

Initial Requirement Model

Group 5 (G5) - Aerial Imagery Initiative

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1. Functional Requirements

1.1 Business Rules

- ❖ 1.1.1 The system must be able to accept a batch of aerial images and map the extent of flooding within them.
- ❖ 1.1.2 The system will utilise a machine learning model to classify areas of interest as either flooded or not flooded.
- ❖ 1.1.3 The system will extract appropriate feature vectors from the images that will determine accurate classifications of flooded/un-flooded areas on new images.
- ❖ 1.1.4 The system will perform feature reduction and data cleaning operations as appropriate before passing the feature vectors into the machine learning model.
- ❖ 1.1.5 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.

1.2 External Interfaces

- ❖ 1.2.1 The system must utilise a machine learning model from AWS SageMaker¹. The specific model (e.g. Convolutional Neural Network, Decision Tree Algorithm, etc.) will be determined at a later stage in the design process. The SageMaker console itself utilises Jupyter Notebooks² for data pre-processing, model training, and hyper-parameter tuning.
- ❖ 1.2.2 The system must utilise AWS SageMaker GroundTruth³ for data labelling and pre-processing of input aerial images and feature extraction.
- ❖ 1.2.3 The AWS CLI⁴ (command line interface) will be used for accessing AWS services.
- ❖ 1.2.4 The output of the system must be compatible, or at least transferable, to ArcGIS⁵, a mapping and data analytics program used by NSW government departments for generating geo-spatial information.

¹ AWS, *Amazon SageMaker*, <https://aws.amazon.com/sagemaker/>

² Jupyter, *Project Jupyter*, <https://jupyter.org/>

³ AWS, *Amazon SageMaker Ground Truth*, <https://aws.amazon.com/sagemaker/groundtruth/>

⁴ AWS, *AWS Command Line Interface*, <https://aws.amazon.com/cli/>

⁵ Esri, *ArcGIS Overview*, <https://www.esri.com/en-us/arcgis/about-arcgis/overview>

1.3 Authentication & Auditing

- ❖ 1.3.1 Use of the AWS services entails costs while code is executing, or a service endpoint is up-and-running. The system and its development environment must only be accessed by authenticated developers.
- ❖ 1.3.2 The project has an allocated budget of \$50 000. The system development environment must allow for auditing of resource use and cost.

1.4 Storage & Capacity

- ❖ 1.4.1 The output of this project is to serve as an historical record of flooding events. This requires long-term storage of the system's output.
- ❖ 1.4.2 If the project proves successful, the scope may be expanded so as to analyse up to ten years of past flooding events. The system must have the ability to scale its storage capacity.
- ❖ 1.4.3 The system must be able to process raw input images that are approximately 10 GB in size. The pre-processing stage of the machine learning process will likely reduce the eventual inputs of the machine learning model, but the system must be able to handle this size of initial files.

1.5 Functional Requirement Priority Matrix

| Functional Requirement | Priority | Justification |
|------------------------|----------|--|
| Business Rules | High | These form the core deliverables of the project. Given that the output of the project is a product to be used by multiple government agencies in their emergency response planning to flood events, it is imperative that all goals are met to a satisfactory standard. Substandard outcomes will nullify the business case for the project. |
| External Interfaces | High | The use of external interfaces will drastically decrease the project workload and assist in overcoming technical difficulties in the machine learning process which is a highly skilled and specialised area of software engineering |

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|---------------------------|-----|---|
| | | and data science. It is important that these interfaces are incorporated into the project development and final outcome. |
| Authentication & Auditing | Low | The AWS services for system development will be accessed through DCS's <i>ss-identity</i> account, so authentication for users interacting with the system will already follow best-practices. Furthermore, AWS CloudTrail allows authenticated administrators to access each API call from all AWS products for a given account. This provides a high level of auditing. Secure distribution of the final product is beyond the scope of this project. |
| Storage & Capacity | Low | AWS will host the infrastructure for the system, hence many of the details of storage and capacity will be accommodated by its scalable IaaS services. |

2. Non-functional Requirements

2.1 Performance

- ❖ 2.1.1 The system is automating and consolidating a process that is performed by several government departments manually. Although no exact figure has been outlined by the stakeholders in terms of the model's classification accuracy, it must at least out-perform the current process.
- ❖ 2.1.2 Emergency response planning operations will use this product as a source of information. Considering that the process of taking the aerial images and post-processing tasks takes 48 hours, it is important that the response time of the system is efficient.

2.2 Cost

- ❖ 2.2.1 The development of the system must not exceed the allocated \$50 000 budget from DCS.

2.3 Security

- ❖ 2.3.1 Since the data to be used for the project will be stored in AWS S3 Buckets owned and managed under the DCS *ss-identity* account, it is assumed that any relevant laws, policies, or regulations pertaining to data confidentiality, integrity, and storage will be adhered to. G5 will only access the data through the AWS CLI environment which will leave a log of any access operations through AWS CloudTrail, thus providing a record of all user interactions that can be examined to ensure compliance.

2.4 Usability

- ❖ 2.4.1 Users will be skilled in aerial image analysis and familiar with command line interfaces, API calls in Python, and the AWS services particular to this project. As a result, a user interface with a conventional layout is not necessary. More emphasis will be placed on system performance and reliability.
- ❖ 2.4.2 One of the business goals of the system is to simplify and consolidate data processing tasks so they are not duplicated with variance amongst government agencies. It is important that all organisations in the wake of a flooding event have a single authoritative dataset to use for recovery planning and historical record keeping.

2.5 Reliability & Availability

- ❖ 2.5.1 Given the infrequency of flooding events, the system will be in sporadic use. But when it is needed the system must be able to perform uninterrupted and in a time-efficient manner as the results are to be used by multiple government departments and agencies for emergency response planning.
- ❖ 2.5.2 The time between taking aerial shots and their readiness for processing is forty eight hours. It is essential that the next steps of outputting a polygon layer in an ArcGIS environment does not add too much extra time to the process.

- ❖ 2.5.3 When the system is in use, it is imperative that the system does not crash. Loss of data half-way through model training, or generation of prediction set will require restarting the program. In other words, progress cannot be incremental.

2.6 Non-functional Requirement Priority Matrix

| NFR | Priority | Justification |
|----------------------------|----------|---|
| Performance | High | The business case for the system is premised on the efficiency and accuracy of an automated machine learning pipeline. The system must therefore achieve its goals with a high degree of efficiency and accuracy. |
| Cost | Moderate | The budget allocated for the project is likely to be sufficient. In particular, AWS Lambda offers pay-as-you-go pricing options in which customers are only charged for as long as their code is executing in a cloud environment. |
| Security | Moderate | The constraint of the AWS Cloud Practitioner environment for development and data storage already enforces authentication, customisable access control, and secure storage options. |
| Usability | Low | The users for the system are a skilled set of employees at DCS and SS who are familiar with the processing of aerial images and geospatial mapping software. Development of an API has already been deemed unnecessary. As a result, little emphasis will be placed on making the system accessible to new users. |
| Reliability & Availability | Moderate | The system will be deployed on a continuous basis. Rather, it will be required in the wake of flooding events. However, it is important that the system does not fail while it is in use. Utilisation of AWS infrastructure services is likely to ensure reliability and availability. |

3. Use Case Descriptions

3.1 Use Case - Flood Area Classification

3.1.1 Brief Description

When a DCS/SS employee,
Wants to generate a map of flooding extent, they access the AWS lambda function to initiate a batch upload of the aerial images to the SageMaker endpoint to receive a classification of flooded areas,
So that they can distribute this information to other Emergency Service Organisations.

3.1.2 Actors

- ❖ DCS/SS Employee - An employee of one of the NSW Department of Customer Service and/or the Division of Spatial Services. They are responsible for the processing of aerial images of flood affected areas and providing products to other NSW government departments and agencies in their emergency response planning.

3.1.3 Pre-conditions

- ❖ The SageMaker endpoint is active.
- ❖ The user has a set of aerial images that have undergone pre-processing operations such as colour balancing, orthorectification, and stitching.

3.1.4 Normal Flow

The use case begins when the ESO employee calls the AWS lambda function.

| User | System |
|--|--|
| 3.1.4.1 User passes batch of aerial images through AWS lambda function | 3.1.4.2 The system performs pre-processing tasks on images for feature reduction and extraction. |
| | 3.1.4.3 The system identifies segments |

| | |
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| | of images as affected/unaffected by flood on a pixel by pixel basis. |
| | 3.1.4.4 System returns its classification of flooded areas to the user. |

3.1.5 Alternate Flow

If at 3.1.4.4 the system has the capability to transform its pixel-by-pixel analysis to an ArcGIS shapefile object.

| User | System |
|------|---|
| | 3.1.5.1 The system transforms the data into an ArcGIS shapefile object to return to the user. |

3.1.6 Key Scenarios

3.1.5.1 Classification success

The SageMaker endpoint returns an accurate set of predictions of flood-affected areas at the pixel level of granularity.

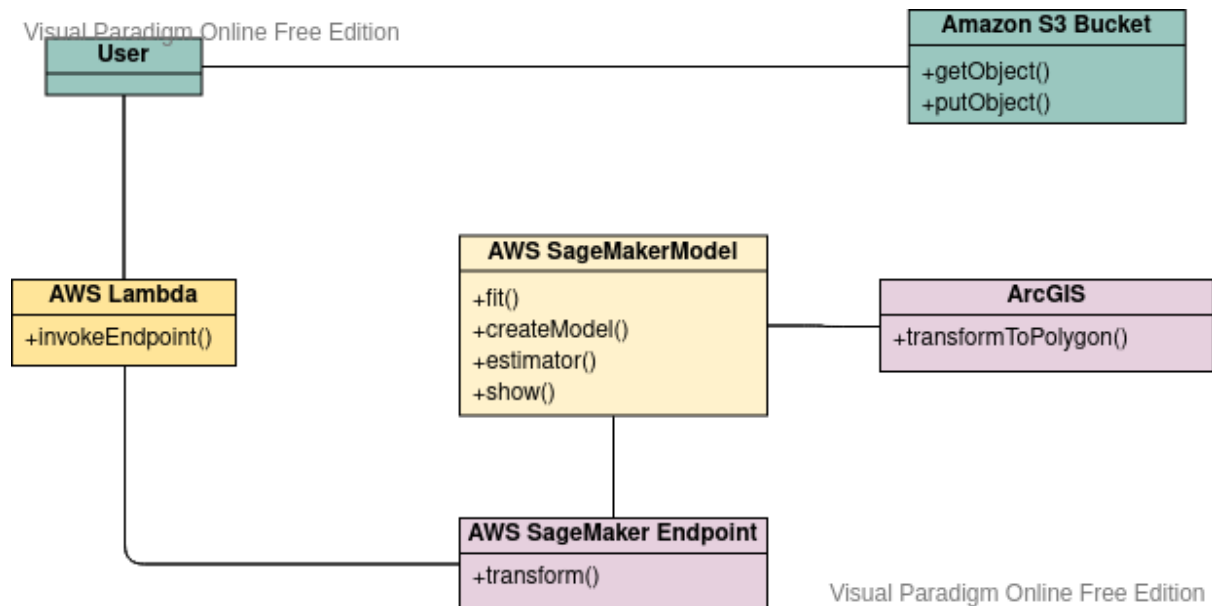
3.1.5.2 Classification success - Alternate scenario

The system returns an Esri shapefile object. This is a polygon overlay that will represent the flood extent map, usable by NSW ESOs.

3.1.6 Post-conditions

6.1 DCS/SS employees are able to provide a flood extent map to other Emergency Service Organisations.

4. Domain Class Diagram



Note: Although domain class diagrams do not normally specify details of implementation such as the use of the AWS Lambda service, the constraints of the project have made such design implementations clear, hence they have been included in the above diagram.