Tevin Achong

NIHERST/NASA Internship 2019

Final Report

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1 Introduction

My name is Tevin Achong and as of November 2019, I am in the final year of my bachelor's degree in Computer Science at the University of the West Indies (UWI) in Trinidad and Tobago. My journey through the UWI has been the most incredibly fruitful experience of my academic career thus far; from being awarded the UWI Open Scholarship, to having the opportunity to participate in interesting research projects with one of my lecturers, Dr. Phaedra Mohammed, it has all been simply amazing.

In 2019, to put the icing on the cake, I was one of six (6) Trinbagonian nationals selected to participate in an internship at the National Aeronautics and Space Administration (NASA) AMES Centre in Mountain View, CA, USA, facilitated by Trinidad and Tobago's National Institute of Higher Education, Research, Science and Technology (NIHERST). I will use this report as an opportunity to discuss the project I was involved in at NASA, my overall experience being an international intern there, and the aftermath of the entire programme.

2 The Internship Experience

The dream location for computer scientists and software engineers, **Silicon Valley**. I was there! Looking back, its absolutely insane that I was given this opportunity; Tevin Achong from Princes Town, Trinidad went to NASA! Excuse the exclamation marks, but the recaps still give me goosebumps. Here, I'll just share some of the experiences I had during my time at NASA AMES and in California in general. A picture is worth a thousand words, so I'll let these images from my time there do the majority of the talking.

Figure 1: Standing at the Entrance of the NASA AMES Research Centre

Figure 2: Snapshots from our trip to San Francisco

Figure 3: Variety of Foods tried in California

Figure 4: Scenes of a hike with the Intelligent Robotics Group (IRG)

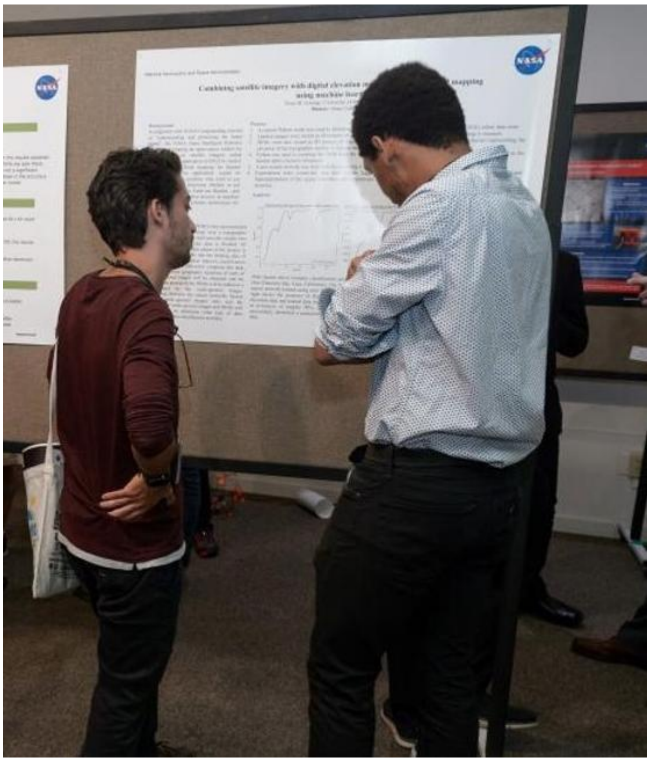

Figure 5: Presenting my poster at the NASA AMES Poster Symposium

Figure 6: Some of My Awesome Friends

As you can see, being able to work at NASA and to live in Mountain View was an absolutely exhilirating experience. Lifelong connections, awesome food, beautiful sites, and a fulfilling academic experience. Thank you for hosting me NASA, Mountain View. Until next time...

3 Research Project

3.1 Overview

Both myself and fellow Trinbagonian intern, Keanu Nichols, were employed as members of NASA AMES' Intelligent Robotics Group (IRG). Furthermore, we were both also tasked with working on the same overarching project, **Deep Earth Learning Training and Analysis (DELTA)**, under the mentorship of Dr. Brian Coltin. The aim of DELTA is to develop an open-source toolkit for deep learning on satellite imagery to be used by Earth scientists, who are often novices in machine learning. The first application being developed as part of DELTA's toolkit uses LANDSAT imagery to perform fully automated flood mapping for disaster response. Despite being a part of the same team and the same project, my core project differed from Keanu's. The project I worked on was entitled ***Combining satellite imagery with digital elevation models (DEMs) for flood mapping using machine learning***. The primary objective of this project was to incorporate a new type of data, in the form of digital elevation models, into the learning pipeline in order to improve the accuracy of the flood mapping classifier.

Before, delving too deeply into the details of the project, it is important to outline some important, frequently occurring definitions and terminology.

3.2 Definitions and Terminology

RGB Image

RGB stands for red, green, blue. RGB images are created via the addition of red, green and blue light in varying proportions to produce and extensive range of colors. We can think of RGB images then as 3-tuples, or as having 3 bands of information: the first band contains a numeric value representing the amount of **red** light in each pixel of the image, the second bands contains values representing **green** light and the third contains values representing **blue** light. These are the types of images produced by typical cameras.

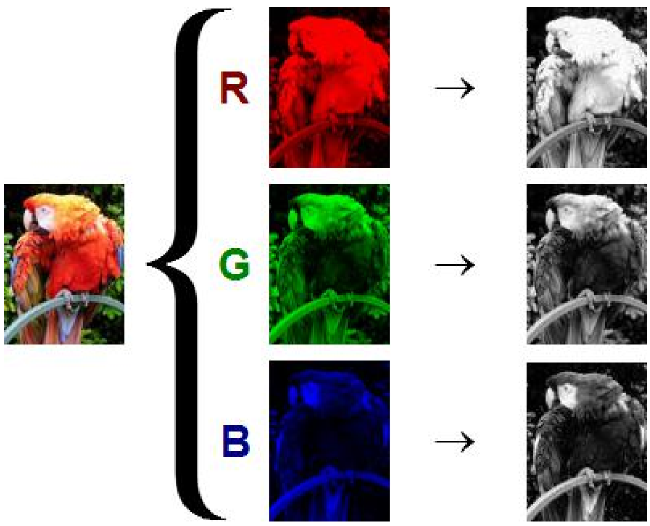

Figure 7: RGB Image (3 channels/bands of information)

LANDSAT Images

According to the United States Geological Survey,

The Landsat program is a series of Earth-observing satellite missions jointly managed by NASA and the U.S. Geological Survey. Landsat satellites have the optimal ground resolution and spectral bands to efficiently track land use and to document land change due to climate change, urbanization, drought, wildfire, biomass changes (carbon assessments), and a host of other natural and human-caused changes.

More simply put, a satellite (LANDSAT) orbiting the Earth continually captures images of the Earth's surface. Unlike RGB images, however, these images contain 7 channels of information - far more than just red, green and blue values.

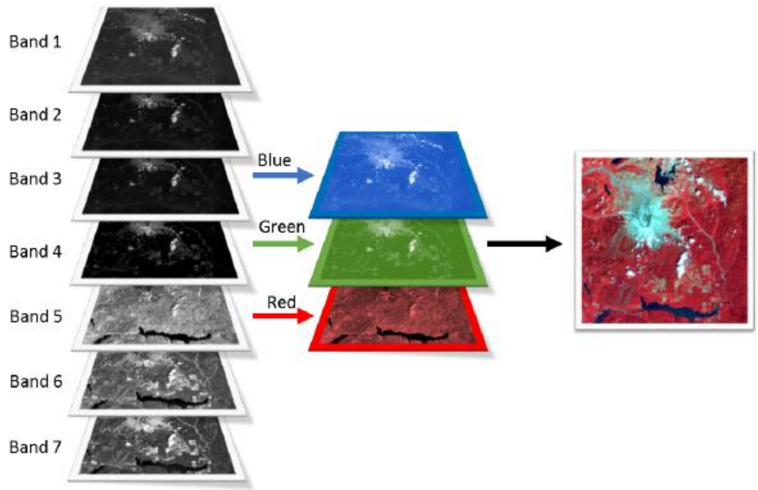

Figure 8: LANDSAT (7 channels/bands of information)

Digital Elevation Models

A digital elevation model (DEM) is a 3D representation of a terrain's surface created from elevation data. A DEM only contains one (1) band of information, that being the elevation level (height).

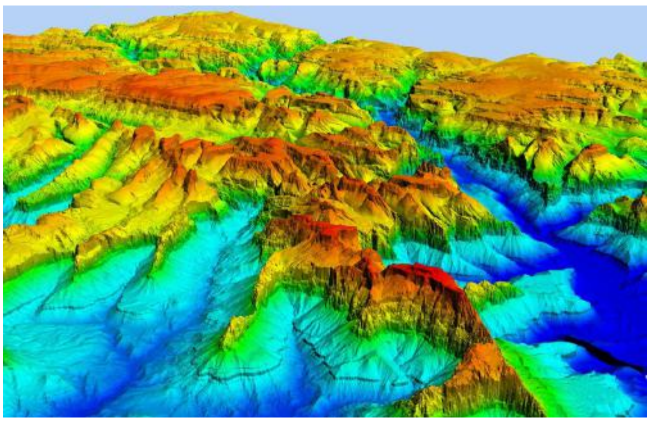

Figure 9: Digital Elevation Model

Neural Network

Neural nets take inspiration from the learning process occurring in human brains. They consist of an artificial network of functions, called parameters, which allows the computer to learn, and to fine tune itself, by analyzing new data. Each parameter, sometimes also referred to as neurons, is a function which produces an output, after receiving one or multiple inputs. Those outputs are then passed to the next layer of neurons, which use them as inputs of their own function, and produce further outputs. Those outputs are then passed on to the next layer of neurons, and so it continues until every layer of neurons have been considered, and the terminal neurons have received their input. Those terminal neurons then output the final result for the model.

3.3 Objective

Before my arrival at NASA, LANDSAT images were being used as the only form of data to train the neural network. The network would give some outputs in the forms of classifications. The classifications in this instance were 0 (not flooded) or 1 (flooded); the neural network was a binary classifier being trained solely on LANDSAT images.

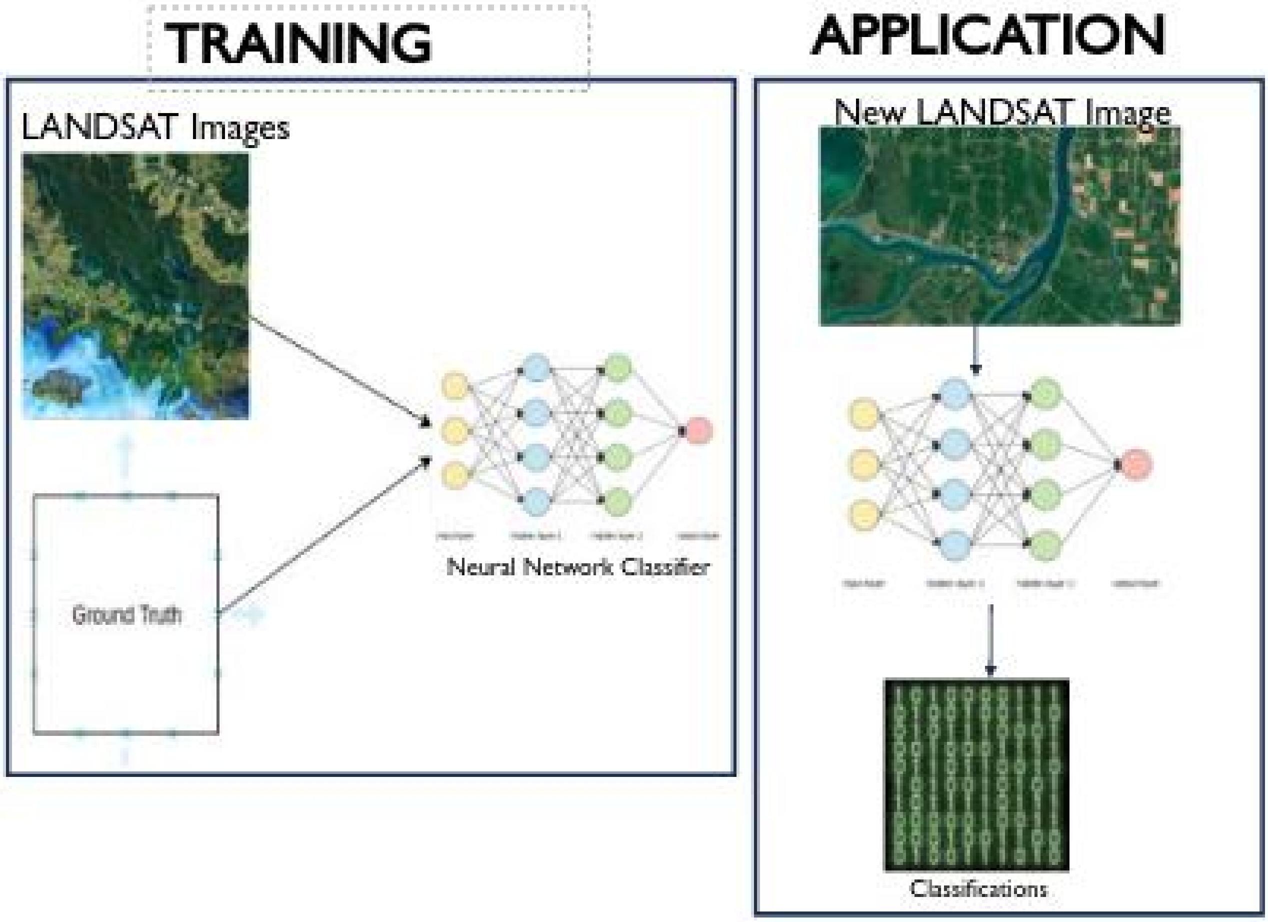

Figure 10: Training Network on LANDSAT only

As mentioned, the primary objective of my project at NASA was to find an effective way to use digital elevation models to improve the accuracy of the classifier, i.e. to get the network to produce a higher percentage of correct classifications. Initially, accuracies on different sample data ranged from $\sim 90\% - 98\%$.

3.4 Methods and Results

All programs for this project were written using Python 3. Moreover, the Keras open-source neural network library was ran on top of Tensorflow and used extensively throughout this

project to build, train and evaluate neural network models.
After discussions with my mentors, the approach I initially decided to attempt was combining digital elevation models with LANDSAT images by creating a new type of image with 8 bands of information. The first 7 bands in this new image type contained the information present in regular LANDSAT images, while the final band contained the elevation values present in digital elevation models. In order to do this effectively, however, it was required that we obtained digital elevation models for the exact geographic locations for which we had LANDSAT images. These DEMs were obtained via the United States Geological Survey open data website. This new image type was then used to train the neural network classifier, in an attempt to improve accuracy classification. An abstraction of this process is depicted below.

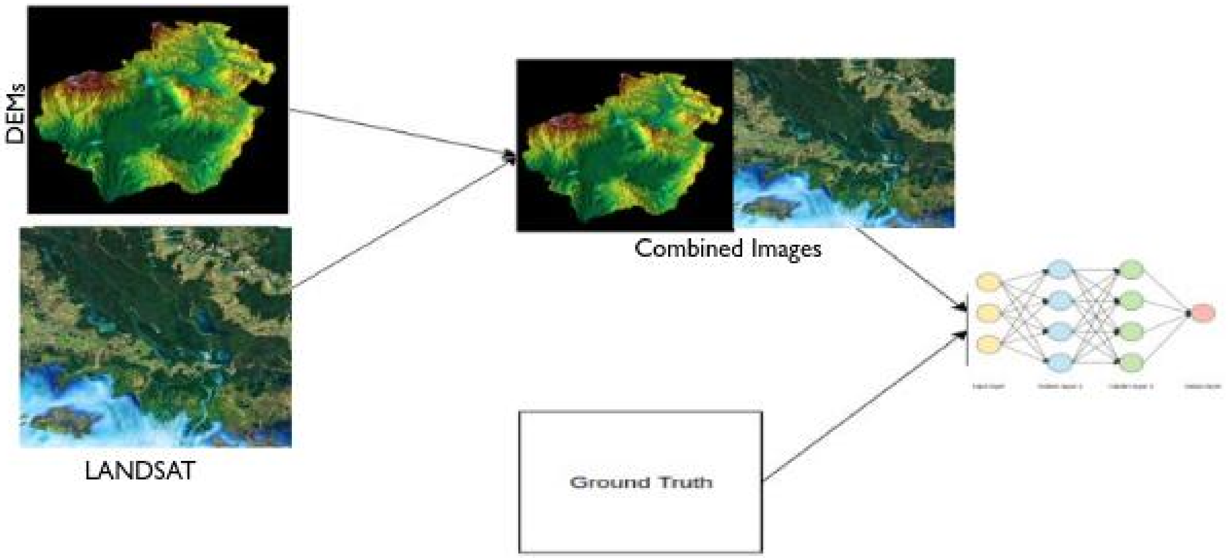

Figure 11: Training Network on LANDSAT only

Unfortunately, however, and as I would learn is usually the case with many research projects, the initial approach did not yield exactly what we had hoped for. For much of the sample data, the accuracy of the predictions made by the network trained on the combination of DEM and LANDSAT images performed roughly the same as the network trained on LANDSAT images only; no clearly visible improvement. In some cases, the accuracy even decreased. A sample of these results are depicted below.

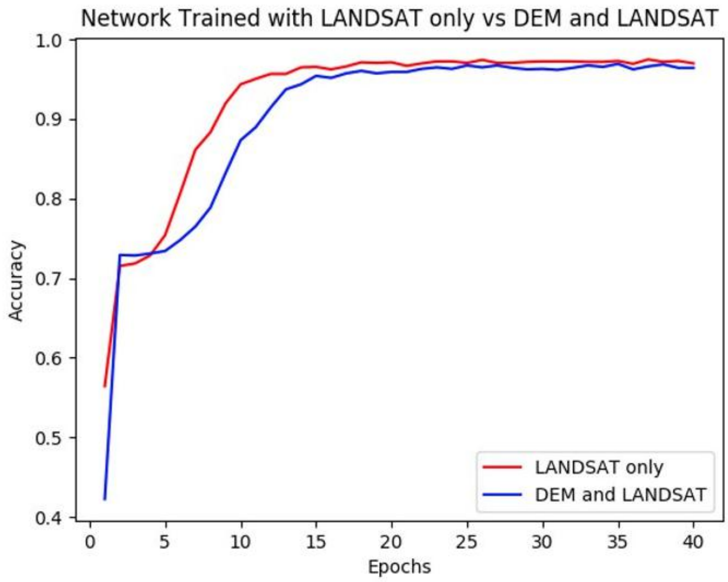

Figure 12: Comparing networks trained on different data

Following the less than satisfactory results of my initial approach, I needed to make a new attempt to improve the accuracy of the classifier.

Explanation: This approach involved using two different neural networks. The first network was trained on LANDSAT images only, and was allowed to make classification predictions. The output from this first neural network, was then combined with the data present in the digital elevation models. This new combined data was then used to train a second neural network. Considering the fact that my internship was nearing its end during the conception of this approach, I was not able to test it as extensively as my initial approach; however, preliminary testing showed average increases in accuracy of $\sim 1.5\% - 3\%$.

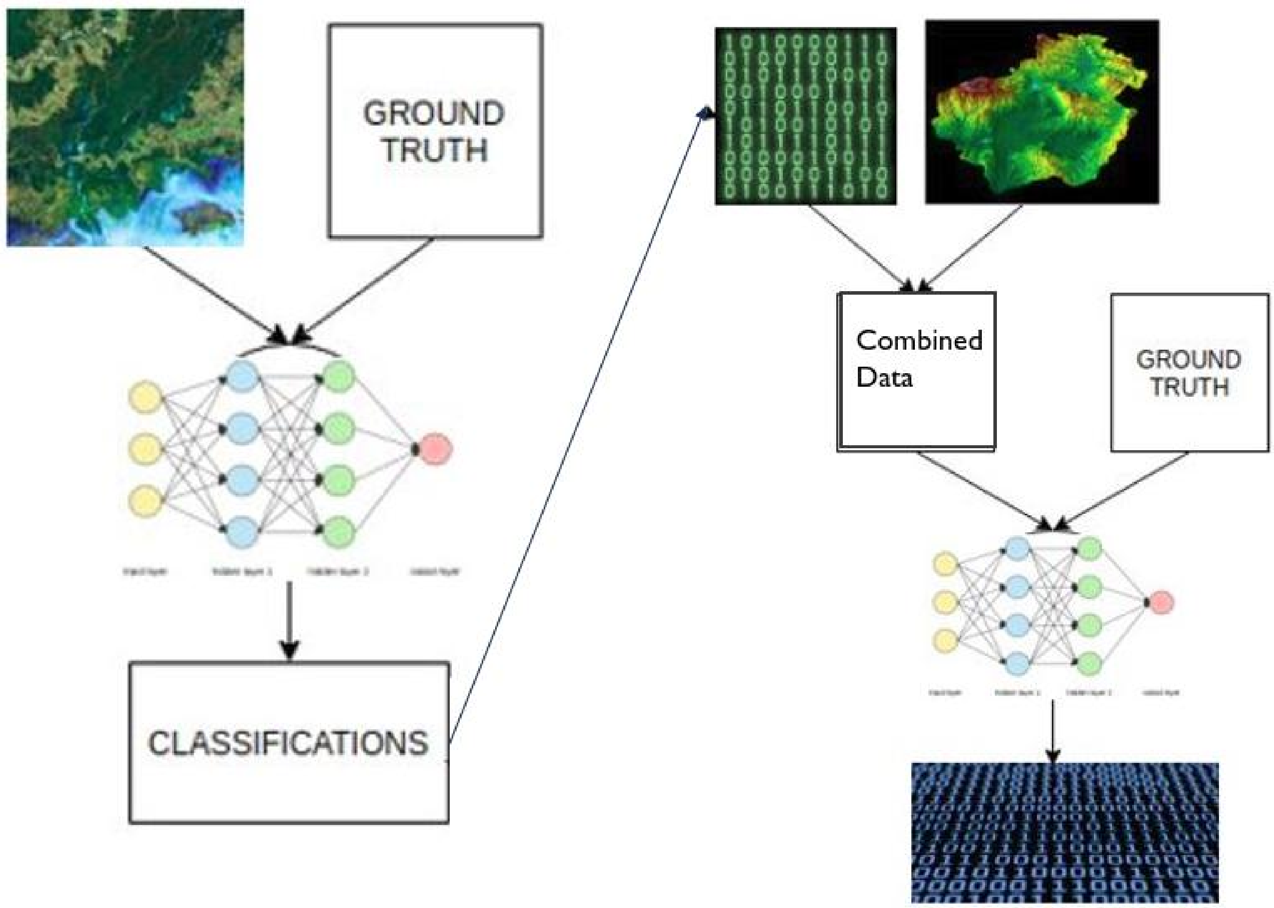

Figure 13: Using output from one neural net to train another

4 Lessons Learnt

4.1 Academic Perspective

Participating in this internship programme was a truly life-changing experience. Before the start of the internship, I was largely an interested onlooker in the field of machine-learning (barring a few small projects). My project necessitated a complete change; from onlooker to practitioner. Before I could even begin working on the project, I needed to get up to speed with a plethora of machine learning principles and paradigms. I can now proudly say that I have a much more solid grounding in the field, and am confident that it is an area I wish to explore much more deeply in the future. More generally, working alongside world-class professionals and established engineers at NASA, it would have been impossible NOT to learn at least a bit about proper software engineering practises; as a budding software engineer myself, I believe that these skills will be indispensable in the future. Essentials I managed to gain a greater appreciation for, and improve my skills in include:

- Git for version control
- Understanding and modifying existing code bases
- Time management
- Proper code structure

4.2 Personal Perspective

When asked, I always make sure to stress that this aspect of my experience at NASA AMES was equally as important as the academic aspect. Being my first time in the United States, I was exposed to a somewhat different way of life. It was really eye-opening to be able experience this new culture, and really important to learn to co-exist with people who come from different backgrounds than myself. What stood out to me, perhaps the most, was the amount of networking I was able to do. It was absolutely insane to be able to pick the brains of scholars from the world's premier scientific institutions, and talk to them on a peer-to-peer level. Furthermore, gaining a sense of independence was a great by-product of this experience. Being responsible for my own meals, laundry, etc. for this period of time will go a long way in my development as a responsible member of society.

5 Project Impact

As mentioned, my work at NASA will contribute to an application which aims to perform automated flood mapping for disaster response. Earth scientists will be able to use the application to automatically survey the Earth and determine whether or not a certain location is flooding. The necessary disaster response teams can then be dispatched to areas where they are required more quickly. This is why it was essential to design the system in such a way that classifications are done as accurately as possible.

5.1 Within Trinidad and Tobago

The flood mapping capabilities of this application will not be limited to one particular geographic location. Meaning that these classifications can be applied to any locations for which Earth scientists can obtain satellite imagery, including Trinidad and Tobago.

But more generally, and I think more importantly, the state-of-the-art techniques to which I was exposed during my time at NASA can be applied to future projects within Trinidad and Tobago, which aim to improve the country in some way. For instance, I am currently working with Dr. Phaedra Mohammed (again) and some of my peers on a project which aims to help better the representation of the Trinbagonian accent in software applications. The core machine learning principles I learned from working at NASA will aid me in helping to develop this system in as robust a manner as possible.

Furthermore, I believe it is important to raise awareness of this programme. Seeing that these types of opportunities are actually available to Trinbagonian students definitely inspired me to perservere through the tough times in my academic career, as well as to get my feet wet in the world of research early on. Upcoming students will undoubtedly be inspired to push the limits of what is currently possible in STEM in Trinidad and Tobago, in the hopes of one day becoming a NASA intern themselves.

6 What's Next?

Through my involvement with this internship programme, I feel as though many of my goals are much closer within reach. I have always intended to pursue my Master's degree at one of the world's top universities; so while the internship may not have necessarily CHANGED my perspective per se, I will now feel much more confident in applying to the next institution on my journey.

As for the present and the near future, I shall complete my bachelor's degree at the UWI, while continuing to work on fascinating research projects with my peers and seniors, relevant to Trinidad and Tobago, the Caribbean or otherwise.

I am not 100% sure what the future holds at this point in time, but after this experience, it definitely seems like nothing but positivity is in store.

7 Acknowledgements

Of course, this was not a solo venture; none of this would be possible without the outstanding support received from numerous persons and organizations. Firstly, to the corporations who opted to support this internship programme, I offer a heartfelt thank you. Secondly to the every single person who contributed to getting me to California, be it financially or by simply spreading the word, this could not have been done without you! To my family, for the emotional and financial backing you have provided me with over the years and throughout this process, I genuinely appreciate it. After arriving at AMES, none of the work I was able to complete would be possible without daily assistance from my awesome mentors and co-workers: Brian Coltin, Michael Furlong, and Scott McMichael. And finally, to those at NIHERST, I wish to extend my sincerest gratitude to you for facilitating this programme and providing young Trinibagonian students like myself the opportunity of a lifetime.