Grid-i Tool Development Proposal

Mission

To apply affordable modern technology and smart software for detecting and identifying invasive mammal pests to assist in achieving a predator free NZ2050.

Background

There is a growing demand for in-field close to real-time identification of target pest species using purpose built equipment. Grid-i has been purpose built to monitor and identify pest populations in unattended sites over many weeks. It gathers objective data that is repeatable, reliable and robust. By using more data collection devices to increase the data pool, pest detection and population analysis will be more reliable.

This technology will non-invasively gather "what is where" data on pest population in near-real time. The surveillance is done by a thermal sensor connected to an embedded processor. A sensor with a Field of View (FOV) 1.5 m x 1.5 m detects infrared heat given off by warm blooded objects. (mice, rats, stoats, possums).

Grid-i is new and unique because it applies new technology to extract heat signatures from objects and to use smart software to compare and match in-built library heat-signatures. Packaged as a small, compact and affordable pest surveillance detection tool with networking capability, Grid-i provides a step-change in design and functionality of current pest monitoring tools by using Artificial Intelligence (AI) to provide information on activity time, species identification and location.

Current pest detection tools have limitations

The current monitoring tools require direct animal interaction with un-natural objects. For example, traps and tracking tunnels. These methods require active interaction of animals with the device and therefore are less sensitive than passive devices such as Grid-i (e.g. rats don't like ink on their feet in tracking tunnels [6]). Some examples of current device limitations include:

- Bite marks for chew cards (interpretation is required, and is unreliable because of some individuals being device shy)
- Ink on feet for ink-cards in tracking tunnels (interpretation is required, unreliable)
- Target lure to attract animal onto small touch pad for PAWS project [5]. (presence of water interferes with touch pad sensor and leads to inaccuracy)
- Moving animal physically weighed on load cell inside tracking tunnel (Tunnel detection LoRa-enable TED (Tunnel Electronic Detection) at ZIP) [1]. The mechanism has the potential to jam and be made in-operable)
- Captures in some traps (some individuals are trap shy and there are animal welfare issues)

For more information on pros and cons of PAWS, thermal and optical technology see [4]

Proposed solution

Grid-i is designed as a non-invasive (passive) surveillance tool to detect and identify pest species. It targets activity within a small FOV (2.2 square metres) resulting in less power consumption and processing resources. It is not targeting large pest surveillance areas such as in the cacophony project using a single monitoring station. It uses a hi-resolution camera with intended coverage of 100 square meters. This methodology requires higher power consumption and a higher end processor is has limitations for small battery confined systems.

The detection method used by Grid-i is non-intrusive. It does not require the animal to directly interact with unnatural stimuli (apart from lure) potentially influencing pest behaviour.

Target applications:

1) Community driven urban predator free programmes. To monitor activity before and during eradication programmes and for on-going monitoring. Objective information on pest population is available to the wider community. Using the “what is where” data allows effectiveness of programmes to be gauged

2) Urban consumers, schools with ‘back yard’ compost bins can monitor pest activity. The compost provides an ideal food and shelter source for invasive predators (mice, rats) to inhabit and breed. This was highlighted as an emerging urban trend by James Prier as a WWF conservation innovation idea for an integrated compost trap. Grid-i would monitor external activity before, during and after trap integration.

3) Non-urban open areas, bush locations, special protected areas and remote locations where invasive pest problems are present. Grid-i can be positioned where trapping or on-going monitoring is required.

4) To replace outdoor trail cameras with a purpose-built device to monitor and identify pest animals. It is specifically designed for close proximity coverage but could be used as sentinels in areas/island where pests have been eradicated.

Innovation section

There are many innovative features that Grid-i incorporates, which are not present in any in-field devices on the market today targeting pest monitoring and identification as a turnkey solution.

To improve understanding on the grid-i innovation features, it is necessary to outline what is present in the current unit (prototype 1). This unit was trialled at Otari-Wilton bush in Wellington (Figure 1) as a human pedestrian counter. It showed a successful proof of concept in operation and indicates that low-resolution thermal imaging can detect the direction, speed of moving object and size.

Figure 1. Grid-i prototype 1 trial at Otari-Wilton bush with close-up view.

What does the current technology and software do now

- Thermal Sensor recording low-resolution image at 10 fps in FOV.
- Sensor captures raw 64 pixels per image
- Software processes image (interpolates) data to higher resolution 225 or 841 pixels
- Software uses image processing to isolate object from background
- Software extracts single and multiple objects within image
- Records basic object direction and movement to on-board memory card.

What innovative features will be incorporated to prototype 2.

The project is to add classification and identification functionality for the target pest. This is done by creating animal thermal signatures for the all target species (Project with Agritech, Lincoln). Once held in the software library the templates will be matched to real-world data by using Artificial intelligence (AI) borrowed from the computer vision field. The AI will use templates held in the library plus other processes to find the best match against the incoming sensor data.

Software specifications (new innovations)

- AI software to use template matching (unknown species signature matched to in-built library signature to best fit and identify)

- Al software to use species movement pattern within the FOV to aid in template matching and animal identification (each target species will have its own unique movement pattern)

- Al software to be self-learning. Species heat signature library to be used as starting foundation. The learning algorithm (e.g. Adaboost) learns from past in-accuracies (incorrect species identification) and incorporates improved features into the future template library.

- Long battery life (3-4 weeks). Integration of power saving features in software and hardware that are incorporated and tested at design time (not added after design built).

- Add optical camera to hardware, so thermal and optical images (same FOVs) are recorded concurrently and stored on hi-capacity memory card in real time. This feature is to allow image data to be recorded and played back in the future to determine correlation accuracy in pest identification. Optical image with matching time line can be viewed by human to examine results or machine learning to optimise target species heat signature for the library.

Other in-built features of Grid-i:

Due to the nature of the project, purpose built project tools need to be built to assist in development, testing (field trialling) and, most importantly, product validation. This is to ensure the product has a high level of accuracy for target species identification. One of the tools, as mentioned previously, is incorporation of an optical camera in parallel with the thermal camera.

A second feature requires a record data mode (data logger). All sensor data are read from a thermal sensor and stored on a high capacity memory card.

Benefits

1) Site data can be replayed and used for validation to confirm pest identification accuracy.
2) Better AI learning algorithms can be developed in Grid-i.
3) Site data can be stored in a growing database to build a species heat signature identification library. This will aid in developing a large pool of data that other researchers can utilise in the future (Information sharing)

Data compression

Recording in-field data over long periods requires robust (non-lossy) data compression techniques for storing to memory card or sending low volume data over network from individual sensor devices. For example, a single frame of thermal sensor 64 pixels data with time and date stored on the card requires 140 bytes; with a simple non-lossy method, this is reduced to 73 bytes (approx. 50% improvement)

Remote data access

Including efficient digital radio (LoRa) technology mounted on each unit is capable of transferring low volume sensor data over long distances. ZIP, in their annual report [1] page 31, indicated very good results using this technology for automated field reporting in remote terrain. They used the LoRaWAN specification to network data.

This technology is under test and will be integrated into prototype 2. (Figure 2)

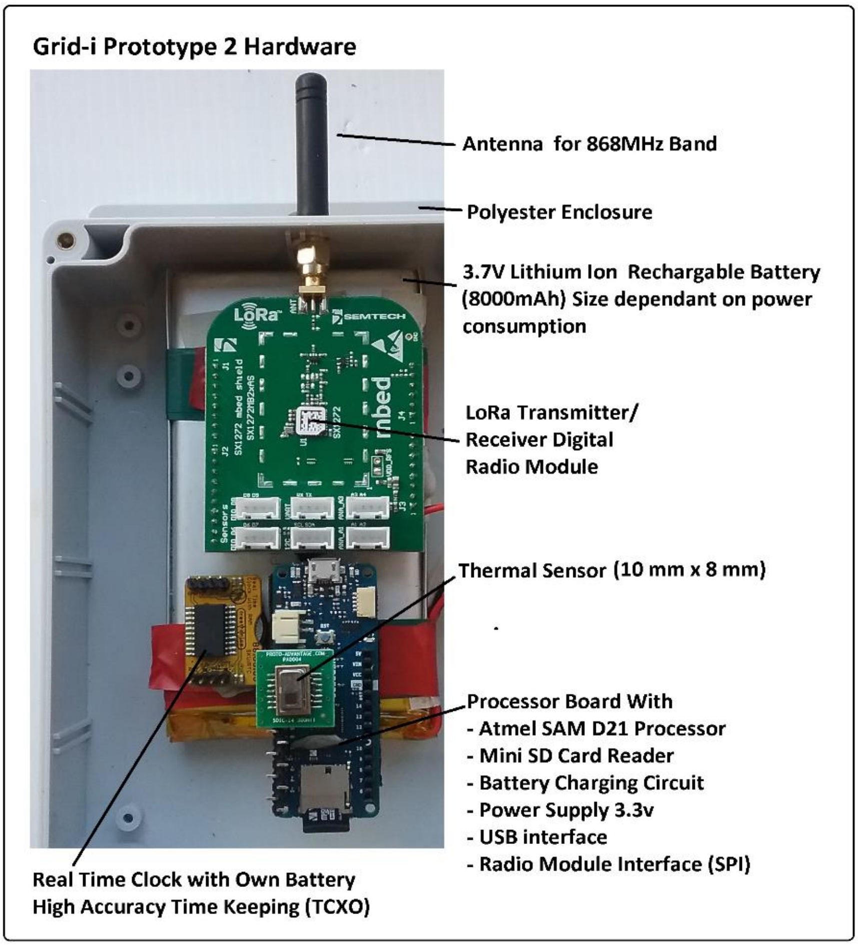

Figure 2. Grid-I Prototype 2 using "off the shelf" hardware

The project development risks:

The development risks are low as similar software has been developed for a human thermal detection product with field trials undertaken on site (Otari-Wilton). This proves the concept that the thermal sensor used in the project provides enough resolution for larger objects, but there are unknowns

1) *Sensor resolution is too low for small heat emitting objects*
   The data present in the image does not contain enough data resolution to ensure accurate object identification.

   Mitigation: In conjunction with Bruce Warburton, a Research Proposal was created to undertake in-field species identification trials at Landcare Research, Lincoln. Heat signature data on various pest mammals (possums, rats and stoats) will be collected and data analysed to determine;
   - if target species have different heat profiles
   - if target species can be identified by low-resolution thermal imaging.

   If the thermal sensor resolution is not adequate then a higher resolution thermal sensor is available for investigation e.g. Melaxis MLX90640 (32 x 24 pixel resolution) [2]

2) *Environmental*
   Field trials indicated that the differentiation was poor between the target object and the background during the conditions of;
   - Bright sunlight shining directly on or reflected onto the sensor.
   - Hot background (similar temperature to object of interest)
   These situations lead to poor discrimination and poor identification of the object.

   Mitigation: Use dual technology, have an optical camera in parallel with the thermal sensor. On detection of high heat background to enable optical recognition and identification. A case study in [3] demonstrated the strengths and feasibility of this method.

   It must be noted that the target pest mammals are predominately nocturnal and more active during the night hours. The activity during the day in bright sunlight is likely to be minimal. Activity during high background temperatures during the day is likely to be low. However, evening temperatures (> 20°C) are possible during summer requiring switching to optical data sensing.

3) *Sensor positioning on-site not standardised*
   The field installation of Grid-i onto a site without a mounting system would create variation in sensor positioning that can be detrimental to optimal operation leading to poor detection and identification. Other potential side effects can expose the sensor to bright sunlight and orientate the sensor to increased exposure to water leading to poor operation, poor detection and poor identification.

Mitigation: A standardised field setup to be used to increase protection for the sensor and reduce the impact of climatic elements (rain, mist and sunlight) on the operation. The standardised setup would have Grid-i mounted on a pole, with the sensor directed at the ground (Figure 3).
Having a standard operation setup will allow for standardised data collection, as the sensor is at a fixed height above the ground. It has the added benefits;

- Mammal interaction is reduced if animal restrictor is on the upper end the mounting pole.

- Extra dispensing electronics (optionally controlled by Grid-i) can be located at ground level next to the mounting pole for example, to dispense long life lures or electronically control trap activation.

- Mounting the enclosure above the ground with the antenna on top of the enclosure improves radio RF reception and reduces losses in the transmission signal. The ground acts like a large RF sponge.

4) *Battery*

Using rechargeable battery requires a recharging system. A possible method is to recharge the battery using a large portable power bank to recharge battery. (This can be time consuming) A more practical method is to replace the battery pack. By using a key locking mechanism, the old battery pack can be removed and new pack reconnected and locked securely into place.

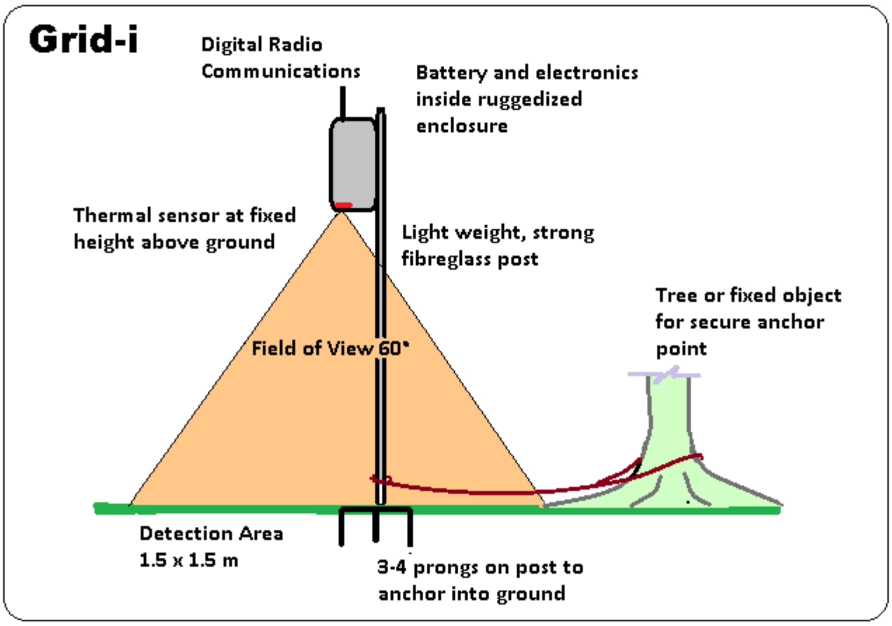

Figure 3. Grid-i in-field mounting setup.

Technical Features

How is long battery life achieved?

This is a combination of hardware and software optimisation whether built in the architecture (processor), done by the compiler, or tuned by the developer during coding.

Hardware features:

- Atmel SAM D21 processor with ARM Cortex-M0+ core (very power efficient)
- Utilises low power sleep modes on the processor to reduce power consumption.
- Dynamic switching of processor clock speeds, higher speeds for intensive image processing for high data through-put, slower for house work routines for example, checking peripheral states. Note higher speeds equates to greater power consumption.

Software features:

- Software optimised by the programmer to run more efficiently (functions for image capturing and processing). Common image processing conversion functions (e.g. averaging minimum and maximum temperatures, standard deviation) tuned to run faster. Many existing functions can be tuned to run up to 50% faster or more.
- Functions interfacing peripherals (via SPI and IIC) can be tuned to be more efficient, software using con-current features e.g DMA to read thermal sensor data into memory while the software processes the previous image.

What tasks or activities is the investment needed for

- Funding of labour to develop and test software.
- To build data recording tools for recording heat signatures (optical and thermal sensor data recording.
- To use recording tool for collect animal heat signature data. The work will be done at Landcare Research, Lincoln.
- To build software analysis tools to analyse heat signatures of target species.
- To build 5 prototype units for field trials. The predator free Ngaio community group has agreed to collaborate in undertaking in field trials).
- To build AI software to include thermal signature library for target pests (mice, rats, stoats, possums.)
- To gather field data to improve AI processing techniques (a bigger data pool provides a better learning pool).
- To build network functionality using (LoRa) digital radio technology.
- To employ external resource to design small foot print PCB.
- To employ external resource to design environmentally robust enclosure and secure mounting system.
- To upgrade software development tools to more efficient tools (the current software tools are free-ware).

Project timeline and milestone targets

Completion by end of December 2017

- Build dual recording tool (optical and thermal sensor in one tool)
- Build software for recording dual data (utilise dual recording tool)
- Gather heat-signature data of target animals at Landcare Research, Lincoln

Completion by end of February 2018

- Build test tools to display and analyse thermal and optical data
- Analyse heat-signature data from target animals
- Determine what level of heat signature data quality is required to differentiate targets.
- Build Grid-i digital radio network using customised LoRaWAN.

Completion by end of March 2018

- Build 5 prototype2 units
- Build AI software to support digital signature library
- Build and test AI software to use template matching of thermal signatures
- Operational testing of AI software for thermal signature template matching

Completion by end of April 2018

- Basic field trials of prototype2 units for operational functionality
- Basic field trials around home (monitoring outdoor compost pest activity)

Completion by July 2018

- Field trials in collaboration with Predator Free Ngaio.

Completion by August 2018

- Design of PCB for prototype 3 by external resource
- Enclosure design and development by external resource.
- Enclosure build prototype
- Enclosure field trials
- Design battery mounting system (external battery clip on and off device, with keylock)

Business details

This is a start-up company in the early stages of product development with two supporting co-workers, John Manning and Alan Reeve. The co-workers initially provided some financial support for the initial prototype 1 design but will not support further development with more financial assistance. Therefore, outside sources are required to develop the prototype 2 into a production unit.

A start-up grant from Callaghan Innovation (2017) provided some financial assistance in protoype1 development. This is now finished.

Gerald Dickinson designed, developed and tested the prototype1 unit into a working proof of concept product. At least 80% of the labour is non-paid or classed as “sweat labour”.

Previous work and research experience

Gerald Dickinson is a software and hardware developer, and electronic systems designer with project management skills.

His work experience includes:

- 20 years in embedded software and hardware design interfacing real time sensor devices.
- Interfacing networking devices such as, RF transceivers in the ISM band for short or long range, (<10 metres to many kilometres)
- Digital design experience (PIC, Atmel, Intel micro-processors)
- 10 years software manager at MAS Zengrange . This is a military based company designing remote controlled detonation devices for explosives. Many remote controlled RF products are used by special forces around the world e.g. NZ Army, Australian Army.
- Project management of remote controlled initiation products (MAS-Zengrange)
- Bachelor of Science in Psychology 2016. (Victoria University of Wellington)
- Research assistant, Animal Behavioural laboratory at Victoria University, to investigate the effects of drugs on rats.
- Presently self-employed undertaking embedded software development in the AI field using battery operated technology and sensor interfaces (thermal, movement)

John Manning

- Project manager
- Business manager

Alan Reeve

- Sales manager

Design requirements / specifications

- To use dual technology (optical and thermal sensor), where thermal detection and identification is poor (in hot and sunny environments) optical detection can be used for detection and identification)
- To locate thermal sensor enclosure above the FOV. This reduces impact of water and sunlight on the sensor.
- To provide a fixed detection field of view 1.5 x 1.5 m.
- To use a thermal sensor that utilises low power (16mW) to extend battery life. (Note: FLIR Lepton 3 thermal detector consumes 145 mW)
- The thermal sensor to have an operating temperature range (-20C to +80C) to allow for wide operating temperatures from sub-freezing to hot environments.
- To use a light weight fibre glass support and mounting pole. This is to minimise the weight carried into the field for remote site deployment.
- To position and fit grid-i on fibreglass pole by a secure locking mechanism. The location further from ground reduces effects of animal interference such as chewing.
- The sensor and electronics (main enclosure) mounted in ruggedised water proof box.
- The main enclosure to be attached in a secure lockage manor to the mounting pole.
- The battery to be removable and enclosed in a separate ruggedised enclosure;
- The battery to be attached to the main enclosure by a lockable secure means (key required to attach and remove battery).
- To use a power efficient embedded processor (32bit) that can utilises low power sleep modes (operational 82mW). Note: Raspberry Pi3 operating power consumption is 450mW
- To minimise the thermal image frame size to reduce processing overheads.
- To have enough data resolution for image processing to reliably identify target from non-target objects.
- The thermal sensor to have 10 frames per second data capture rate. To allow for faster response time for moving objects.
- Grid-i to be mounted on pole 1 m to 0.8 m above ground to create a standardised operating condition for data recording.
- To use efficient software algorithms to process images in near-time.
- The source code to be written in C language, with optimised compiler options enabled.
- To use efficient image filtering methods in software such as, nearest neighbour, gravity points.
- To use AI methods such as animal template matching. This method is ideal for fixed mounted pole height and machine learning methods such as Adaboost.
- To have post processing image data methods to modify object image quality such as interpolation.
- To use digital radio communication for network connectivity (LoRa) (The technology is efficient for long distance communication and low power consumption)

- To use anti- theft/ deterrent mechanism. Methods can be motion detector such as car alarm or, kiwi favourite, anchor chain secured to secure object.

References

[1] ZIP Annual Report 2016-2017 http://issuu.com/zipnz/docs/zip_annual_report_2016-17?e=27473090/53875016

[2] Melexis Thermal Sensor

https://www.melexis.com/en/product/MLX90621/Far-Infrared-Sensor-Array-High-Speed-Low-Noise

[3] Ji Hoon Lee, 2015, Robust pedestrian detection by using visible light and thermal infrared cameras mounted in parallel. PDF file. www.mdpi.com/1424-8220/15/5/10580/pdf

[4] Gerald Dickinson 2017 Technology to detect and identify NZ invasive mammal pests, PDF file

[5] Helen Blackie, no date, Novel automated pest detection and monitoring devices, PDF file

https://www.landcareresearch.co.nz/__data/assets/pdf_file/0004/66487/Blackie_Novel_automated_pest_detection.pdf

[6] Kate Guthrie, 2017, Do Rats Mind Inky Feet?

http://predatorfreenz.org/rats-mind-getting-inky-feet/?utm_source=PFNZ+Trust+Newsletter&utm_campaign=3b76ea9022-EMAIL_CAMPAIGN_2017_10_04&utm_medium=email&utm_term=0_fee93e1adc-3b76ea9022-525796781

Annex

Figure 4: Prototype 1 simulation of predator trap surveillance.

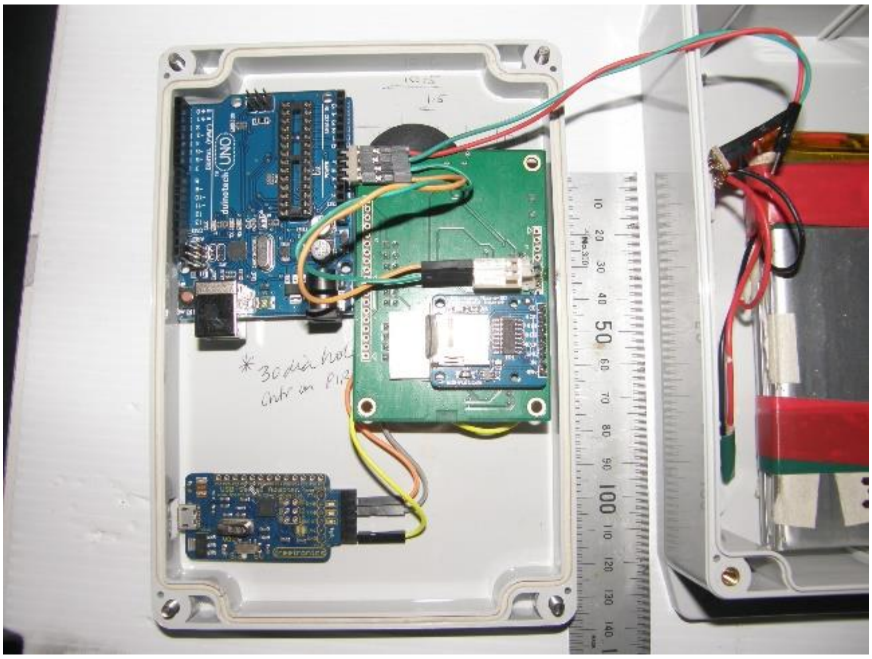

Figure 5: Prototype 1 hardware used at Otari-Wilton bush.

Unit contents in enclosure

- Power supply (top left)
- Main processor development board with thermal sensor and mini-SD card reader (centre)
- Serial to USB interface (bottom left)
- Li-Ion Recharging battery (right)