FRONTIER SI

QUEENSLAND DEPARTMENT OF TRANSPORT & MAIN ROADS (TMR) SPATIAL ANALYTICS LAB PROGRAM

2022

PROPOSAL BRIEFING DOCUMENT

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Objective

TMR Spatial Analytics Labs Program 2022 (TMR Spatial Labs), delivered by FrontierSI, has been created to help Queensland Transport and Main Roads (TMR) rapidly engage with industry and academia to explore novel approaches to using artificial intelligence / machine learning (AI/ML) for automated imagery analysis and product generation, including object classification.

Specifically, TMR is keen to attract a wider pool of companies and technologies with existing capabilities to draw on for automated geospatial data extraction and processing to support state-wide planning and decision-making, and enable future focused smart, connected and autonomous infrastructure, networks and vehicles. The Program consists of two rounds of short-term capability demonstrator / research projects with Australian companies and universities.

What is TMR Spatial Labs?

The TMR Spatial Labs initiative aims to improve TMR's access to timely, efficient, accurate, and sustainable information and insights for Queensland's roads. The Program is a way for Queensland Transport and Main Roads (TMR) to harness industry and research Artificial Intelligence/Machine Learning (AI/ML) capabilities to extract insights from airborne, drone and vehicle mounted remote sensing data to address critical challenges and gaps in Queensland's future 'single integrated transport network accessible to everyone'., across the Queensland road network to support critical current and future transportation use cases.

FrontierSI and TMR are seeking demonstrations of novel approaches to accurately and efficiently supplement TMR's understanding of what's on and near the road, and road corridor, across the Queensland transport network. This work will support state-wide planning and decision-making, and enable future focused smart, connected and autonomous infrastructure, networks and vehicles. Airborne, drone and vehicle mounted visible, multispectral and thermal imagery data (Appendices B and C) focused on a case study area, is available on request to support proposal development and demonstrator project delivery.

Four challenge questions have been developed which explore different aspects of applying AI/ML to high-resolution imagery data to create derivative products, and to extract information from lower-resolution imagery data, both within the case study area and at larger scales. These challenge questions have the ultimate objective to understand exactly what features can be derived from different imagery products, at different resolutions, with certain levels of accuracy and confidence. Applicants can apply for more than one challenge topic.

Successful projects will be funded up to $50,000 for projects up to four months in length. There will be two rounds of TMR Spatial Labs projects arising from this current proposal call, with the first two projects to be completed by the end of July 2022, and the second two projects to be completed by November 2022. Challenge topics listed herein are for both rounds. The four TMR Capability Challenge Topics are briefly described below. It is recommended that organisations read the full description of each challenge topic (provided in Appendix A of this document) to understand each challenge's background, use cases and evaluation criteria.

Timeline

Interested parties may submit a TMR Spatial Labs project proposal by completing a short proposal, using the template downloaded from the TMR Spatial Labs page (https://www.frontiersi/tmrlabs/), and emailing to the FrontierSI TMR Spatial Labs Project Manager, Roshni Sharma, at tmrlabs@frontiersi.com.au **by 5:00 pm (AEST), Friday 8th April 2022**.

Projects will be shortlisted by a panel with representatives from both TMR and FrontierSI. Applicants may be contacted to provided further details on their proposals.

Successful projects will be notified in April 2022. The first round of projects is expected to start in April 2022 and be delivered by the end of July 2022. A second round of projects, selected from the same application intake, is expected to start after July 2022 and be delivered within three to four months.

Challenge Topics

Challenge Topic 1: How many can you get?

TMR is seeking demonstrations of novel approaches of using AI/ML to extract information and insights about what's on the road, around the road and in the road corridor from very high-resolution imagery products. How many quality derivative datasets (target list provided in Appendix B) can you extract from the provided datasets to augment TMR's existing transport network data in a reliable, timely and automated way?

Challenge Topic 2: To infinity and beyond

TMR is seeking demonstrations of novel approaches to the creation of derivative products trained on very high-resolution data which can be applied to generate these same derivate products from lower-resolution aerial photography data. How effectively can you scale up the extraction of information and insights about what's on the road, around the road and in the road corridor for a larger area, and how good is the data, really?

Challenge Topic 3: Viva le resolution

TMR is seeking a research-based investigation into the accuracy and precision limits when using AI/ML algorithms to extract enriched road information and insights at different image resolutions. When derivate products are made from different source datasets that have different ages and accuracies, how can we have confidence they can work together effectively? How well can we quantify how different data extraction methodologies (including training AI/ML models for lower-resolution imagery), and image resolutions affect the accuracy and utility of derived datasets for specific use cases?

Challenge Topic 4: Seeing in the dark

TMR is seeking demonstrations of novel applications of AI/ML to mine non-visual (i.e., multispectral, hyperspectral, thermal, LiDAR/point cloud, radar, other) remote sensed data to detect information and insights about the roads, and road corridor. Can we detect problematic unplanned changes due to natural disasters, vegetation growth, drainage issues, subsurface changes before they become a major problem?

Additional Resources

A public information session webinar will occur on Friday 31 March, 2022. This webinar will include a presentation of the aims of the TMR Spatial Labs program, as well as interactive Q&A with TMR and FrontierSI representatives.

A registration link for the webinar will be provided on the TMR Spatial Labs page (https://frontiersi.com.au/tmrlabs/). Additional questions can be directed to FrontierSI at tmrlabs@frontiersi.com.au

Project Data

Target derivative data products for this data are described in Appendix B of this document, and a full list of datasets available from TMR for this project is available in Appendix C. Please register your interest here to be provided with access a portal where this data is held. This data is available for use on this project only.

TMR-provided datasets

TMR is providing high-resolution visible, multispectral and thermal data for a case study area in South-east Queensland (the RACQ Mobility Centre and a section of Mount Cotton Road next to the centre), with a full list of available datasets and brief metadata available in Appendix C. Data types available include aerial imagery, aerial LiDAR, mobile Laser Scan data, vehicle-mounted aerial imagery, and drone-captured LiDAR, multispectral and thermal imagery. Derivative datasets that arise from this project should be created and considered within the context of broader TMR transport network data, including the ability to be associated with and related to existing linear reference systems and common spatial reference systems.

Linear Reference System

TMR's pavement assets are managed using a linear referencing system with TMR's road asset management system (ARMIS) that includes combinations of road section ID's, carriageways and lane encoding. This linear referencing model is by "road section" and has a zero location to indicate the road section start by carriageway. Calibration points are located along the road section length at physical features such as intersection, island or bridge abutments. A carriageway level centreline (GIS) is calibrated and validated against the linear reference information for each road section to enable the translation of linear reference to spatial location and vice versa.

It is important to note that linear references for the same spatial location can change over time as the centreline is updated to reflect changes to the physical road alignment. Centreline and linear reference versioning is essential to ensure locations are consistent.

It is expected that responses to the challenge questions in TMR Spatial Labs are able to work within this linear reference system as well as GDA2020.

Budget

Challenge projects will be funded with a budget of up to $50,000. There is no requirement that additional funding will be provided to the project by applicants.

Project deliverables

Successful projects will be required to, at the end of their round, provide a presentation and final report to FrontierSI and TMR outlining:

- the approach they have taken
- a description of the project outcomes within the context of the selected challenge question
- a demonstration of the outcomes showcasing achievements
- an overview of lessons learnt.

The delivery of derivative datasets and related source code created during the project is not required, however it would be seen as preferable to allow TMR to independently evaluate suitability of derived outputs.

Evaluation Criteria

Projects that meet the following criteria will be considered, for further information please refer to the TMR Labs Template found at the TMR Labs website https://frontiersi.com.au/tmrlabs/

Required

- Project approach and outputs that address the challenge topic (or multiple challenge topics if applicable)
- Intended approach is appropriate in scope, proposed methods and measurement of success
- Presence of project management and communication strategies to support the project approach
- Derivative products that arise from this project should sit within the context of broader TMR data and hence be able to be related to a linear reference system as well as GDA2020.
- Project offers value for money
- Potential for collaboration following the Challenge project stage

Desirable

- Commitment to Diversity and Inclusion
- In-kind contributions from project partners (e.g., staff time, equipment, IP).

Intellectual Property

The products delivered to TMR (TMR owned IP) as part of the challenge projects are limited to defined reports, presentations, learnings, recommendations, and potentially output datasets.

All background IP brought to the projects and developed as part of the projects remains owned by the 3rd parties. This may include, but is not limited to software, code, applications, data and methodologies.

Constraints and Requirements

- The Queensland Government contribution will be limited to $50,000 per project
- Projects should be completed in a period of approximately three to four months
- A final project demonstration and presentation accompanied by final report is required at the end of the TMR Labs project
- The lead organisation must be a company from Australia or New Zealand
- Project participants are expected to participate in or contribute to promotional events and publicly available reports and/or press releases.

Appendix A – Challenge Topics

Challenge Question 1: How many can you get?

Extracting as many road surface, asset and surround datasets as possible from high-resolution data

Overview

TMR is seeking demonstrations of novel approaches of using AI/ML to extract information and insights about what's on the road, around the road and in the road corridor from very high-resolution imagery products. How many quality derivative datasets (target list provided in Appendix B) can you extract from the provided datasets to augment TMR's existing transport network data in a reliable, timely and automated way?

Problem Statement

Queensland Department of Transport and Main Roads is responsible for managing the single most valuable asset in the state, the road network. Maintaining a digital representation of this network that is current, complete, accurate and sustainable is critical to TMR supporting key current (asset management and monitoring) and future transportation use cases (smart transport networks, autonomous vehicles). TMR are looking at how they can leverage Machine Learning algorithms, and high-resolution imagery from a variety of sensors to improve their insights and understanding of their roads.

This challenge is seeking demonstrations of AI/ML to reliably and sustainably map what's on the road, near the road, and around the road corridor with the highest degree of confidence possible. It is important that derived products can be sustainably maintained over time and are compatible with key TMR transport network datasets, linear reference systems and datums (GDA2020). Likewise, it is important that each derivative product is reliable and reproducible, and consideration is made for the trade-off between generating highly reliable and accurate datasets against rapidly producing numerous datasets without a high degree of confidence in the results of each.

Specific examples include:

- recognising to a high degree of confidence lane connectivity at intersections, including possible movements, stop bars, etc.
- automating the detection of the number of usable lanes, including the width of sealed road surfaces and the position of line markings
- identifying and classifying various assets surrounding the road, including poles, street signs, footpaths and gutters, buildings, and trees
- detecting defects in the road surface such as cracks or potholes

A list of target derivate products is provided in Appendix B which provides an overview of potential target areas for derivative products, however it should be noted that this is not an exhaustive list of possibilities.

Desired Outcomes

Demonstrations of commercial, innovative, or novel approaches for automated detection of key road surface, asset and corridor features, from high resolution imagery datasets, in an effective, efficient, and sustainable way. The provision of output derived datasets with associated metadata, accuracy estimates and links into TMR transport network datasets (linear referenced) is desired, though not essential.

Use Cases

- As a **passenger in a connected or automated vehicle**, I expect to have confidence that the vehicle I am travelling in will stop at the right place at an intersection and turn in the right lane.
- As a **transport planner / analyst,** I want to be able to model current and future projected road condition and capacity to effectively plan upgrades to Queensland's transport network.
- As an **asset manager** for the Queensland road network, I want to know the location of potholes, cracks, and cavities accurately so I can understand the risks and proactively plan for appropriate maintenance measures.

Challenge Question 2: To infinity and beyond

Can you train a model on high-resolution data to extract road surface, asset, and surround datasets, then apply this model to extract the same features from lower-resolution data?

Overview

TMR is seeking demonstrations of novel approaches to the creation of derivative products trained on very high-resolution data which can be applied to generate these same derivate products from lower-resolution aerial photography data. How effectively can you scale up the extraction of information and insights about what's on the road, around the road and in the road corridor for a larger area, and how good is the data, really?

Problem Statement

In order to create a single integrated smart transport network, TMR require current, complete, accurate, and continuously improving datasets at required resolutions across the entire state of Queensland. While very high-resolution imagery data is ideal for creating these datasets using AI/ML from remotely sensed geospatial data, due to the high cost of capture, this data is not available or sustainable for large areas at a time.

TMR has are looking at whether very high-resolution visible, multispectral and thermal drone/vehicle captured imagery could be used to train up AI/ML models to improve the extraction of information and insights about what's on the road, near the road and in the road corridor (target list provided in Appendix B) and whether these models could then be used effectively on lower-resolution aerial and satellite remote sensed imagery.

This challenge question is seeking novel applications of AI/ML for data extraction and processing to create derivative products about what's on the road, near the road and in the road corridor. Algorithms would initially be trained on the TMR-provided dataset to extract these features from very high-resolution remotely sensed data, the aim would then be to extract the same data about the road network and surrounds from lower-resolution remotely sensed data (such as satellite aerial photographs). To be sustainable over time, this modelling would need to be able to extract these derivative products from lower-resolution imagery at more than one location around the state, demonstrating a moderate degree of confidence.

A specific example could be:

- Training an AI/ML model with very-high resolution visible imagery to extract a derivative line markings dataset to 10cm resolution with 80% confidence, then applying this modelling to extract the same features from 30cm satellite visible aerial photography with 60% confidence.

It is important that derived products can be sustainably maintained over time and are compatible with key TMR transport network datasets, linear reference systems and datums (GDA2020).

Desired Outcomes

Demonstrations of commercial, innovative, or novel approaches for automated detection of key road surface, asset, and corridor features, from high- and lower-resolution imagery datasets, in an effective, efficient, and sustainable way. The provision of output derived datasets with associated metadata, accuracy estimates and links into TMR transport network datasets (linear referenced) is desired, though not essential.

Use Cases

- As a **passenger in a connected or automated vehicle**, I expect to have confidence that the vehicle I am travelling in will be able to travel safely no matter whether I am at a busy intersection with pedestrian crossings in the CBD or travelling along a rural Highway.
- As a **transport planner / analyst,** I want to be able to model current and future projected road condition and capacity to effectively plan upgrades to Queensland's transport network.
- As an **asset manager** for the Queensland transport network, I want to be able to understand the state of my assets across different geographies across the state, including rural and regional areas.

Challenge Question 3: Viva le resolution

What problems do different resolutions across a road network at scale create? How can we have confidence in derivate products working together when created from data of different data ages and accuracies?

Overview

TMR is seeking a research-based investigation into the accuracy and precision limits when using AI/ML algorithms to extract enriched road information and insights at different image resolutions. When derivate products are made from different source datasets that have different ages and accuracies, how can we have confidence they can work together effectively? How well can we quantify how different data extraction methodologies (including training AI/ML models for lower-resolution imagery) and image resolutions affect the accuracy and utility of derived datasets for specific use cases?

Problem Statement

An integrated smart transport network requires confidence that the underlying transport network model is current, complete, accurate and fit-for-purpose. With the increasing reliance on AI/ML analytics methods to create critical inputs to the network, there is a corresponding increasing requirement to understand the limitations of these methods. TMR is looking to better understand the limits of derived datasets, particularly with regards to expected accuracy and repeatability, from AI/ML algorithms, such as those demonstrated in Challenge 1 and Challenge 2.

This challenge question seeks to consider this problem at a network scale to understand the limitations and benefits of AI/ML methods to establish and maintain a viable state-wide smart transport network for Queensland. Part of this consideration will include understanding the levels of spatial and temporal accuracy (and their confidence intervals) needed in data in different resolutions across the road network for different use cases.

Specific examples include:

- Conceptual proposals of how to solve the problem of integrating derivate products created in data rich environments into less data rich environments within a smart transport network.
- Statistical exploration of the differences in the data required to facilitate safety for autonomous vehicles in urban and rural environments

Desired Outcomes

An improved understanding of how to have confidence in data extracted from different data ages and accuracies. This could be, for example, statistical analyses exploring the effectiveness of different factors (including, but not limited to, AI/ML methodologies, image spatial resolutions and use cases).

Use Cases

- As a **passenger in a connected or automated vehicle**, I expect to have confidence that the vehicle I am travelling in will be able to travel safely no matter whether I am at a busy intersection with pedestrian crossings in the CBD or travelling along a rural Highway.
- As a **transport planner / analyst,** I want to be able to model current and future projected road condition and capacity to effectively plan upgrades to Queensland's transport network.
- As an **asset manager** for the Queensland transport network, I want to be able to understand the state of my assets across different geographies across the state, including rural and regional areas.

Challenge Question 4: Bonus Round - Seeing in the dark

Can AI/ML and non-visual remote sensed data be used to identify early warnings of road problems?

Overview

TMR is seeking demonstrations of novel applications of AI/ML to mine non-visual (i.e., multispectral, hyperspectral, thermal, LiDAR/point cloud, radar, other) remote sensed data to detect information and insights about the roads, and road corridor. Can we detect problematic unplanned changes due to natural disasters, vegetation growth, drainage issues, subsurface changes before they become a major problem?

Problem Statement

An efficient, maintained and highly functioning transport network is critical to the success of every industry, individual and supply chain. This means that unplanned outages, delays, and inefficiencies can literally cost millions of dollars and mean the difference between life and death. TMR are looking to see if non-visual remote sensing datasets can be used for early detection of potential problems affecting the transport network.

Very high resolution multispectral and thermal data can provide information about a suite of features that are on the road, around the road and in the road corridor. These include indicators of vegetation location and density, animal presence, drainage issues as subsurface voids, and road defects (including cracks, cavities, and holes).

This challenge question is seeking demonstrations of AI/ML algorithms which extract indicators of risk areas across road assets such as those listed above with moderate confidence (at least 60%). Very high resolution multispectral, thermal data and LiDAR datasets are provided by TMR; however, participants are welcome to bring additional datasets into the project as background IP (such as night-time satellite imagery, radar, etc.).

Specific examples include:

- Creation of a model that can detect degradation in pavement or road surface
- Creation of a model that can map drainage patterns in the road corridor in order to predict where sinkholes might arise and to plan for flood impacts
- Creation of a model that can map vegetation densities along road corridors to predict where areas of soil erosion might occur during high rainfall events

It is important that derived products can be sustainably maintained over time and are compatible with key TMR transport network datasets, linear reference systems and datums (GDA2020).

Desired Outcomes

Demonstrations of commercial, innovative, or novel approaches for automated detection of road asset changes and degradation, from non-visual remote sensed datasets, in an effective, efficient, and sustainable way. The provision of output derived datasets with associated metadata, accuracy estimates and links into TMR transport network datasets (linear referenced) is desired, though not essential.

Use Cases

- As a **logistics company**, I want to have confidence that the roads that I am driving on are safe and reliable to use, and that my drivers will not be delayed due to significant unplanned disruptions to the transport network.
- As a **transport planner / analyst**, I want to understand which sections of road are most susceptible to sinkholes and erosion to understand flooding impacts when designing transport upgrades.
- As an **asset manager** for the Queensland transport network, I want to prioritize areas for proactive maintenance where the road surface is degrading more quickly than planned
- As an **ecologist**, I want to understand where a certain weed species exists across a road corridor.

Appendix B – Target derivative data products

Data category	Target derivate products
Road surface and markings	Width of sealed road surface
	Number of usable lanes
	Width of each lane
	Angle of road surface across road
	Angle of road surface along road
	Type of road surface (gravel, concrete, asphalt, etc.)
	Types of line markings on edges, lanes, centre (wide centre lines, double lines, rumble strips, etc.)
	Lane centrelines, road centrelines
	Location and type of pavement defects (crack, pothole, etc.)
	Location and type of speed calming device
Intersection design and markings	Intersection mapping:
	Possible movements
	Lane connectivity
	Stop bars
Road corridor assets and environment	Speed assigned to zones on a road network
	Location of speed signs
	Location and content of advisory signs (non-regulatory signs)
	Location and content of regulated signs
	size, volume, and type of vegetation in road corridor
	Drainage patterns and storage volumes
	Location and type of curbing and islands
	Location and type of structures/assets, e.g., buildings, car parks, light poles, etc.
	Location, size and type of barriers
	Limitations to visibility for different vehicle types
	Surface soil types within the road corridor
	Slopes of area adjacent to the road in the road corridor
	Paths, pedestrian crossings, accessibility assessment

*This is not an exhaustive list of potential derivative products and is intended to be used as a guide only. Achieving all potential derivative products listed here is not the expectation.

Appendix C – List of datasets provided by TMR to support these challenge questions

Data type	Description (including spatial resolution)	Spatial extent and year captured	Data available on request
Aerial imagery	Aerial imagery over Southeast Queensland, captured at 10cm resolution.	8 tiles (1km square each) around Mt Cotton, 2021	Urban areas of Queensland, historic data
Aerial imagery	Aerial imagery over parts of Queensland, captured at 20cm resolution		Selected areas of Queensland, historic data
Earth I Satellite imagery	Satellite imagery RGB Geotiff at 80cm resolution		All of Queensland 2018 data
Georeferenced images from a vehicle	Annually collection of data for the state-controlled road network from a vehicle. From 2017/18, up to 7 directions are captured - forward, left, right, rear, left side, right side and the road surface.	Mt Cotton Road and Mt Cotton Centre, 2021	TMR roads across Queensland annually
Aerial LiDAR	Aerial LiDAR	8 tiles around Mt Cotton included, 2021	Urban areas of Queensland on request
LiDAR (MLS)	driven LiDAR	Mt Cotton Road	Mt Cotton Road included
LiDAR (Static)	static LiDAR collected at points within the Mt Cotton centre	Mt Cotton centre, 2021	Mt Cotton Centre included
LiDAR (Drone)	LiDAR collected by drone within the Mt Cotton Centre	Mt Cotton centre, 2022	Mt Cotton Centre included
Imagery (Drone)	Imagery collected by drone within the Mt Cotton Centre	Mt Cotton centre, 2021, 2022	Mt Cotton Centre included
Imagery (Drone)	Imagery collected by drone within the Mt Cotton Centre	Mt Cotton centre, 2021, 2022	Mt Cotton Centre included
Hyperspectral (Drone)	Hyperspectral data collected by drone within the Mt Cotton Centre	Mt Cotton centre, 2022	Mt Cotton Centre included
Thermal (Drone)	Thermal data collected by drone within the Mt Cotton Centre	Mt Cotton centre, 2022	Mt Cotton Centre included