Final Project - Precision agriculture

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Internet of Things

Abstract

The goal of this project is to partially implement a smart agriculture gadget with a Fishino Piranha board. It can measure the environmental conditions of a particular plant, plantation or greenhouse, upload them to a remote database and control actuators to maintain them in a desired range. The implementation is called *partial* because the real actuators are not used; instead, a set of LEDs indicate the action that would take place.

Contents

1 Project overview

1.1 Operation

The general operation of the device is depicted in figure 1. During the setup, some parameters are defined and the WiFi connection is made. After that, and endless loop is repeated. The *happy path* consist of a measurement, the activation/deactivation of actuators to make environmental parameters fall into the desired range, and sending the acquired data to the database via an HTTP request. In case of a lost measurement, the value is estimated using a moving average. If too many consecutive measurements fail, it is assumed that the sensors are not functioning correctly and thus the actuators are shut down for safety reasons and the user informed of the situation. If the sensors start to function correctly again, the *happy path* is resumed.

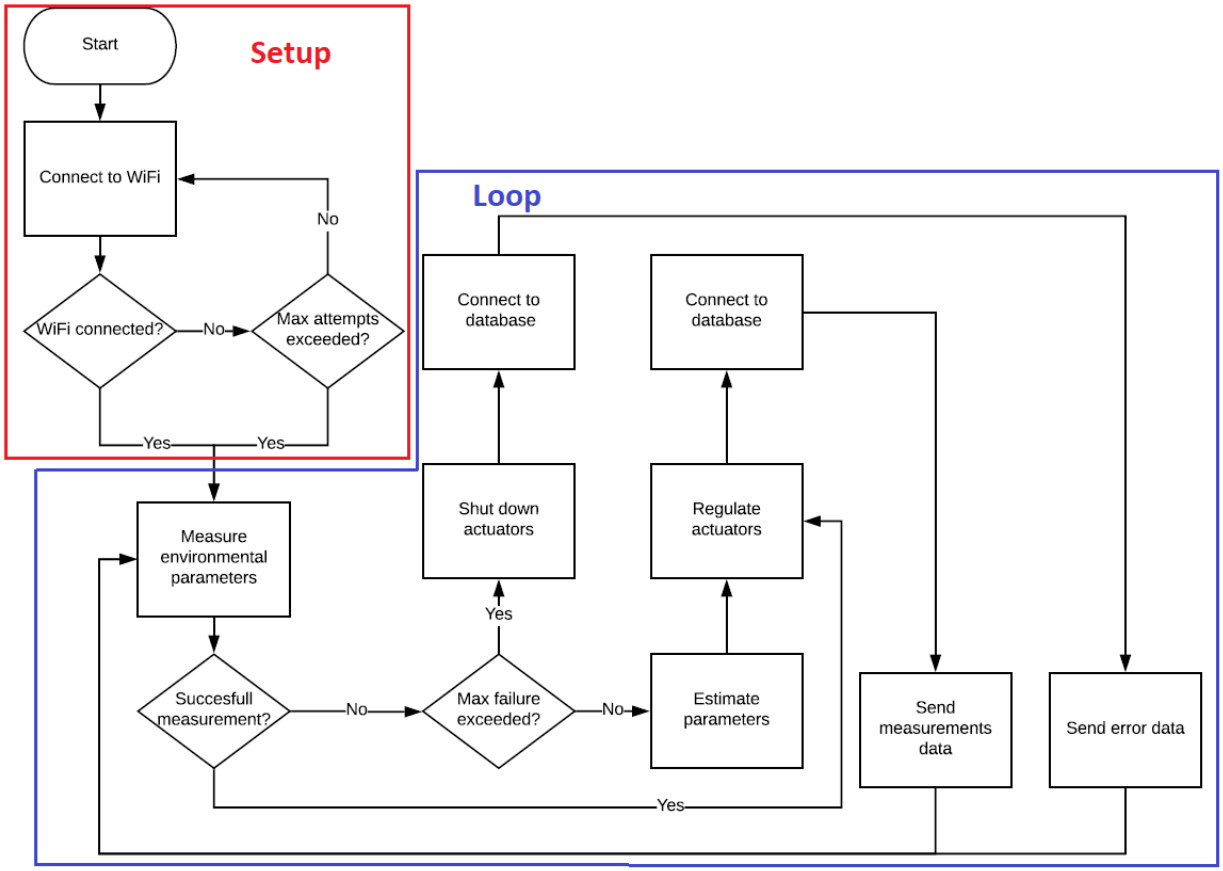

Figure 1: Algorithm implemented

1.2 Hardware used

The list of the parts used is the following:

- Fishino Piranha board
- DHT11 temperature and humidity sensor
- Proto board
- Flat cables
- Computer [1]
- 5V USB power source
- USB to micro USB cable (also used for flashing the device)
- LEDs
- 100Ω resistors

The setup can be seen in figure 2

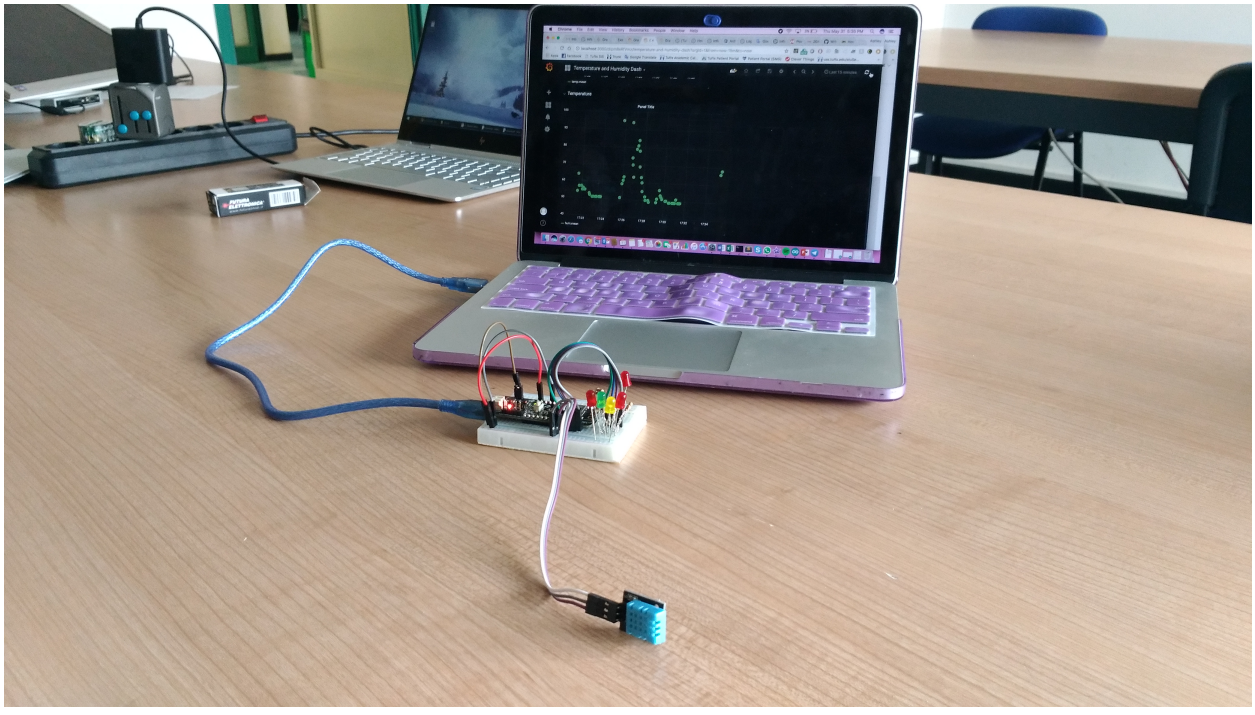

Figure 2: Setup used

[1] used to flash the device, store the database and visualize the data. In a real deployment, these three functions would be carried out by different entities

In the figure 3 we can see how the Piranha board is connected to the actuators (LEDs) and the sensor. All connections are pretty straightforward. The LEDs are connected with their cathodes to ground and their anodes to the pins that control them through 50Ω resistors (made of pairs of 100Ω resistors). The humidity and temperature sensor has a common ground and V_{cc} with the board and sends the measurements through one cable connected to pin D2.

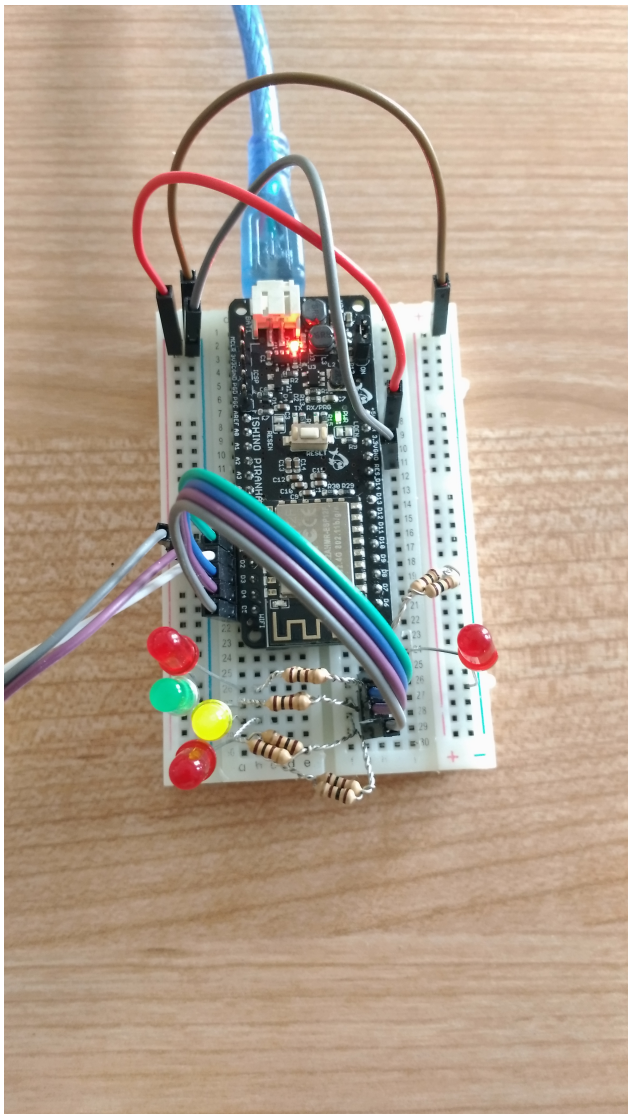

Figure 3: Board connections to sensors, power source and actuators

The LEDs on the left represent, form top to bottom, heating, cooling system, sprinklers and ventilation system. They are activated if temperature is too low, too high, humidity too low or too high, respectively.

The red LED on the right side of the board is the system failure alarm. It is turned on only if the sensors are lost and the system shuts down for safety reasons.

1.3 Flashing the device

In order to upload the code to the Fishino, the Arduino IDE was used. The drivers for the Fishino Piranha, as well as some Fishino libraries, used in the code, such as *Wireless Fishino*, were all downloaded from the fishino website www.fishino.it. Once all the software is ready, in order to flash the device, it must be connected to the computer with a USB to micro USB cable, the reset button of the Fishino has to be pressed until the *reset light* starts blinking, and then the code can be uploaded through the Arduino IDE.

2 Enviromental sensing and control

2.1 Sensors

In this implementation, the environmental parameters measured and controlled are temperature and humidity. This is done with the DHT11 sensor. The physicall connection costists of a shared ground and V_{cc} (5V) with the Fishino board and a single cable through which data is sent serially into the digital pin two (D2). Its acquisition is done periodically, with the same period for both magnitudes and with a 16 bit resolution. It's worth noting that adding another sensed parameters would be very straighfoward and could be done with little modifications to the code. Also, while the control is applied on the same parameters that are sensed, this is not needed, and not controlled parameters could be registered if the extra information was usefull or desirable.

2.2 Estimation and control

Long term data is stored in the data base. The device only retains a small number of samples used for control and prediction. An *on-off control* has been implemented, but the locally stored data could be used to implement algorithms adapted to particular plant dynamics [2].

In case of sensor malfunction, the lost measurement is estimated as the average of some of the previous samples. This estimated measurement is then used to assess which actuators should be activated or deactivated. If too many consecutive measurements are lost, estimation becomes pointless, for the error can grow arbitrarily large. In such a case, actuators are turned off for safety and economy reasons and an *alarm* is turned on, as to alert the user that the device needs maintenance.

3 Database and visualization

3.1 Storage

To store the data, we use the open source time-series database system InfuxDB. A time-series database is ideal because we want data to be constantly added to the database over time. Thus, it makes sense for the data to be indexed by time and use a database that is optimized for this usage. One of the reasons this particular database was chosen is that it provides integration with data analytics and visualization software like Grafana.

[2] the word *plant* here is used as a general control theory term, not as *plant* in botanics.

The database was created on a laptop which is connected to the same network as the IoT end device. As data is generated, it is sent through HTTP requests with the format shown in figure 4. It is necessary to concatenate an i to the number so InfluxDB knows to read that number as an integer. Without this, InfluxDB reads the number as a float by default, which cannot be properly processed later in Grafana.

```
POST /write?db=mydb HTTP/1.1
Host: 192.168.43.137:8086
User-Agent: Arduino/1.6
Connection: close
Content-Type: application/x-www-form-urlencoded
Content-Length
tempLine.length()

temp value= temperature + "i";
```

Figure 4: HTTP request format

When an error occurs and the system shuts down because it doesn't have enough information to act properly, it sends a Boolean value of failure to a special column of the database that triggers an alarm to inform the user.

3.2 Visualization

The Grafana software provides a solution for the visualization of the stored time series data. A dashboard is created with a panel for every graph the user wants to display. Here, the user can access and easily interpret the complete history of the monitored environmental parameters.

Setting up Grafana had its challenges. For each panel, we had to enter the metrics for the graph which consists of a query to the database. For testing when the data failed to show up on the graph, we were able to determine whether or not the data reached Grafana through looking at the results of the Query Inspector. When it didn't, we checked whether or not the data reached the database by searching the same query directly in the database via the command line.

Then, Grafana allows users to customize the label and scale of the axes, how the data is displayed, what time period of data gets displayed, and more. Another helpful feature is the alert. This is useful for the error panel. On that panel, we display a graph which shows each instance that a failure occurs. Since we probably want the user to be notified when this happens, we configure alerts to alert the user, so they know when something is going wrong, like a sensor malfunctioning.

4 Examples

4.1 Example 1: *Happy path*

When the device is turned on, it first attempts to connect to the wireless network. This usually fails on the first try, so several attempts are allowed. Once it has connected, it makes measurements, saves them temporarily (in a five measurement vector initialized with all values in zero), connects to the database and sends the data. In figure 5 the start up of the device is shown. For demonstration and debugging purposes, everything is sent to the computer through the serial monitor, but this would obviously not be necessary in

a real application scenario. Also, during this example, only the *sprinklers* actuator is turned on, because humidity levels are below the minimum threshold. This is shown in figure 3.

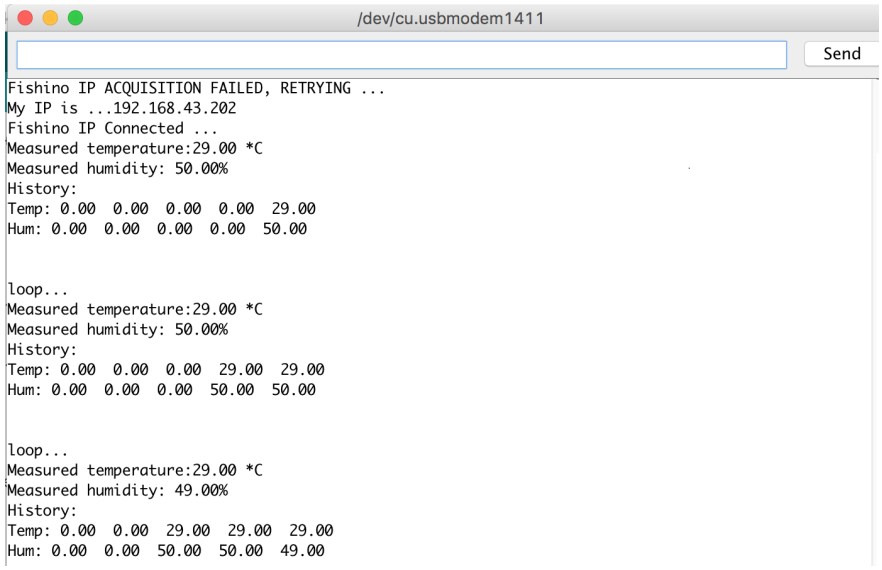

Figure 5: Device functioning correctly

4.2 Example 2: Sensor failure

To simulate sensor failure, it was disconnected from the Fishino board. When this occurres, the device compensates by using the previous measurements to predict the missing ones. This can be seen in figure 6.

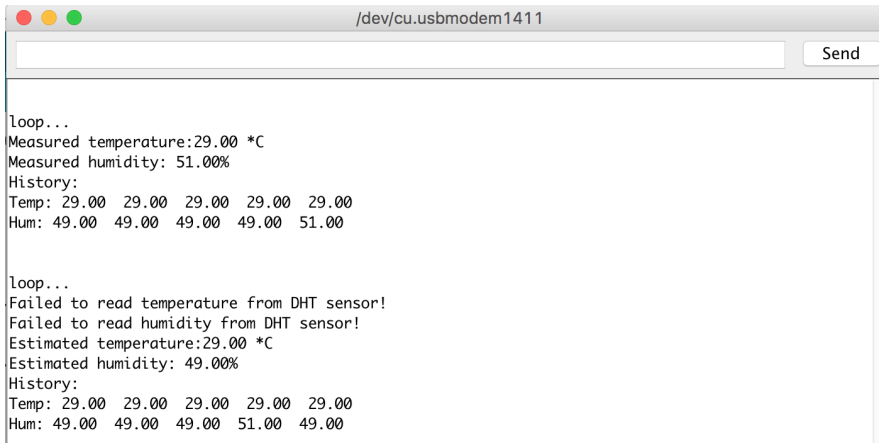

Figure 6: Device reaction to failed measurements

If several consecutive measurements fail, predicting becomes pointless. When this happens, the sensors

are turned off and the user is notified of the situation so he can act accordingly. This scenario is shown in figures 7 and 8

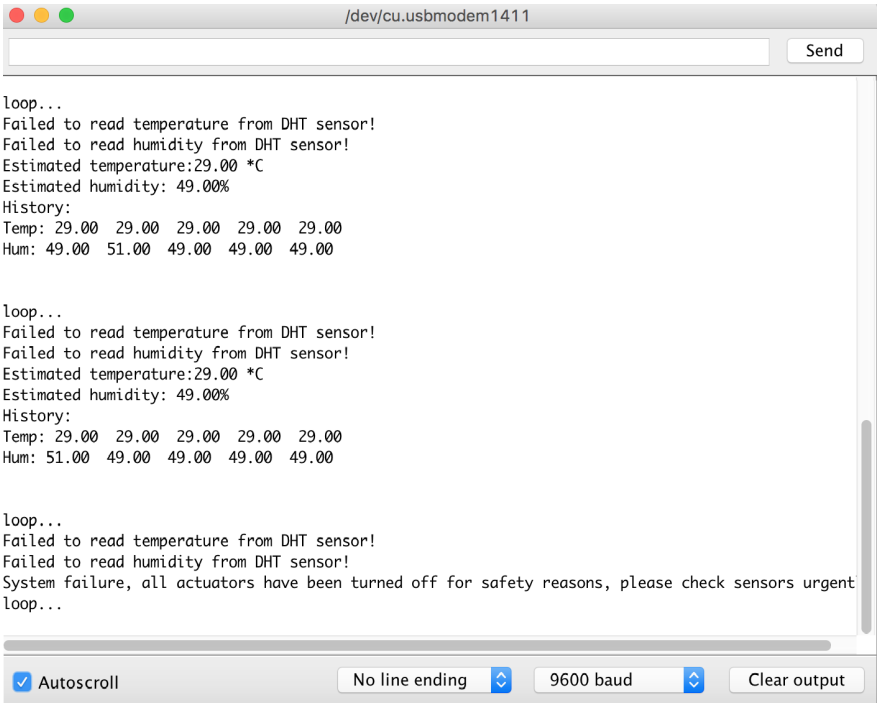

Figure 7: Device reaction to a high number of failed measurements

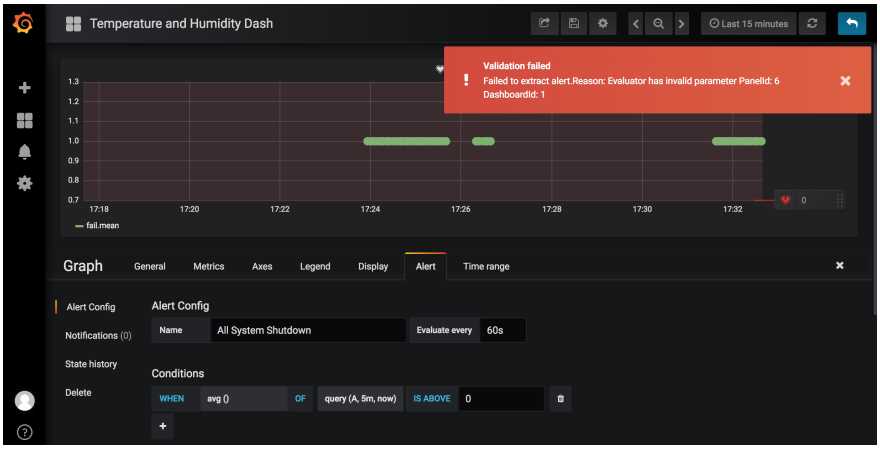

Figure 8: User notification for a high number of failed readings

5 Conclusions

The project goals have been reached. The prototype has been successfully implemented and all of the features tested. The device can measure, estimate and control the environmental parameters as desired, as well as upload the data to the database, from which it can be visualized by the user.

The control algorithm and actuator control were correctly implemented, and although it must be noted that a fully functional implementation would possibly imply revisiting their design, this can be done with no mayor modifications to the code, but just some to the specific functions that describe the prediction and control. It was considered that these details, more related to the architecture of particular greenhouses and the field of botanics, exceeded the scope of this work.

In this work, the power of tools such as InfluxData and Grafana, as well as pre-built boards, together with their IDE, is clearly depicted. They allow a straightforward and fast implementation of IoT solutions.

Finally, for future works, the analysis of other wireless connections, as well as battery optimization could be usefull, and possibly necessary, for real outdoor scenarios.