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Development of an IoT based Smart meteorological station & horticultural irrigation system's controller using a Raspberry Pi Linux server

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In my current project an IoT based device has been developed, the main function of which is to allow the control of its own flexible meteorological station and irrigation system. Besides the control computer, there are meteorological sensors attached, based on which we control our agricultural irrigation apparatus.

Keywords— meteorological station; remote monitoring; remote control; Raspberry Pi; Linux; IoT, irrigation control

I. INTRODUCTION

In the building mechatronics headquarters IoT based systems' design and construction takes place, and this project is part of those developments as well. [20][21].

The improvement of the production of plants usable as food has increasing importance. Presently, the continuously growing population requires more and more food and nutrition. Unfortunately, due to the rapid and extensive urbanization the area and size of arable lands is significantly decreasing. As a result, during the usage of the arable land – be it smaller or larger horticultures or industrial agricultural areas – the best, cheapest and most environmentally friendly way to improve productivity is watering plants. Nowadays, due to organic farming gaining ground, and the endangerment and decrease of the water reserves of our Earth, it is increasingly necessary to attend to planning and implementing the irrigation processes.

In my thesis, an irrigation system augmented with a meteorological station's controller takes the aforementioned requirements into consideration and according to the resources available ensures the operation of the irrigation system in the most effective, and precise way.

The purpose of the controller is the synchronization of the weather and quality crop production, by which the causeless and unnecessary reduction of our current water reserves can be prevented. The finished program calculates the crop's water requirements in its different stages of development, based on measured meteorological parameters.

II. IOT BASED REMOTE CONNECTION

In our society, information flow has greater importance nowadays. The internet seems to be the obvious solution to satisfy this need. Using it allows us the creation, implementation and operation of remote control and monitoring systems.

The remote control and supervision of the system can be operated using a Windows remote desktop connection, the benefit of which is that one can connect using anything above Windows 7 operating systems, through a local network. [11]. Furthermore, it is currently the most popular "old" operating system on Microsoft's product range.

For the finalized system the program called XRPD has been used on the Raspberry Pi [12]. The program allows the use of wired and wireless connections, knowing the IP (Internet Protocol) address. [13].

Since among the objectives was the ability of long term development of the later discussed designed meteorological station, the Raspberry Pi 3 model B was chosen [1]. The hardware was published with a 64 bit 1.2GHz ARM Cortex-A53 processor.[2].

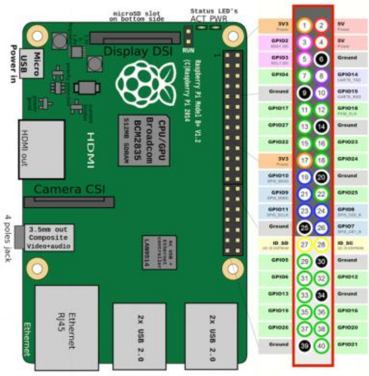

Figure 1: Raspberry Pi 3 model B [2]

The original operating system of the device is the Raspbian, which is a version of Debian optimized for the Raspberry Pi [3]. The Debian systems nowadays are built on Linux or FreeBSD kernel. [4]. Their Open-Source qualification should be classified among their trademarks [14].

After the release at 2012.02.29 many other Linux distributions have been ported for the ARM CPUs, like Risc OS, Ubuntu MATE, and the Osmc, among others [15]. During the execution of the project the Raspbian PIXEL OS has been used.

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III. BME680 SENSOR

One of the key elements of the meteorological station are the built-in sensors, in light of this they had to be carefully dimensioned. Furthermore, a long lifecycle had to be guaranteed as well.

For the aforementioned conditions the product made by Bosch Sensortec, the BME680 sensor has been chosen, which is an ultra mini 4-in-1 combined sensor. With this, we can measure temperature (°C), relative humidity (RH), air pressure (P), and the air quality in (KOhm) [5].

Considering its structure, an ADC circuit, a high-speed I^2C and SPI-compatible interface gives its distinctiveness. In the BME680 the activity of different sensors can be turned on and off independent from each other, thereby the regularity of measurements can be idealized for each sensor, thus minimizing the average power consumption [5].

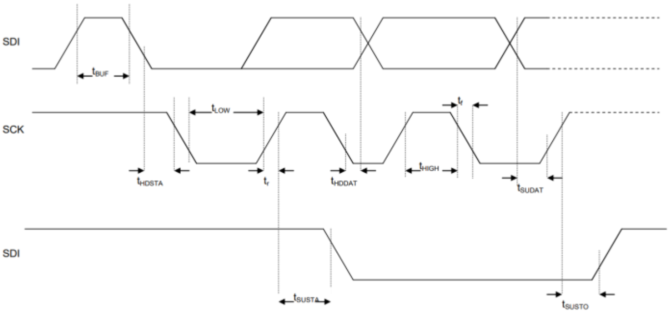

Figure 2: I2C timing diagram [9]

The sensor is suitable for installation in small mobile devices, and equipments [5].

General features of the BME680:

- Four built-in sensors
- Industrial temperature range -40…+85°C
- I^2C, SPI interface
- Miniature surface mounted enclosure, LGA8 [5].

TABLE 1 [5]

The measuring and operating parameters of BME680		
Name	**Rating/Accuracy**	**Unit**
Supply voltage	1,71-3,6	[V]
Active current	1-849	[µA]
Temperature measurement range	-40-85	[°C]
Temperature measurement accuracy	±1.0	[°C]
Humidity range	0-100	[%]
Humidity measurement accuracy	±3	[%]
Pressure measurement range	300-1100	[hPa]
Pressure measurement accuracy	±0,12	[hPa]
Gas measurement accuracy	±0,11	[%]

IV. TSL2561 SENSOR

The TSL2561 light sensor is a precise digital sensor. Its task is the measurement of luminous intensity and illumination. Its usability is extensive, because the configurable amplifier and timer allow the measurement of a remarkably wide lux range [6]. Its special feature is that it also contains infrared and full spectrum diodes for sensing light. Thanks to this, we can measure in different ranges with it, which can be infrared, full spectrum, or the human eye perceptible range.

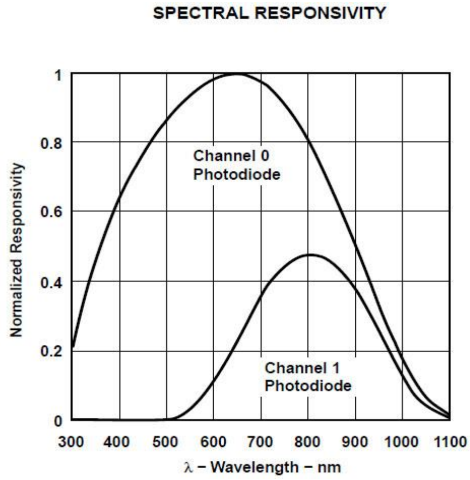

Figure 3: The measuring range of photodiodes [6]

Usually light sensors cannot measure in different spectrums, and so are not usable for measurements which are closest to the perception of the human eye.

The Analog/Digital converter built into the TSL2561 ensures the sensor to operate with any controller with a digital input. It can be directly connected to the Raspberry Pi's I^2C interface operating at 3,3V signal level, just like the BME680 sensor [6].

TABLE 2 [6]

The measuring and operating parameters of TSL2561:		
Name	**Rating/Accuracy**	**Unit**
Supply voltage	2,7-3,6	[V]
Active current	3,2-600	[µA]
Measurement range	0,1-40000	[lux]

V. TX20 WIND DIRECTION AND SPEED METER

The wind direction and speed meter is an important part of the meteorological station.

For the project the TX20 wind direction and speed meter has been chosen (fig. 4).

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Figure 4: TX20 anemometer [10]

The size of TX20 according to the documentation, is 250 x 77,9 x 277,6 mm, for the ABS version, which is also used in industrial applications because of its durability [7] [16].

Since the anemometer is complex it can perform many functions, however before the actual application it has to be disassembled and hook everything up based on the given IC.

TABLE 3 [7]

The measuring and operating parameters of TX20		
Name	**Rating/Accuracy**	**Unit**
Supply voltage	5	[V]
Wind speed measurement range	0-180	[km/h]
Wind speed measurement accuracy	0,1	[km/h]
Wind direction measurement range	360	[°]
Wind direction accuracy	±11,25	[°]

VI. Determining the plant's water needs

For the operation of the irrigation system we calculated a reference value by measuring the temperature, humidity, wind speed, duration of sunshine, as well as the exact coordinates of the meteorological station, height above ground, and the altitude (12 cm high grass' evapotranspiration). If we multiply this value with the plant's Kc factor we get the amount of water evaporated by the environment in 1 hour for the given plant. The Kc factor is defined by the plant's current stage of development.

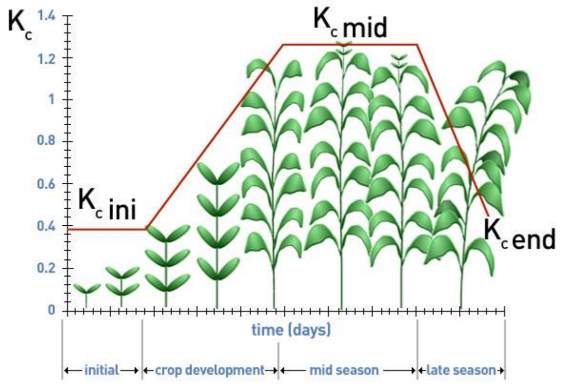

Figure 5: The plants' Kc factor diagram per stages of development [8]

The database contains the Kc (Kc ini,Kc mid,Kc end) (Figure 5**Hiba! A hivatkozási forrás nem található.**) factor and the length of the stages of development, based on which this diagram can be created for each plant individually.

The water needs of the plant's growth phase can be determined using the weighted average of Kc ini and Kc mid factors.

$$t = \frac{ET_c}{Q} * T \qquad (8)$$

t: Length of watering [minute]
ETc: Plant's water needs [mm]
Q: Watering system's volume flow at the pump [l/perc]
T: Area of the watered zone [m2] [8].

If the formula outlined above is entered, the program will calculate the duration of the watering based on the area and volume flow, after determining the water needs, which, further on, the user will define via the GUI.

VII. Connections

The BME680 and the TSL2561 sensor needs to be connected on the I^2C [SDA: GIPO 3, SCL: GPIO 5] and needs 3.3[V] for their operation. The wind gauge needs 5[V].

Connections of TX20 RJ11:

TABLE 4 [10]

Pin	Color	Description
1	Black	Txd (signal)
2	Pink	Vcc
3	White	DTR (data)
4	Yellow	GND

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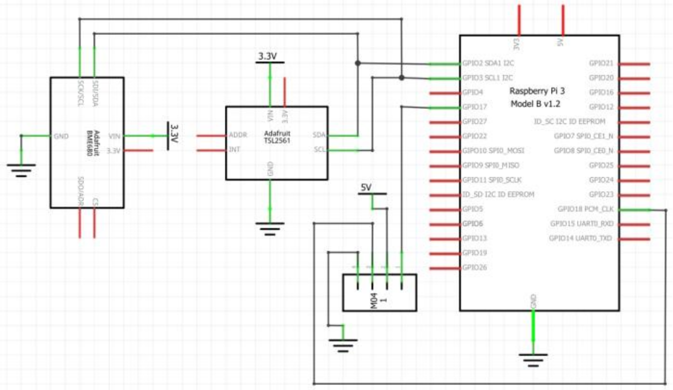

Figure 6: Schematic illustration of connecting the sensors

For the output, which controls the pump, and opens and closes the electric water valves, an RELC-8CH relay module has been used, which can be used up to 230[V] and 10[A], so virtually any type of magnetic switch can be connected to it. If our pump is below 1500[W] a more powerful magnetic switch is not necessary, and can be directly controlled through this. The relay is also optically isolated, which protects the controller in case of possible errors.

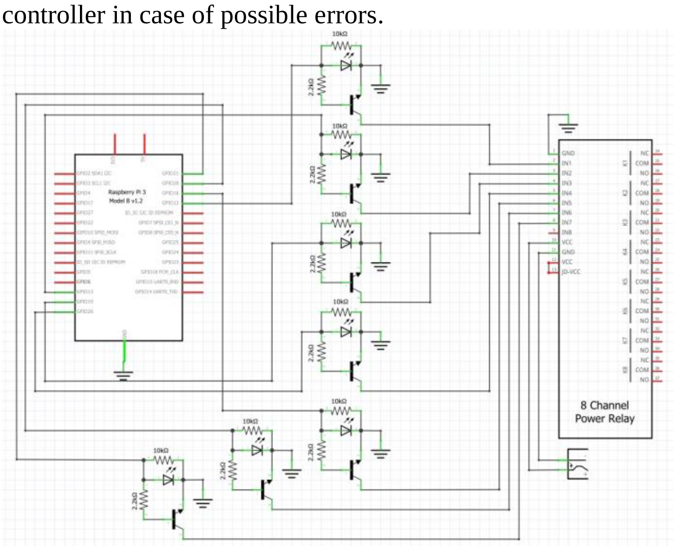

Figure 7: Schematic illustration of the relay's connections with LED feedback

The control switches are needed to allow us to easily turn it off without any additional devices. The control switches were put on this unit because this way it allows easy switching from automatic mode, and we can perform manual watering as well, if necessary.

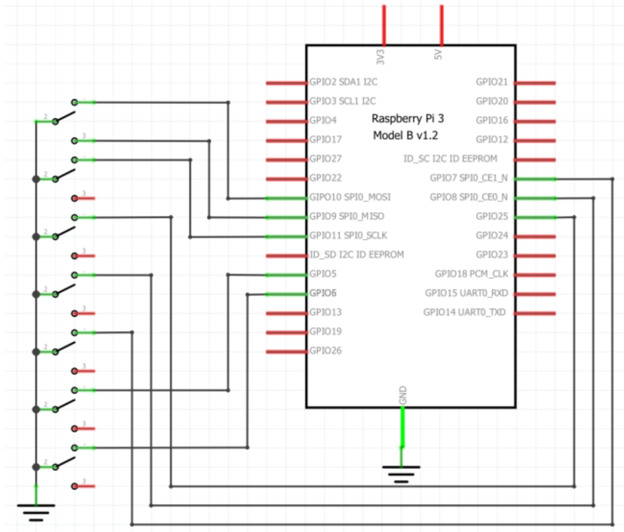

Figure 8: schematic illustration of connecting the control switches

After hooking it up the electronics were mounted in a water proof container that meets the ipv6 standard's requirements.

Figure 9: Meteorological station & irrigation system

VIII. Software background & GUI

The achieved target task's controlling program has been created in the version 9 of Raspbian PIXEL operating system, using version 3.5.3 of the Python programming language [17].

During the programming language's selection running in a simplified system, automatic memory management, widespread usability, and that most Linux programs are based on Python dominated.

The documentation of the program is also written in the subprogram, which creates a folder called 'adatok' (data), which contains the folder 'év' (year), which contains the folder 'hónap' (month) where the files marked with days and with (.txt) extensions are placed. The program inserts data one after another into the file as follows:

Hour:minute:second	[h:m:s]
Temperature	[°C]
Humidity	[%]
Pressure	[hPa]
Air resistance	[KOhm]
Illumination	[lux]
Wind direction	[compass points]

Wind direction	[°]
Wind speed	[km/h]

This data can be retrieved at any time, as long as the saved data is not deleted.

In the main program, after requesting and storing the data, the program decides, based on the entered parameters, how much water evaporated in the given hour, and based on this, the amount of water needed to be sprinkled.

The irrigation's scheduling is deleted for the day in case the soil dampness measuring sensor detects more than 5 mm rain. An Arduino UNO has been used to digitalize the values, since the sensor outputs analog signals [18]. The Arduino communicates with the Raspberry Pi with the help of the Pyfirmata program, through USB [19].

The user can enter the key parameters for the calculation through the graphical use interface (GUI). With the help of the graphical interface the data is easier and clearer to interpret, and the program's usage is easier.

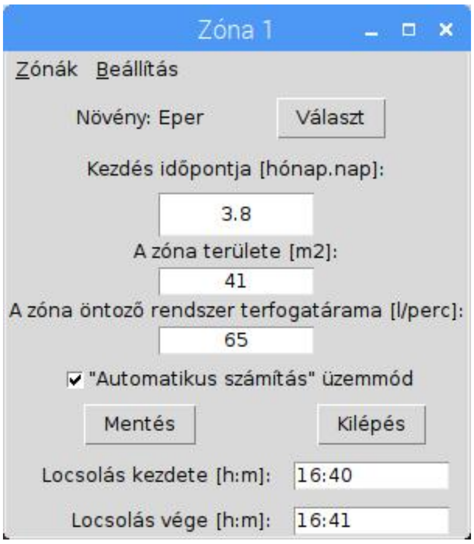

Figure 10: The interface of the GUI's main window

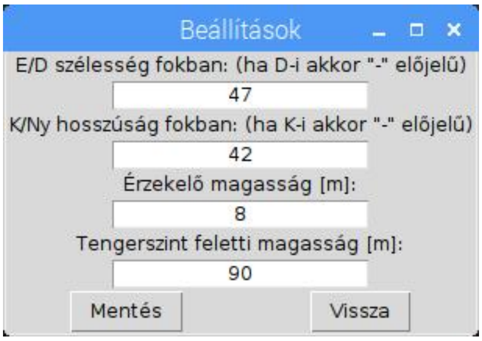

Figure 2: The interface of the GUI's settings

IX. Summary

The meteorological station's setting up, wiring, programming, remote control and monitoring has been implemented, which allows communication through IoT based networks using Linux distributions, meeting the main aspects of the IoT requirements.

From the aspect of accuracy I came to the conclusion that the sensors meet the authentication requirements too, which means that data can be sent to weather forecasting and displaying websites, thus helping the accuracy and preciseness of the weather forecasts.

Furthermore, the irrigation system provides an optimal amount of water for the given zone's section, thus preventing the deterioration of the area.

Nevertheless we can say the remote control and monitoring works in a stable, reliable and safe way. The mobile device provides the one performing the remote operation with mobility along with the supervision and programming of the device.

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XI. References

[1] „Raspberry Pi rövid áttekintése," [Online]. Available: https://malnapc.hu/raspberry-pi/verziok/. [Date of access: 14 11 2018].

[2] „Raspberry Pi 3 Model B 1GB RAM," [Online]. Available: https://malnapc.hu/wp-content/uploads/2015/06/raspberry_pi_3_model_b.jpg. [Date of access: 14 11 2018].

[3] „Raspbian," [Online]. Available: https://hu.wikipedia.org/wiki/Raspbian. [Date of access: 2 12 2018].

[4] „Ismertető a Debianról," [Online]. Available: https://www.debian.org/intro/about.hu.html. [Date of access: 14 11 2018].

[5] „BME680 kombinált környezeti paraméter érzékelő," [Online]. Available: https://www.ret.hu/ret/hirek/bme680-kombinalt-kornyezeti-parameter-erzekelo-308. [Date of access: 14 11 2018].

[6] „TSL2561 digitális fényerő / lux / fényérzékelő szenzor I2C interfésszel," [Online]. Available: https://www.rpibolt.hu/termek/tsl2561_digitalis_fenyero__lux__fenyerzekelo_szenzor_i2c_interfesszel.html. [Date of access: 14 11 2018].

[7] „La Crosse TX20 Anemometer Communication Protocol," [Online]. Available: https://www.john.geek.nz/2011/07/la-crosse-tx20-anemometer-communication-protocol/. [Date of access: 14 11 2018].

[8] „Crop Description and Climate," [Online]. Available: http://www.fao.org/land-water/databases-and-software/crop-information/cabbage/en/. [Date of access: 1 12 2018].

[9] „BME680 datasheet" [Online]. Available: https://cdn-shop.adafruit.com/product-files/3660/BME680.pdf [Date of access: 14 11 2018].

[10] „TX20 anemometer" [Online]. Available: https://www.amazon.com/Crosse-Technology-TX-23U-Weather-

Stations/dp/B0016MYA7U
[Date of access: 14 11 2018].

[11] „Ms Windows 7" [Online]. Available: https://www.microsoft.com/hu-hu/software-download/windows7
[Date of access: 14 11 2018].

[12] „Raspberry Pi - xrdp" [Online]. Available: https://www.datenreise.de/en/raspberry-pi-install-remote-desktop-xrdp/
[Date of access: 14 11 2018].

[13] „Internet Protocol" [Online]. Available: https://www.lifewire.com/internet-protocol-explained-3426713
[Date of access: 14 11 2018].

[14] „Open-Source" [Online]. Available: https://opensource.org/
[Date of access: 14 11 2018].

[15] „Raspberry Pi Os" [Online]. Available: https://www.raspberrypi.org/downloads/
[Date of access: 14 11 2018].

[16] „ABS" [Online]. Available: https://www.creativemechanisms.com/blog/everything-you-need-to-know-about-abs-plastic
[Date of access: 14 11 2018].

[17] „Phyton" [Online]. Available: https://www.python.org/
[Date of access: 14 11 2018].

[18] „Arduino UNO" [Online]. Available: https://store.arduino.cc/arduino-uno-rev3
[Date of access: 14 11 2018].

[19] „Pyfirmata" [Online]. Available: https://pypi.org/project/pyFirmata/
[Date of access: 14 11 2018].

[20] T. I. Erdei, Zs. Molnár, N. C. Obinna, G. Husi, „A Novel Design of an Augmented Reality Based Navigation System & its Industrial Applications," 15th IMEKO TC10 – Technical Diagnostics in Cyber-Physical Era Budapest, Hungary, 6 – 7 June, 2017 - Organised by: MTA SZTAKI – Hungarian Academy of Sciences - Institute for Computer Science and Control.

[21] N. C. Obinna, T. I. Erdei, Zs. Molnár, G. Husi, „LabVIEW Motion Planning and Tracking of an Industrial Robotic Manipulator (KUKA KR5 arc): Design, Modelling, and Simulating the Robot's Controller Unit," FMTÜ - XXII. International Scientific Conference of Young Engineers - Kolozsvár, 23-24.03.2017.