G5

PROJECT DOCUMENTATION

Project Vision

Aerial Imagery Initiative

Ver. LCAM

Index

1. Introduction

The NSW Spatial Services division of the Department of Customer Service (DCS) collects aerial and LiDAR images of the NSW landscape and is responsible for providing reliable spatial information to NSW Emergency Service Organisations (ESOs). In order to better facilitate rapid responses and recovery efforts to emergency flood events, this project aims to develop a program that will analyse aerial and LiDAR imagery to generate flood extent maps.

The current standard of practice for DCS during a flooding event is to fly an aeroplane over flood-affected regions of interest (ROI) to capture aerial images. These images are taken as long continuous strips which must be stitched together, colour-balanced, and orthorectified to produce a surface model representation of the ROI. This surface model is distributed to other government departments for identifying flood boundaries; however, this does not provide an authoritative record as each client utilises their own processes for identifying the exact boundary. The aim of this project is to consolidate and standardise this task into a repeatable, accurate, and time-efficient process to improve the quality of the product offered by DCS and eliminate variance and redundant workloads by DCS's clients.

This project will include an extended phase of testing and development to determine the eventual architecture for the project. The first option is to utilise computer-vision libraries and their associated clustering and contouring algorithms (OpenCV, 2021; Scikit-learn, 2021). For each pixel in an image, there are several channels depending on the colour-space being used such as RGB (red, green, blue), HSV (hue, saturation, value), or NRG (near infra-red, red, green). Using a combination of these channels as input, unsupervised clustering algorithms can group pixels based on their overall homogeneity. Homogeneity can be assessed on Euclidean distance, as with the K-Means clustering algorithm to give a hard assignment, or it can be calculated as a weighted probability distribution across multiple Gaussians, as with the Gaussian Mixture Model (Zheng et al. 2018; Ban et al. 2018).

Addition part of change 2.1 (See change log)

Programs that are able to generalise relationships between input variables and output labels through inductive inference, are categorised as machine learning programs (Guo et al., 2020). Many of the difficulties in machine learning research deal with defining problems that are simple for people to perform but hard to formally describe because they entail a high level of intuitive and subjective knowledge of the world, such as recognising faces in an image (Goodfellow, 2016). One class of problems that machine learning programs are effective at solving are classification problems through the use of convolutional neural networks and support-vector machines (Hasan et al., 2019).

Designing and implementing an original machine-learning model requires a prohibitively high level of technical expertise (Goodfellow et al. 2016). The use of a machine-learning model provided by AWS SageMaker will significantly reduce the workload and technical barriers for the project. All machine-learning models require a large training dataset to reach an effective performance measurement (Goodfellow et al., 2016). A dataset of over 100 images will be manually labelled to train the SageMaker model.

The efficacy of both methods will be considered against their respective processing requirements. Due to its computational complexity, the machine learning model approach is likely to be more accurate. However, if it is only marginally more accurate, yet computationally much more expensive than the alternative, it may be beneficial to forgo using a machine learning model in favour of the first approach.

By using computer-vision libraries and machine learning models, this project aims to develop a system capable of accepting new aerial and LiDAR images of the NSW landscape and classifying specific segments as either affected or unaffected by floods. This information will be used to provide accurate flood extent maps to NSW ESOs.

2. Positioning

2.1 Problem Statement

The problem of	providing reliable and expeditious spatial information of flood affected areas
affects	NSW Spatial Services and NSW Emergency Service Organisations
The impact of which is	Implementing disaster-relief and recovery plans based upon current and accurate information
A successful solution would be	A program that automates the process of taking aerial and LiDAR images as input and classifies specific segments as either affected or unaffected by floods, producing a map of peak-flood extent

2.2 Product Position Statement

For	NSW DCS, Spatial Services, ESOs
Who	Need access to reliable spatial information on disaster-affected areas
The	Computer vision methods and machine learning model trained in AWS Sagemaker
That	Will be able to take aerial and LiDAR images and classify segments as affected or unaffected by floods, classification will be performed as soon as the images are available
Unlike	Human inspection of images which has a degree of error and lack of time-efficiency
Our Product	Will provide accurate and up-to-date flood extent maps

3. Stakeholder Descriptions

3.1 Stakeholder Summary

Name	**Description**	**Responsibilities**
NSW Department of Customer Service - Spatial Services	Spatial Services is a division of the NSW Department of Customer Service which provides authoritative spatial and land information. Spatial Services has invited Charles Sturt University students for work experience with the Business Technology Services Team until December 2021.	Provide project scope, approach and timelines. Provide roles/responsibilities and governance arrangements. Define high-level requirements of the system. Provide ongoing liaison for project updates. Distribution of final product output by the system.
Intellify	Intellify specialise in the delivery of Artificial Intelligence solutions. Being the second consultant in Australia and New Zealand to be awarded the Amazon Web Services Machine Learning Competency makes Intellify well placed to assist with Machine Learning projects.	Create the AWS environment to use AWS SageMaker and associated AWS services. Upskill Spatial Services & Team 5 in the use of ML/AI. Provide ongoing support to Spatial Services. Outline technical implementation of requirements.
Dr. David Tien	Dr Tien is a Senior Lecturer in Information Technology at Charles Sturt University. He has over 34 years experience in AI related research.	Supervise and Mentor Team 5. Liaise with DCS and Intellify.
Team 5	Team 5 consists of five undergraduate students studying at Charles Sturt University undertaking the ITC 303 and ITC 309 Software Development Project subjects during 2021.	Produce deliverables in line with ITC 303 / 309 requirements and project requirements as requested by DCS.

3.2 User Environment

As the project involves a period of testing and development to determine the final architecture, certain aspects of the user environment are subject to change. The and will be discussed as two alternative scenarios with certain details remaining constant regardless of the outcome of the testing and development phase.

The DCS users who will utilise the machine learning model to produce the flood extent mapping are familiar with the AWS CLI (command line interface) and ArcGIS (Esri, 2021), a geospatial information system that combines topographic, qualitative, and quantitative data. These users will be situated in the Spatial Services division of DCS. An interactive graphical user interface is not within the scope of this project. The end product is required to perform the core use case utilising a command line interface. If the project utilises the computer-vision libraries without any machine learning technology, then the user environment will either be a CLI or integrated development environment in conjunction with the ArcGIS software. If the project incorporates the AWS SageMaker machine learning model, the user environment will likely consist of the AWS CLI, using the AWS Lambda (AWS, 2021a) functions as an entry point, AWS S3 Buckets (AWS, 2021b) for storage, and a AWS SageMaker Endpoint (AWS, 2021c) to host the trained machine learning model.

The final output will be a surface model object for the ArcGIS software application. This will be distributed by DCS to multiple government agencies such as the NSW RFS (Rural Fire Service) and NSW DPI (Department of Primary Industries) and ESOs who will use the flood extent maps for emergency service planning. For example, NSW DPI may use the product to identify stranded herds of cattle and organise food drops. This implies there will be multiple users of the end product with different priorities.

The process of manually processing aerial images into a usable format for ArcGIS applications including image stitching, colour-balancing, and orthorectification takes approximately 48 hours. The system being developed will take these images as its input to generate flood-extent maps as outlined in the figure below.

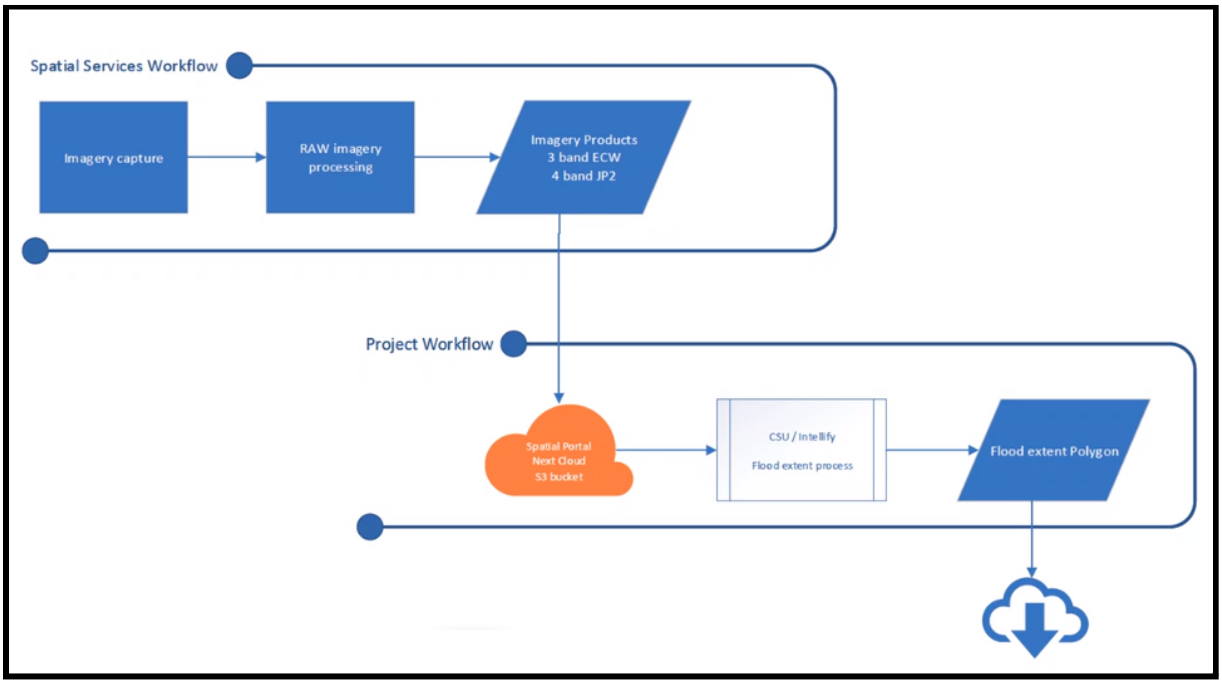

Figure 1 - DCS workflow for fooding aerial imagery

4. Product Overview

4.1 Needs and Features

The functional requirements and non-functional requirements of the project are outlined in detail in the Initial Requirements Model document. Some of the functional requirements that directly relate to the business needs of the project are briefly outlined below.

Need	Priority	Feature
4.1.1 The system must be able to accept a batch of aerial images and map the extent of flooding within them	Low	AWS Simple Storage Service (S3) for storage and retrieval of images
4.1.2.a The system will utilise a machine learning model to classify areas of interest as either flooded or not flooded. **4.1.2.b** The system will utilise computer vision libraries to perform image segmentation to isolate the flooded area within an image.	High High	AWS SageMaker inbuilt machine learning algorithm Use of scikit-learn and OpenCV libraries for clustering algorithms and contour extraction
4.1.3 The output of the system will be a map of the flood extent. The machine learning model will perform classifications at a pixel-by-pixel level. A subsequent process will be necessary to transform this output into a product that can be distributed to clients.	High	QGIS library to generate ESRI shapefile objects. ***Addition part of change 2.2 (See change log)***

4.2 Other Product Requirements

Requirement	Description	Priority
Performance	The output of the system must be accurate. Ideally the model will correctly segment the input images at the pixel level. The resolution of the image will determine the accuracy in terms of metric measurements (e.g. 5m margin of error ~~confidence interval~~).	High
Cost	The development and deployment of the system must not exceed the allocated budget from DCS of $50 000.	Moderate
Security	The storage of Spatial Service data must adhere to the NSW Data & Information Custodianship Policy which outlines data handling and storage requirements for government agencies.	Low
Reliability & Availability	The system will not be in need of continuous use. Usage patterns will depend upon frequency of flood events. However, it is important the system is available and reliable when it is in need as its output will serve as a basis for emergency response planning.	Moderate
Usability	The system does not require a graphical user interface. A program that can be run either in a command line prompt or integrated development environment will suffice.	Low

Change Log

Changes highlighted either side of the change like below.

Example change or addition

Addition part of change x.x (See change log)

Example of paragraph containing additions AND removals

Edoted for clarirty part of change x.x (See change log)

Example ~~removed~~ or old but relevant information

Removed or superseded from change x.x (See change log)

Version	Date	Change	Author
1.0	-	LCOM document	Andrew Smith
1.1	31-5-21	Edited paragraphs in Introduction for clarity and updated approach.	Andrew Smith
1.2	08-06-21	Updated the features and requirements to reflect the testing and development phase of the project, the results of which will determine the architecture and its requirements and features. Also removed labelling of training dataset as a system requirement as this is done manually by the team.	Andrew Smith
1.3	12-6-21	Added paragraph in Introduction outlining colour spaces and clustering algorithms. Included additional references for K-means and Gaussian Mixture Models. Included information on testing two approaches and choosing the optimal outcome.	Andrew Smith
2.0	19-6-21	LCAM submission document.	Andrew Smith
2.1	19-7-21	Corrected incomplete sentences on KMeans and GMM assignments.	Andrew Smith
2.2	19-7-21	Added use of QGIS library for generating ESRI shapefile objects as final output.	Andrew Smith

References

AWS. (2021a). *AWS Lambda*. https://aws.amazon.com/lambda/

AWS. (2021b). *AWS S3*. https://aws.amazon.com/s3/

AWS. (2021c). *AWS SageMaker*. https://aws.amazon.com/sagemaker/

AWS. (2021d). *AWS SageMaker Ground Truth*. https://aws.amazon.com/sagemaker/groundtruth/

AWS. (2021e). *AWS Command Line Interface*. https://aws.amazon.com/cli/

AWS. (2021f). *AWS CloudTrail*. https://aws.amazon.com/cloudtrail/

Ban, Z., Liu, J., & Cao, L. (2018). Superpixel Segmentation Using Gaussian Mixture Model. *IEEE Transactions on Image Processing*. 27(8). DOI: 10.1186/s13640-018-0309-3

Esri. (2021). *ArcGIS Overview*. https://www.esri.com/en-us/arcgis/about-arcgis/overview

Goodfellow, I., Bengio, Y. & Courville, A. (2016). *Deep Learning*. MIT Press

Guo, H., Wu, S., Tian, Y., Zhang, J. & Liu, H. (2021). Application of machine learning methods for the prediction of organic solid waste treatment and recycling process: A review. *Bioresource Technology*. *319*. 124114-124127

Hasan, H., Shafri, H. Z. M. & Habshi, M. (2019). “A Comparison Between Support Vector Machine (SVM) and Convolutional Neural Network (CNN) Models for Hyperspectral Image Classification” In *IOP Conference Series: Earth and Environmental Science* (Vol. 357, No. 1, pp. 012035). IOP Publishing

Jupyter. (2021). *Project Jupyter*. https://jupyter.org/

OpenCV. (2021). *OpenCV Homepage*. https://opencv.org/

Scikit-learn. (2021). *Scikit-learn: Machine Learning in Python*. https://scikit-learn.org/stable/

Zheng, X., Lei, Q., Yao, R., Gong, Y., & Yin, Q. (2018). Image segmentation based on adaptive K-means algorithm. *EURASIP Journal of Image Processing and Video Processing*. *68*. DOI: 10.1186/s13640-018-0309-3

Title page cover photo.

Milton Coronation Drive flooded. (2011). Retrieved from https://www.abc.net.au/news/2011-06-03/brisbane-floods3a-before-and-after-article/2742794?nw=0