Technology to detect and identify NZ invasive mammal pests

This article compares the differences in pest animal detection and recognition technologies for 1) Touch screen print recognition (PAWS), 2) Optical camera and 3) Thermal imaging camera (Cacophony and Grid-i). It outlines the pros and cons of animal detection and identification of thermal imaging against touch and optical camera techniques. It provides comments on how the new product (Grid-i) using thermal technology would function with a range of temperatures and other climatic and operational conditions.

1) Touch screen animal foot print recognition

Lincoln Agritech developed a touch screen animal foot print recognition product called PAWS (Print Acquisition and Wildlife Surveillance).

PAWS is an enclosed touch screen located in-field that can detect animals contacting the touch pad and identify animals using inbuilt software algorithms. Animals are attracted to the area by olfactory based lures. It identifies pests (stoats, ferrets, possums, cats, rats and mice) with a high level of accuracy [1] and can be left in-field for long periods with little human intervention.

Advantages

- High accuracy for pest footprint detection and identification
- Can detect target animals with attractant lure.
- Small touch detection area (12 x 10cm approximate, estimated from slide picture in [1]).
- Small, light and portable.
- Good battery life [2], but exact device time unspecified.

Limitations

- Requires direct interaction (contact with sensor pad)
- Requires target lure to attract target species to detection area.
- Requires attractant lure located on end of device.
- Some targets are non-detectable. Percentage of target population will not be attracted by lure and remain outside detection area.

- Lure needs to be refreshed periodically. (Unsure if automatic electronic dispenser is used to dispense long life lure)
- Small detectable area. Larger animals may not contact detection area while investigating lure.
- Open to unwanted animal interaction (chewing or over pressure)
- Reduced detection accuracy when surface water present on touch sensor. (Investigated by testing response on a Samsung tablet. It resulted in poor detection accuracy).
- Detection accuracy poor when sensor pad has obstructions due to leaf litter. Obstructions act as insulators and detection accuracy reduced. The detection technology is unknown and if using capacitance then object acts as insulator between species limb and sensor pad. (This is observable on commercial tablets when wearing gloves and due to a limitation in capacitance touch technology)

Unknown (not enough information)

Response rate from first animal presence to automatic detection. If PAWS enters a sleep mode (to preserve battery power) and reactivates on animal presence, then a wake up period is required (time for sensor to fully operate and read data) This period determines the response rate to gather data from the sensor for object identification. Longer periods (e.g. > 100ms) create non-recordable windows. Detection and identification of fast moving animals such as Wessels) is not accurate. This limitation is common for in-field trail cameras (can be up to 1.5 seconds).

PAWS temperature and environmental specifications are unknown. Temperature extremes will impact on performance such as in direct sunlight or cold alpine conditions (sub-freezing, frost). The touch sensor and electronics need to be specified for the automotive temperature operating range. Commercial products (Tablet) of commercial specification is 0°C to 70°C while automotive is -25°C to 85°C. operating conditions. Product in-field must be specified for automotive otherwise there will be reliability issues.

When recording in-field data onto memory cards such as SD cards, the storage cards are vulnerable to data corruption especially during data write operation in extreme hot or cold. The memory card needs to be specified to automotive temperature specifications not commercial grade. If operating in extreme conditions data integrity is required.

A common problem especially in populated areas is the removal of the device (whether stolen or disturbed). By providing defence mechanism or deterrents this issue is reduced. Mechanism can be motion detector and siren (e.g. car alarm) or kiwi favourite, securely chained to tree.

The battery life of PAWS is unspecified. When stating a good battery life in [2] The exact period is unknown (whether days, weeks or months). This information is important especially for long term in-field monitoring devices.

2) Comparison of Thermal recognition projects

It is intended to use Grid-i with a thermal sensor and pest detection and identification done by image processing techniques derived from the computer vision AI field (Artificial Intelligence) using a powerful but power efficient processor. The resolution is 8 x 8 or 29 x 29 pixels (64 or 841 pixels per frame) with a frame per second rate of 10 fps. The field of view is small 1.5 x 1.5 m and the sensor located 1 metre above the active area.

A parallel active project (The Cacophony Project) uses the FLIR Lepton 3 thermal imaging camera and the Raspberry Pi embedded device for image processing and uses AI algorithms. The resolution is 160 x 120 pixels (total 19,200 pixels per frame) with a frame rate of 9. The surveillance area is 100 m2 and are targeting a wider area for animal presence.

The targeting of the two projects should complement each other in the future. Grid-i is targeting small areas, it is ideal for small closed in areas or of dense vegetation such as close to food sources in home backyard or schools (compost), trapping corridor locations. Having low resolution thermal data provides good object detection response time minimising battery draw and pro-longing battery life. Trialling of Grid-i at Otari-Wilton bush in Wellington indicated this approach works very well. The trial did indicate limitations with thermal sensor technology

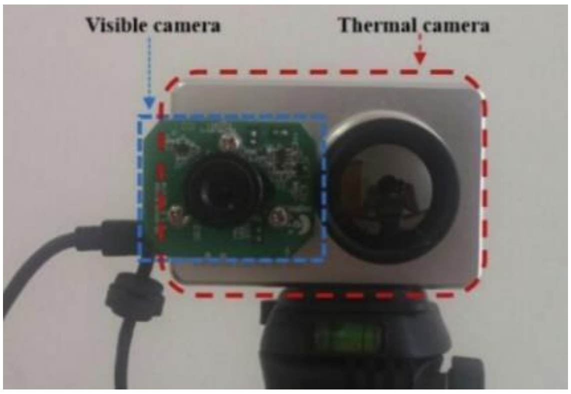
- When an object passed over a hot background, the object could not be identified
- The presence of direct sun light on sensor caused false positives.

These Grid-i limitations are addressed in the G**rid-i product design requirements** section below

2) Comparison of Optical and Thermal technology

A comparison using a case study provides information on the advantages and disadvantages of the optical and thermal technology and the limitations of object detection and identification.

A case study titled "Robust pedestrian detection by using visible light and thermal infrared cameras mounted in parallel" [3] provides a comparison of the optical and thermal imaging technologies. The study was performed on humans and would be comparable to mammalian pests.



The technology used a thermal FIR camera (similar to The Cacophony Project) and optical web camera. The cameras were mounted 10 to 15 meters from target zone. Dual images in parallel were captured and processed on a laptop using image processing techniques with AI.

Optical visible light camera vs thermal comparison

Advantages

- Non-invasive surveillance method
- Detected and identified objects during daylight of high background temperature.
- Detected images in high resolution (640 x 480 pixels), 30 frames per second.
- Identification of multiple single objects with single frame
- Identification of dual overlaying objects as two single objects

Disadvantages

- Poor object identification when non-uniform illumination present e.g presence of shadows or low external light during sunrise and sunset.
- Poor object detection and identification during night time (when no external lighting source)
- Poor object detection and identification during presence of rain or mist.
- Power consumption high (requirement for external power supply. Laptop battery life limited)

- Image processing data volume is large. Size of single image (640 x 480 = 307,200 total pixels) and at 30 fps requires high data volume processing.
- High end powerful processor required (laptop).

Thermal imaging vs optical camera comparison

Advantages

- Non-invasive surveillance method
- Object detection during daylight of low and medium background temperature was good.
- Detection at night, during rainfall and mist was good
- Detection using high resolution camera was good, good image resolution for post image processing.
- Identification of multiple single objects with single frame
- Identification of dual overlaying objects as two single objects

Disadvantages

- Object detection was poor when in presence of high background temperature such as during full sunlight or hot temperatures.
- Processing power high (need a high end processing platform, Laptop)
- Power consumption was high.
- Image processing time was slow as quantity of data processing high.
- Resolution of camera high (320 x 240 pixel). Requires high processing requirements therefore limited battery life using a laptop platform.

Table 1: Technology Pros and Cons

Method/Situation to detect and differentiate object from background	**Thermal object detection**	**Optical object detection**	**Touch pad object detection**
During daytime (uniform illumination)	**Good**	**Good**	**Good**
During non-uniform illumination (shadows)	**Good**	**Poor**	**Good**
During low light (dawn and evening)	**Good**	**Poor**	**Good**
During rain (water on ground)	**Good**	**Poor**	**Medium**
During mist	**Good**	**Poor**	**Good**

During night time (no external lighting)	**Good**	**Poor**	**Good**
During cold environment (<10°C)	**Good**	**Good**	**Good**
During warm environment	**Good**	**Good**	**Good**
During hot environment (>20°C)	**Poor**	**Good**	**Good**
During bright sunlight	**Poor**	**Good**	**Good**
During windy condition	**Medium**	**Good**	**Good**
Sensor detection area	**Large**	**Large**	**Small**
Animal size that is detectable	**All**	**All**	**Larger less so**
Non-mammalian animals detectable	**No**	**Yes**	**Yes**
Invasive or non-invasive method for sensing object	**Non-invasive**	**Non-invasive**	**Invasive**
Lure required to attract animal to detection area	**Optional**	**Optional**	**Required**

Summary

Based on the technology comparison in Table 1, each technology has strengths and weaknesses. When targeting thermal technology, it is non-invasive and can detect different sized mammalian animals. It can detect and identify a wide range of animal sizes and shapes in different environmental conditions, however it does have limitations in direct sunlight and in hot environments. This impact for daylight detection is less due to the animal nocturnal behaviour. It is less likely to be active during bright daylight hours.

Given a situation where one technology works well and the other less so. It is envisaged the ideal design combines the two technologies into one unit, so improving the accuracy of object recognition and identification.

To achieve this reliability and battery life the design features are outlined below.

Grid-i product design requirements

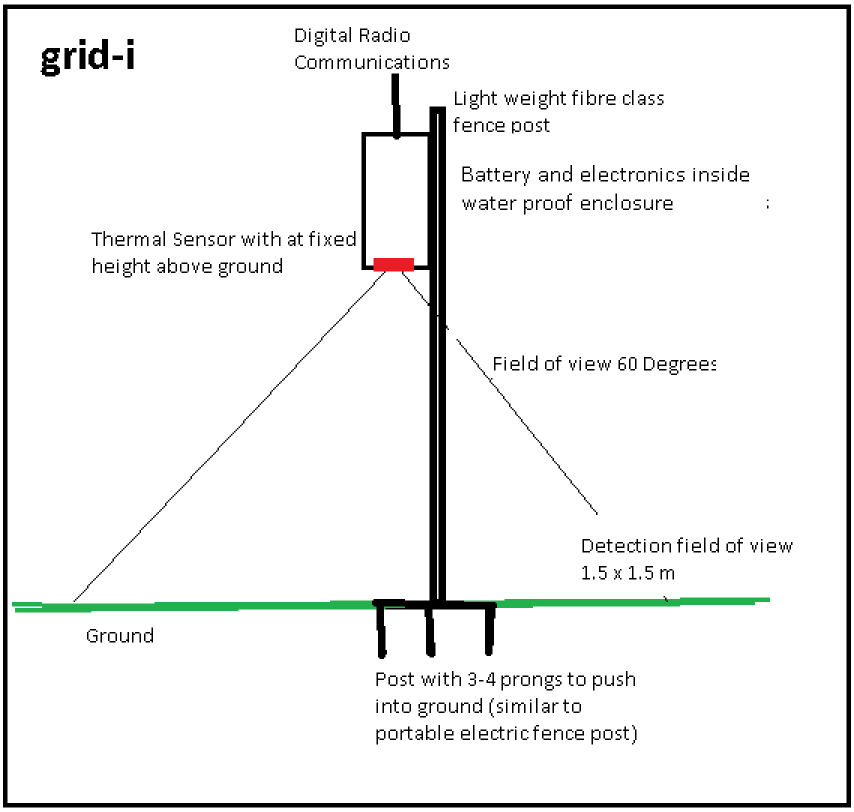


Diagram of proposed Grid-i in-field setup.

Design features

- Use dual technology (optical and thermal, where thermal detection is limited during hot environments, optical detection can be enabled for detection and identification)
- Locate thermal sensor to point down over object. This reduces the impact of water and direct sunlight on sensor.
- Provide fixed detection field of view 1.5 x 1.5m. (This can detect range of object sizes)
- Thermal sensor utilises low power (16mW) to extend battery life. (Note: FLIR Lepton 3 thermal detector consumes 145 mW)
- Thermal sensor operating temperature range (-20C to +80C). Functional operation ranges from sub-freezing to hot environments.
- Light weight fibre class post (light weight to carry into field)
- Position Grid-i on fibreglass pole and located above ground (this reduces effects of animal damage such as chewing).
- Sensor and electronics mounted in ruggedized water proof box

- Use power efficient embedded processor (32bit) that can utilises low power sleep modes (operational 82mW). Note: Raspberry Pi3 operating power consumption is 450mW.
- Reduce thermal image frame size to reduce processing overheads. (reduce image resolution from 320 x 240 pixels as used in case example [3], to 8x8 or 29x29 pixels). The design requirement is to have enough data resolution for image processing to reliably identify object. (Animal heat signature identification data will be gathered at Lincoln Agritech animal behavioural unit)
- Thermal sensor to have 10 frames per second data capture rate. Fast moving objects potentially detectable.
- Grid-i mounted on pole 1 m above ground to create a standardised operating condition for data recording.
- To use efficient software algorithms to process images in near-time. The software is written in C language. It can easily be optimised by coder and is efficient.
- Efficient image filtering methods in software such as nearest neighbour, gravity points. This is already tested and efficient method for processing data volume from thermal sensor.
- Use AI methods such as animal template matching. This method is ideal for fixed mounted pole height (standarded data) and machine learning methods such as Adaboost.
- Post processing data methods to modify object image quality such as interpolation.
- Efficient digital radio communication for network connectivity (LoRa)
  This technology is efficient for long distance communication and low power consumption.
- Anti- theft/ deterrent mechanism. Use motion detector such as car alarm or kiwi favourite, anchor chain to secure to tree.

The Grid-i design features a platform for a robust novel design. It is a long term solution for invasive pest monitoring to help achieve a predator free NZ 2050.

References

[1] 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

[2] PAWS MP3 sound file http://www.bbc.co.uk/programmes/p02z77zw

[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