Doctor of Philosophy
Examiner's Report

Candidate's Name:	Mr Gilbert Eaton	ID: 2795921
Title of research:	Machine vision approach to identifying and grading Strawberries	
Examiner:	Examiner 2	
Date submitted:	2020-02-11	

Criteria Questions

1. Does the thesis make an original and significant contribution to knowledge and understanding of the field of study with which it is concerned?

Criteria Response: Yes

Criteria Comments:

2. Is the standard of literary presentation in the thesis satisfactory?

Criteria Response: Yes

Criteria Comments:

3. Is the methodology applied in the candidate's research effective and appropriate for the thesis topic and the degree sought?

Criteria Response: Yes

Criteria Comments:

4. Does the thesis reflect competence in the survey of literature and documentation of statements?

Criteria Response: Yes

Criteria Comments:

5. Is the thesis suitable for publication as a book or in a learned journal in the form submitted?

Criteria Response: No

Criteria Comments: After modification according to the comments as suggested, the thesis should be suitable for publication

6. Is the thesis suitable for publication as a book or in a learned journal with modifications?

Criteria Response: Yes

Criteria Comments:

Recommendation

Recommendation Submitted**: 2.1 Award with Minor Revisions**

Recommendation Definition: *The candidate should be awarded the degree, subject to minor revisions being completed as follows: typographical, referencing or formatting errors as specified in the General Report Form completed to the satisfaction of the Chairperson of Examiners.*

Recommendation Comments: The review has done in two parts. Main review is submitted as Examiner report and attached as a separate file. Few comments are added to the thesis for minor modifications and attached as well.

CONFIDENTIALITY

The University's normal practice is to provide the candidate with copies of the examiners' reports with the examiners' identities expunged. A candidate will be informed of the name of the examiner responsible for each report after the examination is finalised.

Doctor of Philosophy
Examiner's Report Form

CANDIDATE'S NAME:	Gilbert Eaton	ID: 2795921
TITLE OF RESEARCH:	Machine vision approach to identifying and grading Strawberries	
EXAMINER:	Examiner 2	

Recommendation

The degree be awarded to the candidate subject to minor amendments, including typographical errors, being completed.

Overview of the thesis

Thesis presented for evaluation is based on industrial project for development of an online system for grading the strawberry punnets using image analysis approach. Grading of fruits and vegetable is the industrial need worldwide with increasing demand for high quality produce in the market. A real-world problem being considered in collaboration with Magnificent Pty Ltd.

Main focus of the thesis is to design and development of hardware for vision system (feeding v-belt conveyors and mostly lighting for consistent imaging), control systems (micro controller, sensors and ejector mechanism) for sorting fruit punnets (includes software), and making system to integrate into the existing sorting facility with a speed of 2 punnets/sec.

Colour images are used for ripeness, small fruit and visible foreign objects, while infrared images were used for bruise detection (hardware implementation only). Chapter 6 presents the colour based ripeness grading and chapter 7 presents the small fruit and foreign object identification algorithms using HALCON^{TM}. Chapter 8 presents the deep learning approach for classification using open-source software.

Title

The title of the thesis "Machine vision approach to identifying and grading strawberries" seems very broad. Throughout the thesis the work carried out deals with grading strawberry "punnets" not individual strawberries, and involves design and development of online system for "strawberry punnets" . Thus, I strongly recommend to change the title.

Recommended title:
Design and development of in-line grading system for strawberry punnets using machine vision
or
Machine vision based in-line grading system for strawberry punnets
or
Machine vision approach to identifying and grading strawberry punnets"

Chapter 1

The research question is clearly mentioned along with the necessary requirements.

Chapter 2

Author collected enough references under the literature of review. Summary at the end of the chapter is well written. However, there are several typographical errors need to be

corrected which are marked as comments in the thesis. One such example is, “et al.” is wrongly mentioned as “et al” throughout the thesis.

Chapter 3
This chapter mainly focused on **prototype development** (not in-line system) for finalizing various parameters for lighting, polarizing, power source, USB based camera specifications (shutter speed matching speed of punnets), software requirements, control system (Phidget micro controller, sensors, and ejector), and computer requirements. The flow of multiple threads including the RGB camera, IR camera acquisition machine vision process and input/output control were presented. Simple colour algorithm was tested for finding under ripe fruits using HSV colour space, saturation based thresholding and morphology using the industrial HALCON.

Chapter 4
This chapter explained the use of DC power source and cross polarizing, for creating stable lighting for vision system in the designed enclosure. Using LED light source is increasingly popular in sorting systems for machine vision. However, DC power source experimentations along with cross polarizing give added advantage to this chapter.

Chapter 5
This chapter mainly presented the integration of the developed prototype into the in-line system and describes the LED and halogen lamp setups, electronic control system and power supply unit. Author covered all the points including safety that are required for online integration. The power circuit design and schematic provided (5V and 12V with fuse boxes, relays and microcontrollers) were nice and clean.

From the results of this chapter (i.e., after two season testing) overall system functionality is good but the algorithm confidence is low. Noisy background caused by void space was explained by blocking the top and bottom panels but this also effected the illumination, thereby effecting the segmentation algorithm. The chapter concluded that with some modifications and testing the objective analysis of fast-pace strawberry punnets was feasible.

Chapter 6
This chapter presented the improved algorithm for under ripe and over ripe strawberries detection. Under ripe was identified by simply taking the difference of a, b channels in CIE lab colour space, whereas intensity (V) threshold used for over ripe berries.

Chapter 7
A new design enclosure for dust, accessibility and lighting has been developed. Segregation of hardware components in the new design is good. Old lighting system demonstrated in chapter 3 and 5 been replaced with new 100W COB LED for both visible and IR region. MOSFET in place of relays, and Arduino Nano for automatic triggering the cameras and LED was used in version 2. Controllino microcontrollers replaced Phidget and Arduino in the final version. Strobing function reduced the power consumption to 98.6% is impressive. Overall the improvements made to the system hardware suitable to industrial safe design along with the circuit diagrams were presented well.

Algorithms for small fruit (min and max distance across blob, and using distance transform for converting into real-size) and foreign object detection (features used colour, texture, edges and shape) were explained clearly. For size algorithm, occlusion creates main difficulty in identifying the individual strawberries. Large and small structuring elements based on area used for dealing this issue.

The angle of strawberries in the punnet also makes the large strawberries look small, and might be one of the reasons for false positives.

From the statement in the conclusions, the hardware investigation and setup was done by the author for hyperspectral bruise analysis, whereas the algorithm development was done by some other.

Chapter 8
Python on Linux platform with OpenCV and Tensorflow is the well accepted and popular choice for deep learning and machine vision. With ease of dragging and dropping widgets and with signal slot mechanism, PyQt is also good option for developing GUI. It is interesting to see the simple Logistic Regression (with pre-trainedResnet-50 feature extraction) analysis performed better in classifying the under ripe, over ripe and foreign objects among the 12 classifiers tested.

Chapter 9
Conclusions were clearly mentioned.

Overall the thesis is well written and the author has done impressive work in design and development of strawberries punnets sorting system with a speed of 2 punnets/s suitable for industrial in-line integration. Major part of the work is devoted towards the designing of the system and controls development for making system suitable for grading fast-moving strawberry punnets.

Questions:

Can this system be adopted for different speed conveying systems? What modifications needed?

How different varieties of strawberries, or strawberries grown at different regions did effected the algorithm for ripeness evaluation?