



**Enhancing Accuracy in Optical Character Recognition of
Sensor Readings: A Comparative Study of Tesseract and
CRNN Models with Emphasis on Image Preprocessing**

by

Aidan Dennehy [R00145278]

For the module DATA9003 - Research Project as part of the
Master of Science in Data Science and Analytics, Department of Mathematics

Supervisor: Dr Alex Vakaloudis

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Declaration of Authorship

I, Aidan Dennehy , declare that this thesis titled, "Enhancing Accuracy in Optical Character Recognition of Sensor Readings: A Comparative Study of Tesseract and CRNN Models with Emphasis on Image Preprocessing" and the work presented in it are my own. I confirm that:

- This work was done wholly or mainly while in candidature for an undergraduate degree at Munster Technological University.
- Where any part of this thesis has previously been submitted for a degree or any other qualification at Munster Technological University or any other institution, this has been clearly stated.
- Where I have consulted the published work of others, this is always clearly attributed.
- Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this project report is entirely my own work.
- I have acknowledged all main sources of help.
- Where the thesis is based on work done by myself jointly with others, I have made clear exactly what was done by others and what I have contributed myself.

Signed:

Date:

Munster Technological University

Abstract

Faculty of Engineering and Sciences

Department of Mathematics

Master of Science in Data Science and Analytics

by Aidan Dennehy [R00145278]

This research is primarily dedicated to the formulation of an innovative method for accurately interpreting sensor data obtained from digitized images. Confronting inherent challenges such as diminished contrast and subpar image quality, often associated with sensor readings, the study exploits Optical Character Recognition (OCR). This is accomplished employing two distinct techniques: Tesseract and Convolutional Recurrent Neural Network (CRNN) models.

An unique feature of the research lies in its novel image preprocessing steps, specifically the masking of red and green colors prior to conversion to grayscale. This process considerably augments the efficacy of OCR. Additionally, the study underlines the critical importance of correct font selection for each sensor to enhance reading accuracy.

The findings highlight the essential role of image quality and contrast in OCR, while presenting an innovative approach to image preprocessing for improved results. The potential implications of this research are extensive and could shape future undertakings in the fields of OCR and sensor digitization. The research underscores the vital aspects of image preprocessing and reveals how precise interventions can markedly improve sensor data interpretation from digitized images.

Acknowledgements

The acknowledgements and the people to thank go here, don't forget to include your project supervisor (term one and two)...

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Abbreviations

LAH List Abbreviations **Here**

For/Dedicated to/To my...

Chapter 1

Introduction

Optical Character Recognition (OCR) technology has seen substantial advancements in recent years, transforming the process of data extraction from visual mediums to digital formats. This technology, crucial in numerous fields ranging from document digitization to automated data entry systems, holds specific importance when it comes to interpreting sensor readings, a key aspect of data-driven industries. The necessity for accurate, efficient, and automated reading of sensor-generated data has led to the investigation of various techniques and models within the OCR domain.

Two models have prominently emerged as potential solutions, namely Tesseract, an open-source OCR engine sponsored by Google, and Convolutional Recurrent Neural Network (CRNN), a combination of CNN, RNN, and Connectionist Temporal Classification that offers promising results in scene text recognition tasks.

In OCR applications, image preprocessing has a pivotal role. It prepares an image for further processing by reducing noise and unnecessary details and enhancing features that are important for later stages, thereby directly influencing the accuracy of the final output. Among various preprocessing techniques, the novel approach of red and green color masking, followed by conversion to grayscale, has shown to significantly improve the accuracy of digit recognition.

In addition to these techniques, the selection of the correct font for each sensor is another critical element that affects the accuracy of the OCR system. Despite its importance, this aspect has been less emphasized in existing literature, thereby forming a crucial area of exploration in this study.

This literature review explores the current state of OCR technologies, with a particular focus on Tesseract and CRNN models. It delves into various image preprocessing techniques, emphasizing the unique method of red and green color masking before conversion

to grayscale. Lastly, it investigates the role of font selection in enhancing OCR accuracy, thereby setting the context for the subsequent research.

1.1 Motivation

Why is it important to do a project on this topic? This should cover your key motivation for this. For example an excellent student from 2016 noticed a large number of homeless sleeping rough in Cork and was motivated to develop a system that load balanced the homeless shelters to try to accommodate the maximum number of homeless. This section can include the personal pronoun but the rest of the report should be third person passive, this is the case with most technical reports! For example here it is fine to say "... I decided to develop an app to help ...".

1.2 Contribution

Enumerate the main contributions. Here try to zoom out, to talk from the perspective of a Computer Science graduate. In other words, imagine you are talking to a job panel, and you want to show your computer science skills by enumerating how they are reflected in your project work. A good guide here is to look back over the modules you have covered as an undergrad from 2/3rd year, how many tools and techniques from these modules do you have in the project and to what extent? How have you advanced beyond the module content? Do you have anything new?

1.3 Structure of This Document

This section is quite formulaic. Briefly describe the structure of this document, enumerating what does each chapter and section stand for. For instance in this work in Chapter 2 the guidance in structuring the literature review is given. Chapter 3 describes the main requirements for the problem definition and so on ...

Chapter 2

Background

The key question to answer in this chapter is: "What has been done/is being done".

This chapter comprises around 4000 words and should put your project into context within Computer Science. Your focus here should be on the final section "Current State of the Art". This should be at least 2500 of the 4000 words of this section.

2.1 Thematic Area within Computer Science

Position your topic within Computer Science. This activity will aid you in your literature review also. We zoom out to see three levels:

1. What is the core topic your project is about? e.g., Mobile app for online voting.
2. What core area(s) does the project fall under? e.g., Mobile applications, Social Networking, Service Providers.
3. What main area(s) of Computer Science does the project fall under? e.g. Software Development, Cloud Computing.

The ACM Computing Classification System (<http://www.acm.org/about/class>) will aid you in this, use the 2012 categories. Make sure to use figures and illustrations were appropriate. LaTeX will take care of the formatting of these. Do not try to get fancy here, you should concentrate on the content and not the formatting, this is why we are specifying LaTeX.

You can specify the width and label for a figure which allows you to reference the figure and you can attribute a source in the figure caption as is done for figure 2.1. Make



FIGURE 2.1: A picture of the success kid![1]

sure you reference all external figures (i.e. figures you did not create yourself). Also use references for all figures e.g. use "... in figure 2.1 ..." NOT "... in the figure above ...".

2.2 A Review of -INSERT THEMATIC AREA-

The focus of this section is at the heart of the project research phase. You must identify the main sources of information you should be aware of within your chosen area and pay regular attention to so as to strengthen your knowledge in the core topic you are working at. So here you should develop an knowledge of not only your core topic but also about the area of computer science the topic falls under. More specifically you should research the following:

- The top 5 International Conferences and Journals most related to your topic. This is crucial, as it represents the main source for keeping you aware of what the state-of-the-art in your topic is.
 - In particular it will make you aware of what other projects related to yours have been already done (so that you can compare/position your project w.r.t. these).
 - What new techniques are being developed, so that you can apply them in your work. e.g. new frameworks for data visualization
- The top 3 most recent books/texts related to your topic. There are many free resources from which you may download a relevant text on the topic of your project. Try to either download or borrow 3 recent (no older than 10 years) texts relating

to the topic your project is on which you will use throughout the project as reference material and to aid in tackling a number of the technical problems you may encounter. Any PhD/MSc thesis that have published in the last 5 years relating to the topic are also invaluable resources as they will contain a state of the art and references in your project topic. Approach these only after reading/viewing the wikis/Youtube videos you find as a certain level of knowledge will be assumed about the topic.

- The top 5 companies/organizations potentially interested in the product you are developing. Finally, this is also crucial, as it forces you extend to purely programmer view of the project to a wider view considering the market, potential stakeholders and niches where your product can become useful. Moreover, Computer Science is a huge topic with loads of different works and roles. If you pick a project in the area you feel passionate about, and you identify what the market in this area is about, then you can drive your future professional career (from the very beginning) towards the path that makes you happier. I know that this does sound as a very technical reason, but I suppose we all agree is probably the most important of all reasons for choosing a particular project focus.
- The top 5 wiki/forums/blogs/Youtube channels most related to your topic. This is crucial to you as well, as it represents a more accessible, personal and less informal way of communication with people working/interested on the same topic as you are. This communication is extremely helpful for improving your skills, solving potential doubts and increase the interest/relevance of the topic/area itself.

You should begin your journey of discovery in reverse order to the listing above (which is given in order of academic importance/significance). So when you are researching your topic first look up some TedX talks or youtube tutorials, then research what companies are doing in the area, then get a handful of very good texts on the core topics of your area (anything older than 5 years usually is not helpful here) and finally start reading conference or journal papers (again newer is better here). In particular during this section you may need to use tables to list resources. These are also automatically formatted in latex thus allowing you to concentrate on content. for example table 2.1.

What has been done before in your community w.r.t. your topic? Once you have gotten an understanding of the topic and technologies and have identified the top 5 formal conferences/journals, wiki/forums/blogs/Youtube channels and companies/organizations the next step is to research in depth on them! And here in depth means in depth. Make sure you cite[1] a number of papers [2], luckily Latex will take care of the ordering of the citations [3] for you.

Parameter	PET
Youngs Modulus	2800-3100MPa
Tensile Strength	55-75MPa
Glass Temperature	75°C
Density	1400kg/m ³
Thermal Conductivity	0.15-0.24Wm ⁻¹ K ⁻¹
Linear Expansion Coefficient	7×10^{-5}
Relative Dielectric Constant @ 1MHz	3
Dielectric Breakdown Strength	17kVmm ⁻¹

TABLE 2.1: PET Physical Properties

The aim here is that you find the trends in your topic (3), and more in general in the area in which your topic resides (2) your project falls under and from these trends you develop your initial project question further and begin to get insights into how others have solved/approached similar problems. Think of this section as colouring in your initial idea. Before you approach this section you should read at least 4/5 good literature reviews (a selection of last years projects will be posted on blackboard to aid you but you should find other sources also).

In particular in this section, you must find and analyze at least 5 (ideally around 10) works belonging to, or at least related to, your work. You must describe these works and position your project w.r.t. them (i.e., clearly identify the similarities and differences between your project and each of these works). Also remember if you find that you are detailing topics that you have not introduced already here you need to add something to the earlier Scope section.

Chapter 3

Problem - rename to project title

The key question to be addressed in this chapter is: "What do I want to achieve".

This chapter should comprise around 1500 words and describe the problem you are trying to solve. Try to be as specific here as you can, this will help you to anticipate possible risks such as lack of support from APIs.

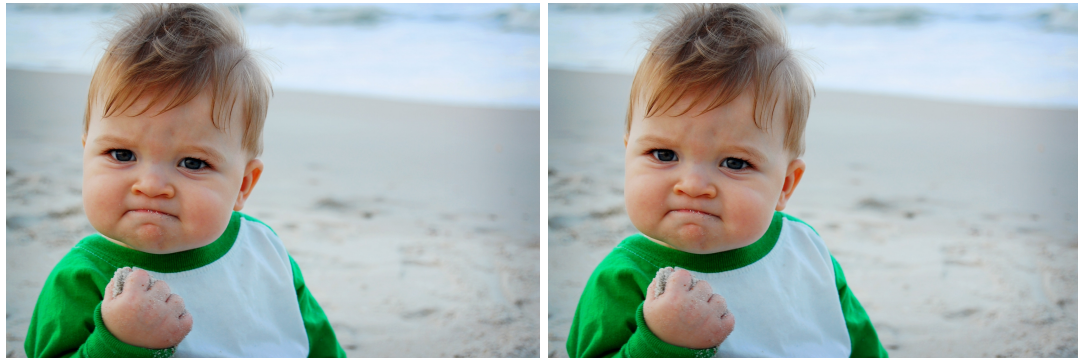
3.1 Problem Definition

Describe the problem you are trying to solve in this project. There will sometimes be a need at some point during the report to display an equation that may be core to your project. For example if the project is on gait detection what equation are you using to determine gait? If the project is on localization what is the method/formula? The formatting of these is reliably done in Latex also as we can see in equation 3.1.

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{c}_i}\right) - \frac{\partial L}{\partial c_i} + \frac{\partial P}{\partial \dot{c}_i} = F_i, \quad (3.1)$$

3.2 Objectives

Enumerate the objectives you want to achieve in your project. Again as this is an early stage these will tend to change but there should be a rational explanation for this change. Always document your work, keep a lab book during the term that you only use for FYP!



(a) Figure A

(b) Figure B

FIGURE 3.1: Two Success kids

3.3 Functional Requirements

Enumerate the functional requirements you want your project to have.

Please, do not include the use cases here. If you want to create a one-to-one mapping between functional requirements and use cases (which does not necessarily need to be the case, indeed most likely this will not be the case) do it elsewhere. Here should purely describe what do you want to do. In no case should you use this section to provide a description of how to implement them, that is for later. For people doing projects that are not heavy implementation projects (e.g. deploying an architecture or testing a novel tool in specific conditions) this structure can still be used as it will force you to think about what you plan to achieve and what possible metrics you may need to measure success.

Let me explain this with more detail. A common mistake is that people confuse the problem description with the solution approach. This is a common mistake by confusing the *what* with the *how*. Here we are purely focused on the *what*: What is this project about? What are the objectives? What are the functional and non-functional requirements?

How are we going to do all these things? Well, this is a question for next chapter. Provided a problem, an objective or a functional requirement, obviously there will usually be many ways of doing it, thus there will be many *hows*, but the definition, the *what* we want to achieve will be unique.

One other display structure you may wish to use at some stage during the report is a figure array. This can also be easily done with Latex and is shown in figure 3.1

3.4 Non-Functional Requirements

Enumerate the non-functional requirements you want to achieve in your project (i.e. broadly speaking how your system will operate).

Chapter 4

Implementation Approach

The key question to be addressed in this chapter is: "How do I plan to achieve what I have outlined in the previous chapter".

This chapter should comprise around 5000 words and specify your planned implementation approach. Again all sections below are suggestions and will vary significantly from project to project, the key element to be addressed is the core question of the chapter.

4.1 Architecture

Describe the architecture of the solution that you have in mind, including:

- Technologies involved (e.g., frameworks, programming language).
- The hardware needed to develop the project (and to support at deployment stage)

Provide a high level view of the system you have in mind, including any package of classes, what is it responsible for and what other packages it communicates to. Provide a high level view of the database (or structure) needed to support the project, including what each table/document is responsible for and the hierarchy among them. You need to be as specific here as you can, why? Because this will aid you in identifying parts of the project you are vague on, this may be fine for some components but cause problems in term 2 for others. If you have hardware element in your project this is also where you provide a high level view of how these elements integrate into the project. So for a project that is cyber-physical you will have both a hardware and software architectural diagram. N.B. This is NOT a full system design but a high level overview of what you can credibly develop. This architecture should be informed by prototyping activity.

Some of the implementation focused projects may describe how do you envision tackling the functional requirements of your project via a set of use-cases. DFDs are also helpful here to understand elements of your project that may cause problems. You should describe the role of the different parts of the architecture of the solution, and the interaction among them.

4.2 Risk Assessment

Identify any potential risk precluding you from successfully complete your project. This section is really important and often neglected by students resulting in fatal risks occurring in some projects. Make sure to give this section the time it requires. Classify the risk according to their importance, possibility of arising and enumerate the decisions you can make to anticipate them or mitigate them (in case they finally arise). Table 4.1 may help with this classification. This section should include your mitigation approach for any critical risks.

TABLE 4.1: Initial risk matrix

Frequency/ Consequence	1-Rare	2-Remote	3-Occasional	4-Probable	5-Frequent
4-Fatal					
3-Critical					
2-Major					
1-Minor					

4.3 Methodology

Describe your personal approach on how to tackle the different parts of this project, including:

- How to tackle the needed research to fulfill the background chapter.
- How to set up your Computer Science skills to the project needs (e.g., describe your plan to learn any new technology involved on the project that you are not familiar with).
- What core project managing approach will you follow (e.g., Waterfall, Scrum, etc).

4.4 Implementation Plan Schedule

Come up with a schedule for the remaining time (including second semester), so as to describe how do you envision to achieve the implementation of your project by the end of semester 2. This plan SHOULD be ambitious but MUST be realistic and SHOULD be informed by early prototyping and MUST be discussed with your term 1 supervisor.

4.5 Evaluation

Come up with an evaluation plan that allows you to measure how much have you actually achieved the goals of your project. This again is a section that is often neglected where students loose marks. How do you plan to measure the output of your project? A binary it works/does not work is insufficient. You need to be able to quantify the success against both the functional requirements and the initial idea. These are not the same as you may meet all function requirements outlined but not solve the overall problem because you have failed to revisit these and update them with new information which you learn as you are developing the project.

4.6 Prototype

Although you do not have a fully functional project yet, you should show wireframes, snapshots or representation on how do you envision your project to look once the implementation phase has been completed. The nature of this section will vary significantly from project to project and can include anything from code snippets to snapshots of service deployments. Any prototyping you have done during the term should be summarized here that has not been captured in earlier sections. For example if you are planning to host your project using AWS in an EC2 instance you should have at least created a "hello world" setup to determine the basics, this probably should have been discussed in section 4.1.

Chapter 5

Conclusions and Future Work

This chapter should comprise 2-3 pages and enumerate conclusions of this phase of work. In your final report Discussions and Conclusions will form separate chapters and be significantly longer and more detailed.

5.1 Discussion

A reflective discussion of some of the problems you encountered during this phase of the project and how that may influence how you proceed with the next phase.

5.2 Conclusion

Enumerate the main conclusions you have got in terms of background, problem description and the solution approach you have come up with.

5.3 Future Work

Enumerate all the things you would have wanted to do should you have more time to work on this report.

Additional resources on the use of latex is below.

Tutorials:

- <https://www.latex-tutorial.com/tutorials/beginners/how-to-use-latex>

- <https://en.wikibooks.org/wiki/LaTeX>
- https://www.sharelatex.com/learn/Main_Page
- <http://www.math.harvard.edu/texman>
- https://web.stevens.edu/hfslwiki/images/a/a0/ShareLatex_Tutorial.pdf

Presentations:

- <http://www.iu.hio.no/~frodes/rm/ppt/latex.ppt>
- https://classes.soe.ucsc.edu/ams200/Fall09/Latex_intro.ppt
- <http://www.menet.umn.edu/~blake/latexcourse/courseslides.ppt>

Bibliography

- [1] C. J. Hawthorn, K. P. Weber, and R. E. Scholten, “Littrow configuration tunable external cavity diode laser with fixed direction output beam,” *Review of Scientific Instruments*, vol. 72, no. 12, pp. 4477–4479, December 2001. [Online]. Available: <http://link.aip.org/link/?RSI/72/4477/1>
- [2] A. S. Arnold, J. S. Wilson, and M. G. Boshier, “A simple extended-cavity diode laser,” *Review of Scientific Instruments*, vol. 69, no. 3, pp. 1236–1239, March 1998. [Online]. Available: <http://link.aip.org/link/?RSI/69/1236/1>
- [3] C. E. Wieman and L. Hollberg, “Using diode lasers for atomic physics,” *Review of Scientific Instruments*, vol. 62, no. 1, pp. 1–20, January 1991. [Online]. Available: <http://link.aip.org/link/?RSI/62/1/1>

Appendix A

Code Snippets

Put appendix material in this section e.g. code snippets

USE THE APPENDICES

Appendix B

Wireframe Models