The University of Southern Queensland

USING A REMOTELY CONTROLLED PLATFORM TO ACQUIRE LOW-ALTITUDE IMAGERY FOR GRAIN CROP MAPPING

A Dissertation submitted by

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Dedication

To my Mother, the motivation behind my education

Abstract

Agricultural crops exhibit within-field spatial variation. This variation partly results from relevant bio-physical and environmental factors that influence the crop during the growing season. The plant integrates the effects of nutrition, water, pests and disease, and displays the results in the foliage. Remote sensing techniques allow the foliage to be monitored and the crop status to be assessed.

While the use of conventional remote sensing systems has found many applications in agriculture, it is constrained by a number of issues and problems related to spatial resolution, repeat cycle, minimum area acquired, timeliness of data, etc. Thus, this research explores the potential of developing and assessing low-cost sensing technologies to overcome these limitations. The specific objectives were to: a) identify, evaluate, and analyse the different options for a low-cost low-altitude (LCLA) remote sensing system that has potential for precision agriculture, b) develop a LCLA remote sensing system that is appropriate for use in mapping selected crop attributes (i.e. grain protein, yield, maturity and crop type), and c) evaluate the accuracy of classification and prediction of the cereal crop attributes.

A low-cost sensor system was developed that incorporated two consumer digital still cameras. One camera captured the colour portion of the spectrum, while the other one (with the addition of a band-pass filter) captured the near infrared light. Both cameras were modified to be remotely triggered and externally powered. This sensor arrangement utilised 1.0 megapixel cameras in the earlier investigations and then 5.0 megapixel cameras in most recent missions. The sensors were equally well suited to mounting on a remotely controlled aircraft or suspended beneath a helium balloon.

Various approaches were taken to determine and evaluate the relationships between imagery and crop attributes. Statistical methods included the use of correlation and discriminant function analysis, along with partial least squares regression. Image analysis techniques included the use of both pixel-based

(supervised approach) and object-orientated (multi-resolution segmentation) classifications.

The results showed that low-cost low-altitude remote sensing systems (incorporating consumer digital cameras with helium balloons or remotely controlled aircraft) have great capacity to quantify variability in cereal grain crops. Excellent relationships were found between the 'at-harvest' yield (R^2=0.902) and protein content (R^2=0.660) of wheat using a single image recorded at flowering. Partial least squares regression, using the cross-validated approach, produced a stronger relationship with a prediction accuracy of 94.2% for yield and 88.5% for protein. This relationship exceeded all other studies reported in the literature.

The same LCLA system has also accurately discriminated (using statistical methods) between: a) different nutrition levels in a wheat crop with 75.6% of the cases correctly classified, and b) between different cereal grain species (with differing nutrition levels) with 86.3% accuracy. These classification accuracies are comparable with, or exceeding other more expensive and/or complicated methods. Attempting to discriminate using image analysis procedures, the pixel-based methods yielded an overall accuracy of 65.9% when classifying cereal grain crop species comprising of nine classes. When merged to six classes, the accuracy improved to 82.1%. Using an object-orientated approach has improved the overall accuracy to 81.0% for the nine-category classification. This study also demonstrated LCLA's ability to assess the various growth stages of a barley crop prior to maturity with 83.5% of cases correctly classified.

This study concluded that it is feasible to accurately assess selected cereal grain crop attributes using low-cost consumer technologies. The accuracies achieved using this system were comparable with, or exceeded, other reported studies that used more complicated and expensive sampling systems. Further work is needed to continue refining the initial work on a fully autonomous unmanned aerial vehicle (UAV) started in the later part of this study, to extend the use of the LCLA system into broader scale applications.

Certification of Dissertation

I certify that the ideas, experimental work, results, analyses, software and conclusions reported in this dissertation are entirely my own effort, except where otherwise acknowledged. I also certify that the work is original and has not been previously submitted for any other award, except where otherwise acknowledged.

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Signature of Candidate Date

ENSORSEMENT

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Signature of Supervisor Date

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Publications

Published International Journal

Jensen, TA, Apan, A, Young, F & Zeller, LC 2007, 'Detecting the attributes of a wheat crop using digital imagery acquired from a low-altitude platform', *Computers and Electronics in Agriculture*, vol. 59, no. 1-2, pp. 66-77.

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Abbreviations

AGL ..... Above ground level
AMSA ..... Australian Maritime Safety Authority
ANOVA..... Analysis of variance
AOI ..... Area-of-interest
ARCAA..... Australian Research Centre for Aerospace Automation
ASTER ..... Advanced Spaceborne Thermal Emission and Reflectance Radiometer
B ..... Blue
BSD ..... Best separation distance
CASA..... Civil Aviation Safety Authority
CCD..... Charged couple device
CF..... CompactFlash
CIR ..... Colour infrared
CMOS..... Complementary metal–oxide semiconductor
DA ..... Discriminant function analysis
DAS ..... Days after sowing
DC ..... Direct current
DGPS ..... Differential GPS
DN ..... Digital number
DPI&F..... Department of Primary Industries and Fisheries (Queensland)
DVI ..... Difference Vegetation Index
G..... Green
GCP..... Ground control point
GIS ..... Geographic information system
GLCM ..... Grey level co-occurrence matrix
GNDVI ..... Green Normalised Difference Vegetation Index
GPS..... Global positioning system
GRDC..... Grains Research and Development Corporation
JPEG ..... Joint Photographic Experts Group
LCLA ..... Low-cost low-altitude
LED ..... Light emitting diode
ML ..... Maximum likelihood
NASA..... National Aeronautics and Space Administration
NDVI..... Normalised Difference Vegetation Index
NiMH ..... Nickel-metal hydride
NIR ..... Near infrared
NIRB..... Near infrared detected with the blue sensor
NIRG ..... Near infrared detected with the green sensor

NIRR..... Near infrared detected with the red sensor
NOTAM ..... Notice to airmen
PA..... Precision agriculture
PCI ..... Peripheral component interconnect
PCMCIA ..... Personal Computer Memory Card International Association
PLS..... Partial least squares
PPR ..... Plant pigment ratio
PSRI ..... Plant Senescence Vegetation Index
QUT..... Queensland University of Technology
R..... Red
RCA..... Remotely controlled aircraft
RGB..... Red-green-blue
RMS ..... Root mean squared
RMSEP..... Root mean squared error of prediction
RTK ..... Real-time kinematic
RVI ..... Red Ratio Vegetation Index
SIPI..... Structure insensitive pigment index
SLR ..... Single lens reflex
SSCM ..... Site-specific crop management
TARMAC ..... Toowoomba Amateur Radio Model Club
TM ..... Thematic mapper
UAV ..... Unmanned aerial vehicle
UQG ..... University of Queensland Gatton
US ..... United States
USQ..... University of Southern Queensland
UV ..... Ultra violet
VRT ..... Variable rate-application technology
VMC ..... Visual meteorological conditions