The Technology of Tracking and Tagging Insects

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Overview

- Insect tags
  - Active vs passive
- Tracking insects
  - Tracking methods
  - Limitations
- Tagging insects
  - Types of tag
  - Limitations
- Future directions
Overview of Techniques

Technology

Tracking

Radio

Radar

RFID

Optical

Combined

Other
Passive vs Active Tags

• Passive tag
  • Tag does not require power
  • Power obtained from energy from the reader
  • Limits reading distance

• Active tag
  • Tag has own power source
  • Larger reading distance
  • Heavier and larger due to power supply (battery)
  • Can be more complex (signal processing, memory storage, calculations, security, etc)
Tag Tradeoffs

• Weight
  • Guidelines state less than 10% of body weight
  • May have to be lower if flying insect

• Detection distance
  • Distance is a function of frequency and antenna size
  • Many tags have read distances less than 50cm
Radio Tags 1

• Three basic forms:
  • “beepers”
  • “coded tags” – can also include sensor information (e.g. temperature)
  • “smart” tags
Radio Tags 2

- Tags need individual frequency – limitation on number
- Coded tags can share the same frequency
- Weight is as low as 0.36g (Lotek)
- Can integrate GPS but much heavier ~10g
  - Need to be retrieved in order to download data
  - Position fix changes battery life
    - E.g. 1 fix per day = 180 days
    - 1 fix per second = 2.5 hours
    - Need to consider memory size
Smart Radio Tags

- Uses microcontroller and signal processing
  - Can store data for periods, contains memory
  - Data downloaded at intervals
  - More complex radio communications - bidirectional
- Example – ear temperature tag for pigs
  - Stores tympanal membrane temperature
  - Up to 32 sensors operating at the same time
  - Up to 30m range indoors
Pig Ear Tag

- Weighs 2.16g (battery is 15% of total weight)
- Lasts 2 weeks on 1 battery
- Stores up to 256 temperature values
- 7 year old technology
  - Can now store 1000’s of readings
- Problem is time taken to transmit data
Scanning Radar

• Provides location, distance
  • Can also provide velocity (Doppler) and estimate of size of object

Distance $D = \frac{cT}{2}$
where $c = 3 \times 10^8$ ms$^{-1}$
and $T =$ time of flight of pulse

Received signal = $fn \left( \frac{P\sigma}{D^4} \right)$

Insect has radar cross-section $\sigma$

Location via alt, az

Mayfly Hatching on Radar
Radar Cross-section

• Amount of energy scattered by body depends on:
  • Orientation wrt the radar
  • Wavelength of RF signal wrt body size
  • Make up of body (fat, water, etc)
• Flying insect will impose wing beat frequency on signal
Scanning Radar
Application and Limitations

- Good for large scale monitoring, e.g. swarms of locust
- Entomological Radar is vertical-looking (VLR) which is static and provides information on migration, e.g. aphids, moths (Rothamsted)

- Limitations
  - Minimum distance due to time of flight of pulse and processing speed
  - Can detect small insects close and large insects at a distance

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VLR

http://www.pems.adfa.edu.au/~s9104004/trews/ww_re_ph.htm#nriqx

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From Chapman et al (2002)
Harmonic Radar

• This uses a non-linear device to re-radiate RF energy at twice the frequency
  • E.g. 917MHz radar signal will be radiated as 1845MHz
  • Needs separate transmitter and receiver – can be $10k-50k for static system
• Tag can be very small
  • Tag used for butterflies (Cant et al., 2005) was 12mg in weight (8% of weight of A. urticae)
Harmonic Radar

Incoming RF at f Hz

\[ \text{Antenna length } L = \frac{\lambda}{2} \]

\[ \text{diode} \]

Outgoing RF at 2f Hz

\[ \text{Antenna length } L = \frac{\lambda}{4} \]

Tag on *A. urticae*

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Cant et al, (2005)
Harmonic Radar
Applications and Limitations

• Low weight tags good for flying insects (butterflies, flies, bees)
• Static radar allows tracking in 3-d up to 1km
• Hand-held allows for location up to 20m (used for ground beetles)

• Limitations
  • Cannot track if insect is in clutter (e.g. behind a hedge)
  • Cannot identify individuals if more than 1 is tagged
RFID Tags

• Tags characterised into passive and active

• Passive tags use inductive coupling to provide power to tag from a reader

• Simplest is 1-bit transponder which indicates whether the tag is present or not
  • Used in shop security systems
  • Size is around 50x50mm
  • Reader antenna more than 1m²
1-bit EAS Transponders

1-bit Electronic Article Surveillance

- RF
- Microwave
- Frequency divider
- Electromagnetic
- Acoustomagnetic

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1-bit Transponder Operation

http://RFID-handbook.com

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Inductive Coupling

EM Backscatter

http://RFID-handbook.com
Passive Integrated Transponder (PIT) Tags

- Loligo PIT tags
  - 0.09g
  - 12x2.12mm
  - Operates at 134.2kHz

- Lower frequencies can be read at up to 1m and through soil, wood, etc

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www.loligosystems.com
RFID Tags

• Several manufacturers
• Hitachi Mu
  • 0.05x0.05x0.001 mm
  • RF is 2.45GHz
  • Read distance only cm

• BUT antenna is:
  • 54mm long
  • 1.5mm wide
  • 0.22mm thick

http://www.hitachi-eu.com/mu/
Hitachi Mu Chip

From Hitachi Mu Data sheet

Reader

Antenna

Tag-It HF-I Transponder

Read distance only cm
Optical and Hybrid Tags

- Optical tags use light to power the tag (e.g. laser) and light to transmit data (e.g. LED)
  - Read distance is very small
- Hybrid tags use optical energy for power and RF for transmission
  - p-Chip from PharmaSeq
  - Very small and can be implanted under skin due to IR laser penetration of skin.
Other Tracking Methods

• **Passive acoustic**
  - 2-d and 3-d tracking of animals using their own sounds (including ultrasound)
  - Can be used underwater

• **Sonar**
  - Similar to radar but underwater

• **Lidar (light radar)**
  - Same as radar but uses laser
  - Much higher spatial resolution due to shorter wavelength
  - Mainly used for tracking airborne pollution
Other Tagging Methods

• Barcodes
  • Have been used for bees
  • Complex codes such as 2-d
  • Problems with physical size & reading
  • Problems with dirt

• Reflective and luminescent tags
  • Simple but operate in dark
  • Have been used for bats, Orthoptera
Future Directions

- Looking at tradeoffs: weight, distance
- Decrease in weight
  - Smaller power supply:
    - Piezoelectric (vibration)
    - Paper batteries, other new technologies
  - Higher frequency RF – smaller antenna BUT shorter distance
- Greater distances can only be achieved with active tags (power transfer ability inversely proportional to distance)