Low-cost Sensors Using Raspberry Pi Technology

High resolution leaf fall monitoring and low adhesion forecasting using hemispherical Near Infrared imagery

Jennifer Kirby
Doctoral Researcher
University of Birmingham, UK
JXK067@bham.ac.uk

Professor Lee Chapman
Reader in Climate Resilience
University of Birmingham, UK
l.chapman@bham.ac.uk

Dr Victoria Chapman
Scientific Manager, Met Office
Victoria.chapman@metoffice.gov.uk

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Aim

- To develop a scientifically robust method to monitor leaf canopies at a high spatial and temporal resolution

- Why? To improve low adhesion observations and forecasts

- How? Adapt a Raspberry Pi in order to capture and automate leaf fall observations

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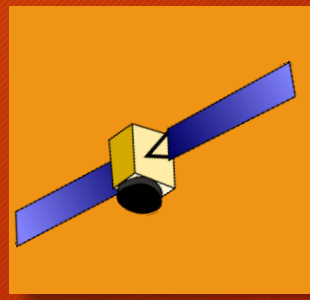
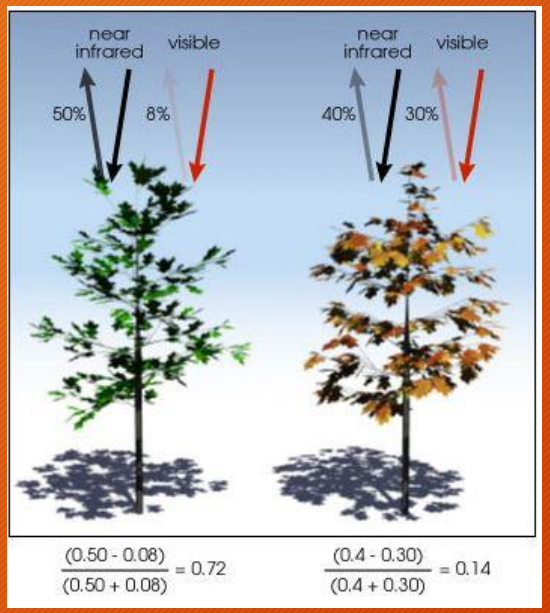
Low Adhesion and Leaf Fall

- **Leaf fall** coupled with adverse weather conditions causes low adhesion on the UK rail tracks.
- Low adhesion **reduces the friction** between train tracks and wheels
- Causes trains **difficulty in stopping** and accelerating away from a station
- **Costs** the UK rail industry **£100 million per year** in rail treatment, delay repayment, treatment trains and adhesion forecasts (*Rail Delivery Group, 2018)*.
- Need to record leaf fall in order to **predict** when **low adhesion** will occur on rail lines.

1. Current technology – remote sensing and satellite data





Theory – NDVI calculated from **Infra red and near infra red technology on satellites to detect reflectance of vegetation - different methods give different results**

Sensitive to tinting not reflective of leaf fall

Satellites affected by weather conditions e.g. cloud, haze, rain, atmospheric aerosols, snow.

Requires composite images of representative of 8 days or longer

Complex land use e.g. urban forests and agriculture NDVI is less accurate

https://earthobservatory.nasa.gov/features/MeasuringVegetation/measuring_vegetation_2.php

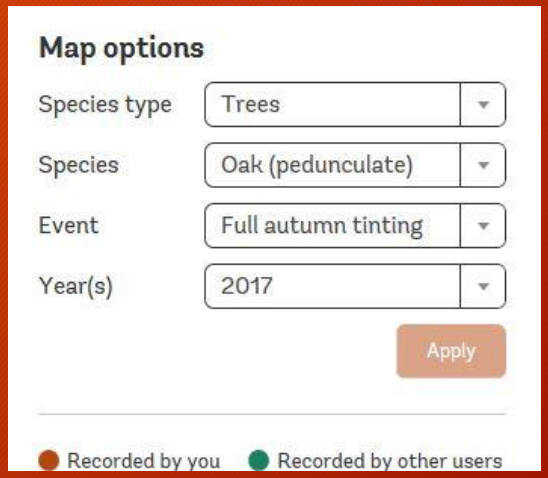
Other Data Collection Techniques

- Leaf fall observer networks based on citizen science e.g. natures calendar, Met Office UK

- However, high resolution adhesion models would benefit from high resolution observations

https://www.metoffice.gov.uk/services/transport/railways/low-adhesion-forecast

https://naturescalendar.woodlandtrust.org.uk/

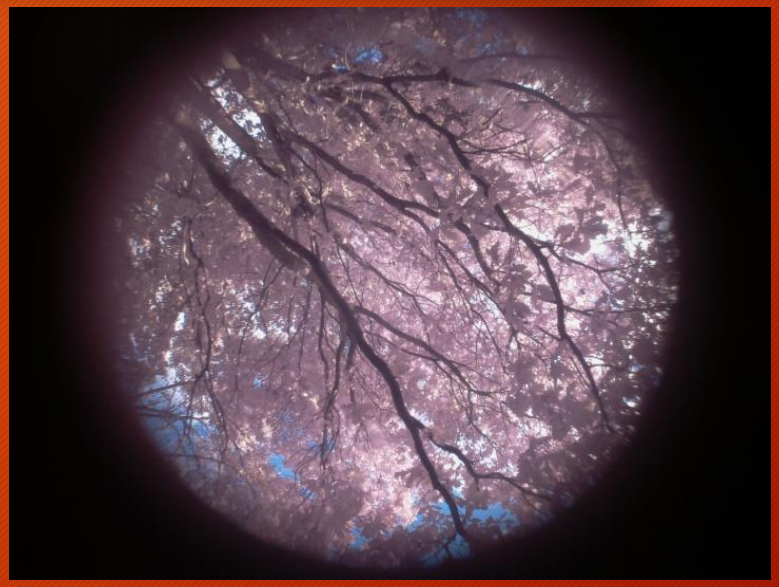


Reference: Chapman, L., 2007. Potential applications of near infra-red hemispherical imagery in forest environments. *Agricultural and Forest Meteorology*, *143*(1-2), pp.151-156.

2. Cost effective high resolution device

Fish-eye cameras in Near Infrared will be used to understand leaf fall progression through the season with a fish eye lens on a Canon camera (Chapman, 2007)

COST: £1000



Fish-eye cameras in Near Infrared will be used to understand leaf fall progression through the season with a fish eye lens on a raspberry pi

COST: <£100

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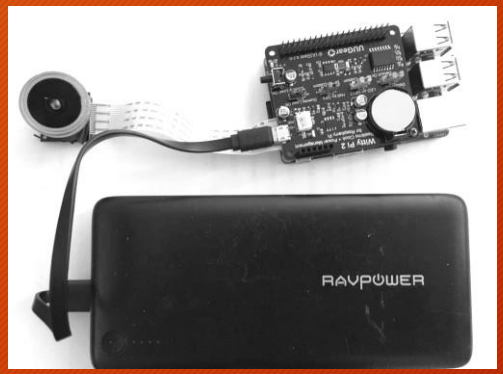
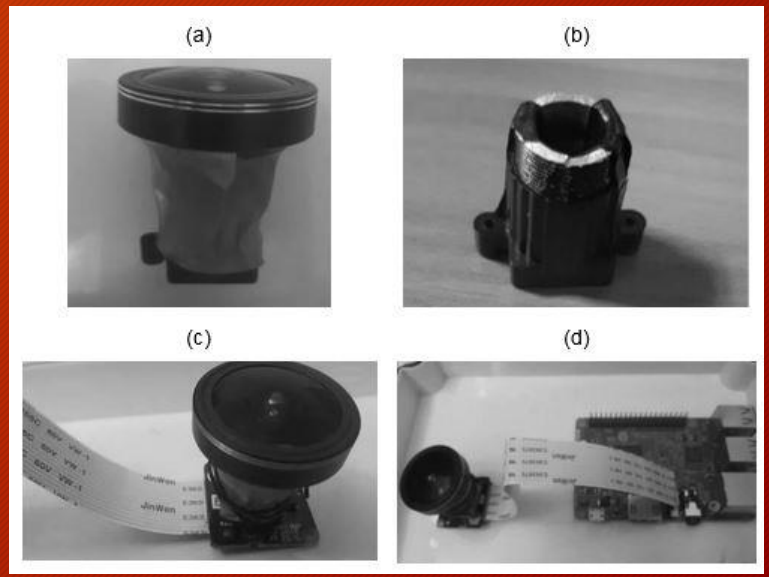
How does the Pi work?

Step 1 – Adapt the Raspberry Pi camera to capture hemispherical images using a mobile fisheye lens

Step 2-Program a Raspberry Pi to take images everyday

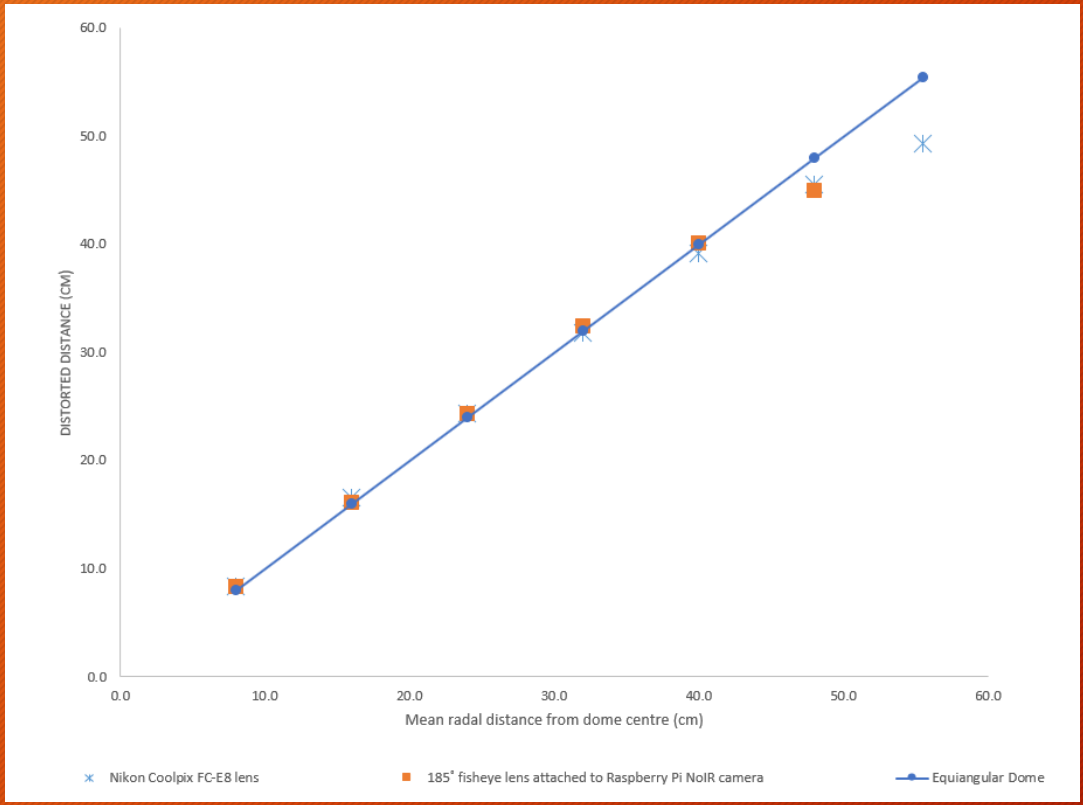
Step 3 – Attach and code a ‘Witty pi’ time managing device - turns pi on/off

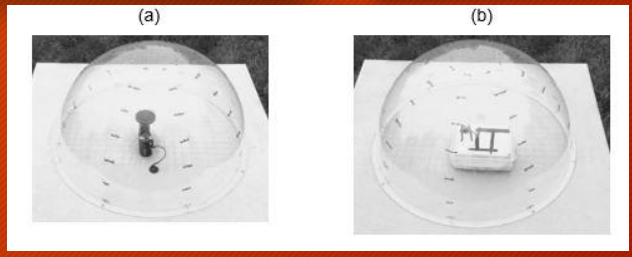




How does the Pi work?

- Step 4 - Compare the Pi to the market hemispherical camera (Nikon Coolpix).

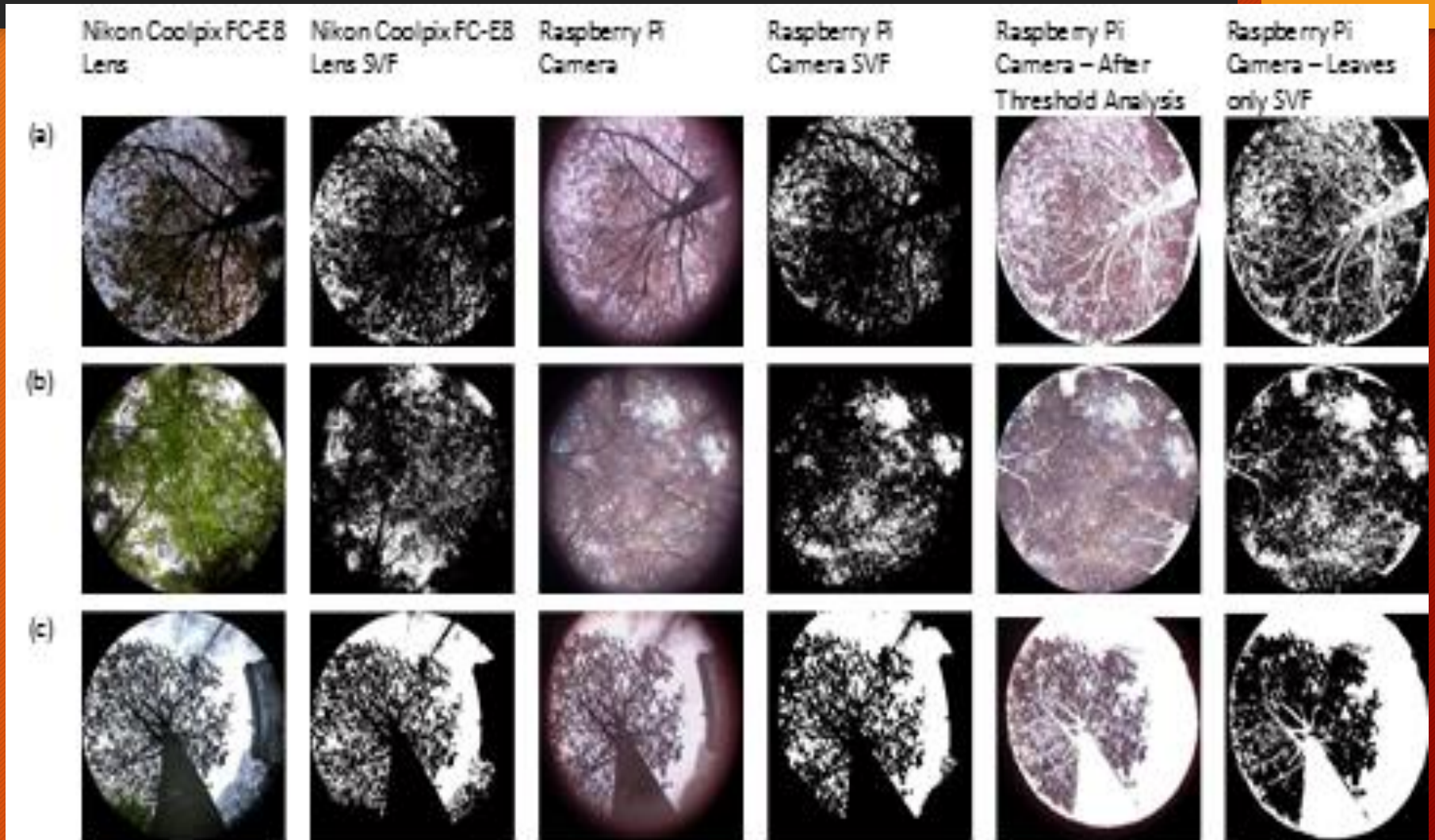




A Pyrex dome was used to measure equiangularity of the fisheye lenses of both a Nikon and a Raspberry Pi camera.

The results showed that the two methods strongly correlated

How does the Pi work?

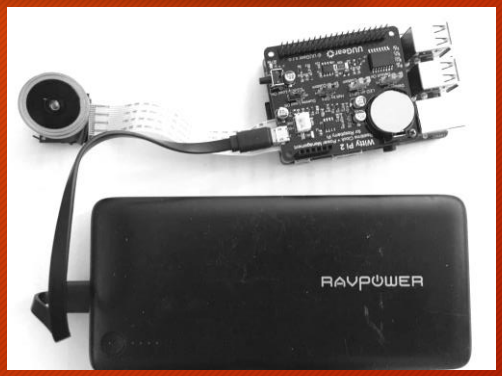


3. How does the Pi work?

Step 5- The Pi was powered using a 26800mAh Power Bank

Step 6 – The sensor was encased in an adapted IP rated box

Step 7 – Placed in the field to collect data over autumn (sending daily images over Wi-Fi)



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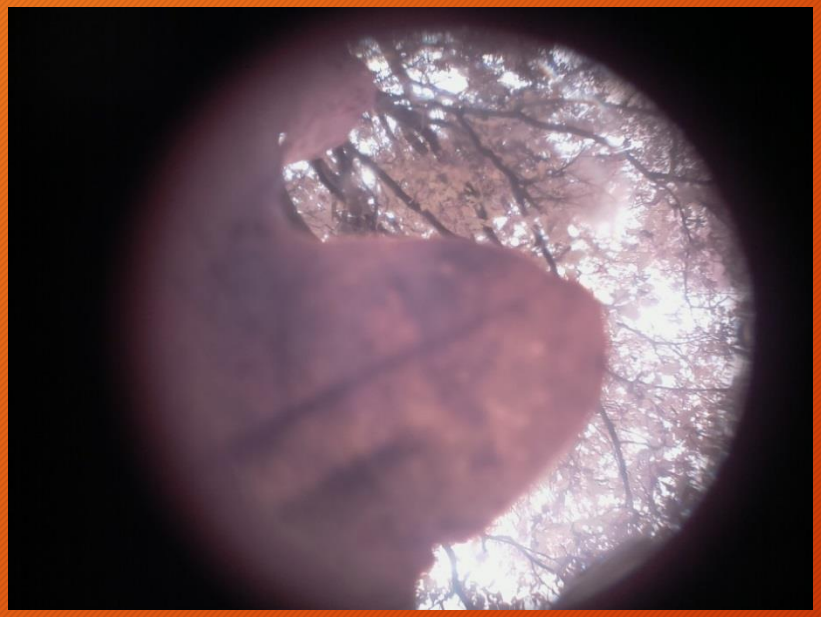
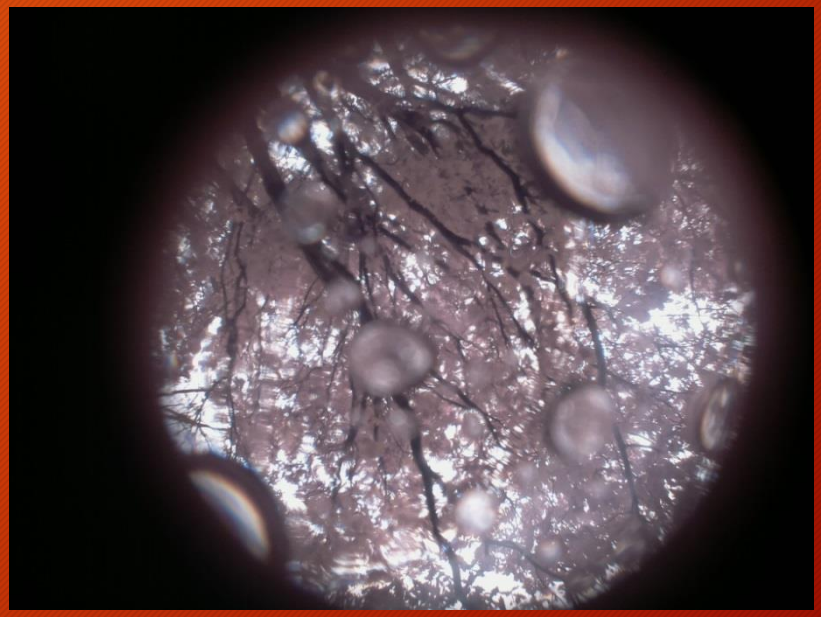
Problems with the technology



OAK LEAF OVER CAMERA LENS

Solution – Blown off by wind



HEAVY RAIN SHOWER ON LENS

Solution- Hydrophobic solution
Glass dome over lens

Potential for Scientific Understanding Advancements

- Objective low cost technique that can be used to answer scientific questions objectively such as
  - Assess how leaf fall is affected by topography, frost and drought
- Cheap robust measuring device that could be used to measure sky view factors to improve rail temperature/wind throw risk and moisture modelling.
- Potential to record bud burst

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More detail:

Kirby, J., Chapman, L. and Chapman, V., 2018. Assessing the Raspberry Pi as a low-cost alternative for acquisition of near infrared hemispherical digital imagery. *Agricultural and Forest Meteorology*, *259*, pp.232-239.

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