Machine vision approach to identifying and grading strawberries

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-Thesis Examiners feedback response-
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Examiner 1:

Title page / preamble:

Comment:
None

In text comments:
None

Chapter 1 - Introduction:

Comment:
None

In text comments:
None

Chapter 2:

Comment 1:
"It would be helpful to have a paragraph defining hyperspectral data (and contrasting with multispectral and RGB). The term seems to be used on p28 without much introduction for the reader so far (EDIT just got to the later section 2.4 defining the terms – can you link forward to this from the earlier references?) Also in this section, you might want to provide more detail on hyper versus multispectral versus normal colour imaging, especially in terms of number of samples throughout the spectrum range."

Response 1:
Accepted - Moved subsection "Hyperspectral / Multispectral Imaging" to precede other sections referencing hyperspectral methods to address reader understanding.

Comment 2:
"Fig 2.5 Add citations for where the figure came from to the legend, so readers are clear of the source (and that it is not yours)"

Response 2:
Accepted – Added citation as requested.

Comment 3:
“Section 2.7 Intro. It would be helpful to provide a few sentences introducing deep learning more ie. how it is a neural network approach, and how its different from older ANNs”

Response 3:
Accepted – Paragraph explaining the brief concept of deep learning models added, with reference to how they relate to neural networks and were modelled from the human brain.

Comment 4:
“On p53 you introduce ReLU without introducing what an activation function actually is. Also, the definition of ReLU isn’t quite right (negative values are set to 0, not negated). The benefits of ReLU also aren’t clearly expressed.”

Response 4:
Accepted – Expanded ReLU section to include description of activation function.

Comment 5:
“Network architecture p54. I think these need annotations to explain why you are listing them. What is they key point of each example?”

Response 5:
Partly accepted - The reason for the inclusion was to indicate that many architecture designs are possible, but there is no way of really knowing which one will suit an individual problem. The examples simply show potential variations of layers between input and output. Added sentence to further explain this reasoning to reader.

In text comments:

- Minor spelling/grammatical corrections.

Chapter 3:

Comment 1:
“On a first read, I thought the polarizer was not well evaluated. Later I read Chapter 4 and noted some evaluation in this chapter. I think it will be clearer for the reader if you point out here that further consideration of the polarizer happens in Ch 4.”

Response 1:
Accepted – added reference to Chapter 4.

Comment 2:
“Fig 3.15 P 95. You state in the text above many iterations of the GUI have been developed to arrive at this figure. Wouldd it be possible to include some snapshots of the GUI Development as an appendix, with some annotations as to what worked and what didn’t at each step?”

Response 2:
Accepted – Added GUI development screenshots to Appendix C.

Comment 3:
“Clarify use of saturation on p. 100 (See highlighted text and comment)”

Response 3:
Accepted – Clarified saturation description.

Comment 4:
“P102, with the circular nature of hue, does red wrap around to 360 or does it really start at 0?”

Response 4:
Accepted – Clarified hue circle wrap around from 360-0.

Comment 5:
“P102. Could you provide more example output images demonstrating that your approach works? It would also be good to see some numerical analysis of the thresholding approach. It is hard to tell how well it works, and as you mention at the end of the section, it does have problems which need addressing. Are these addressed later in the thesis? Hard to tell at this point - please provide a pointer to a future section if they are addressed later.”

Response 5:
Accepted – Nine images added gives numerical relationship to saturation threshold step, with 3 examples from each below, equal to, and above chosen threshold level of 180. Reader referred to Chapter 6 where concerns are further addressed.

Comment 6:
“P113. Section 3.4.5 Image Processing. You need to describe in detail the algorithm here that you are using. You mention the approach, show a screenshot, and present a few select results. This section needs to much more clearly show the final method, and tabulate some results (or at the very least present more output image examples – good and bad). The text about the size of the test set is also very confusing, and I am unsure if this work has happened or if it is to do in the future?”

Response 6:
Accepted – Algorithm outlined in Algorithm 1. Eight images added of both underripe and overripe algorithm results (good and bad) to give reader visual examples and defining the final method for this initial process. Clarified text regarding test set and future work.

In text comments:

- Minor spelling/grammatical corrections.
- Labelled parts of Figure 3.8 appropriately to give the reader better understanding.
- Corrected technicalities in chapter 3.3.7.3 Image Processing.

Chapter 4:

Comment 1:
"To note, this chapter seems to be directly from a paper, and refers to itself as such. I am not sure if the text could be altered in a few places to better fit as a thesis chapter rather than a paper – this would not be much work and would make the flow better."

Response 1:
Noted - No response required

Comment 2:
"Related, there is quite a bit of repetition between ch 4 and ch 3...due to the nature of Ch 4 as a paper. Read both, and edit where possible to prevent this."

Response 2:
Ignored – Chapter 3 explanations of power systems and polarisation are required to make sense to the reader. Chapter 4 includes further explanations to topics (as addressed in Chapter 3, comment 1 from this examiner), and therefore kept as is.

Comment 3:
"P125 I am unclear what "average pixel area" is. I think this section could benefit from a rewrite to make the exact image processing steps more clear."

Response 3:
Accepted – Chapter 4.6 rearranged and paragraph added to more clearly explain average pixel area. Some descriptions were potentially confusing and therefore re-worded and added to make clear the experimental process.

Comment 4:
"P128. You conclude the chapter with "Experiments were also performed that showed that the cross-polarization technique has the ability to entirely remove of the specular reflections in most cases". I would argue the last part of this claim is not true, given the results presented. The example image (4.5b), whilst clearly improved and impressive, still has a small amount of reflection. I think to justify the "in most cases" claim, I'd like to see some results from more images (numerical and/or qualitative images), rather than just one."

Response 4:
Accepted – 24 images added to show example results of specular reflection removal justifying the "in most cases" claim.

In text comments:

- None

Chapter 5:

Comment 1:
"P146 The motion blur section is OK, and the results look nice, but I had a few questions marked in the text about some of the terminology used."

Response 1:
Accepted – Terminology clarified

Comment 2:
"P148 What is described as optic flow is actually a difference image. There is no concept of how far pixels have moved, so I would not refer to this as optical flow."

Response 2:
Accepted – Changed definition to 'image difference'.

Comment 3:
"P152 This is another example of where more experimental results would be beneficial. Final parameters of the pneumatic system are presented which are based on "initial testing". It would much improve the section if the testing was described in more detail, and results presented (presumably these exist, but are not presented here at the moment)."

Response 3:
Accepted – Paragraph added to further explain the experimental methodology. Records do not exist for the testing as it was quite simple with around 20 punnets used to fine-tune the ejection requirements.

Comment 4:
"Minor point. I was curious when reading this section what would happen if the conveyer systems stops after a "bad" punnet has exited the image processing station but before the ejector. Will it still be ejected correctly in this case?"

Response:
Accepted – this point has been addressed with the explanation of the conveyor feedback system allowing the micro-controller to add the additional stop time to the ejector logic.

Comment 5:
"P160 please describe the two new algorithms mentioned"

Response:
Accepted – Removed reference in this chapter as the methods are described in Chapters 6 and 7.

Comment 6:
"P166 "A dataset of 500+ images".. This is great! A sizeable evaluation on a realistic test set has clearly taken place, but is not clearly described here. Please expand this section for more fully describe the process and results, and provide more example images."

Response 6:
Accepted – Added description of images used for testing and the process to obtain them, as well as 18 sample test images and their description.

In text comments:

- Minor spelling/grammatical corrections.
- Removed unnecessary reference to Fig. 5.2.
- Adjusted hyperspectral images so that they are bigger and the bruising is more visible.

Chapter 6:

Comment 1:
"Section 6.4 This is a clearer consideration of the image analysis processes developed, but would still benefit from showing the final algorithms in their own box for clarity (as a flow chart, or pseudo code, for example, as on p 221)"

Response 1:
Accepted – added both updated underripe and overripe methods as algorithms as requested.

In text comments:

- Minor spelling/grammatical corrections.

Chapter 7:

Comment 1:
"P221. Is algorithm 20 really algorithm 1? To note, this is exactly the kind of algorithm presentation I would like to see elsewhere in the work. Happens again with Algorithm 19 p225"

Response 1:
Accepted – corrected algorithm numbers. Have added more detailed algorithms as requested.

In text comments:

- Minor spelling/grammatical corrections.

Chapter 8:

Comment 1:
"P241. Is there a reason why the training set is so small (27) compared to the test set (579)? I would normally expect this division to be the other way around."

Response 1:
Accepted – further explanation regarding small number of training examples due to computational time, with each of the region's pixels assigned to feature inputs in the SVM classification. As this was preliminary testing, the results were indicative of final solutions and therefore did not require lengthy training.

In text comments:

- Minor spelling/grammatical corrections.
- Figure 8.3 size/resolution increased.
- Clarified training and testing information shown in Table 8.2
- Added references to VGG, GoogLeNet, and BN-Inception papers as requested.
- Corrected reference to table in Chapter 8.7

Examiner 2:

Title page / preamble:

Comment 1:
1. "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."

Response 1:
Ignore based on chairpersons comment. Thesis main title unchanged.

Chapter 1 – Introduction:

Comment:
None

In text comments:

- Approximate reject numbers used opposed to real recorded numbers in "Contributions" subsection – Accepted and updated to accurate quantities.

Chapter 2:

Comment 1:
"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."

Response 1:
Accepted and changed all occurrences of “et al” to “et al.” (added period).

In text comments:

- Minor spelling/grammatical corrections - Accepted and changed as stated in text.

Chapter 3:

Comment:
None

In text comments:

- Minor spelling/grammatical corrections
- Label parts of Figure 3.6 appropriately to give the reader better understanding – Accepted and updated figure with annotations.
- Figure 3.7 is not appropriate to text – Accepted, referenced more clearly in text.
- Figure 3.9 regarding use of spherical items in target images not understood – Accepted, added descriptive comment.

Chapter 4:

Comment:
None

In text comments:

- None

Chapter 5:

Comment:
None

In text comments:

- Bruised images labels added in order to more clearly illustrate the bruise regions highlighted in the method used.

Chapter 6:

Comment:
None

In text comments:

- None

Chapter 7:

Comment:
None

In text comments:
- Minor spelling/grammatical corrections

Chapter 8:

Comment:
None

In text comments:
- None

Chapter 9:

Comment:
None

In text comments:
- None

Examiner 2 Questions:

Q1: Can this system be adopted for different speed conveying systems? What modifications needed?

Response 1:
Accepted – Additional paragraph added to Chapter 5.11 conclusion addressing this question considering the impact of speed increases to lighting, computational power, and ejection control systems.

Q2: How different varieties of strawberries, or strawberries grown at different regions did effected the algorithm for ripeness evaluation?

Response 2:
Accepted – This problem is mostly addressed by switching from naive methods to machine learning/deep learning processes. Avoiding thresholding reduces much of the variation problems including lighting changes and cultivar variation, although concept shift will continuously require analysis. This has been further described in Chapter 8.1.

Chairpersons requirements:

1) The candidate should respond to the comments in the examiner's reports (particularly those in red type) with a decision to accept and change or to ignore. A detailed list of the comments and the candidate's responses should be presented to the principal supervisor and, following their approval, to me for verification. - **Complete**

2) The in-thesis comments should be followed where appropriate. There is no requirement to provide a detailed list of these minor changes. - **Complete**

3) The candidate must ensure that all copied figures are properly referenced (with permission) in the figure captions. - **Complete**

4) The list of references should be edited to a uniform format. - **Complete**