Inland Revenue
Te Tari Taake

Research & Development Tax Incentive (RDTI)

R&D ACTIVITY ELIGIBILITY

DIGITAL TECHNOLOGY SECTOR

Digital technology sector guidelines

The purpose of this document is to provide businesses in the digital technology sector with some further guidelines to help them when accessing funding under the RDTI. It will provide businesses with the following outcomes:

- An understanding of the type of R&D that qualifies for funding in this sector,
- An insight into the type of technical information that we would expect to be included within any application,
- Practical examples of completed General Approval applications.

These sector specific guidelines build on the general principles of RDTI eligible activities. Further detail can be found in the following locations:

Go to **www.ird.govt.nz/**
Enter keywords: "r&d eligible activities" in search box

Go to **www.rdti.govt.nz/** Click "RDTI Eligibility"

We recommend you review this content before continuing further.

AT A GLANCE

General principles of RDTI eligible activities

CORE R&D ACTIVITIES MUST:

Occur in New Zealand

Seek to resolve scientific or technological uncertainty

Follow a systematic approach

Seek to create new knowledge, or new or improved processes, services or goods

* *See definitions of Science and Technology at the following link*: Go to **www.rdti.govt.nz/** Click "RDTI Eligibility"

What information is needed in the application

After a review of the general principles of the RDTI, you may believe that you are doing R&D that could be eligible for funding. If this is the case, it is important you provide us with the correct type of information to help process your application efficiently.

A business will naturally describe its R&D in commercial terms. However, for us to determine whether it meets the requirements of RDTI funding, the focus of the narrative must be at a scientific or technological level.

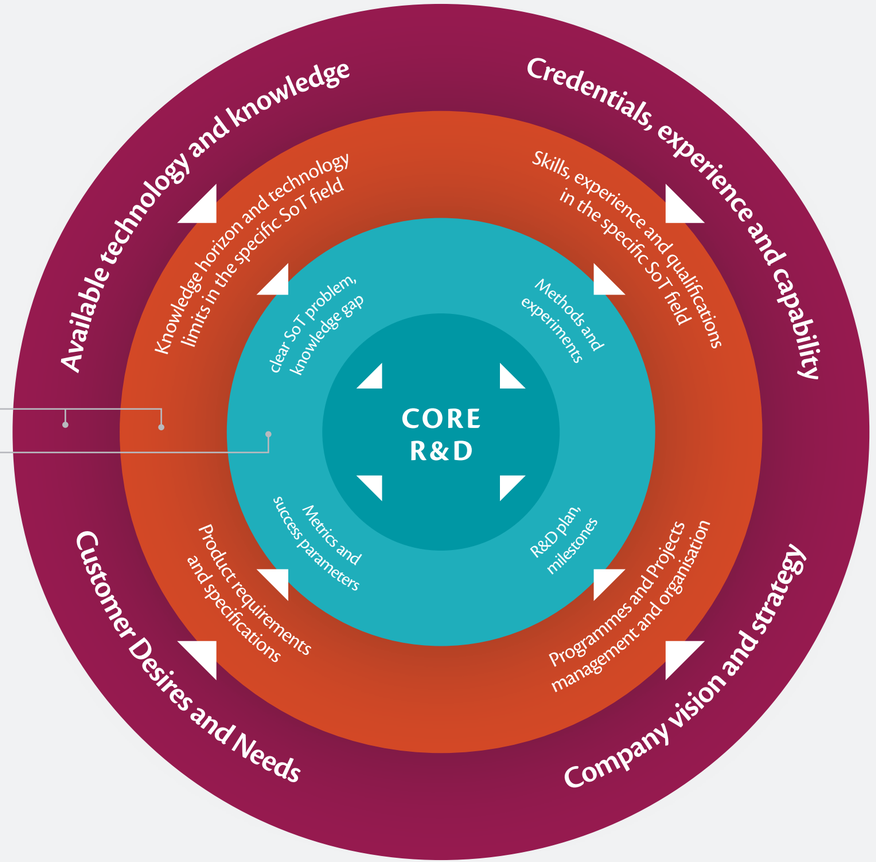
We have developed a tool to help you provide this information. The tool is similar in nature to a dart-board. The information required to process your claim must hit the teal bullseye. Information from the outer red and orange sections of the dart board can provide useful context for the R&D, but you cannot solely rely on that information.

Examples of questions you should be seeking to answer when completing your General Approval are from the teal bullseye and may include (but are not limited to):

- What is the scientific or technological problem you are trying to overcome?
- What is the gap in knowledge that you have (in a scientific, engineering or technological context)?
- What methods or experiments do you plan to undertake to solve the problem?
- What is your R&D plan and milestones?
- What are your metrics and success parameters?

Information from the outer **red** and **orange** sections can provide useful context for the R&D – but you cannot solely rely on that information.

The information required to process your claim must hit the **teal** bullseye. All features in the lighter teal circle must be present to be R&D.



Key: SoT – scientific or technological

How does the RDTI work for the digital technologies sector?

Many digital technologies businesses doing R&D will be eligible for funding, but not all software development or innovation will be. It is important to understand what gets funded and what does not.

Preliminary step: Identify technology(ies) used for R&D

To understand how the RDTI framework applies to this sector, it is useful to first consider the underlying technology that underpins the R&D within your business. Examples may include:

- Cognitive / Analytics
- Security
- Future networking
- Digital reality
- Cloud
- Robotics
- Quantum technologies

The focus is purposely drawn to the technology used in the R&D, rather than the commercial product developed. In many cases, businesses may be using a combination of technologies to undertake their R&D.

Once you have considered what technologies the business uses to undertake its R&D, you now need to consider whether the R&D meets the general principles of RDTI eligible activities. See the "refresher".

We have developed a number of examples focusing on different aspects of technology development to bring the tax legislation to life for the digital technologies sector. These examples are detailed below, with a guide to show you which focus area of the RDTI rules are demonstrated*.

**Note: each example has a different focus, the examples are not intended to cover all aspects of the RDTI rules*

EXAMPLE	TECHNOLOGY	DEMONSTRATING			
		General principles of RDTI eligibility	Benchmarking technological uncertainties	Core vs supporting R&D	R&D start & finish
The development of a security system on a building site	Cloud based facial recognition engine	✓	✓	✓	✓
The development of a legal search platform for the building code	Machine learning-based natural language processing (NLP) and rule-based models	✓		✓	✓
Example 3	In development				
Example 4	In development				

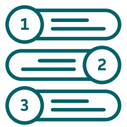
REFRESHER

AT A GLANCE

General principles of RDTI eligible activities

CORE R&D ACTIVITIES MUST:

Seek to resolve scientific or technological uncertainty



Follow a systematic approach

Seek to create new knowledge, or new or improved processes, services or goods

ELIGIBILITY TESTS	QUESTIONS *(additional detail IR: Eligible R&D activities (ird.govt.nz) RDTI hub: What R&D activities are eligible? | RDTI NZ)*
What is the technological uncertainty?	What is the problem within the technological field that you are trying to overcome? Where is the knowledge gap?
What is the systematic approach?	How are you planning to solve the above problem? What is the R&D plan? What technical metrics and success parameters demonstrate success (or failure)?
What is the new knowledge or improved processes, services or goods?	Why are you undertaking R&D? What is the expected outcome?
How do I demonstrate that scientific or technological uncertainty exists? **Is the knowledge required to resolve the uncertainty either publicly available, or deducible by a competent professional in the relevant field?**	Has some one done this before, and you have access to that knowledge? Do you have to investigate and experiment in a systematic way?

EXAMPLE 1

The development of a security system on a building site

The business applied for one year of funding using the General Approval method. We recommend reading the applications in examples 1a and 1b in the Appendix before continuing.

The highlights

The commercial project

The commercial project was to develop a solution to ensure security of personnel on building sites in different locations with a minimum impact on workers.

The technical problem

To develop a security solution that uses AI facial recognition, a cloud-based server and cameras to identify personnel.

The project had technical constraints of accuracy, speed and hardware cost.

How the technical problem became a technological uncertainty

Interconnected technological uncertainties resulted from the technical constraints of speed, accuracy and hardware costs and related to:

- Image compression
- Acutance
- Resolution
- Facial recognition engine selection

Further details are provided in example 1a of the General Approval application in the Appendix.

Remember – the colour coding represents the different levels of the dart board tool. The teal layer (being the bullseye) is the critical information required to efficiently process the funding application.

The following diagram demonstrates the progress of the project from its commercial objectives, to its technological uncertainties.

The Commercial Project

Commercial objective

Develop a solution to ensure security of personnel on building sites in different locations with minimum impact on workers

The practical idea

- Use camera with a full http stack
- Capture **facial images**
- Upload to a **cloud-based server**
- Perform the **facial recognition**
- Send approve/decline for entry

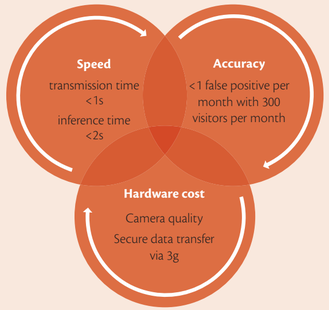
The Technical Problem

Problem Statement

To develop a security solution that uses **AI facial recognition, a cloud-based server** and **cameras** to identify personnel

Technical constraints of accuracy, speed and hardware cost

Performance parameters



The Technological Uncertainties

Activity One

What level of **image compression** was required to resolve the trade-off between transmission speed vs inference speed and accuracy

Activity Two

What **acutance** (constrained by cost of hardware) and **resolution** (constrained by cost of hardware and total identification time) would meet the required recognition performance metrics while still meeting the time and cost constraints

Activity Three

Which **facial recognition engines/models** were suitable for use with the images we were capturing, and which facial recognition models worked best in changing and challenging environments (including, what was most efficient for speed of throughput - edge based facial recognition vs cloud engines)

POINTS TO NOTE

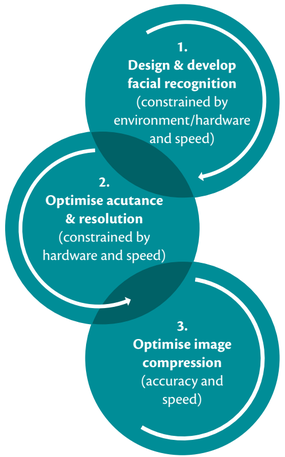
The general principles of RDTI eligibility

The general principles of RDTI eligible activities require all 3 aspects of the eligibility requirements to be met. The following table and diagram demonstrate the relationship between them using the approach of Problem > Plan > Investigate > Outcome.

The technological uncertainties	The technological uncertainties in this example are interrelated demonstrating the "problem". This problem has technological principles underpinning it.
The systematic approach	The "plan' and "investigate" phase are directly related to the relevant technological uncertainties. Stepped through the R&D plan with investigative steps to work towards resolving the specific technological uncertainties.
The new or improved...	The resulting outcome is clearly stated. The "why" the R&D was undertaken.

Core Activity

The Technological Uncertainties



Systematic approach*

R & D plan	Investigate
Facial recognition engines/models	
• Literature review • Edge-based vs cloud-based • Iterative development of a novel facial recognition engine using DCNN	Testing, modifying and retesting: • Matching faces to known faces in a prepared database • Testing edge-based vs cloud-based for speed • Training the recognition models and optimising hyper-parameters through seven steps of machine learning
Acutance and resolution	

• Review available camera technology
• Identify 3 cameras to test (different acutance levels)
• Iterative development when unsatisfactory result to find alternative technology choices if not satisfactory
	Testing for the following outcomes:
	• The minimum acutance for recognition in lab conditions
	• Impact on acutance under differing:
	  • Environmental conditions
	  • Resolutions

Image compression	
• Development of novel compression algorithms for facial images • Iterative development when unsatisfactory result to find alternative technology choices if not satisfactory	• Tests of speed for compression algorithms – must retain accuracy • Develop matrix - accuracies vs compressions vs speeds, in various environmental conditions • Evaluation of results • Modifying and retesting

New or improved

Problem → Plan → Investigate → Outcome

*refer to example 1a of the General Approval application in the Appendix for additional detail.

POINTS TO NOTE

Benchmarking the technological uncertainties

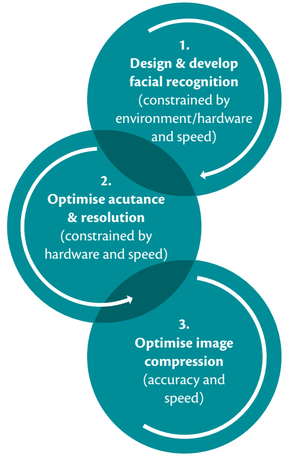
Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties are not publicly available, or deducible by a competent professional in the relevant field.

The following table and diagram demonstrate how to benchmark the technological uncertainties.

The publicly available test	There is a known solution for facial recognition and security. For example, e-passport scanning at Customs. Therefore, it is important to explain why this R&D is different.
The competent professional test	This test is demonstrated in the scientific and technological methods required by the business to resolve the uncertainty through the systematic course of investigation and experimentation.
Example demonstrating when these tests are not met	If the competent professional is only undertaking tests to confirm that a common solution to a common problem could be resolved, then the R&D is not eligible for funding under the RDTI. This is demonstrated in example 1b of the General Approval application in the Appendix.

Remember – the General Approval application example provides a full description of the eligible RDTI activities. This is the expected level of detail required by us. You must focus on the teal bullseye (dart board tool) and be technical in nature.

The Technological Uncertainties



Benchmarking the technological Uncertainties

Publicly available

Initial info gathering – literature reviews and patent searches

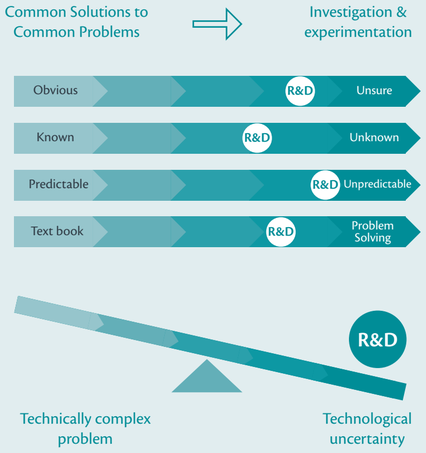
Engagement with solution providers

Testing available tech

Findings

- Recognition rates were too low; or
- Speed did not meet the requirements.

Competent professional



POINTS TO NOTE

Core & supporting R&D

REFRESHER

Core vs supporting R&D

Eligible R&D activities must involve core R&D activity. There may also be supporting activities.

TYPE OF ACTIVITY	DEFINITION
Core activity	An activity that has the material purpose of creating new knowledge or new or improved processes, services, or goods. It must also attempt to resolve scientific or technological uncertainty using a systematic approach.
Supporting activity	An activity that has the only or main purpose of supporting the core activity.

Excluded activities

Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

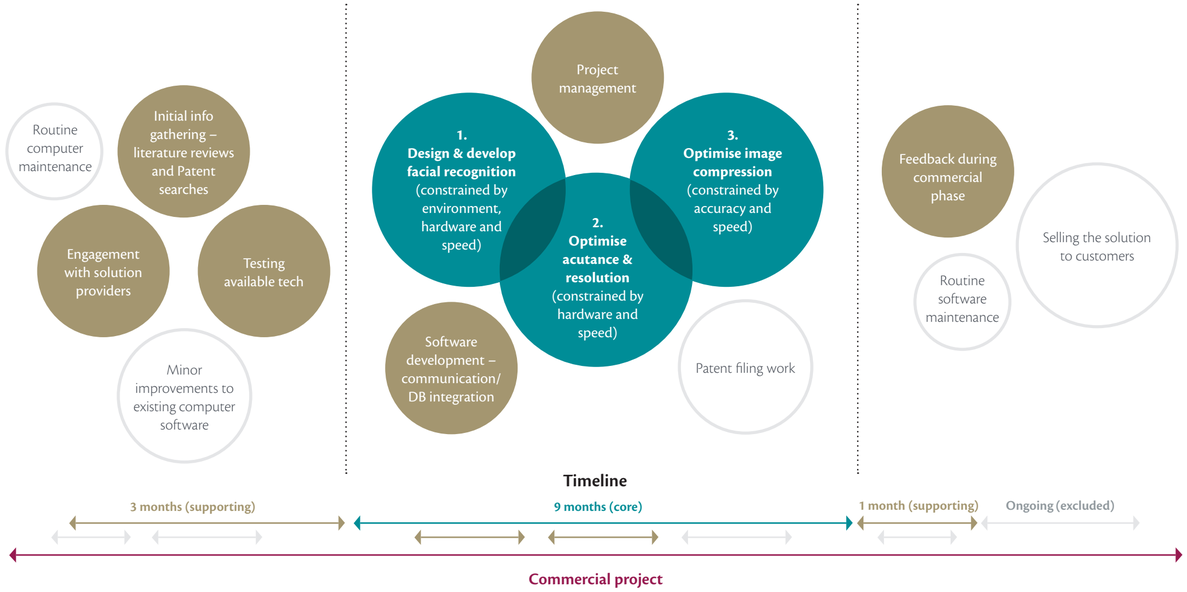
Further information on supporting R&D activities can be found on the IRD website. Go to **www.ird.govt.nz/** Enter keywords: "r&d eligible activities"or "ineligible activities" in search box.

To demonstrate the core and supporting R&D activities for the security systems example, and the ineligible excluded activities, we have included the following table and diagram.

Core (Teal) & Support (Brown)	Only core and supporting activities are funded under the RDTI.
Excluded activities (Grey) – Do not get funded!	Certain activities the business undertook in the security systems example are ineligible for funding.
Commercial project vs RDTI funded activities	The whole commercial project does not get funded, only the Core & Supporting activities are funded, being a slice of the wider project.

What are core and supporting R&D activities?

What are excluded activities?



POINTS TO NOTE

When does the R&D start and finish?

REFRESHER

Beginning and end of core activities

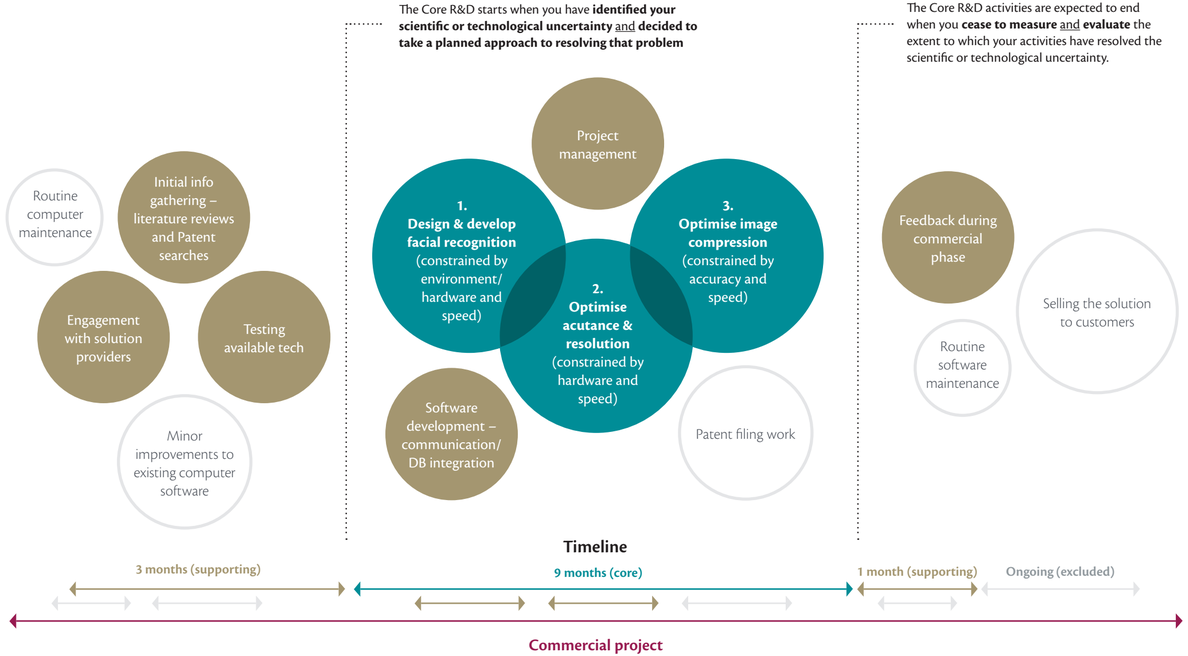
The Core R&D starts when you have identified your scientific or technological uncertainty and decided to take a planned approach to resolving that problem.

The Core R&D activities are expected to end when you cease to measure and evaluate the extent to which your activities have resolved the scientific or technological uncertainty.

Further information on when R&D activities start and finish can be found in the Research and Development Tax Incentive IR1240 Guidance. Go to **www.ird.govt.nz/** Enter keywords: "r&d eligible activities" in search box.

The following diagram demonstrates at what time the R&D started. Note: Supporting R&D activities can still be claimed before the core R&D starts and after the core R&D finishes. A timeline for the application is included for reference purposes only.

When does the R&D Start and Finish?



EXAMPLE 2

The development of a legal search platform for the building code

The business applied for a one year approval of funding using the General Approval method. The business had yet to complete its R&D at the point of filing. We recommend reading the eligible application (example 2) in the Appendix before continuing.

The highlights

The commercial project

Development and operation of a smart legal search platform that makes the NZ Building Act accessible to a large variety of users without legal jargon.

The technical problem

Develop a semantic search engine that can identify relevant legal passages using a mixed semantic model (rule based Machine Learning/Natural Language Processing) significantly better than random.

The performance parameters of the project are:

- timely (sub 3s) search results;
- high accuracy; and
- close to 0 false negatives with a minimum of false positives.

How the technical problem became a technological uncertainty

Constraints like a limited corpus, unknown required and achievable semantic depth, and varying legal interpretations render success uncertain.

Remember – the colour coding represents the different levels of the dart board tool. The teal layer (being the bullseye) is the critical information required to efficiently process the funding application.

The following diagram demonstrates the progress of the project from its commercial objectives, to its technological uncertainties.

The Commercial Project

Commercial objective: smart platform

Development and operation of a smart legal search platform that makes the NZ Building Act accessible to a large variety of users without legal jargon

The practical idea: semantic search

Development of a semantic search engine that will not only allow search for legal key words, but understand search items and questions by determining their intent and contextual meaning

The Technical Problem

Problem Statement: high accuracy mixed model

Develop a semantic search engine that can identify relevant passages using a mixed semantic model (rule based & ML NLP based) significantly better than random

Performance parameters

Timely (sub 3s) search results at a high accuracy: close to 0 false negatives with a minimum of false positives

The Technological Uncertainties

Technological uncertainties resulting from **constraints** like a limited corpus, unknown required and achievable semantic depth, and varying legal interpretations render success uncertain

POINTS TO NOTE

The general principles of RDTI eligibility

The general principles of RDTI eligible activities require all 3 aspects of the eligibility requirements to be met. The following table and diagram demonstrate the relationship between them using the approach of Problem > R&D Plan & Investigate > Outcome.

The technological uncertainties	The technological uncertainties are described using the technical principles of the software engineering used to develop the semantic model.
The systematic approach	The "R&D plan & investigate" phase is directly related to the technological uncertainties. Stepped through the R&D plan with investigative steps to work towards resolving the specific technological uncertainties. This R&D is yet to happen, so the plan is high-level, but still demonstrates how the business expects to resolve its technical problem and technical knowledge gap that it currently anticipates.
The new or improved...	The resulting outcome is clearly stated. The "why" the R&D was undertaken. In this case to develop a new service.

Remember – the General Approval application example provides a full description of the eligible RDTI activities. This is the expected level of detail required by us. You must focus on the teal bullseye (dart board tool) and be technical in nature.

Core Activity

The Technological Uncertainties

Technological uncertainties resulting from **constraints** like a limited corpus, unknown required and achievable semantic depth, and varying legal interpretations render successes uncertain

Problem

Systematic approach*

Performance parameters

Data preparation and pre-processing

Manual benchmarking

Model development

Run and compare both models against each other and against manual benchmark

R&D Plan & Investigate

New or Improved

The development of a **new service** using a mixed semantic model (rule based & ML NLP based)

Outcome

*refer to example 2 of the General Approval application in the Appendix for additional detail.

POINTS TO NOTE

Benchmarking the technological uncertainties

Remember, a key matter to consider is how to demonstrate that the knowledge required to resolve the technological uncertainties are not publicly available, or deducible by a competent professional in the relevant field.

The purpose of this example is to mainly demonstrate the application of the general principles of RDTI eligibility through tabular and diagrammatic form. However, further detail of how to benchmark the uncertainty can be found in the General Approval application Appendix, example 1a.

The security systems example, also provides further detail regarding benchmarking the technological uncertainty and is demonstrated above (pages 14 & 15) in tabular and diagrammatic form.

POINTS TO NOTE

Core & supporting R&D

REFRESHER

Core vs supporting R&D

Eligible R&D activities must involve core R&D activity. There may also be supporting activities.

TYPE OF ACTIVITY	DEFINITION
Core activity	An activity that has the material purpose of creating new knowledge or new or improved services or goods. It must also attempt to resolve scientific or technological uncertainty using a systematic approach.
Supporting activity	An activity that has the only or main purpose of supporting the core activity.

REFRESHER

Excluded activities

Certain activities are ineligible core R&D activities. A smaller number are ineligible supporting R&D activities.

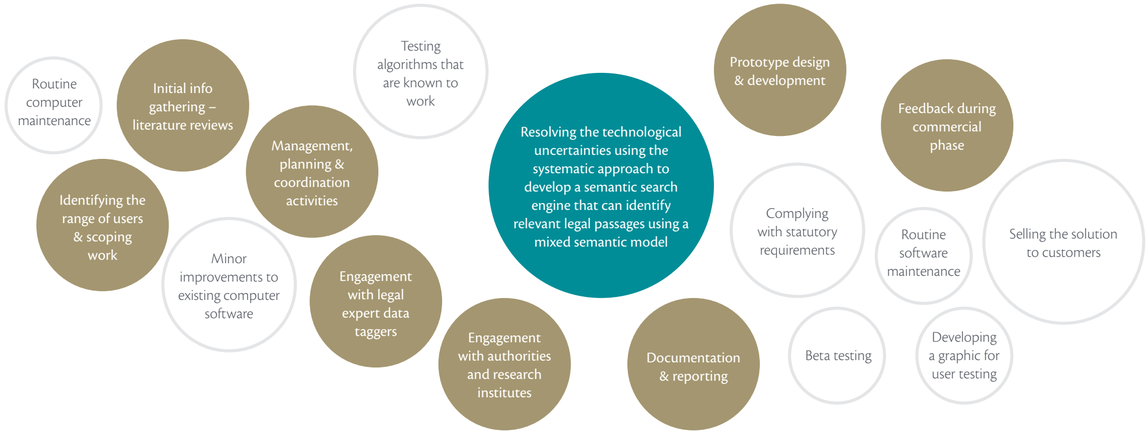
Further information on supporting R&D activities can be found on the IRD website. Go to **www.ird.govt.nz/** Enter keywords: "r&d eligible activities"or "ineligible activities" in search box.

To demonstrate the core and supporting R&D activities for the legal search platform example, and the ineligible excluded activities, we have included the following table and diagram.

Core (Teal) & Support (Brown)	Only core and supporting activities are funded under the RDTI. A number of business-as-usual activities can be funded as supporting R&D activities. To get funding the main purpose of these activities MUST be to support the core R&D activity (in other words, the R&D could not go ahead without these activities).
Excluded activities (Grey) – Do not get funded!	Certain activities the business undertook in the legal search platform example are ineligible for funding.
Commercial project vs RDTI funded activities	The whole commercial project does not get funded, only the Core & Supporting activities are funded, being a slice of the wider project.

What are core* and supporting* R&D activities?

What are excluded activities?



Key

Supporting activities may happen at the same time as the core R&D. For example, integrated documentation and reporting on the uncertainties.

*refer to example 2 of the General Approval in the Appendix for additional detail – this diagram shows the relationships between activities (not a timeline).

POINTS TO NOTE

When does the R&D start and finish?

REFRESHER

Beginning and end of core activities

The Core R&D starts when you have identified your scientific or technological uncertainty and decided to take a planned approach to resolving that problem.

The Core R&D activities are expected to end when you **cease to measure** and evaluate the extent to which your activities have resolved the scientific or technological uncertainty.

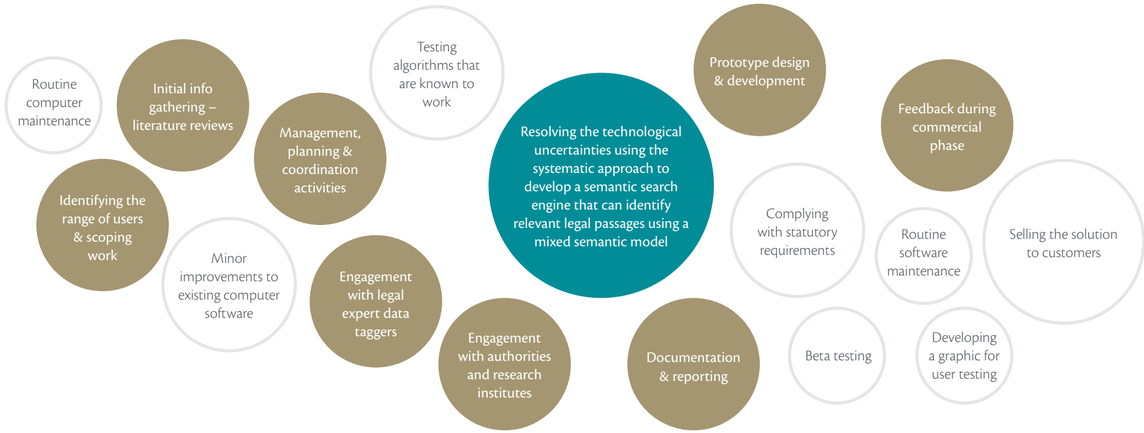
Further information on when R&D activities start and finish can be found here Research and Development Tax Incentive (Go to **www.ird.govt.nz/** Enter keywords: "r&d eligible activities" in search box) in IR1240, page 37.

The following diagram demonstrates at what time the R&D started. Note: Supporting R&D activities can still be claimed before the core R&D starts, after the core R&D finishes or during the core R&D activities (for example, integrated documentation & reporting on the uncertainties is a supporting activity happening alongside the core R&D).

When does the R&D Start and Finish?

The Core R&D starts when you have **identified your scientific or technological uncertainty** and **decided to take a planned approach to resolving that problem**

The Core R&D activities are expected to end when you **cease to measure** and **evaluate** the extent to which your activities have resolved the scientific or technological uncertainty



Key

Supporting activities may happen at the same time as the core R&D. For example, integrated documentation and reporting on the uncertainties

Appendix

DISCLAIMER

The examples in this guidance are fictitious and are not meant to describe real examples of scientific or technological uncertainty or eligible activities. Rather they are intended to show the types of information needed in an application that will help us assess the eligibility of the activities. The level of information needed will depend on the nature and complexity of the R&D activities you are applying for.

APPENDIX

The development of a security system on a building site

PROJECTS

AN **ELIGIBLE** & APPROVED APPLICATION

PROJECT IDENTIFIER

The real-time staff site identification (RSSI) project

START DATE: 1 APRIL 2019 | **END DATE:** 31 MARCH 2020

PROJECT OBJECTIVE

Develop a smart facial recognition security system to identify authorised personnel entering multiple building sites in New Zealand. This requires:

- Security cameras with a full http stack to capture facial images,
- An investigation into existing technology for small businesses using edge processing and security cameras with an http stack. This demonstrated the limitations of the existing technology and a preference for a cloud based matching system. Thus, a new system was approved for development to upload facial images into a cloud-based server to perform the facial recognition matching technology,
- For a successful recognition match send an approve signal to open the automated gate or, if no successful recognition, send a request to the site manager to consider "validating manually".

Feasibility studies reveal staff have accepted the privacy implications of their photographs being held in the cloud but are concerned about the possibility of false negative or positive results impacting safety and timeliness of entry. Staff have commented that "nobody wants to wait outside in the rain and cold for a computer to decide that somebody who's worked for the company for 20 years is okay to get into work."

CORE ACTIVITY

Related project with a core activity involving 3 interrelated activities

The real-time staff site identification (RSSI) project

The primary objective is to identify personnel on building sites in different locations with a minimum impact on workers. We set a requirement for automatic and secure real-time identification and confirmation of a person visiting a particular site is on an approved list. Secure is defined as "<1 false positive per month with an assumed 300 visitors per month."

This core activity and the technological uncertainty is to resolve whether it is possible to develop a facial recognition engine to match images taken by an on-site security camera with images stored in a database of images, within the required parameters.

The technical requirements for an automatic and secure real-time facial identification and confirmation security system are:

- Develop compression algorithms that would provide the smallest possible file sizes while maintaining accurate and real time results.
- The camera must take an accurate picture in changeable and challenging weather and light conditions.
- The facial recognition needs to be processed either on the edge or through secure and fast transmission of the image to a facial recognition/ inference engine in the cloud.
- The recognition needs to be in near real-time with the decision to use cloud processing made relatively early in the project. It was necessary to research acutance and resolution performance tests required to establish the standards necessary to meet the required recognition performance metrics.
- We undertook Investigative and experimental activity in facial recognition engines, acutance and image resolution requirements, compression and transmission optimisation using a systematic approach designed to resolve our technological uncertainties.

Benchmarking the technological uncertainties:

1. **Is the knowledge to resolve the uncertainty publicly available?**

We conducted literature reviews, patent searches, scoured online journals and engaged with providers of solutions. This included reviews of both edge or cloud based facial recognition engines and models, transmission technology, and compression algorithms.

We established through tests with available technologies that there was no solution currently available that would meet the technical requirements – recognition rates were too low, or throughput speed did not meet the business requirements.

2. **Is the knowledge to resolve the uncertainty deducible by a competent professional in the relevant scientific or technological field?**

We established that a competent professional in the field could not deduce the outcome of the scientific or technological uncertainty without undertaking an investigative and experimental approach to create new knowledge in this field and to develop this new or improved process and service.

Activity 1.

Development of compression algorithms to enable cooperative 1:N matching- capture and pre-processing on the edge, training and inference in the cloud.

SCIENTIFIC OR TECHNOLOGICAL UNCERTAINTY

It was unknown what level of image compression was required to resolve the trade-off between transmission speed vs inference speed and accuracy.

We had a requirement to meet the following performance parameters:

- a total identification throughput turnaround of less than 3 seconds from capture to decision to allow or deny access: and
- as the site had no internet connections site data needed to be transmitted from a mobile connection at the work site, with a minimum of a 3G connection using TCP/IP and SSL protocols: and
- transmission time to be less than 1 second, with less than 2 seconds of inference time (the time to process and recognise): and
- less than 5% false negatives and less than .5% false positives, with an average 300 visits per month.

SYSTEMATIC APPROACH TO RESOLVE UNCERTAINTY

We undertook a systematic approach of research and development of novel compression algorithms for images so that a decision could be made which settings would provide the best overall performance.

We conducted tests in various environmental conditions of throughput speeds for different compression algorithms while satisfying the requirement for accuracy, developing a matrix showing the various accuracies with various compressions compared to throughput speeds.

DESCRIBE NEW KNOWLEDGE; NEW OR IMPROVED PROCESSES, SERVICES OR GOODS.

Through the development of new knowledge in compression algorithms, new processes and services have been developed with the intention of enabling online facial recognition comparison at speeds not achieved previously.

Activity 2.

Research and development of acutance and resolution standards for security camera images for facial

SCIENTIFIC OR TECHNOLOGICAL UNCERTAINTY

It is unknown what acutance (constrained by cost of hardware) and resolution (constrained by cost in hardware and total identification time) would be needed to meet the required recognition performance metrics while still meeting the time and cost constraints.

SYSTEMATIC APPROACH TO RESOLVE UNCERTAINTY

We undertook a systematic approach of research and development to establish the minimum acutance and resolution of images that could still achieve the required accuracy results.

Based on reviews of available technology we chose three different camera

EXAMPLE 1a

systems which presented varying acutance levels and tested the minimum acutance for recognition in lab conditions using ISO12233 charts to measure MTF and confirm manufacturer claims.

We then tested the cameras under differing environmental conditions (weather, lighting) to determine how they impacted on the image acutance. We performed tests at different resolutions to determine the impact on recognition accuracy and throughput in the inference engine.

DESCRIBE NEW KNOWLEDGE; NEW OR IMPROVED PROCESSES, SERVICES OR GOODS.

The outcome of this activity was to establish new knowledge of which cameras offering secure data transfer via a 3G connection:

- produced the best results through various facial recognition engines in the majority of environmental conditions,
- had the acutance levels and resolution to meet the required recognition performance metrics for recognition and identification.

Activity 3.

Development of facial recognition engine for cooperative 1:N matching- capture and pre-processing on the edge, training and inference in the cloud.

SCIENTIFIC OR TECHNOLOGICAL UNCERTAINTY

We were uncertain:

- which facial recognition engines/models were suitable for use with the images we were capturing:
- which facial recognition models worked best in changing and challenging environments:
- what was most efficient for speed of throughput - edge based facial recognition vs cloud engines for facial recognition.

We had a requirement to meet the following performance parameters:

- a total identification throughput turnaround of less than 3 seconds from capture to decision to allow or deny access: and
- as the site had no internet connections site data needed to be transmitted from a mobile connection at the work site, with a minimum of a 3G connection using TCP/IP and SSL protocols: and
- transmission time to be less than 1 second, with less than 2 seconds of inference time (the time to process and recognise): and
- less than 5% false negatives and less than .5% false positives, with an average 300 visits per month.

SYSTEMATIC APPROACH TO RESOLVE UNCERTAINTY

We undertook:

- a significant literature review of facial recognition engines and models, establishing the requirements and possibilities of edge-based processing of images, which showed that the current technology in security cameras did not allow us to provide recognition services at a quality and speed that would satisfy our requirements, and we quickly pivoted to a cloud-based approach for recognition.
- a systematic approach of research and iterative development of a novel facial recognition engine. This involved the creation of a deep convolutional neural network (DCNN) utilising a MongoDB on AWS which provided detection of images that contain a face, image segmentation to locate and mark the face on an image, facial alignment and normalisation, feature extraction and face recognition.
- an iterative approach of testing, modifying and retesting - matching face images against multiple known faces in a prepared database, testing edge-based processing against processing in a dedicated cloud- based server to measure throughput times, while training the recognition models and optimising hyperparameters through seven steps of machine learning.

DESCRIBE NEW KNOWLEDGE; NEW OR IMPROVED PROCESSES, SERVICES OR GOODS.

Through the development of new knowledge in facial recognition services, new processes and services have been developed with the intention of enabling accurate online facial recognition comparison at speeds not previously achieved.

SUPPORTING ACTIVITIES

Camera MTF evaluation

In order to confirm that the manufacturer specifications matched the product, we needed to conduct tests to ensure the veracity of the manufacturer's MTF claims.

Without confirming the MTF performance of the cameras, we could not be certain we were accurately measuring the impact of acutance of image recognition and inference.

Research and development of acutance and resolution standards for security camera images for facial recognition.

Literature reviews and patent searches

In order to establish whether we could use existing technology, or would have to develop our own, we needed to know the state and limitations of the technology.

Without knowing the knowledge gap, it is not possible to develop a plan for creating new knowledge.

Development of facial recognition engine for cooperative 1:N matching- capture and pre-processing on the edge, training and inference in the cloud.

Research and development of acutance and resolution standards for security camera images for facial recognition.

Development of compression algorithms to enable cooperative 1:N matching- capture and pre-processing on the edge, training and inference in the cloud.

Building the test platform

In order to test the performance of the cameras in different environmental conditions, a number of test platforms had to be created in different locations.

In order to test the cameras, test platforms needed to be produced.

Research and development of acutance and resolution standards for security camera images for facial recognition.

AWS server and MongoDB setup

In order to test the recognition and inference engines, a cloud-based software platform needed to be established.

Without the setup of a cloud-based server we would not be able to perform our core R&D of development of compression algorithms to ensure performance requirements were met on the cloud-based server.

Development of compression algorithms to enable cooperative 1:N matching- capture and pre-processing on the edge, training and inference in the cloud.

APPENDIX

The development of a security system on a building site

PROJECTS

AN **INELIGIBLE** AND DECLINED APPLICATION

PROJECT IDENTIFIER

The real-time staff site identification (RSSI) project

START DATE: 1 APRIL 2019

END DATE: 31 MARCH 2020

EXAMPLE 1b

PROJECT OBJECTIVE

Develop a smart facial recognition security system to identify authorised personnel entering multiple building sites in New Zealand. We conducted an intensive investigation into possible solutions in the facial recognition systems for small businesses, assessing and evaluating possible solutions before choosing and adapting the best solution for our business.

The project required:

- Security cameras with a full http stack to capture facial images,
- An investigation into existing technology for small businesses using edge processing and security cameras with an http stack. This demonstrated the limitations of some of the existing technology and a preference for a cloud based facial matching system.
- The acquisition of a new cloud-based system which would upload facial images into the cloud server to perform the facial recognition matching technology.
- A successful recognition match to send an approve signal to open the automated gate or, if no successful recognition, to send a request to the site manager to consider "validating manually".

Feasibility studies reveal staff have accepted the privacy implications of their photographs being held in the cloud but are concerned about the possibility of false negative or positive results impacting safety and timeliness of entry. Staff have commented that "nobody wants to wait outside in the rain and cold for a computer to decide that somebody who's worked for the company for 20 years is okay to get into work." Hence, the key performance requirements for a facial recognition security system for this company are speed, accuracy, reliability, and affordability.

CORE ACTIVITY

Installation, configuration, and assessment of facial recognition systems for use in security applications.

The real-time staff site identification (RSSI) project

We embarked on an R&D project with the primary objective of solving the problem of ensuring identification of personnel on building sites in different locations with a minimum impact on workers. We set a requirement for automatic and secure real-time identification and confirmation that a person visiting a site is on an approved list.

This core activity was to resolve the technological uncertainty of finding a facial recognition product that would match images taken by our on-site security cameras with images that are stored in a database of images.

Feasibility discussions resulted in a process being developed to use security cameras to capture facial images and send the images to a cloud-based server to perform the facial recognition and matching technology. The camera must take an accurate picture in all weathers to ensure the facial recognition software can produce an accurate result.

We conducted reviews of possible solutions in the facial recognition market and established there were five potential products that might meet the requirements. It was unknown which product would be the most appropriate for our needs.

Each solution had a multitude of configuration possibilities and we set about a systematic process to determine which was most likely to meet the requirements. It was established that our competent professionals would require an investigative and experimental approach to create new knowledge in this field that would lead to a new or improved process and service.

Benchmarking the technological uncertainties

1. Is the knowledge to resolve the uncertainty publicly available?

We have researched the available products available in the market and have found there are five potential products in the market. We are reviewing the performance of each of the products to determine whether any can be configured to meet the criteria for our business circumstances including installation areas at out building sites.

2. Is the knowledge to resolve the uncertainty deducible by a competent professional in the relevant scientific or technological field?

On reviewing the manuals of each product our expert was not able to deduce whether it was possible to reconfigure the parameters to meet our business requirements.

SCIENTIFIC OR TECHNOLOGICAL UNCERTAINTY

We were uncertain which facial recognition product was most suitable for our use to capture images which would produce the most accurate results for our business. The manuals that came with the software, while incredibly detailed and complicated, did not provide the information to enable us to choose the best solution without undertaking a systematic process of investigation involving significant trial and error. Our scientific or technological uncertainty was:

- how best to configure the applications to produce the best results, learning and creating new knowledge for the company as we went through the activity.
- the software configuration was technically challenging, and it was uncertain at the start of the activity whether we were going to even have a working solution to meet our needs.
- We spent many hours researching potential configurations provided by the chosen software vendors. We tested the different configurations to see whether they met our required performance parameters, i.e.:
  - a total identification throughput turnaround of around 3-5 seconds from capture to decision to allow or deny access: and
  - as the site had no internet connections site data needed to be transmitted from a mobile connection at the work site, with a minimum of a 3G connection using TCP/IP and SSL protocols: and
  - transmission time to be less than 2 seconds, with around 4 seconds of inference time (the time to process and recognise): and
  - less than 5% false negatives and less than .5% false positives, with an average 300 visits per month.

SYSTEMATIC APPROACH TO RESOLVE UNCERTAINTY

We undertook a systematic approach of research and iterative testing of five separate facial recognition software products.
This involved:

- the installation and configuration of software which provided detection of images that contain a face,
- image segmentation to locate and mark the face on an image,
- facial alignment and normalisation,
- feature extraction, and
- face recognition.

We followed an iterative approach of testing and retesting each product and the different configurations available to discover the throughput times and accuracy of the alternative configurations.

DESCRIBE NEW KNOWLEDGE; NEW OR IMPROVED PROCESSES, SERVICES OR GOODS.

Through the development of new knowledge in installation and configuration of facial recognition services, we now understand which of the different types of facial recognition systems can provide the best results for security on our building sites.

SUPPORTING ACTIVITIES

Installation of Facial Recognition software on cloud server architecture

Software installation on cloud server architecture.

Without installation of the software, we would be unable to test different configuration options.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

Review of available software solutions

Research into available solutions.

Without knowing what is available in the market it is not possible to know which applications would be best to test.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

Security camera installation

In order to test the facial recognition software, we had to install some security cameras first to capture the images.

You need cameras to create images, so without the cameras, the testing could not be performed.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

AWS server and MongoDB setup

To test the facial recognition software, a cloud-based software platform needed to be established.

Without the setup of a cloud-based server we would not be able to test our facial recognition software options.

Installation, configuration, and assessment of facial recognition systems for use in security applications.

APPENDIX

The development of a legal search platform for the building code

PROJECTS

AN **ELIGIBLE** AND APPROVED APPLICATION

PROJECT IDENTIFIER

Legal search platform and interpretation tool for the interrelated rules and language in the NZ building legislation and regulation

START DATE: 1 APRIL 2020

END DATE: 31 MARCH 2021

PROJECT OBJECTIVE

Complex and interrelated legislation and regulations govern all building work in New Zealand. The primary legislation is the New Zealand Building Act 2004 (the Building Act) for building and construction and the New Zealand Building Regulations 1992 (the Building Code) which lists minimum building and performance standards required.

The building rules change as new materials or techniques are integrated. Building quality and performance have trended downwards over recent years, highlighting stakeholders' legal exposure. Human expertise is required to navigate the legislation, identify relevant passages, and understand roles and obligations.

This application is for R&D work on a legal search platform using a mix of machine learning based natural language processing (NLP) and rule-based models to make the Building Act accessible to users with little to no legal background, while providing a valuable and useful tool to legal and construction professionals. The aim is to provide better building code look up and automatic interpretation for a large variety of users including owners, builders, and local authorities.

CORE ACTIVITY

The modelling and lookup functionality technical problem to be solved

The ultimate solution is to develop a machine learning based NLP algorithm to allow an automated lookup. Although the amount of raw data is limited to the contents of the Building Act, the Building Code and relevant case law, the preparation of the relevant text (corpus) suitable for NLP is complex and expensive.

Without such a modelling and lookup tool experts in building law familiar with the Building Code handbooks currently work manually through the primary literature (Building Act and Building Code) and tag semantic meaning of words and concepts against these texts. This is a costly exercise. This means constraints must be placed on the size of the corpus used, which impacts the accuracy of the tool.

Important modelling constraints and opportunities:

- Balancing the relative importance of different rules and classes of building work requires statistical analysis to ensure the rules focus on the most important. i.e., the number of irrelevant passages may far outweigh the number of relevant passages, or vice versa. Thus, the corpus for the tool can be limited to and focus on the relevant passages.
- NLP engines require fine tuning to model complexity to achieve viable model performance with limited training data. Whereas rule-based engines are generally more robust but rely on human expertise.

Therefore, this project is designed to apply a mixed semantic model by:

1. Investigating an automated NLP, and
2. Developing and evaluating rule-based models that require more human expertise but have a better chance of providing useful performance for the search function when dealing with a limited data set.

This will help to make the most of the available data for the building code search and recommendation platform and inform future NLP models for other applications.

This financial year we are working on lookup functionality and will start with preliminary work for automatic text summarisation.

Benchmarking the technological uncertainties

1. **Is the knowledge to resolve the uncertainty publicly available?**

NLP techniques and algorithms have been applied globally to corpuses in many fields including legal text. To our knowledge, this is the first practical application to the NZ building legislation and regulations.

2. Is the knowledge to resolve the uncertainty deducible by a competent professional in the relevant scientific or technological field?

This is a hard task for a bespoke legal search platform and interpretation tool which requires informed statistical analysis and significant problem solving. This means it cannot be predicted with certainty the most accurate and efficient mix of the models (being the automated NLP or rule-based models) will be sufficiently accurate, speedy, and cost efficient within the search platform criteria.

The work will involve several experts who will research and systematically investigate the chosen data sets included in the corpus to find the plain English answer to expected search questions. Thus, the answer to resolving the core activity is not able to be deduced by competent professionals in the relevant fields without undertaking a systematic course of investigation and experimentation.

SCIENTIFIC OR TECHNOLOGICAL UNCERTAINTY

This raises uncertainty about achievable lookup accuracy and if the achievable model performance and inference speed are going to be sufficient for the use case.

While POS tagging and other lexical attributes are well solved, the biggest challenge is the unknown domain-dependent context sensitivity or semantic depth needed.

Therefore, the technological uncertainties to be resolved are:

- Whether the semantic structure in the legislation is suitable for tagging by a rule based or other system and a set of rules can be identified that covers the relevant sample set of documents.
- Whether a machine learning model:
  - can resolve inconsistencies arising from the innate ambiguity in natural and legal texts which is reflected in competing legal interpretations and opinions: and
  - can discover the relevant semantic structure (auxiliary words etc) better than random, especially when common keywords might account for 70% of the majority class.

Success will be achieved when relevant legal passages for a particular role can be extracted automatically at close to 100% completeness while minimising false negatives.

SYSTEMATIC APPROACH TO RESOLVE UNCERTAINTY

- Preliminary work on rule encoding and annotation. This will help define what exactly should be annotated in the context of the building code search engine. Identify roles and obligations.
- Annotate corpus and ensure a variation of legal opinions (at least two different lawyers) and semantic structure are captured.

Pre- and post-processing (e.g., using NLTK, Word2vec etc):

- POS tagging (nouns, verbs etc)
- Named entity recognition
- Text summarisation techniques
- Try out a range of technical encoding standards and pre-processing to identify optimum format for machine learning and rule-based engine (e.g., regular expressions)
- Develop benchmark for manual performance

Statistical sampling:

- Random sampling of cases, identify strata and use stratified examples to refine cases
- Adjust weights to oversample relevant minority classes to improve model performance
- Create rule-based models at sentence, paragraph, clause levels. This will guide machine learning input
- Evaluate utility of ML models that can represent context (e.g., explore application of transformer models)
- Run and evaluate models against each other and against manual benchmarks

New knowledge. New or improved services goods or processes

This R&D work is part of the development of a new legislation lookup service aimed at a variety of users in New Zealand.

SUPPORTING ACTIVITIES

- Engagement with authorities (e.g., councils) and research institutes (e.g. BRANZ)
- Engagement with legal expert data taggers
- Planning, management, and coordination activities
- Identifying the range of users and scoping work
- Preliminary research and literature review (including key documents - building code, Building Act 2004, etc.)
- Prototype design and development - system set up, pre & post processing
- Documentation and reporting.

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