# Climate control system for plants in the cloud
## Bachelor's thesis

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# Table of Contents

# 001

## Introduction

# Motivation

Passion for plants

Latest technologies in cloud computing

Monitor and control growing conditions

# Goals

Use IoT and cloud computing

Monitor and control growing conditions

Arduino as main controller

Provide feedback mechanism

Easily expandable

Detailed data and insights

Cost-effective

# OIO
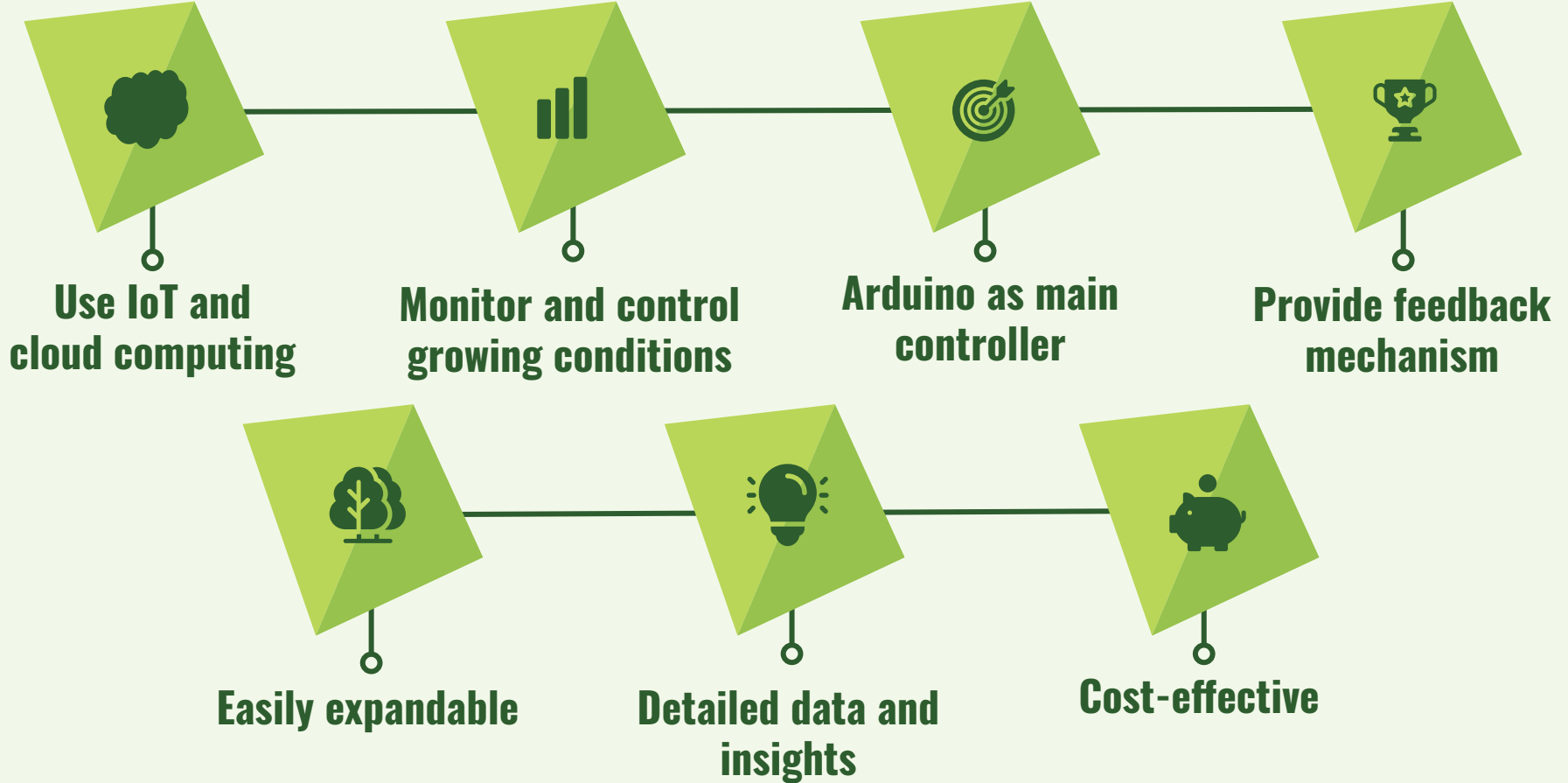
## State-Of-The-Art

# Cloud Computing

Delivery of **computing services** over the internet

Cost **savings**

Access to resources **on demand**

Increase **flexibility and scalability**
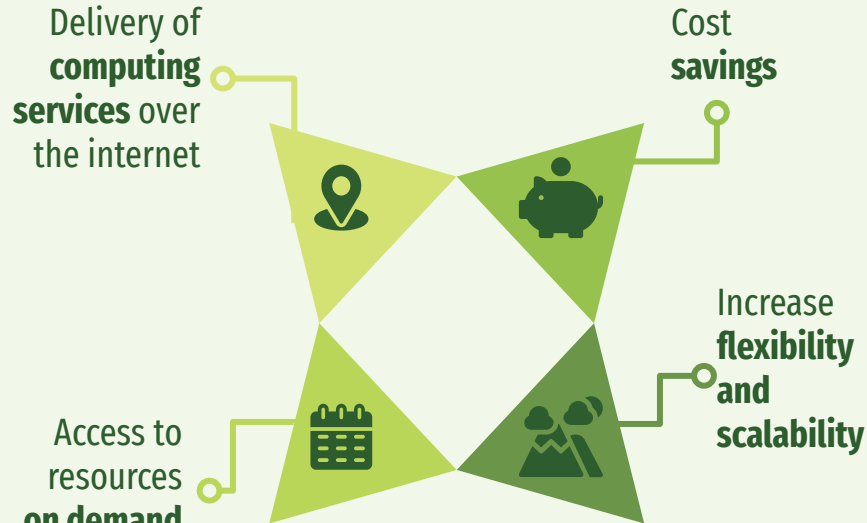
# Internet of Things

Network of physical objects with sensors and connectivity for data exchange.

**Enabling technologies**

- Wi-Fi
- Bluetooth
- RFID
- WSN

**Benefits**

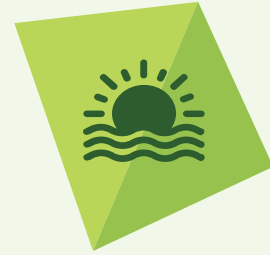- Improved efficiency
- Automation
- Data-driven decision-making.

# Models of the project in the present

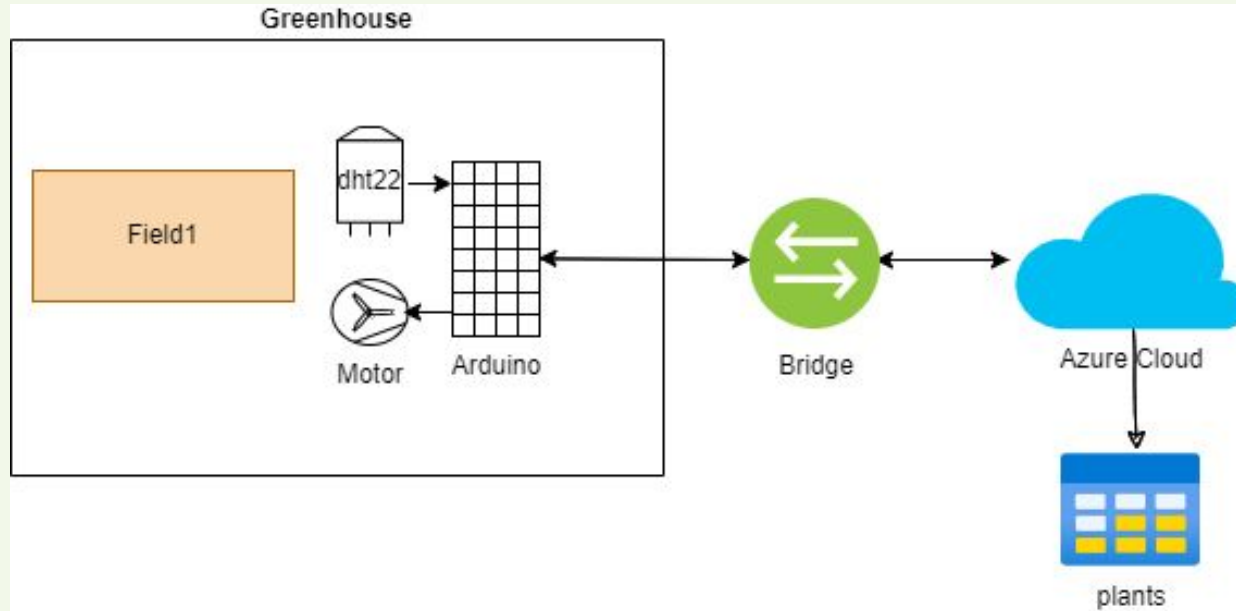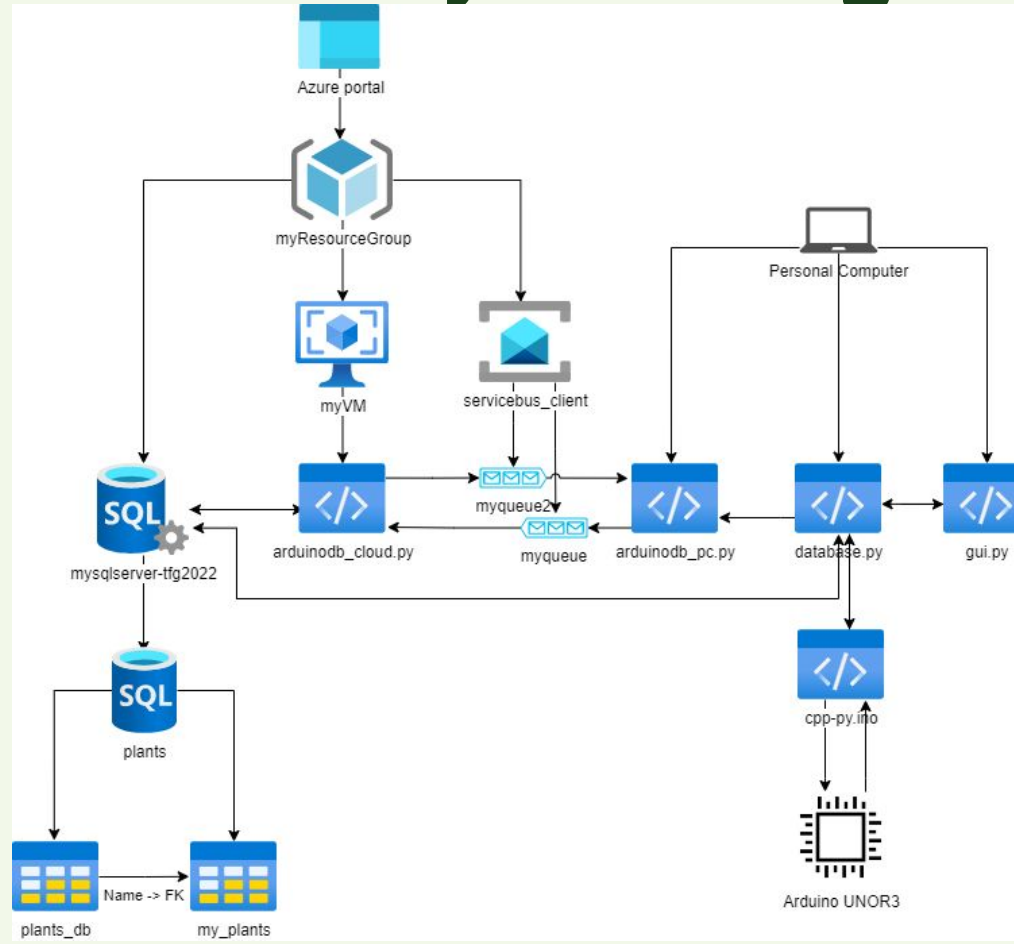Active plant wall for green indoor climate based on cloud and IoT

Camponectado

Postscapes

# Databases used



USA_Zone_8a.xlsx

| | jan_2 | feb_2 | mar_2 | apr_2 | may_2 | jun_2 | jul_2 | aug_2 | sep_2 | oct_2 | nov_2 | dec_2 |

| | name | action |
|---|---|---|
| 1 | Beetroot (also Beets) | Start undercover in seed trays and pl. |
| 2 | Broccoli | Start |
| 3 | Cabbage | Plant |
| 4 | Cape Gooseberry (also Golden Berry, I | Start |
| 5 | Capsicum (also Bell peppers, Sweet pe | Start |

USA_Zone_10a.xlsx

| | jan | feb | mar | apr | may | jun | jul | aug | s |

| | name | action |
|---|---|---|
| 1 | Amaranth (also Love-lies-bleeding) | Plant in garden. |
| 2 | Asparagus | Plant in garden. |
| 3 | Beans - climbing (also Pole beans, Ru | Plant in garden. |
| 4 | Beans - dwarf (also French beans, Bus | Start undercover in seed |
| 5 | Beetroot (also Beets) | Plant in garden. |

## plantinfo_clean

TABLE COLUMNS

T **name** ⓘ
Common name of the plant

T **alternatename** ⓘ
If there are other common names for t...

T **sowinstructions** ⓘ
Basic planting instructions. All temper...

T **spaceinstructions** ⓘ
How far apart to space each plant/see...

T **harvestinstructions** ⓘ
Amount of time between sow and harv...

T **compatibleplants** ⓘ
Other plants that grow well alongside...

T **avoidinstructions** ⓘ
Other plants that should not be grown ...

T **culinaryhints** ⓘ
Unsure what to do with this plant in th...

T **culinarypreservation** ⓘ
Notes on whether this plant freezes, c...

🔗 **url** ⓘ
Original source link this information w...

# OII

# Design of the System

# High-Level diagram

# Low-Level System diagram

# Low-Level Arduino diagram
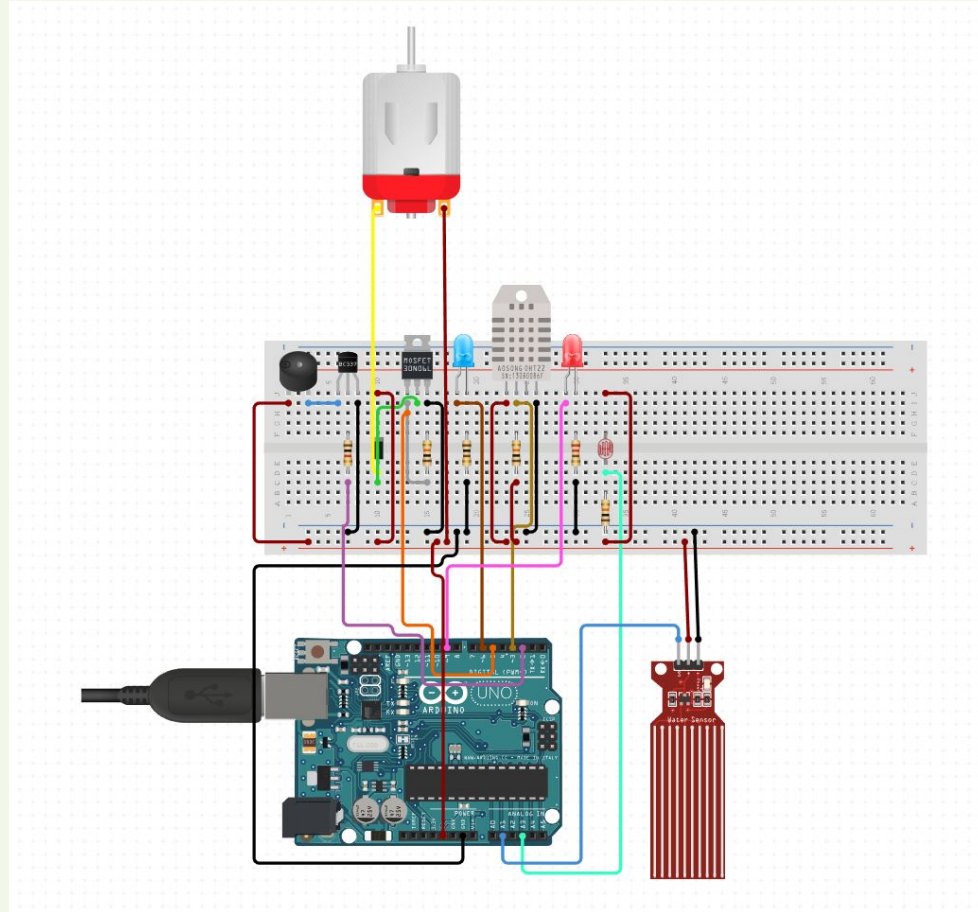
# 100

# Dissertation

# 4.1

## Creation of the database

# Main Database - VBA, Combine to CSV

```vba
1  Public Sub SaveWorksheetsAsCsv()
2  Dim xWs As Worksheet, xDir As String, folder As FileDialog
3  Set folder = Application.FileDialog(msoFileDialogFolderPicker)
4  If folder.Show <> -1 Then Exit Sub
5    xDir = folder.SelectedItems(1)
6    For Each xWs In Application.ActiveWorkbook.Worksheets
7    xWs.SaveAs xDir & "\" & xWs.Name, xlCSV
8  Next
9  End Sub
```

- 1.csv
- 2.csv
- 3.csv
- 4.csv
- 5.csv
- 6.csv
- 7.csv
- 8.csv
- 9.csv
- 10.csv
- 11.csv
- 12.csv
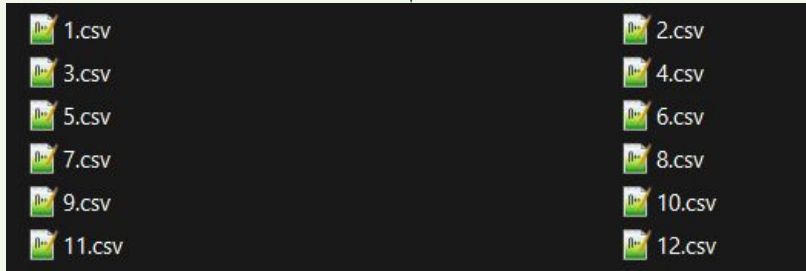
```python
1   import pandas as pd
2
3   # Create the dataframe we will use later
4   merged = pd.DataFrame()
5   # As there are 12 files in total, we create a loop
6   for file in range(1, 13):
7
8       # Read the data from each file
9       month_data = pd.read_csv(f"{file}.csv")
10
11      # Get the name and delete the null rows
12      name = list(month_data["Name"])
13      name = [x for x in name if not(pd.isnull(x)) == True]
14
15      # Get the month you have to sow each plant. Depends on the file it is in
16      sowMonth = []
17      sowMonth.extend([file]*len(name))
18
19      # Create a dicitonary to append it to the file
20      data = {"Name": name,
21              "sowMonth": sowMonth}
22      merged = merged.append(pd.DataFrame(data))
23
24  # Create file
25  merged.to_csv("merged_Xa.csv")
```

merged_8a.csv     merged_10a.csv
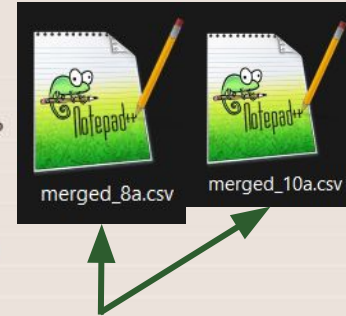
```
1   import pandas as pd
2   import numpy as np
3
4   # With the objective of having the plan...              to unify both files
5   # We read the 2 files we need
6   plantInfo_clean = pd.read_csv("iniF/p...
7   merged_total = pd.read_csv("iniF/mer...
8
9   # We unify the two files
10  plantInfo_clean = plantInfo_clean.merg...                      ="left")
11  plantInfo_clean.drop(columns=["Unnam...                 Delete unused columns
12  plantInfo_clean.drop_duplicates(inplace...
13
14  # Create a new column to check if it is easy to grow or not
15  # We search if in the instructions it says if its easy to grow and create a new table with that information
16  easy = plantInfo_clean.loc[plantInfo_cle...                      "Easy_to_grow", case=False]
17  plantInfo_clean["sowInstructions"] = pla...              map(lambda x: x.lstrip("Easy_to_
        grow_")) # Delte repeated infomat...
18  # Create the new column in the "easy" t
19  easy["easyGrow"] = list([1]*len(easy))
20
21  # we drop all the columns that are not "...                    re the only ones that are going
        to be useful
22  col = ["alternateName", "sowInstructions...
        "spaceInstructions","harvestInstruc...               nstructions","culinaryHints",...]
23  easy.drop(columns=col ,axis = 1, inplace...
24  plantInfo_clean = plantInfo_clean.merg...                   # We merge and drop
        duplicates. If NaN, Not easy to grow. If 1, easy to grow
25  plantInfo_clean.drop_duplicates(inplace='True')
```

```
27  minTinC = plantInfo_clean["sowInstructions"].str.extract("._Best_planted_at_soil_temperatures_between_
        (\w+)[U+FFFD]C.")
28  maxTinC = plantInfo_clean["sowInstructions"].str.extract("C_and_(\w+).")
29  minTinF = plantInfo_clean["sowInstructions"].str.extract("._Best_planted_at_soil_temperatures_between_
        (\w+)[U+FFFD]F.")
30  maxTinF = plantInfo_clean["sowInstructions"].str.extract("F_and_(\w+).")
31  farenheitMin = []
32  farenheitMax = []
33  for i in range(...
34      if (minTin...                      nC[0][i] is not np.nan):
35          min =
36          max =
37          fa...
38          farenh...
39      else:
40          farenh...
41          farenh...
42  plantInfo_clea...
43  plantInfo_clean["maxTinF"] = farenheitMax
44
45  plantInfo_clean["sowInstructions"] = plantInfo_clean["sowInstructions"].map(lambda x: re.sub(r"._Best_
        planted_at_soil_temperatures_between_\d+[U+FFFD]\w_and_\d+[U+FFFD]\w._\(Show_
        [U+FFFD]\w/\w/\w+\)", ".", x)) # Delete the duplicated information
46
47  plantInfo_clean.sort_values(["Name"], inplace=True) # We sort the list first by the sowing month and
        then by name
48  plantInfo_clean.to_csv("prueba.csv") # We store the final file
```

plantInfo-clean.csv

merged_total.csv

prueba.csv

# Main Database

| Name | sowInstructions | spaceInstructionsInches | harvestInstructions | compatiblePlants | sowMonthJan | easyGrow | minTinF | maxTinF |
|---|---|---|---|---|---|---|---|---|
| Amaranth | Sow in garden. Sow seed at a depth approximately three times the diameter of the seed. | 20 | 7-8 weeks. | Onionsor cornor peppersor egg plantor tomatoes | 1 | 1 | 64 | 86 |
| Angelica | Sow in garden. Sow seed at a depth approximately three times the diameter of the seed. | 18 | 18 months. Angelica archangelica has slightly dull leavesor not shiny.. | Any herbs that like dampor shady areas - mintor lemon balm | 0 | 1 | 50 | 77 |
| Artichokes (Globe) | Sow in garden. Sow seed at a depth approximately three times the diameter of the seed. | 71 | 42-57 weeks. | Needs a lot of space. Best in separate bed | 0 | 1 | 59 | 64 |
| Asparagus | Plant as crowns. | 12 | 2-3 years. Plant 'crowns' to harvest earlier . | Parsleyor Basilor Nasturtiumsor Lettuce | 1 | 1 | 61 | 86 |
| Asparagus Pea | Sow in garden. Sow seed at a depth approximately three times the diameter of the seed. | 9 | 8-11 weeks. Pick earlyor pick often. | Best grown in separate bed | 0 | 1 | 59 | 68 |

# 4.2

## Building the Arduino

# Arduino and Breadboard
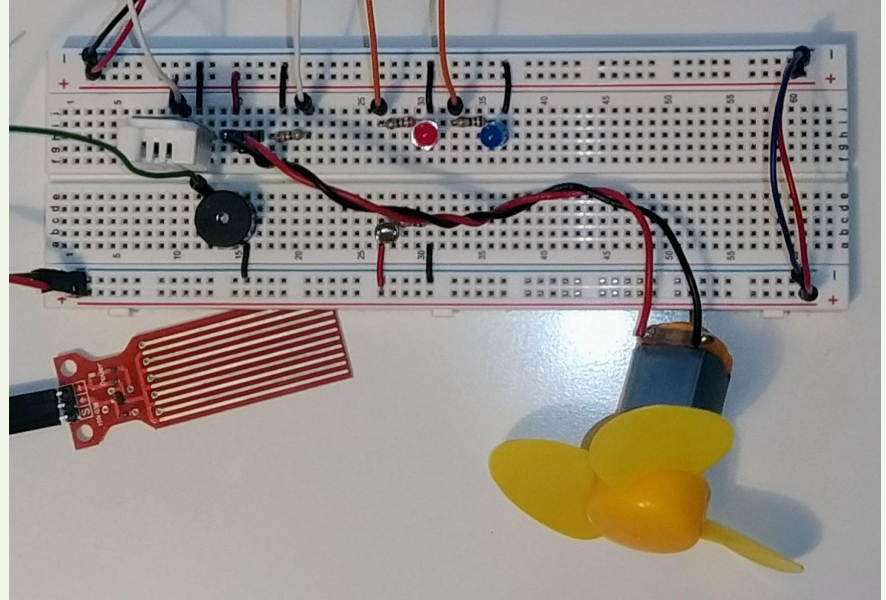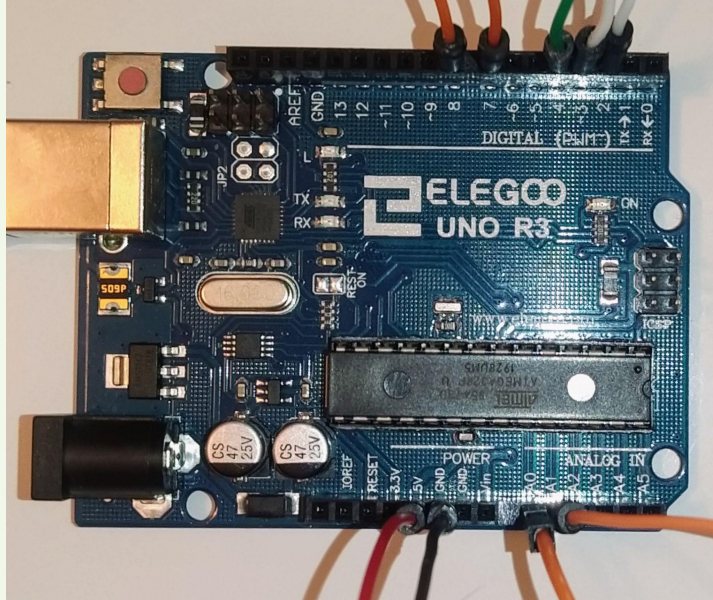
# Temperature and humidity unit
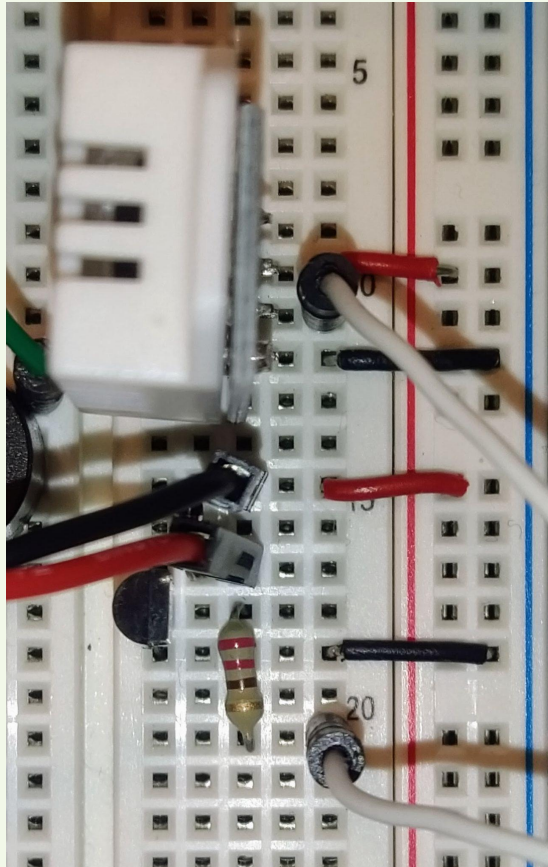


```
33  void loop() {
34     while (!Serial.available());
35     String str(Serial.readString());
36     char str_array[str.length()+1];
37     str.toCharArray(str_array, str.length()+1);
38
39     if (strcmp(str_array, "readT") == 0) {
40        Serial.print(dht.readTemperature(true));
41        Serial.print(",");
42        Serial.print(dht.readTemperature());
43     }
44
45     if (strcmp(str_array, "hot") == 0) {
46        analogWrite(FANPIN, 150);
47        digitalWrite(BLUELED, LOW); // Stop turning up blinds
48        digitalWrite(REDLED, HIGH); // Turn down blinds
49     } else if (strcmp(str_array, "cold") == 0) { // If cold, open blinds
50        analogWrite(FANPIN, 0);
51        digitalWrite(REDLED, LOW); // Stop turning up blinds
52        digitalWrite(BLUELED, HIGH); // Turn up blinds
53     } else {
```

# Light detection unit
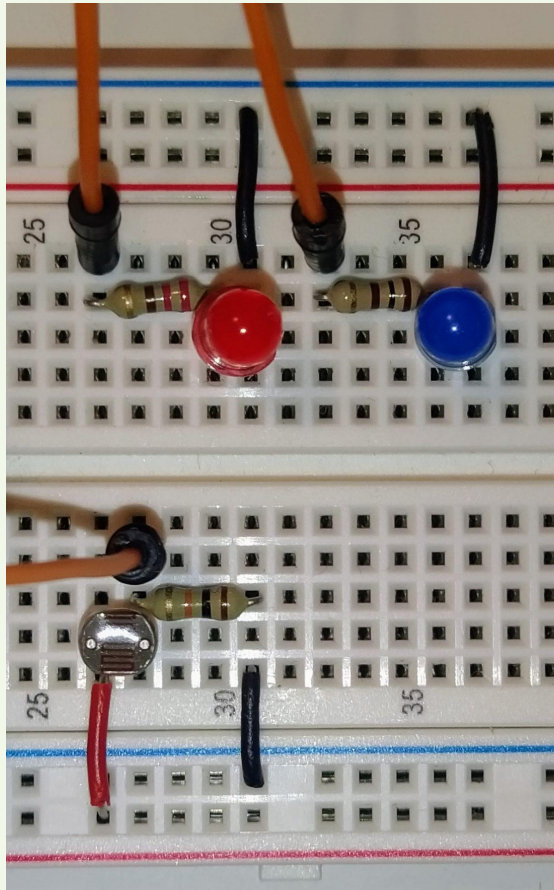


```
53    } else {
54        int light = analogRead(PHOTOPIN);
55        if (light > 900){ // Its bright AND not cold, red led on -> Close blinds
56            digitalWrite(BLUELED, LOW); // Stop turning up blinds
57            digitalWrite(REDLED, HIGH); // Turn down blinds
58        } else if (light < 500){ // Its dark, blue led on -> Open blinds
59            digitalWrite(REDLED, LOW); // Stop turning up blinds
60            digitalWrite(BLUELED, HIGH); // Turn up blinds
61        } else {
62            digitalWrite(REDLED, LOW); // Stop turning up blinds
63            digitalWrite(BLUELED, LOW); // Stop turning up blinds
64        }
65    }
```

# Water supply unit
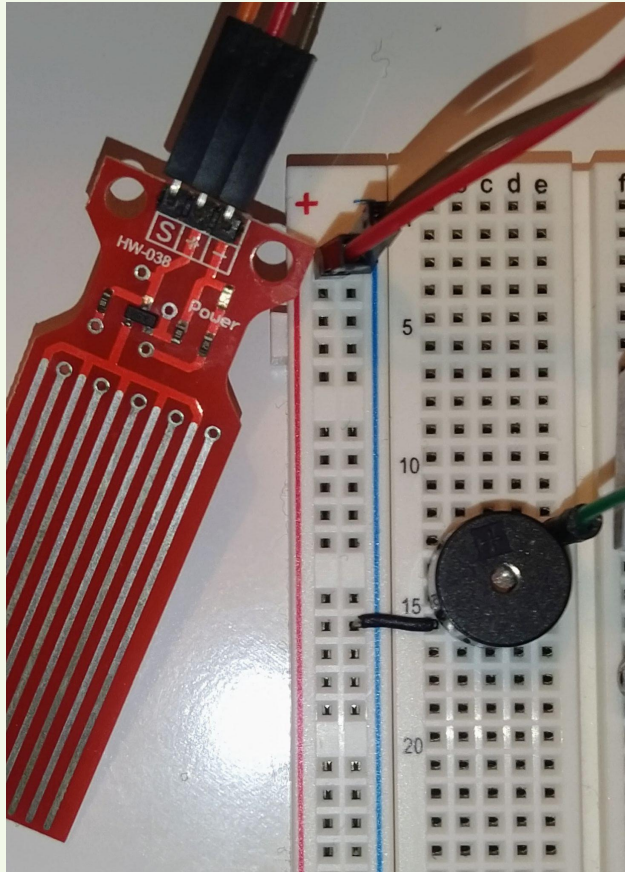


```
67    // Check water level, if less than half, an alarm will turn on
68    int water = analogRead(SENSORPIN);
69    if ( water < 255){ tone(BUZZER, 2500); }// Send 1KHz sound signal...
70    else { noTone(BUZZER); }
71  }
```

# 4.3

## Connecting the PC with the database

# Sequence diagram

# 101
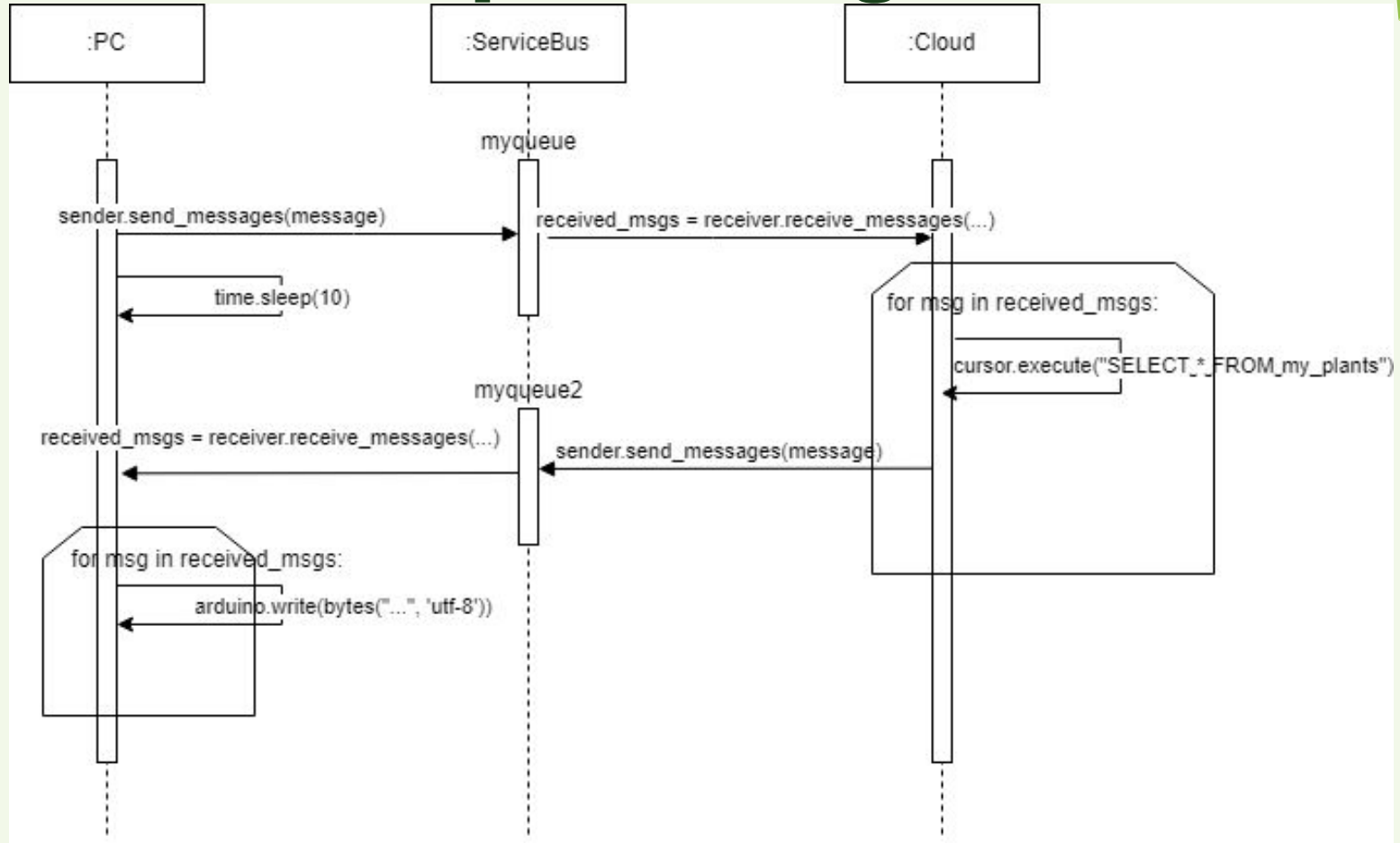
# Results and Discussion

# Statistics
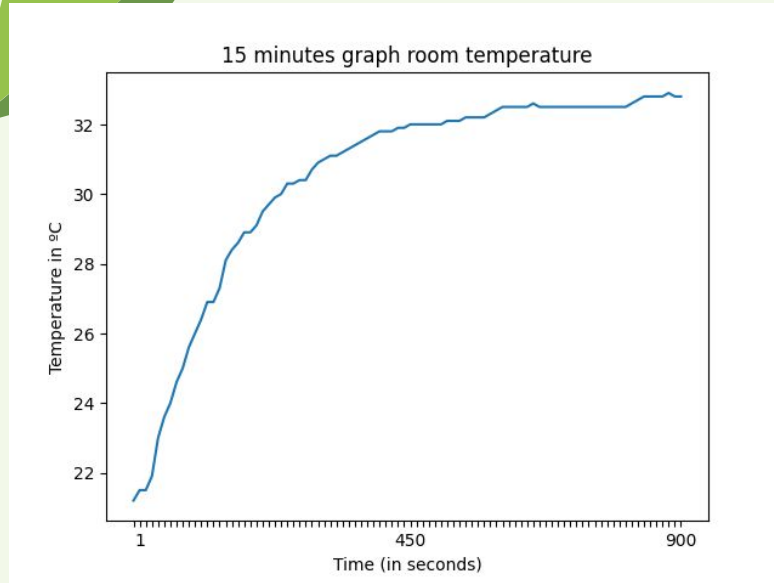


**Temperature before implementation of fan**
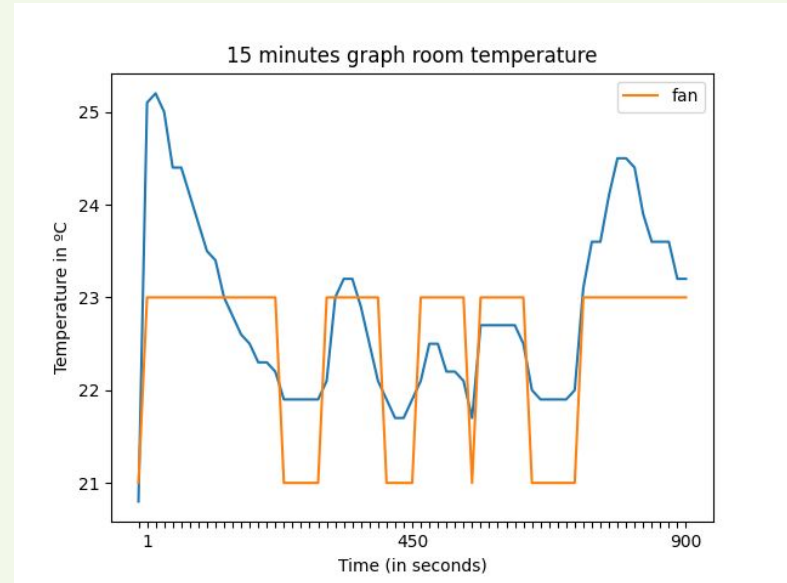
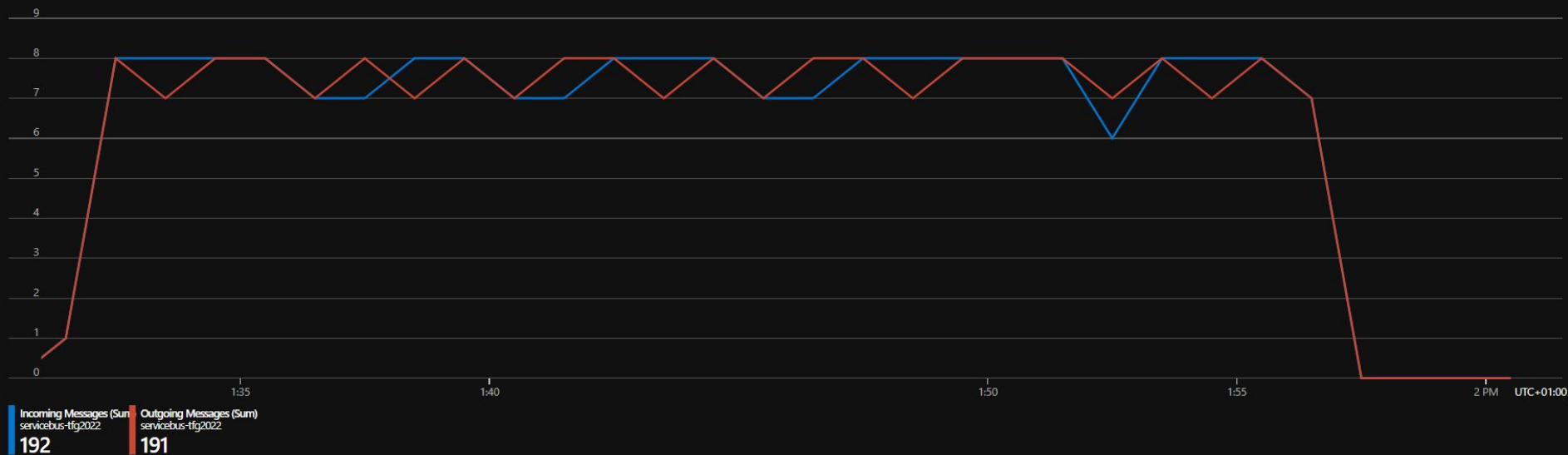

**Temperature after implementation of fan**

# Hot signal

Fan is on and blinds go down

# Cold signal

Blinds go up

# No signal

| Time | Print |
|---|---|
| 13:30:31.539094 | Local sent: 65.3 |
| 13:30:43.850577 | Local received: cold |
| 13:30:47.644026 | Local sent: 63.32 |
| 13:30:59.900718 | Local received: cold |
| 13:31:02.799246 | Local sent: 63.86 |
| 13:31:14.981682 | Local received: cold |
| 13:31:17.943842 | Local sent: 63.86 |
| 13:31:30.167591 | Local received: cold |
| 13:31:33.249010 | Local sent: 63.86 |
| 13:31:45.631100 | Local received: cold |
| ... | ... |

(a) Local python output

| Time | Print |
|---|---|
| 13:30:31.825181 | Cloud received: 65.3 |
| 13:30:33.803240 | Cloud sent: cold |
| 13:30:47.902480 | Cloud received: 63.32 |
| 13:30:49.853312 | Cloud sent: cold |
| 13:31:03.320804 | Cloud received: 63.86 |
| 13:31:05.520761 | Cloud sent: cold |
| 13:31:18.727527 | Cloud received: 63.86 |
| 13:31:20.743666 | Cloud sent: cold |
| 13:31:34.160295 | Cloud received: 63.86 |
| 13:31:36.108277 | Cloud sent: cold |
| ... | ... |

(b) Cloud python output

33

35

# Today, 11/1/2023 at 13:12:11 it's 18ºC

**Strawberries (from seeds).**

Sow instructions: Start inside in pots or trays after chilling seeds.. Sow seed at a depth approximately three times the diameter of the seed.

Plant around 25.5 inches between any other plant

Harvest instructions: 1 years. Seedlings need to grow for about a year before fruiting. Remove first flowers. .

Plants that are compatible: Better in a bed on their own to allow good sun and air circulation

To avoid: Avoid growing close to: If you are using rotation bedsor avoid putting strawberries where you have grown tomatoesor potatoesor peppers or eggplant

Culinary hints: Strawberries can be used in any dessert needing soft fruit or berries. Summer pudding with raspberries and blackberries or boysenberriesor mousseor trifleor dipped in melted chocolate or just with cream. Sprinkle a bowl of strawberries with balsamic vinegar and a little sugar to enhance the flavour and colour.Straight from the gardenor warmed by the sun is best.

For more information visit this link.

Ideal to grow in: Februay,

Minimum temperature: 10.0ºC. Maximum temperature: 20.0ºC

Get If The Current Temperature Is Good For A Plant

Get Which Plants Are Good For The Current T

Search By Filter

Get Recommendation By My Plants Db

Add Plant To My Db

Enter the nam

Name

You can p

37

# IIO

## Conclusions and Future Work

# Conclusions

**01**

**Practical and effective** solution for the problem we had.

**02**

Successfully **achieved all goals** in designing and implementing the system.

**03**

**IoT and cloud computing** technologies were employed to enable monitoring and a response mechanism.

**04**

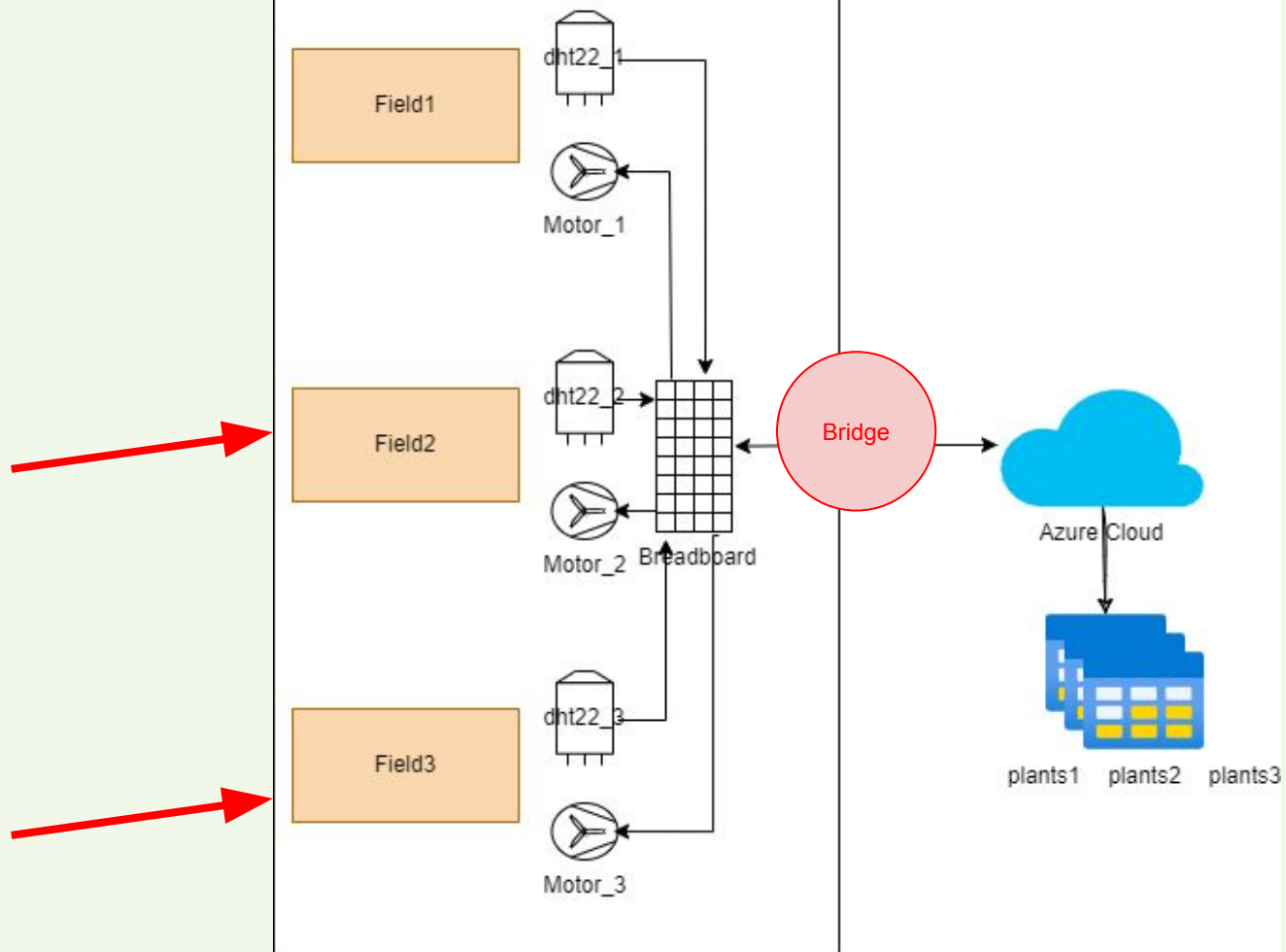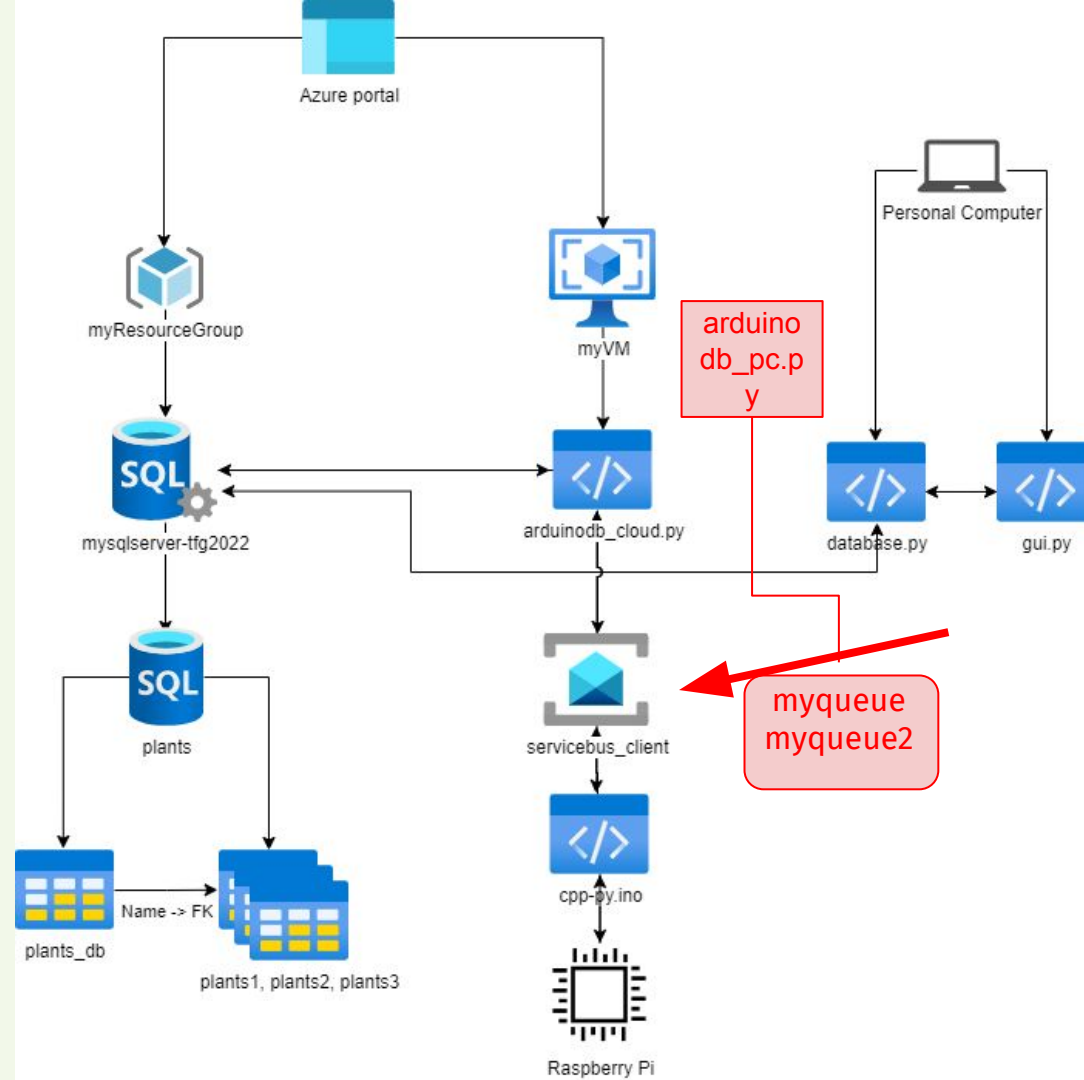**Cost-effective, easy-to-use**, and highly functional system created.

**05**

The **knowledge acquired** during the project process, with cloud services being a new area of study.

# 6.2

# Future work

Azure portal

myResourceGroup

myVM

arduino db_pc.py

Personal Computer

mysqlserver-tfg2022

arduinodb_cloud.py

database.py

gui.py

plants

servicebus_client

myqueue myqueue2

plants_db

Name -> FK

plants1, plants2, plants3

cpp-py.ino

Raspberry Pi

# Thanks!