Small Object Detection in an Outdoor,Time Varying, Dynamic Environment

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PLANT INDUSTRY

HORTICULTURE

CSIRO

Overview of Presentation

- Introduction
- Research Techniques
  - Results and Findings
- Future Directions
- Summary

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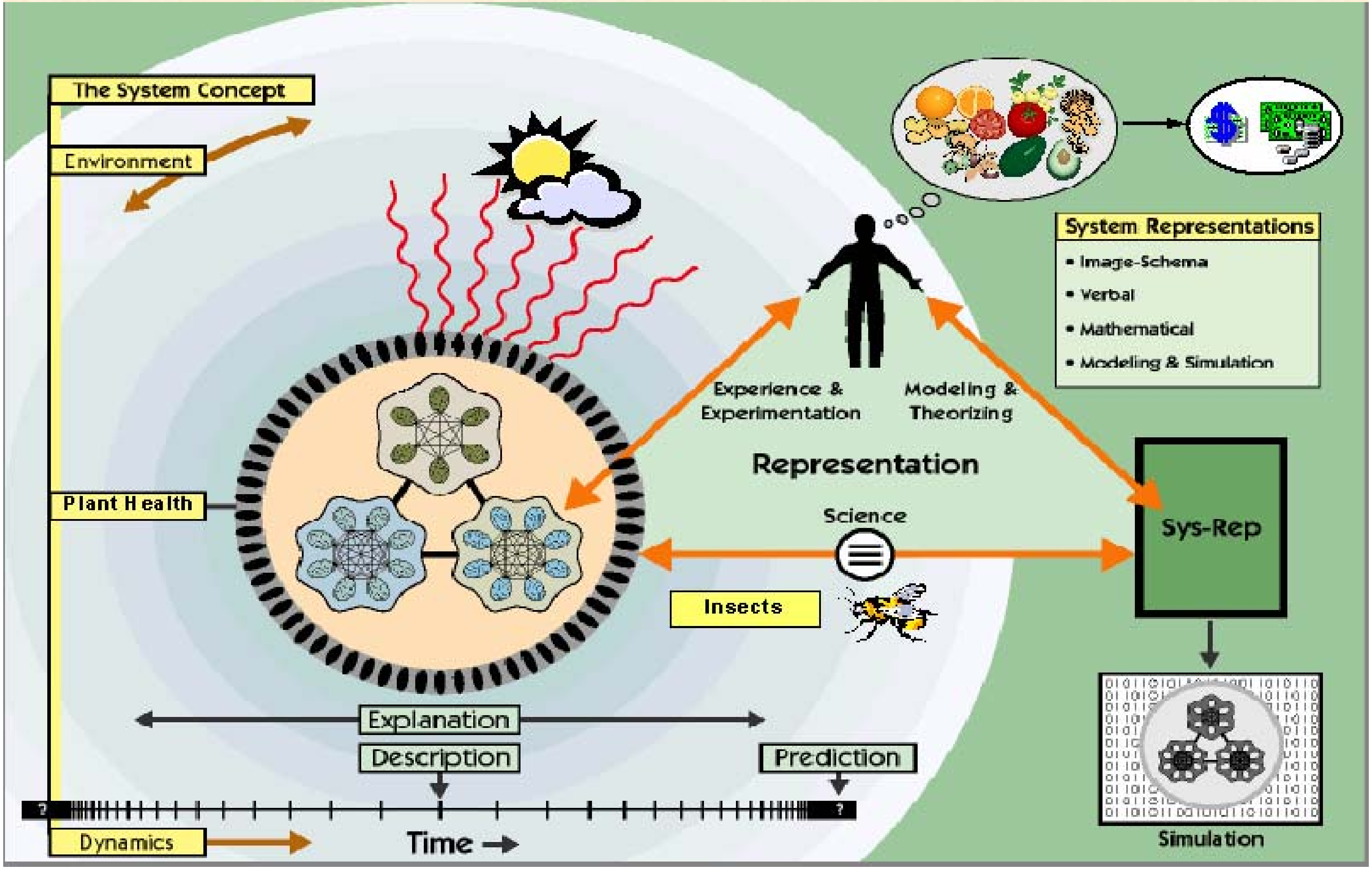
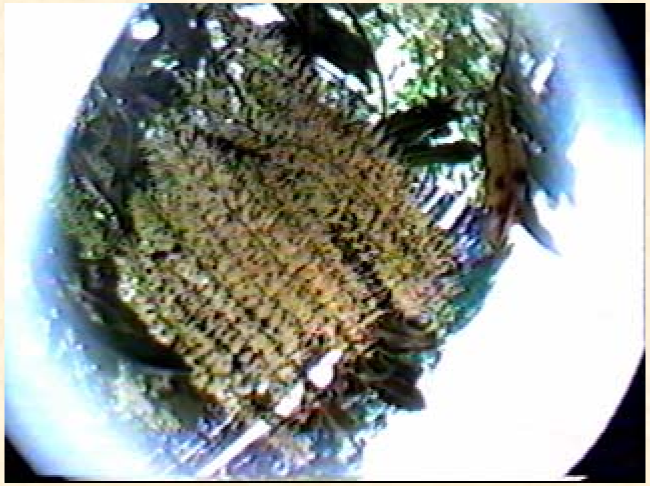
Complex Systems



Research Problem

- To identify small objects (bees) in a video sequence in an outdoor environment

- Faced with three challenges
  - Size of the honeybee
  - Highly dynamic background
  - 3D Environment



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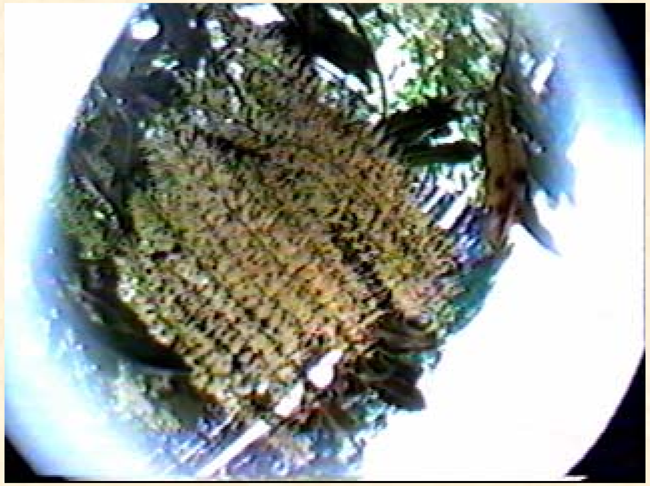

Research Site

- The Macadamia Tree
  - Large evergreen tree which grows in tropical climates
  - Produces the macadamia nut
  - Australia is the world's largest producer,
    - 34,400 tonne in 2001
- Data Collection
  - Portable, CCD cameras placed in a macadamia orchard
  - Video digitized from VCR recordings
  - 320 x 240 pixel resolution

    @ 24 frames per second





Motivation for Research

- Little research has focused on small object detection rather the majority has focused on tracking people and vehicles
- Existing data gathering techniques were of minimal use when attempting to gather information for use in complex system modeling
- Research into an automated data collection tool for the purposes of complex system modeling

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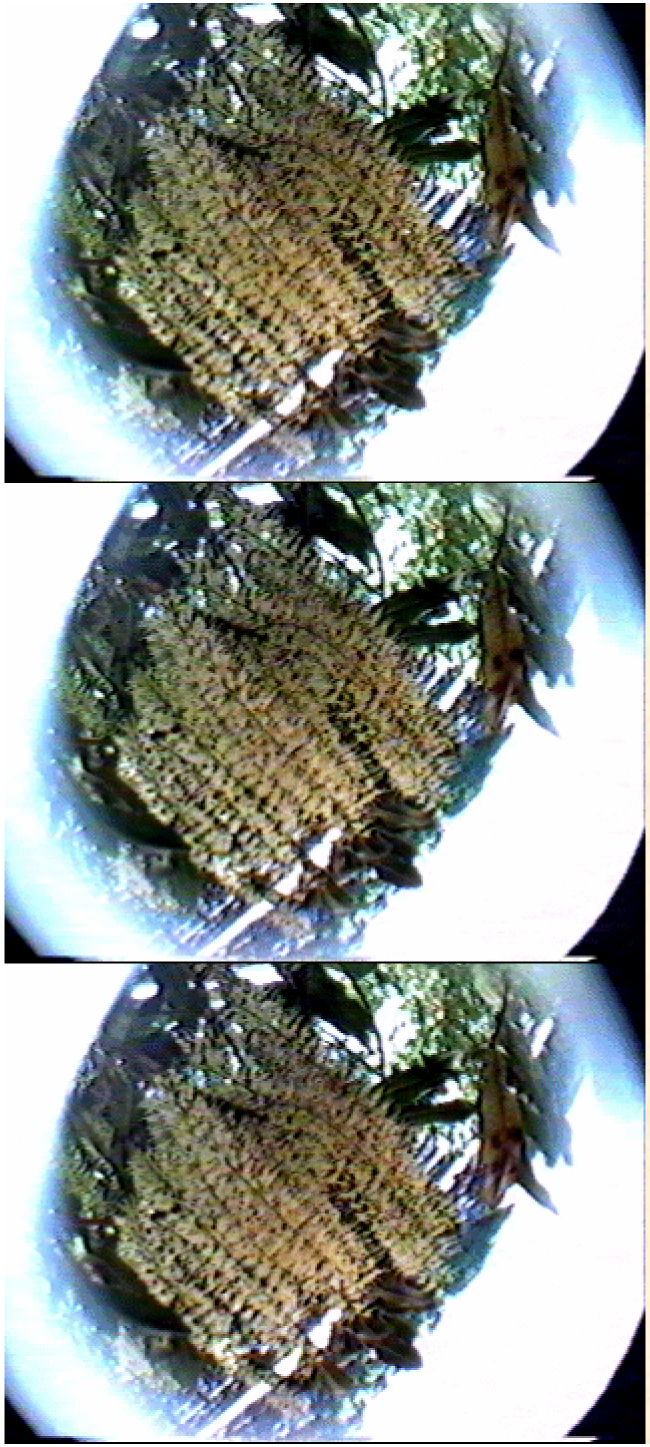
Techniques

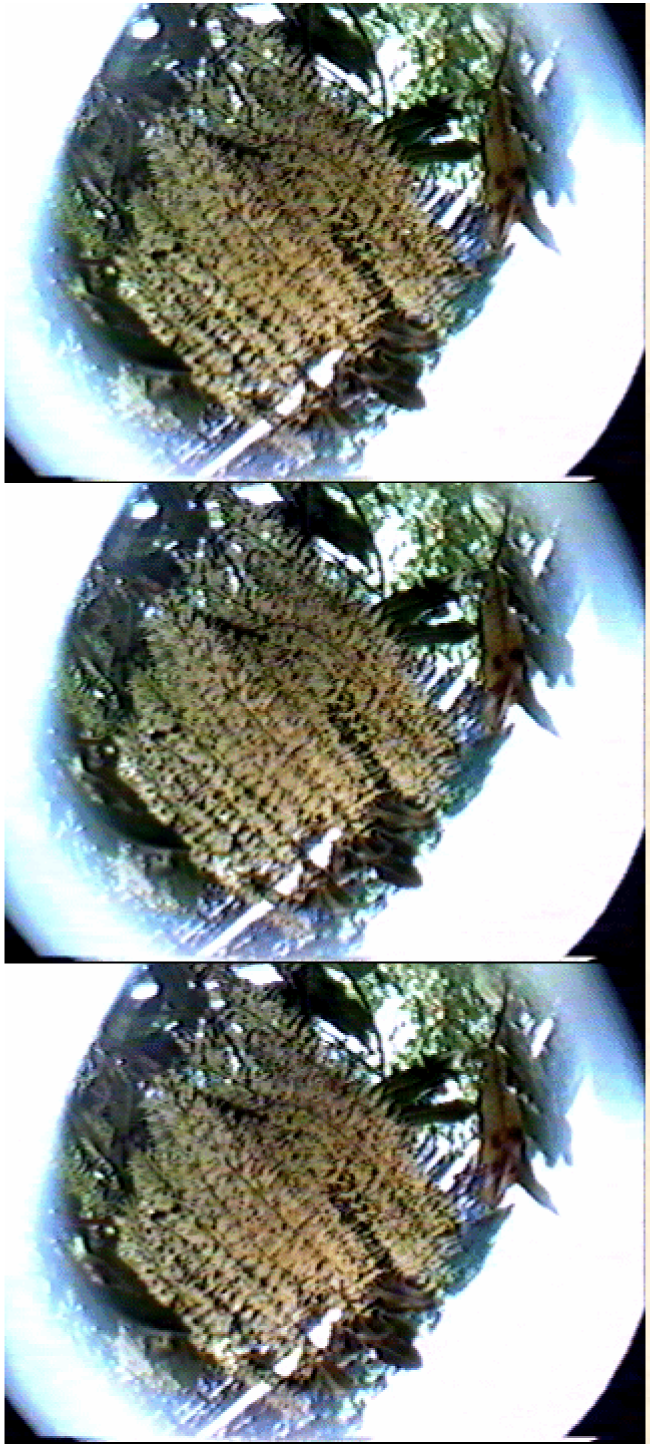
- Balch *et al* (2001) used Colour Segmentation
- Colour is not a viable option in outdoors environments (Horn, 1986)
- Edges, shapes, size or texture segmentation is not a viable option



Frame Differencing

Techniques in Brief

- An adaptive background model generated from 0,…,*n-1* images
- Absolute Difference Subtraction
- Noise Filter
- Local Threshold
- Boundary Restoration

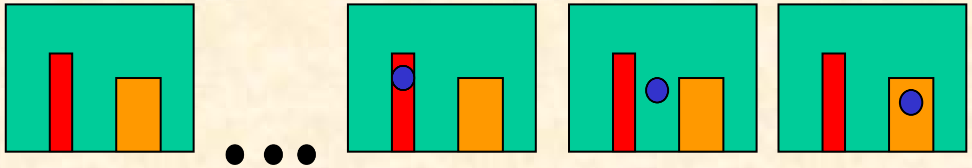


Frame Differencing

Techniques in Brief

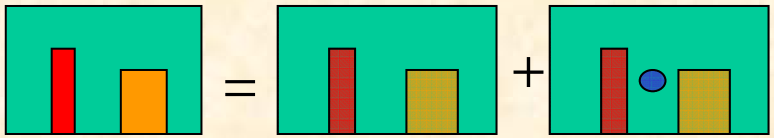
- An adaptive background model generated from 0,…,*n-1* images

Consider the following image sequence



Then the background model, B_T is created by:

$$B_T = (1- \alpha).B_{T-1} + \alpha \,.\, I_T$$

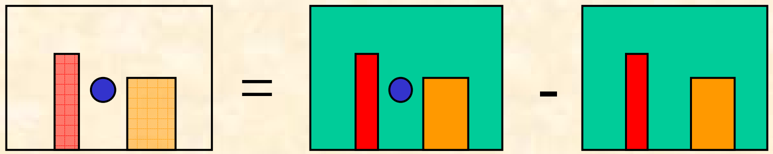


Frame Differencing

Techniques in Brief

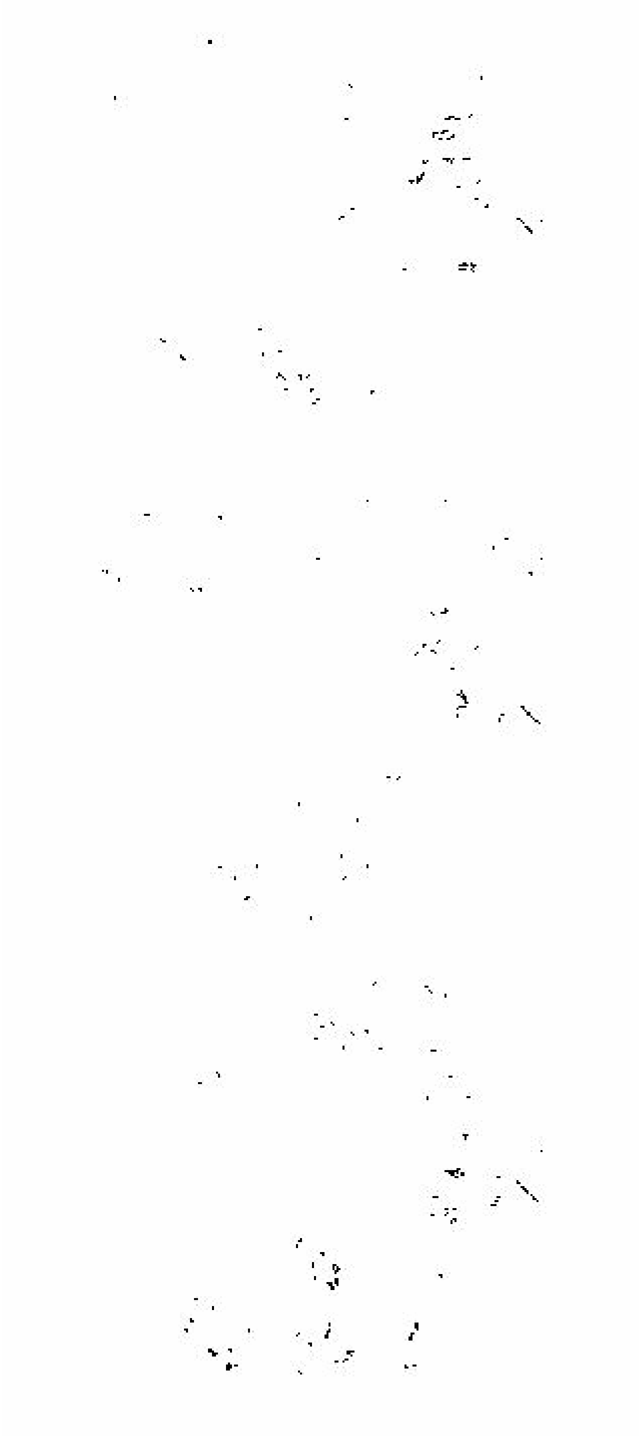
- Absolute Difference Subtraction

$$Diff_T = | I_T - B_{T-1} |$$



- A significant amount of small difference present in the resulting images

- In the images on the left, the lighter the colour, the smaller the difference.



Frame Differencing

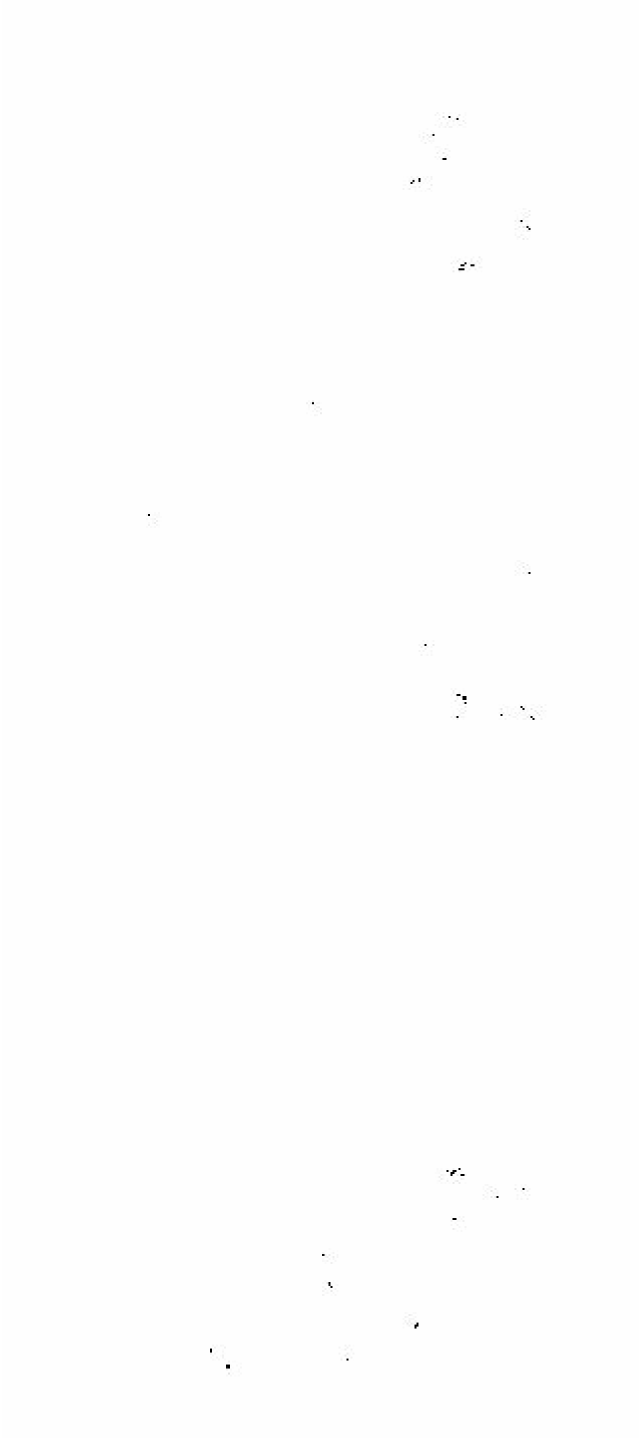
Techniques in Brief

- Noise Filter

$$Th_x = Global_{MED} + 3 \text{ x } 1.4826 \text{ x } Global_{MAD}$$

where $Global_{MED}$ is the median global pixel value, and $Global_{MAD}$ is the median standard deviation

- A global approach to remove the small differences present in the images
- This technique did not erode the boundary or shape of any detected regions of difference
- However, very small high intensity noise remained



Frame Differencing

Techniques in Brief

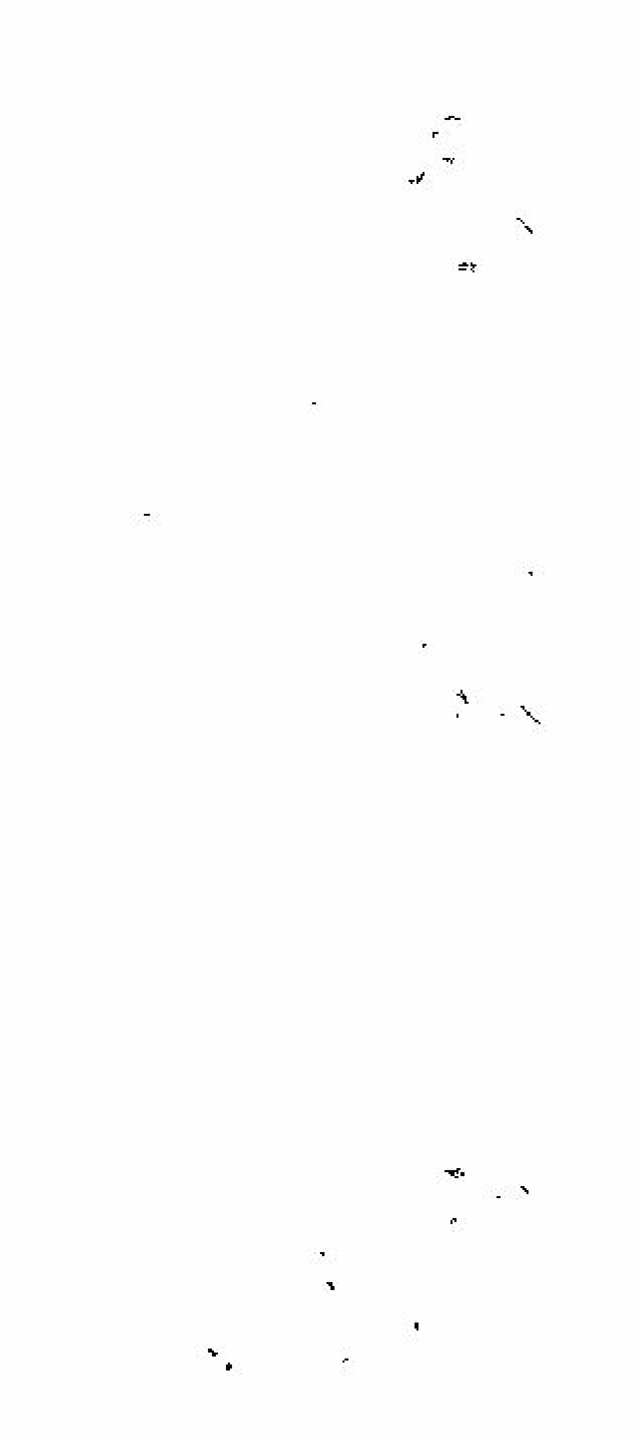
- Local Threshold

$$Th_x = Global_{MED} + NI$$

where $NI = [\ Global_{MAD} / (Local_{MED} / Global_{MED})\ ]$

and $Local_{Med}$ is a local median pixel value in a 3x3 grid

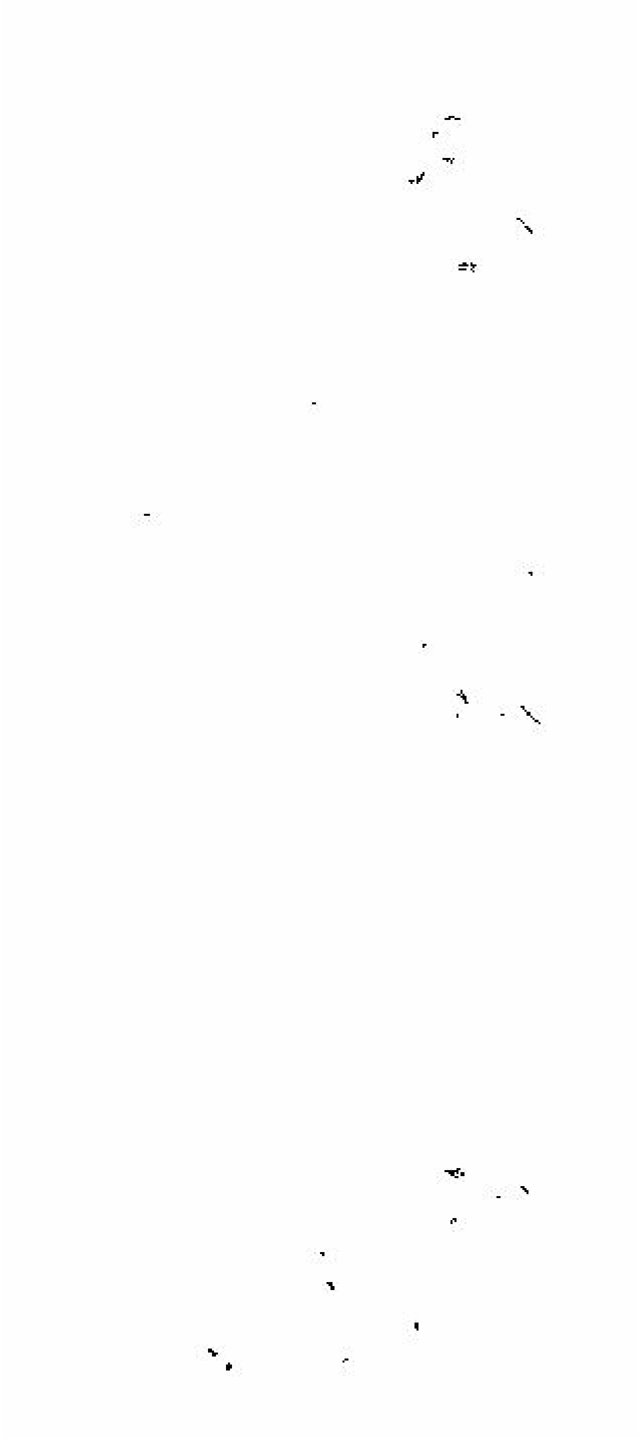
  - A local approach to remove very small high intensity noise by adjusting the global threshold to account for local conditions
  - Successfully removed isolated high intensity noise
  - However, this technique eroded the boundary/shape of any regions of detected difference



Frame Differencing

Techniques in Brief

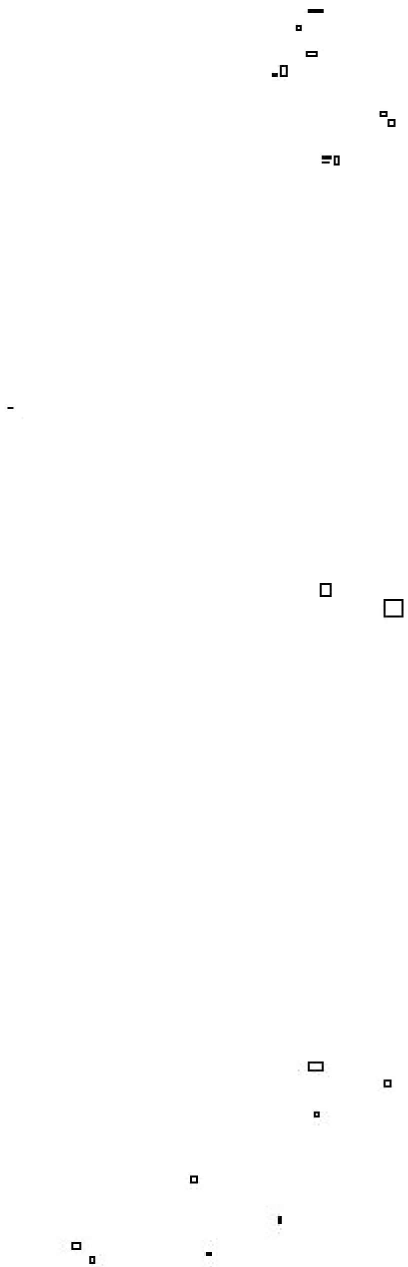
- Boundary Restoration
  - A depth-first recursive algorithm which restores the shape of any detected regions of difference present after the local threshold is applied
  - This is achieved by using the results from the global threshold and applying it to the results after the local threshold
  - Allows the benefits of both the global and local approaches to be used without their associated problems



Frame Differencing

Results & Findings

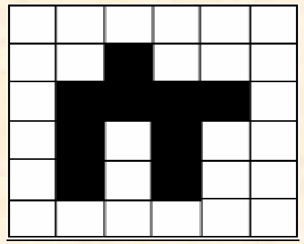
- A very efficient technique for identifying the location of the bee
- Unable to address problems of rapid illumination change and large sustained movement of branches and flowers



Object Creation

Techniques in Brief

- A depth-first recursive search and merge algorithm is used to create objects



- Then, spatially close objects are merged
- Finally, objects containing less then 2 pixels are removed

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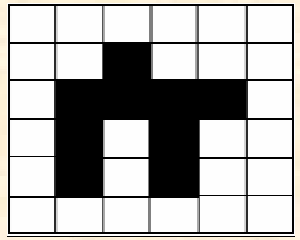

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Object Creation

Results & Findings

- By creating objects, the bees are easier to visually identify
- The minimum box was useful for estimating the size of the bee
- The movement of the flowers are detected as a series of very small objects

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Temporal Analysis

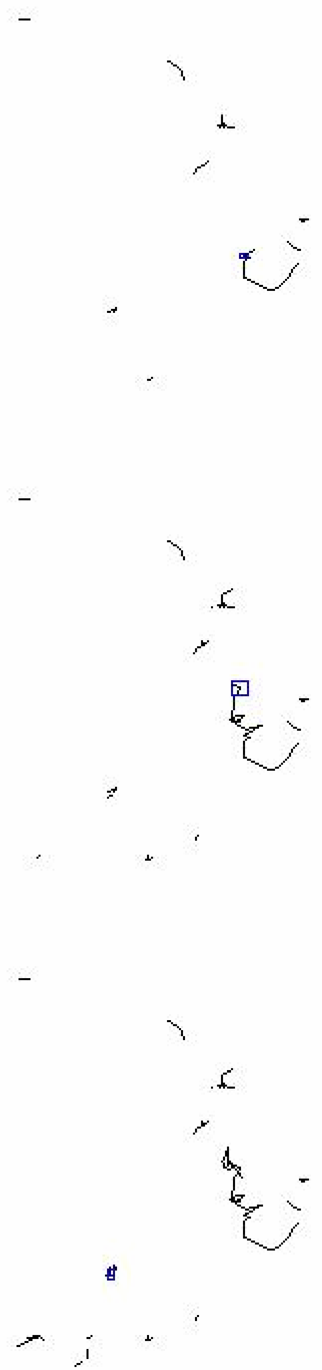
Techniques in Brief

- Two background models
  - Forwards constructed from $I_{T-11},\ldots,I_{T-1}$
  - Backwards constructed from $I_{T+11},\ldots,I_{T+1}$
- The resulting objects from both models are compared and objects which do not match are removed

Temporal Analysis
Results & Findings

- Very efficient for removing the differences caused by the movement of the flowers

- Excellent results at retaining and extracting the difference caused by the movement of the bee



Object Association

Techniques in Brief

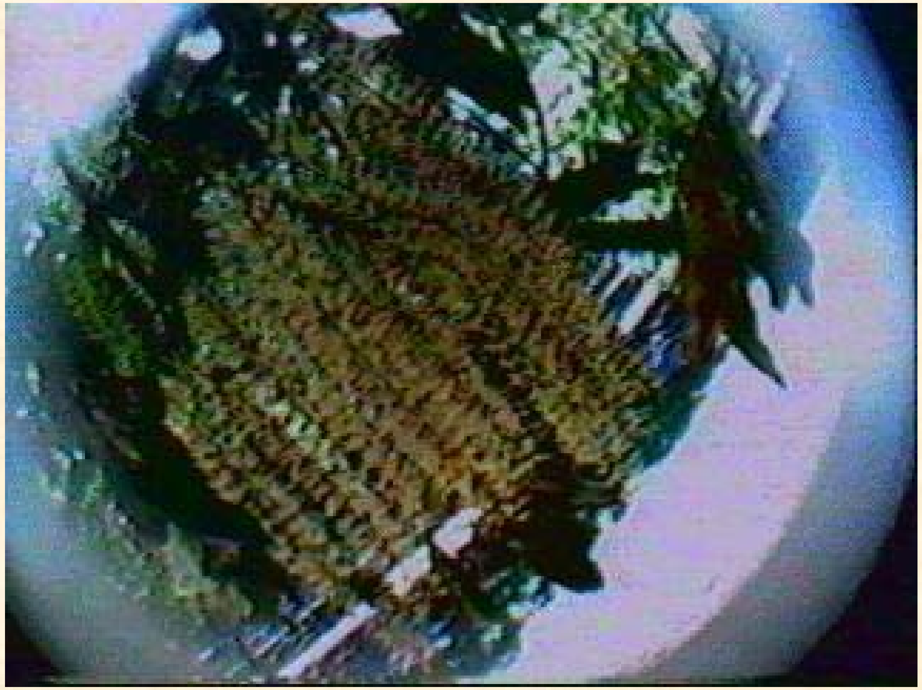
- Association between objects with in a maximum distance
- Euclidean Distance between all points in this distance is calculated
- The closest points in Euclidean Distance are joined by an edge and considered the same object in two separate frames

Object Association

Results & Findings

- Good at tracking a bee’s path assuming the prior conditions are met
- Also tracks the path of moving objects such as branches, which are difficult to distinguish from bees
- Can create paths from random or isolated noise

More Results



More Results

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Future Directions

- The collection of more video data to allow for further investigation and analysis of the techniques used during this research
- Conditions, such as rain, strong wind and rapid illumination changes are commonly found in outdoor environments and will need to be studied before the development of a fully automated data collection system is practical.

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Summary

- Although further research is required to address a broad range of environmental conditions, the results obtained so far, have proven that small object detection is a feasible technique for addressing the current problems of data collection.

- Published Work Arising from this Research

  Estivill-Castro, V. Lattin, D. Suraweera, F. & Vithanage, V (2003) *Tracking Bees- A 3D, Outdoor Small Object Environment*, To be published in the Proceedings of the International Conference on Image Processing, Barcelona, Spain, September 14th – 17th

Questions?