APPLIED MACHINE VISION IN AGRICULTURE AT THE NCEA

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ABSTRACT

Machine vision involves the use of cameras and other imaging technologies to automatically extract information from a two-dimensional representation of a real-world scene. The technology has the potential to reduce resource usage and increase productivity in agricultural applications by performing repetitive and labour-intensive tasks that are conventionally carried out manually by humans.

The National Centre for Engineering in Agriculture (NCEA) is conducting machine vision research projects that aim to improve productivity for a range of agricultural processes in a changing economic climate. These projects include:

- Macadamia yield monitor: Automated yield assessment of individual trees in macadamia plantations is expected to reduce labour costs of varietal trials by 59%. The NCEA has developed and evaluated vision-based automated yield assessment systems featuring counting of macadamia nuts in a pinwheel harvester.
- Grading of fodder quality: A field prototype for automatic grading of hay samples has been developed that aims to save labour and enable development of repeatable scoring standards that may be implemented throughout the fodder industry.
- Body condition scoring of cattle: Cattle condition sensing developed by the NCEA has potential use in automatic drafting and informing management decisions on cattle properties.

An overview of the NCEA's machine vision research activities and their implications will be presented.

Keywords: Automation, image processing, yield monitor, quality assessment, macadamia, fodder, body condition scoring.

INTRODUCTION

Precision technologies are playing an increasing role in agriculture to optimise resource usage whilst maximising production. Manual routine tasks in agriculture that involve visual assessment, including quality or condition grading of produce and yield harvesting and estimation, are potentially highly repetitive and labour-intensive. Imaging sensors (e.g. cameras) provide a mechanism by which real-world scenes that are typically visually assessed can be interfaced with a computer potentially capable of performing analysis and determining conditional post-processing actions (such as automatic quality grading or cattle drafting). The NCEA (National Centre for Engineering in Agriculture) is developing machine vision technologies for several applications, including a macadamia yield monitor, fodder quality assessment and cattle condition scoring, which have the common potential benefits of saving labour and costs to industry while offering consistent and repeatable performance over extended periods in respective tasks.

MACADAMIA YIELD MONITOR

Varietal assessment trials in the macadamia industry require yields of individual trees in a macadamia plantation to be measured. Currently macadamia nuts are hand collected and tagged for each tree in a labour intensive task that potentially necessitates additional casual staff. Mechanised harvesting is estimated to potentially enable cost reductions in varietal trials up to 59% for growers and researchers (Hardner, 2005).

Macadamia harvester yield mapping tools

Commercial macadamia harvesters feature a pinwheel that picks up nuts as the pinwheel traverses the ground (Figure 1). As the pinwheel rotates, collected nuts are dislodged from the pinwheel and are conveyed to a collection chamber. A vision system featuring a camera mounted above the pinwheel was used to detect and count nuts accumulated in the pinwheel. Yield mapping tools for the macadamia harvester were also developed by the NCEA and included GPS, a camera mounted on the side of the harvester to view and estimate location of parent trees (Treecam) and a radar odometer to determine the harvester groundspeed. A software interface with Google Earth was developed.

Figure 1. Pinwheel harvester with yield mapping sensors.

Vision-based nut detection in pinwheel harvester

The vision system for nut detection consisted of a pinwheel that was custom-dyed blue to provide colour contrast with the nuts that were either brown (dehusked) or black or green (husked) (Figure 2). The principal design requirement for the image analysis software was real-time identification of nuts on the pinwheel. The blue pinwheel enabled effective segmentation of the background based on colour such that non-background areas (e.g. nuts) could be identified. However, both nuts and trash (e.g. twigs and leaves) were picked up by the pinwheel and were identified as non-blue objects. Therefore, size checking was required to ensure trash was not counted as nuts, since picked up nuts were typically physically smaller than trash.

Figure 2. Vision-based macadamia yield monitoring: nuts lodged in pinwheel (*left*) and camera between two lights on the harvester (*right*).

Field trials were conducted in Beerwah in mid 2007 to assess the measurement system mounted on the commercial harvester. The initial trials found that the system achieved detection rates of 80% and 86% for green and brown nuts, respectively, but that the detection rate for black nuts was 58%. The variation in detection rates was believed to be due to shadowing on the pinwheel.

Further trials were conducted at Bundaberg and the NCEA in mid 2008 with the pinwheel mounted in a small motorised chassis and the camera and pinwheel enclosed in black canvas for constant lighting and image colour contrast. The trial sites were prepared with varying trash levels and nut spacings. The trials established that the developed colour- and shape-based image analysis techniques were not effective for counting nuts at high density, random nut spacing (Table 1). By inspection of collected video, this was determined to be due to a nut 'pooling' effect in which individual nuts picked up in adjacent pins were misclassified as a large piece of trash by the image analysis algorithm.

Number of nuts	Nut spacing description	Nut spacing (nuts/m^2)	Harvester pick-up rate (%)	Count rate (%)
75	Low density, randomly spaced	21	98.9	95.1
85	High density, equally spaced	49	98.3	96.4
85	High density, randomly spaced	49	98.8	77.9

Table 1. Nut detection using colour-based algorithm, averaged over five replicates for a harvester groundspeed of 2 km/h and different nut spacings.

A new approach using structured lighting was developed to overcome the pooled nuts problem. Structured lighting is the projection of a light pattern onto an object such that object's shape may be inferred when the reflected light pattern is viewed at an angle. A focused line of light from a LED strip light was projected onto the pinwheel and yielded images in which the tips of pins were represented as small circles, nuts as crescents and trash as irregular shapes (Figure 3). The camera (Logitech Quickcam Pro 9000) was mounted 500 mm above the light source and the camera and pinwheel were enclosed in black canvas so that the principal light source in the image was the LED strip light. The reflected light pattern of adjacent nuts formed distinct shapes and hence, nut pooling did not occur.
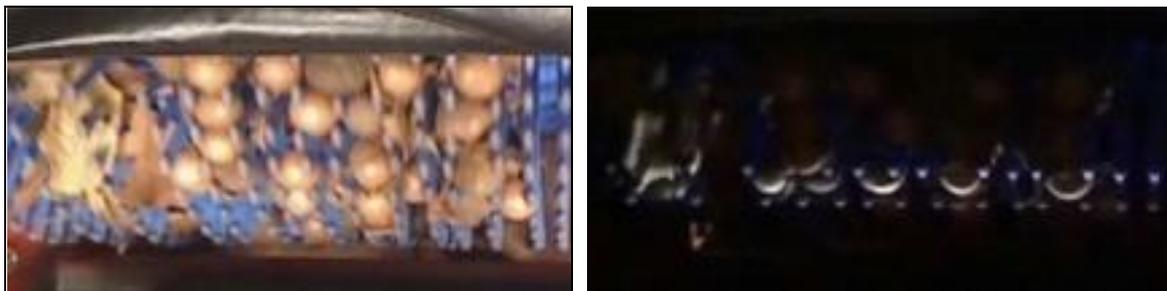

Figure 3. Corresponding images of the pinwheel under uniform (*left*) and structured (*right*) lighting.

Results for preliminary trials conducted with the structured lighting system are included in Table 2. The trials consisted of high density nut spacing and included trash. The preliminary results demonstrated that the nut detection system was effective when the harvester was operated at a groundspeed synchronised with the camera's frame rate, i.e. when each frame featured a unique pinwheel row. The recommended groundspeed was calculated to be 2 km/h. Lower speed caused over-counting of nuts whilst higher speed caused under-counting of nuts. Potential further research includes finalising the nut detection methods and commercial-scale trials.

Harvester groundspeed	Count rate (%)
Twice recommended harvester groundspeed (4 km/h)	56
Recommended harvester groundspeed (2 km/h)	93
Half recommended harvester groundspeed (0.5 km/h)	185

Table 2. Nut detection rates using structured lighting, averaged over five replicates for different harvester groundspeeds and high density, random nut spacing.

FODDER QUALITY ASSESSMENT

The fodder industry presently does not have a uniform colour grading system and fodder is manually graded based on the relative amounts of red and green hues visible in the hay. Fodder colour indicates quality and higher quality fodder raises a higher price. Automated fodder quality assessment will potentially enable a unified and repeatable grading system in the fodder industry and has potential use as a tool to aid growers in determining when to commence baling for optimum bale quality. This project aimed to develop a vision-based fodder grading system that was repeatable and which delivered a colour grading that followed the trend of the manual grading process. A further research aim was added to investigate the potential for vision-based weather (i.e. rain) damage detection due to the prevalence of weather damaged fodder in the 2008 season.

Image analysis algorithms and lighting

Colour grading

Fodder colour grades range from 30 (low quality) to 60 (high quality) with lower quality fodder exhibiting red hues and higher quality fodder exhibiting green hues. An image analysis algorithm was developed that classified pixels as green or red and calculated the ratio of green and red pixels in the image to obtain the final colour grade. Colour classifications of shades of green and red were set from calibration cards which enabled the colour grading algorithm to be less parameterised. Yellow-diffused light was found to enhance the contrast between the green and red hues.

Weather damage assessment

Weather damage in hay samples is indicated by yellow rain stains and blackened fungal spores and is classified into levels of slight, moderate or heavy. Detection using visible colour was found to be difficult in initial investigations due to the similarity in appearance between dark damaged areas and dark shadowed areas in images of hay samples. Therefore, infrared lighting of weather damaged hay samples was investigated.

Vegetation typically has a high reflectance in the near infrared wavelengths and it was considered possible that the infrared reflectance of hay samples may vary as a result of weather damage. Hence, images of undamaged and weather damaged hay samples were captured using a light source of wavelength 850 nm (Figure 4). By inspection of images of weather damaged hay, weather damage causes lower reflectance, i.e. the weather damaged hay appears darker overall than the undamaged hay. Therefore, a weather damage detection algorithm was developed which calculated the proportion of dark pixels in the hay sample infrared images.

Automated vision-based grading system

A portable fodder quality assessment system was developed to automate the grading process (Figure 5). The measurement system consisted of a durable aluminium carry case that housed a camera (Logitech Quickcam Pro 9000), artificial lighting and a rectangular plastic tub (volume 1 L) in which hay was placed for imaging. Images were captured with the carry case closed so that the lighting environment could be controlled. Software written in Borland Delphi Version 6.0 was executed on a personal computer to analyse images from the camera in real-time (i.e. on the spot).

Lighting was provided by infrared LEDs (850 nm) and white LEDs with a yellow diffuser board. After the user issued a 'capture image' command on the computer, each light source was powered on for a short period of time while an image frame was captured for each light source. The colour grading image (yellow light) was used to calculate the proportions of green and red pixels according to the thresholds set from the calibration cards. The weather damage image (infrared light) was used to calculate the percentage of image pixels that were darker than a value expected of a healthy hay pixel. Using the developed technology, automated colour grading that followed the trend of the manual grading process was achieved and automated weather damage assessment was successful. The technology is presently being evaluated by Balco Australia.
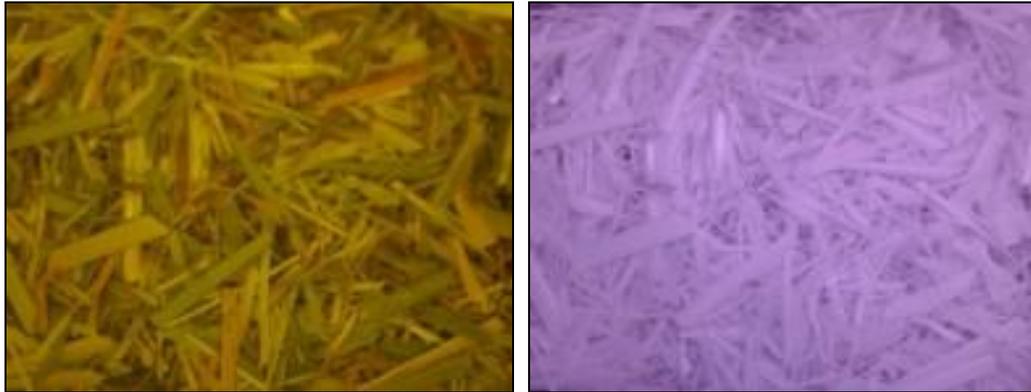
Figure 4. Hay images captured under yellow (*left*) and infrared (*right*) light: (a) undamaged grade 33; (b) undamaged grade 60; (c) slight weather damage; and (d) heavy weather damage. Higher grade samples appear greener in the colour image and heavier weather damage appears darker in the infrared image.

Figure 5. Fodder imaging carry case for quality assessment. *Inset*: **Calibration cards used to set image analysis thresholds for colour grading with tubs of grade 60 hay (*top*) and grade 33 hay (*bottom*).**

CATTLE CONDITION SCORING

In a joint project with the University of Queensland, research has commenced into machine vision estimation of cattle weight and condition score. A trial site has been established near Yelarbon, Queensland featuring 100 head of cattle. The cattle pass imaging equipment approximately daily on their way to water and collected data is referenced with cattle eartag information. The imaging apparatus comprises multiple cameras viewing laser patterns projected onto the animal, such that shape information for the animal may be collected as the animal moves through the laneway. The laneway is depicted in Figure 6. Preliminary results indicate effective description of animal shape in acquired imagery for different coloured animals and different daylight conditions. Further analysis will enable comparisons with animal weights and manually-determined condition scores. Potential outcomes of the project include automatic drafting and informing cattle management decisions.

Figure 6. Apparatus for vision-based cattle condition scoring.

CONCLUSION

Machine vision has a wide range of applications in agriculture and may potentially be incorporated into portable tools (e.g. fodder quality assessment), moving agricultural vehicles (e.g. macadamia

yield monitor) or fixed structures on properties (e.g. cattle condition scoring). The NCEA's vision projects offer potential labour savings to growers and researchers whilst enhancing productivity.

Reference

Hardner, C. (2005) Cost of manual and mechanised yield assessment, Technical Report, Chapter 3, CSIRO.

Acknowledgements