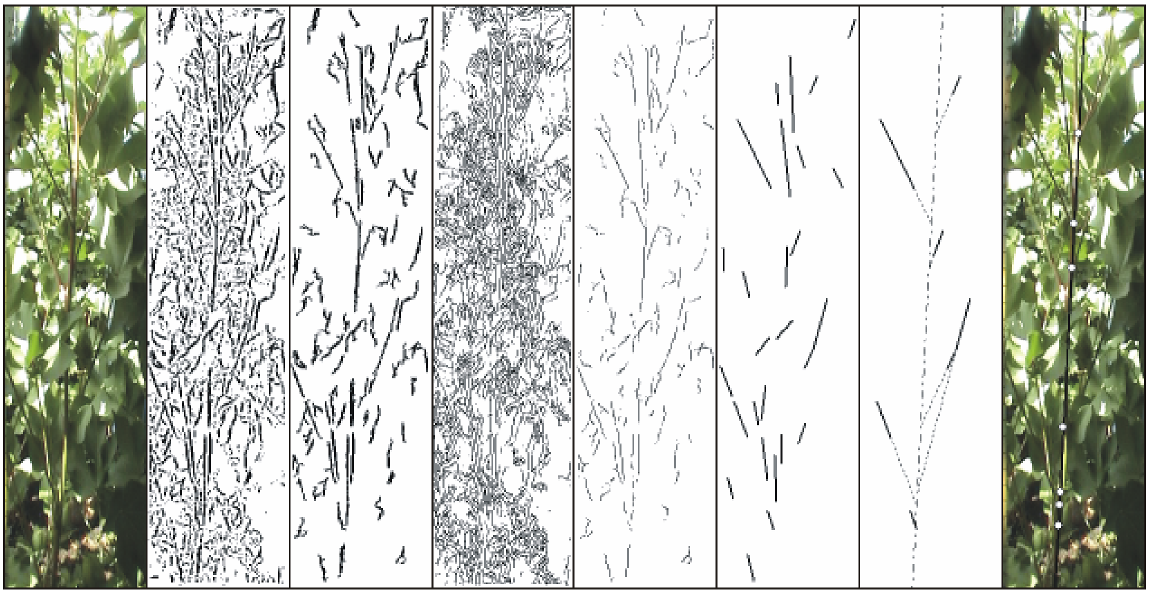
Video sequences of cotton plants were collected throughout the 2005/2006 and 2006/2007 cotton growing seasons. Each video sequence consisted of a single pass of the camera enclosure over a target plant. In fifteen data collection sessions the following parameters were varied:

- time of day, i.e. morning, afternoon and night;
- cotton variety (six in total);
- plant growth stage;
- illumination scheme on camera enclosure (artificial or natural light);
- capture of near infrared/visible light images by use of narrowband optical filters and illumination;
- narrow or wide depth of field about the camera enclosure's transparent window;
- camera enclosure approach angle and orientation and movement down and across rows;
- speed of camera enclosure movement through crop canopy.

Each data collection session featured typically 13 to 16 plants. Manual measurements of plant height as well as internode distance and stem diameter were recorded for the top five nodes of each plant targeted by the vision system. Plant topological features significant for cotton growth and development (e.g. nodal positions of flowers and fruiting structures) were also measured.

Image processing

The initial image processing algorithm development focused on automated measurement of internode length. The internode length measurement algorithm featured two steps. In the first step, candidate nodes were identified from single frames, then in the second step, falsely identified nodes were eliminated by analysis of node trajectories throughout a sequence of frames. The basis for the two-step algorithm was that true nodes could be tracked throughout a video sequence whereas false positive nodes, which were transient in nature, could not be tracked. Typical results for candidate node identification are shown in Fig. 2. The image processing results yielded a correlation coefficient of 0.92 for fourteen measurements of internode length. Analysis of computational requirements indicates that the image processing algorithm could be executed in real-time.



(a) (b) (c) (d) (e) (f) (g) (h)

Fig. 2. Automated image processing steps for single frame analysis: (a) region of interest in sample image; (b) likely line pixels; (c) likely branch pixels; (d) line centre points; (e) branch centre points; (f) lines fitted to *e*; (g) likely branches projected to main stem; and (h) identified candidate nodes represented by white discs.

Conclusions

The feasibility for real-time, automated measurement of cotton plant geometric parameters has been demonstrated. Extensive video footage datasets have been collected to enable evaluation of image processing algorithms under a variety of environmental conditions.

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