Investigation of Low Resolution Point Clouds for Illumination Correction in Pushbroom Hyperspectral Images

A thesis presented in partial fulfilment of the requirements

for the degree of

Master of Engineering
in
Mechatronics

at
Massey University, Turitea Campus
Palmerston North
New Zealand

William B. Haarhoff
February 2018

ABSTRACT

Global food demand is predicted to double between 2015 and 2050. Current agricultural production is unable to facilitate this growth. Consequently, plant breeding must be accelerated to breed improved cultivars that can meet this demand. While technologies such as genomics are suitable for accelerating plant breeding, phenotyping lags behind and is currently considered the bottleneck. Consequently, imaging and remote sensing technologies are being used to provide quantitative, reliable phenotype information. One such technology; hyperspectral imaging can provide physiological, biophysical, and biochemical phenotypic information. While hyperspectral imaging has reached a substantial level of maturity in aerial and satellite based remote sensing applications, it is still underdeveloped in the close-range lab-based phenotyping scenario. In particular is the effect of illumination and complex plant geometry which affects the measured signal and is even more pronounced in the close range hyperspectral imaging. Methods for correction of illumination/geometry effects developed for aerial, and satellite-based imaging are unsuitable for close range hyperspectral imaging. Recently there has been an interest in fusing hyperspectral images with point clouds captured by 3D imaging devices to provide more comprehensive high dimensional phenotype information. However, one study focusses on the possibility of using 3D geometry of the plant to correct for the effects of illumination in hyperspectral images. This study investigates the use of low resolution point clouds captured with low cost devices for use in illumination modelling and correction of hyperspectral images acquired in close range lab-based scenario.

ACKNOWLEDGEMENTS

Firstly, I would like to thank my supervisor Ian Yule for providing me with this great opportunity to learn about the interesting topics of hyperspectral imaging, machine vision, and multiple view geometry and the unique experience of seeing New Zealand from the air while capturing aerial hyperspectral images over the north and south islands. I would also like to thank Ian for both providing me with a stipend and covering my course fees.

I would like to thank Gabor Kereszturi for the many invaluable discussions on all aspects of this project, and especially his excellent feedback and help with the editing of this thesis.

I would like to thank Gourab Sengupta for convincing me that completing a master's degree is a worthwhile endeavour, and for his input with regards to both experiments undertaken, and structure of the thesis.

I would like to thank Kate Saxton for helping to organise my supervisors and I and helping to quickly resolve any administrative issues.

Ian Thomas, Clive Bardell, Kerry Griffiths for their advice and help with manufacturing a precise calibration gauge which was used for assessing the calibration of the hyperspectral camera.

I would like to thank Jacques Johnston for our many interesting discussions regarding clear thinking, postgraduate life, and robotics.

Finally, thank you to my wife Lize for supporting me through the highs and lows of my master's degree.

TABLE OF CONTENTS

TABLE OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

API: Application Programming Interface

BRDF: Bidirectional Reflectance Distribution Function

CAD: Computer Aided Design

DAC: Data Acquisition Computer

DEM: Digital Elevation Model

DLT: Direct Linear Transform

DN: Digital Number

DSLR: Digital Single Lens Reflex (Camera)

FOV: Field of View

GIFOV: Ground Instantaneous Field Of View

HU: Hyperspectral Unmixing

IARR: Internal Apparent Reflectance Ratio

ICP: Iterative Closest Point

IR: InfraRed region of the electromagnetic spectrum

LiDAR: Light Detection And Ranging

NDVI: Normalised Difference Vegetation Index

NGS: Next Generation Sequencing

NIR: Near infra-red region of the electromagnetic spectrum 700-1000nm

PCL: Point Cloud Library

QTL: Quantitative Trait Linkage

RANSAC: RANdom SAmple Consensus

RGB: Red Green Blue

ROI: Region Of Interest

SAD: Sum of Absolute Differences

SFM: Structure From Motion

SIFT: Scale Invariant Feature Transform

SLAM: Simultaneous Localisation And Mapping

SNR: Signal to Noise Ratio

SWIR: Short Wave InfraRed region of the electromagnetic spectrum 1000-2500nm

VIS: VISible region of the electromagnetic spectrum 400-700nm