[TBD: NAME OF TOOL]

TBD: A tool to study microclimates in an orchard

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1 Introduction

In this report I give details of an online tool called [TBD: NAME OF TOOL], an interactive website that collects real time data from Small Brook Farm in Devon. The tool aims to give farmers accessible, specific climate data to help reveal the existence of microclimates over a small area and inform their decision making.

Three sensor clusters were distributed at three points in the farm. Each cluster was powered by a raspberry pico and then a variety of sensors were added to these. Data is then sent in real time back to a backend server which processes the information and allowed for real time data to be presented to farm workers via a website.

Part I

Background

2 Microclimates

2.1 Microclimates in agriculture

A microclimate is generally understood as a set of distinct climatic conditions within a small, localised area [1]. The maximum size of a microclimate is debated, but the World Meteorological Organisation (WMO) regards it as occupying an area of anywhere from less than one metre across to several hundred metres [2]. In practice, microclimates can occur in spaces such as gardens, valleys, caves, or fields. Even human-made structures can generate their own microclimates; for example, tall buildings can create *street valleys* that reduce wind flow and lead to the formation of localised pockets of warmer air, which can also trap higher concentrations of pollution from vehicle emissions [3]. Vegetation plays a critical role in influencing microclimates. The addition of trees to an urban environment can reduce air temperature by as much as 2.8 °C [4].

This localised climatic variation, characteristic of microclimates, is therefore significant in agriculture. The climate that crops are exposed has an enormous impact on overall agricultural yields. Indeed, farmers have modified the microclimate of crop fields for millennia, a clear example of this being the use of fencing to reduce soil erosion and damage to edible plants [5]. Therefore, the relationship between microclimates and agriculture has been the subject of extensive research - particularly as climate change introduces new threats to food security.

2.2 Microclimates in apple orchards

3 *Internet of Things*

4 LoRa

LoRa stands for Long Range radio Long range systems are a way of transmitting data over much longer distances than Wi-Fi allows. LoRa has a range 4000 times greater than Wi-Fi.

Part II

Hardware development

5 Overview of hardware

6 Design

6.1 Nodes

6.1.1 Components

The first step in the design process was selecting hardware components that could operate autonomously without mains power. This required devices that were highly power-efficient, while also capable of transmitting small data packets via LoRa. An equally important consideration was ensuring the final devices could be fully weatherproofed to protect the sensitive electronics from water ingress and environmental damage.

Challenger RP2040 LoRa

The iLabs Challenger RP2040 LoRa is an embedded computer that uses the Raspberry Pi RP2040 chip that was released in 2021. The RP2040 itself is a low-cost and power-efficient processor with ample power to perform the data encoding and transmission in my use case. Additionally, the chip is extremely popular with over 10 million units being produced in the first two years of release [6]. This popularity means there is ample documentation for developing with this processor and it is compatible with circuit python which was my preferred language for development.

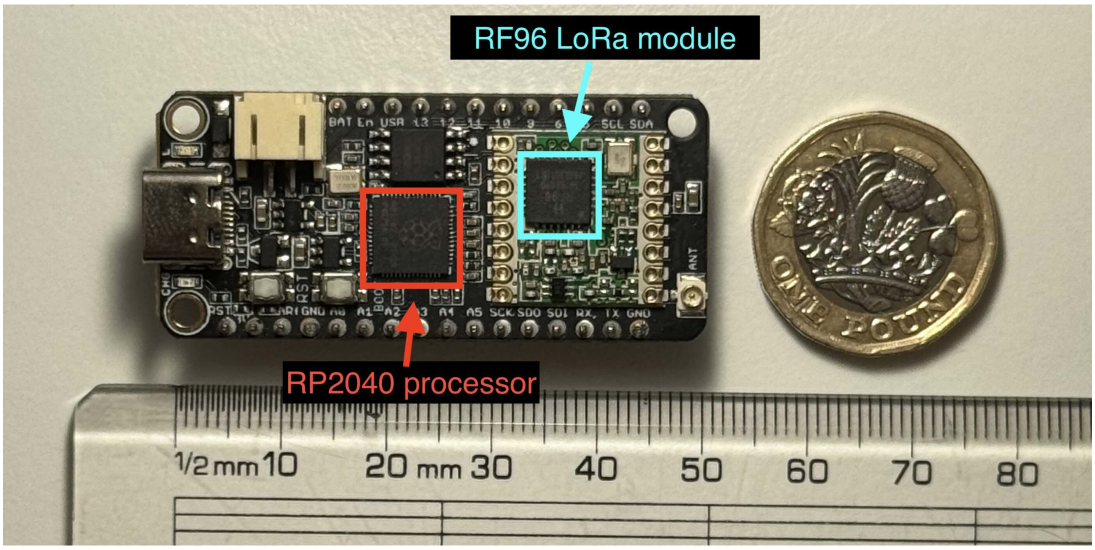

Figure 1: iLabs Challenger RP2040 used in the project. Note the RP2040 chip centre and RF96 LoRa module to the right.

The challenger board itself is well suited for this project for several reasons. It uses the compact Adafruit feather form factor, giving a board dimension of just 5cm by 2cm, making it easy to mount in a small enclosure. The onboard Hope RF96 LoRa modem is built directly into the board and the U.FL antenna connector allows for the swapping of antenna's to different varieties. This board's LoRa module is also set to transmit at a frequency of 868mhz which is a standard UK frequency for LoRa and gives a good balance between range and bandwidth.

Another useful aspect of the board is the abundance of GPIO pins (20 in total) allowing for a large number of sensors to be fitted to the board.

Antennae

The selection of antennae is one of the largest determinants of range and reliability in the context of wireless communication systems [7]. Initially I used a simple PCB antenna as shown in Figure 2, however as explained in the next chapter, the range of this was insufficient for my use.

Figure 2: Low range PCB antenna

To improve overall range I switched to a more capable 170mm whip style antenna kit that was made specifically for the Challenger RP2040. The antenna tuned to perform best at the 868mhz frequency range - which is the range I was using.

Sensor selection

Temperature and humidity sensor

I used a DHT11 temperature/humidity sensor for each node to provide basic readings. It was chosen for it's low cost, availability and compatibility with both the RP2040 Challenger and CircuitPython (via libraries). The sensor can be connected to the microcontroller using a single GPIO pin as well as the usual power and ground pin.

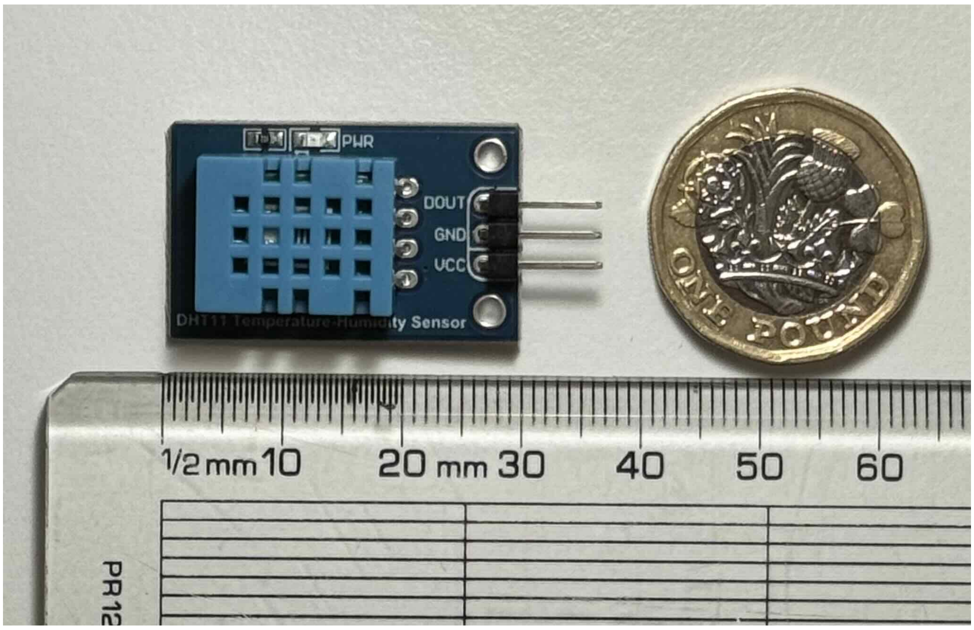

Figure 3: Waveshare DHT11 Temperature/Humidity sensor

Soil moisture sensor

Wind speed sensor

Powering the node

To allow for continuous operation away from power sources, I set up a 5.5v Monocrystalline Silicon Solar Panel to each of the nodes. As the output from the solar panels was too high voltage to directly power the nodes I also installed a solar power management module onto the Challengers. This module powers a battery that is installed on it using a solar panel. It then is able to power the RP2040 using this battery, allowing for overnight or overcast usage of the challenger.

Weather proofing

I 3D printed a water proof enclosure and a separate Stevenson weather shield for the temperature/humidity sensor to allow for accurate outdoor readings.

6.1.2 Programming the nodes

On each challenger I flashed the drives with CircuitPython, an open source interpretted language similar to Python but simplified for use in microcontrollers.

6.1.3 Repeater node

To improve range I made one of the four RP2040 challengers I used act as a repeater. This meant it did not require sensors like I used for the other two nodes and instead it just had a solar panel and battery connected up to it. The repeater would receive signals from the two nodes before relaying them to the final gateway. This had the effect of significantly boosting the range.

6.2 Gateway

The gateway consisted of a fourth Challenger RP2040 connected to a Raspberry Pi (TBD version). The challenger only received messages from the repeater and then would transfer these to the Raspberry Pi. After receiving data the Raspberry pi uploaded this to the internet.

6.3 LoRa settings

LoRa has many parameters that must be aligned for two devices to communicate successfully. These include:

1. **Spreading factor:**
2. **Frequency:** Must match across devices; this project uses 868 MHz, the UK LoRa ISM band.
3. **Bandwidth:** Determines how wide the signal is, I am using 125 kHz.
4. **Coding rate:**
5. **Transmit power:** Affects the power and therefore range. This must be set within legal limits (e.g., 14 dBm in the UK).

6.3.1 Compliance with regulatory limits on radio power

The UK has strict regulations on the usage of radio transmitters under the Ofcom ISM band rules. For the 868mhz band, the maximum effective radiated power that can be used is 25mW. This corresponds to a transmit power of roughly 14dB.

Additionally, the UK has rules on duty cycle rates. This is essentially how long radio signals are permitted to be on air. For example at a spreading factor of 12 a message may take approximately 1 second to send. The duty cycle limit in the UK is 1%, meaning you may only transmit for 1% of the time on a given day. 1% of a day is 864 seconds. This means to stay in line with UK regulations only 864 messages could be sent on a given day - or roughly 1 message every 2 minutes.

7 Development and testing

8 Deployment in the field

Part III

Software development

9 Software design

Part IV

Evaluation

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