# Overview of the Harper Adams Vine Weevil remote activity monitor

## Concept

Vine Weevils are known to seek shelter under dark narrow spaces during daylight. The monitor provides such refuge, but periodically takes photographs and logs activity of any moving insects, whilst simultaneously monitoring light levels, temperature and humidity. Detected insects are classified using Artificial Intelligence (AI) and periodically all the gathered data is emailed to the user.

## Construction

The monitor is based on an existing trap, but it is modified so that the insects are free to come and go at will. A camera is mounted at the apex and a backlight momentarily illuminates the scene during periodic image capture at 10-minute intervals. The modified trap has a clear acrylic base which the camera ‘looks through’. It has 5 mm stand-offs (feet) underneath to provide a suitable gap for insects to feel secure. The monitor sits on a flat white base which ensures the 5 mm gap is uniform and acts as a light-coloured background for the images.

## Electronics

A Raspberry Pi Zero 2w was selected as the microprocessor due to its low power consumption, wide availability of software libraries and excellent connectivity options to the Pi v2 camera and other sensors. The chosen environmental sensors use the I2C connection protocol. An LED light ring is triggered during camera exposure using the Pi’s GPIO pins. Communication to the Internet is via Wi-Fi.

## Image processing

### Region of interest (ROI) generation by pixel differences between frames

Each image taken can be considered as a frame in a very slow movie. Regions where pixels differ between frames represent movement of an insect. Because the monitor has been specifically designed to highlight dark insects against a light background, we can say that in an area where pixels are now dark, where previously they were light, an insect is newly located. Furthermore, we can perform analysis of groups of contiguous transitioned pixels (blob analysis) and use the centres of these blobs as the centres of ROIs to be cropped out from the whole image for classification. 100 x 100 pixels was found to be a suitable size to frame insects of interest whilst minimizing computer memory requirements.

The goal is to single out individuals so that they can be classified and enumerated. Weevils tend to huddle together making this very difficult. It should be noted that it is not possible to know if any individual is counted more than once, so only a general level of activity can be established using this method. Whilst each cropped ROI will contain an insect, the insect may have settled alongside others making that ROI unsuitable for training a deep learning system. For example, a ROI might contain a weevil and an earwig. For development of an inference model, or classification of detections, it is beneficial to filter the ROI images so that they contain a single specimen, centrally located.

### Filtering ROIs for balance

A ROI containing only a single insect will naturally be ‘balanced’ because the centre of the ROI was derived from the center of the blob of dark pixels representing the insect contained within that ROI. A check is made to see if the moment of inertia of the ROI image is located at the centre of the image. If it is ‘off balance’ beyond an empirically determined threshold, suggesting something else is in the frame, the image is discarded. The yellow dots represent the calculated moments of inertia.

A picture containing text

Description automatically generated A close up of a spider

Description automatically generated with medium confidence A picture containing text

Description automatically generated

In the examples above the first frame is correctly discarded as the yellow dot is not centrally located. In this case the earwig moved in alongside the already in-place weevil, so the earwig is centraised, but the frame unbalanced by the weevil. The second frame is correctly accepted. The third frame is incorrectly accepted because it is balanced despite containing muliple insects. A second filter is employed.

### Filtering ROIs for overall brightness

A threshold for how much of the light background remains in each image. The threshold is set empirically to reject images darker than those produced the largest encountered single insect.

A black spider with yellow eyes

Description automatically generated with low confidence

Approximately one in three ROIs pass both filters. During the training phase of the project approx. 2000 of these filtered images were uploaded to a web server to become a training data set.

## Training for classification by deep learning

AI *object detection* was ruled out due to the close huddling of insects making it unviable, and the large processing and memory requirements which would in any case exceed the capability of the Raspberry Pi Zero. Instead, the preprocessing of the ROIs provides an ideal input for simpler AI *image classification*, since each image contains a single specimen uniformly presented like a passport photo. TensorFlow Lite Model Maker was used to train a model in the cloud using Google Colaboratory:

<https://www.tensorflow.org/lite/guide/model_maker>

The dataset of approx. 2000 ROI images were sorted manually into folders containing either weevils or earwigs. These two folders were then input to the Model Maker. The output was a model of less than 4 MB size, which could comfortably run on the Pi Zero.

## Classification of detections

During normal operation of the monitor, every 10 minutes when an image is taken, any ROIs that pass both plausibility filters are input to the inference model for classification. They are classified as earwig or weevil and the confidence level shown.

A picture containing text

Description automatically generated

Unfortunately, no earwigs were present after training.

## Reporting of activity and environmental conditions to the user

Each hour the accumulated detections for that hour, the light level, temperature and humidity are logged as data points. At mid-day the sets of data points are plotted into bar charts and emailed to the user, along with a montage of ROI detections. The montage allows the user to confirm the accuracy of detections or spot anomalies. Additionally, the full image taken each 10 minutes is uploaded to a website so that the user can have a complete view of the monitor in near real time. Each uploaded image overwrites the last to prevent the web server becoming overloaded. The image also has text showing the current environmental conditions.



## Discussion of limitations

The monitor does not allow tracking of individuals nor provide an accurate count (except that there is at least one!)

A wireless link is required to report remotely.

The monitor is currently powered through a mains adapter.

The camera choice (particularly the lens) was governed by the height of the original trap. A taller trap would allow a longer focal length.

## Suggested follow-up research

Could a statistical model representing taking as input detected activity and environmental conditions be developed to accurately predict weevils per m2?

Create a system to offload data to an app on a proximate user’s phone, possibly using Bluetooth Low Energy (BLE).

Try different inference models trained on different insects that may not be as distinct as weevils and earwigs.

Compare performance on models trained on images *not* gathered from the camera.

## Appendix

Function to filter ROIs.

Text

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