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Design and development of Practical Works for Remote Laboratories

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Abstract: *The paper present design and test of two architectures of practical works for remote laboratories using low-cost embedded systems. This practical works are destined to the 3rd year bachelor degree students on renewable energy and others on electronics. The first architecture is based on an Arduino microcontroller to control an irrigation system powered by photovoltaic panels. The second is based on a powerful mini PC, PcDuino, to control remotely a practical work of logic integrated circuits. These architectures can be generalized to others discipline. A simple interface is developed to allow students and instructors to access easily to this practical works. This approach of low-cost remote laboratories shows benefits in Moroccan universities, especially in open access faculties due to the huge number of registered students and the lack of rooms and materials.*

Keywords: *Remote labs; embedded systems; pcduino; remote practical works; e-learning;*

1. Introduction

The information and communication technologies have undergone remarkable development in recent years[1], [11], [12]. Web technologies and communication protocols play a crucial role for users to access shared resources on the net.

Remote laboratories, a new trend of these resources that are used in the field of education. Unlike hands-on practical works,Remote experiments allow students to manipulate via internet online Practical Work (PW) of which may be found anywhere in the world.

Because of the large number of registered students in Moroccan universities, and due to lack of staff, machinery room and saw the great importance of practical manipulations to strengthen the knowledge stores in courses, remote labs become a real need to overcome the problems of hands-on PW that can go up to its absence in the open-access faculties[3].

Our approach inspired project European EOLES [6], is based on the implementation of Practical Work low-cost integrated into remote labs based embedded systems to the multidisciplinary faculty of Beni Mellal.

In this paper, we propose two architectures of remote Practical Work, the first based on an Arduino board to control a solar irrigation system pumping integrating artificial intelligence whose results is discussed above. The 2nd based on a mini PC PcDuino to control a Practical Work of digital electronics.

Both of it are respectively used by the students of the 3rd year bachelor on renewable energy and electronics and industrial systems.

Several students could benefit from remote laboratories without occupying any space or damage any material.

The first practical work is developed to test the optimization of irrigation using solar pumping [5]. We test 2 ways of irrigation through nonlinear algorithms.

2. Renewable Energy Practical Work

2.1. Used architecture

In order to implement our concept we used a 3-tier architecture (client, server and irrigation system)(fig.1)

- Customer: the supervisor who can use a web browser to access a java application (java applet) to control pumps and solenoid valves and supervised the data remotely and in real time.
- Server: it stores the data comes from the embedded system in a database, then through two

controllers (Fuzzy Logic (FL) and Artificial Neural Network (ANN)) processes said data for decision support, and real-time sending data to the web browser.

- Irrigation system: it is the heart of our system, which is based on an Arduino board with the Ethernet Shield connected to the Internet. It is connected to three sensors (humidity, humidity soil and temperature), two solenoid valves and a pump via a relay module. The system is powered by a solar panel.

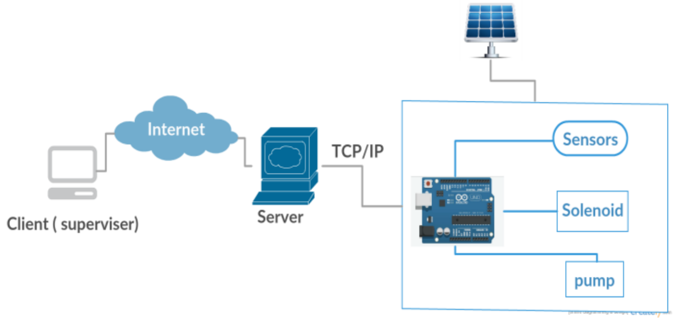

Fig. 1.General architecture

2.2. Hardware implementation

We used Arduino Uno card to process the commands and data acquisition from the sensors. The Arduino is connected to the server through the Ethernet Shield module that has an RJ45 port. DHT100 the sensor measures the temperature and humidity and the value is converted in Arduino by the analog to digital conversion module. The SEN0114 sensor measures soil moisture. In our prototype we used two sensors to make the comparison between the two decision algorithms late. The LCD displays different data should acquire by the sensors. The Arduino receives the commands of the server using our java application to control the pump and 2 solenoid valves during manual use of our system(Fig.2).

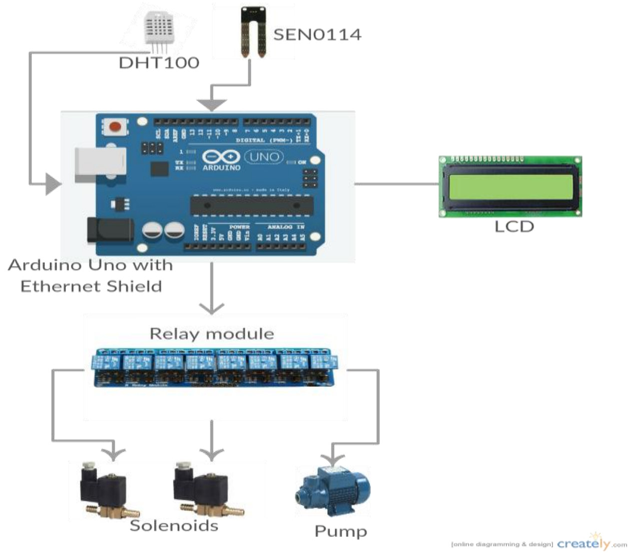

Fig.2.hardware electrical schema

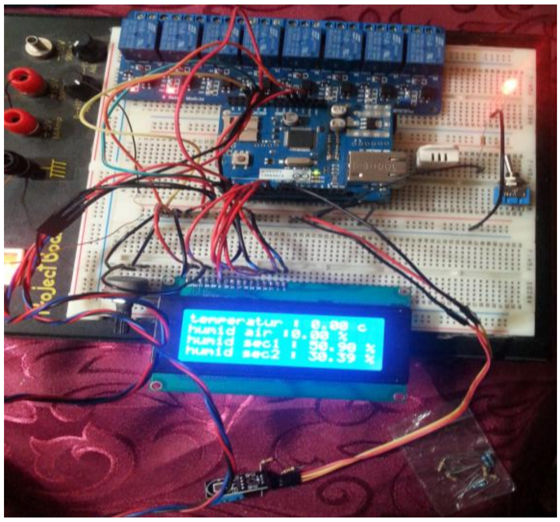

Fig.3.Hardware electrical schema

2.3. Software and algorithms

2.3.1. Irrigation control interface

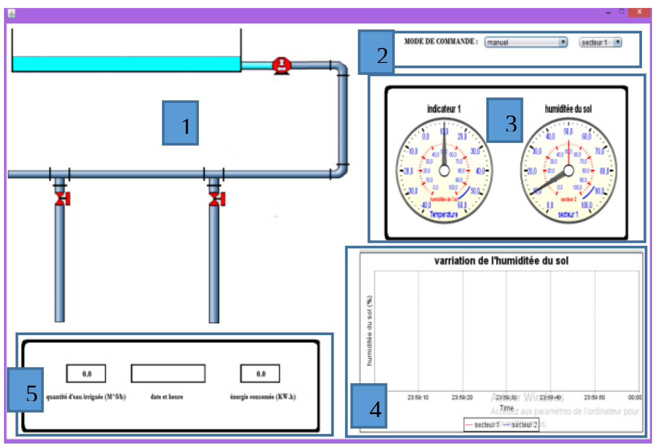

Fig.4. User interface

This window can be separated into 5 zones explained as follows:

- The first zone (1) contains an interface to control a pump and two solenoid valves in case of control mode is manual. If using other work mode it displays the state of the pump and solenoid valves.
- This area (2) allows the user to irrigate the area 1 or 2 by choosing the control mode (manual, fuzzy logic controller, controller RNA, regulation).
- Zone (3) contains two double needle indicators that display the temperature, air humidity and soil moisture of sector 1 and 2.
- For the area (4) it is used to trace the variation of the humidity of the areas based on real time.
- The last zone (5) is constituted by two counters, the first calculates the amount of irrigated water and the second makes it possible to count the energy consumed by the pump.

In this practical work student control a pump remotely and manually and they get as feedback, voltage, current produced by the solar panel and some measure of sol humidity, temperature and air humidity to take decision of irrigation.
We develop this concept to command automatically this installation and allow students to compare between their manually application and the automatic ones.

2.3.2.Fuzzy logic

The main function of this system is to manage irrigation and decide how much water irrigated depending on the soil moisture, humidity of air and temperature. It was therefore decided to retain the following variables:

2.3.2.1. Input variables

- Soil moisture:

The first input was chosen by three qualify crowds subsets (dry, average and wet) defined as (fig.5):
Dry:

$$\begin{cases} \mu_{dry}(x) = \frac{-1}{30}x + 1 & for\, x \le 30 \\ \mu_{dry}(x) = 0 & for\, x > 30 \\ with\ \mu_{dry}(x) \in [0,1] \end{cases} \tag{1}$$

Average:

$$\begin{cases} \mu_{average}(x) = 0 & for\ x < 20 \\ \mu_{average}(x) = \frac{1}{30}x - \frac{2}{3} & for\ 20 \le x < 50 \\ \mu_{average}(x) = \frac{-1}{30}x + \frac{8}{3} & for\ 50 \le x < 80 \\ \mu_{average}(x) = 0 & for\ 80 \le x < 100 \\ with\ \mu_{average}(x) \in [0,1] \end{cases} \tag{2}$$

Wet:

$$\begin{cases} \mu_{wet}(x) = 0 \, for\, x < 70 \\ \mu_{wet}(x) = \frac{1}{30}x - \frac{7}{3} for\, x \ge 70 \end{cases} \tag{3}$$

$$with\ \mu_{wet}(x) \in [0,1]$$

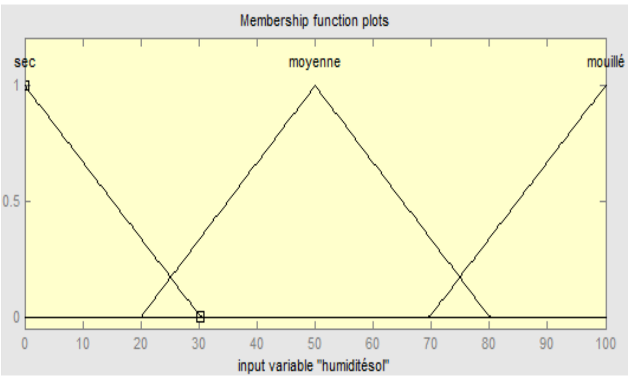

Fig.5. Membership function of soil moisture

- Atmospheric humidity :

Air humidity is treated as soil moisture: three subsets fuzzy (low, medium and high) (fig.6):

Low:

$$\begin{cases} \mu_{\text{low}}(x) = \frac{-1}{30}x + 1 & for\ \ x \leq 30 \\ \mu_{\text{low}}(x) = 0 & for\ \ x > 30 \end{cases} \qquad (4)$$
$$with\ \ \mu_{\text{low}}(x) \in [0,1]$$

Medium:

$$\begin{cases} \mu_{\text{medium}}(x) = 0 & for\ x < 20 \\ \mu_{\text{medium}}(x) = \frac{1}{30}x - \frac{2}{3} & for\ 20 \leq x < 50 \\ \mu_{\text{medium}}(x) = \frac{-1}{30}x + \frac{8}{3} & for\ 50 \leq x < 80 \\ \mu_{\text{medium}}(x) = 0 & for\ 80 \leq x < 100 \end{cases} \qquad (5)$$
$$with\ \mu_{\text{medium}}(x) \in [0,1]$$

High:

$$\begin{cases} \mu_{\text{high}}(x) = 0 & for\ x < 70 \\ \mu_{\text{high}}(x) = \frac{1}{30}x - \frac{7}{3} & for\ \ x \geq 70 \\ with\ \mu_{\text{high}}(x) \in [0,1] \end{cases} \qquad (6)$$

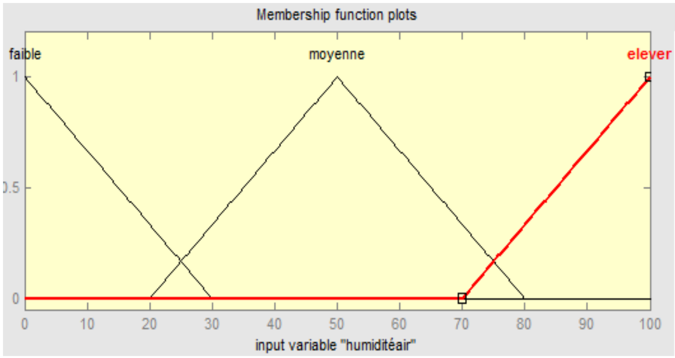

Fig.6. Membership function of air moisture

- Temperature :

The variable temperature consists of three fuzzy sets: cool, normal, warm (fig.7):

Cool:

$$\begin{cases} \mu_{\text{cool}}(x) = \frac{-1}{35}x + \frac{3}{7} & for\ x \leq 15 \\ \mu_{\text{cool}}(x) = 0 & for\ \ x > 15 \\ with\ \mu_{\text{cool}}(x) \in [0,1] \end{cases} \qquad (7)$$

Normal:

$$\begin{cases} \mu_{\text{normal}}(x) = 0 & forx < 10 \\ \mu_{\text{normal}}(x) = \frac{1}{15}x - \frac{2}{3} & for10 \leq x < 25 \\ \mu_{\text{normal}}(x) = \frac{-1}{15}x + \frac{8}{3} & for25 \leq x < 40 \\ \mu_{\text{normal}}(x) = 0 & for40 \leq x < 50 \end{cases} \qquad (8)$$
$$with\ \mu_{\text{normal}}(x) \in [0,1]$$

Warm:

$$\begin{cases} \mu_{\text{warm}}(x) = 0 & for\ x \leq 30 \\ \mu_{\text{warm}}(x) = \frac{1}{20}x - \frac{3}{2} & for\ \ x > 30 \\ with\ \mu_{\text{warm}}(x) \in [0,1] \end{cases} \qquad (9)$$

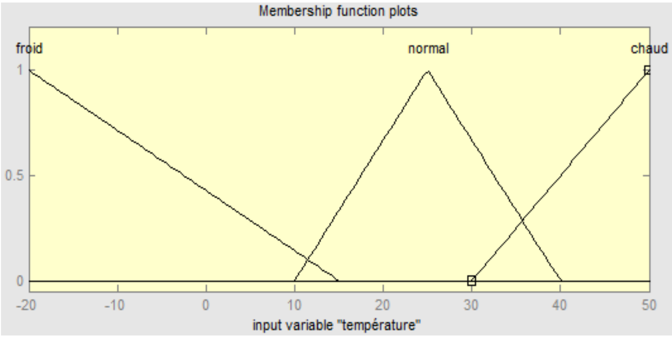

Fig.7. Membership function of the variable temperature

2.3.2.2. Outputvariables:

For the variable of the output it is mobilized as follows (fig.8):

Little:

$$\begin{cases} \mu_{\text{little}}(x) = \frac{-1}{35}x + 1 & for\ x \leq 35 \\ \mu_{\text{litle}}(x) = 0 & for\ \ x > 35 \\ with\ \mu_{\text{littlr}}(x) \in [0,1] \end{cases} \qquad (10)$$

Average:

$$\begin{cases} \mu_{\text{average}}(x) = 0 & for\ x < 20 \\ \mu_{\text{average}}(x) = \frac{1}{25}x - \frac{4}{5} & for\ 20 \leq x < 45 \\ \mu_{\text{average}}(x) = \frac{-1}{25}x + \frac{14}{5} & for\ 45 \leq x < 70 \\ \mu_{\text{average}}(x) = 0 & for\ 70 \leq x < 96 \end{cases} \qquad (11)$$
$$with\ \mu_{\text{average}}(x) \in [0,1]$$

Big:

$$\begin{cases} \mu_{\text{big}}(x) = 0 & for\ x \leq 30 \\ \mu_{\text{big}}(x) = \frac{1}{46}x - \frac{25}{23} & for\ \ x > 30 \\ with\ \mu_{\text{big}}(x) \in [0,1] \end{cases} \qquad (12)$$

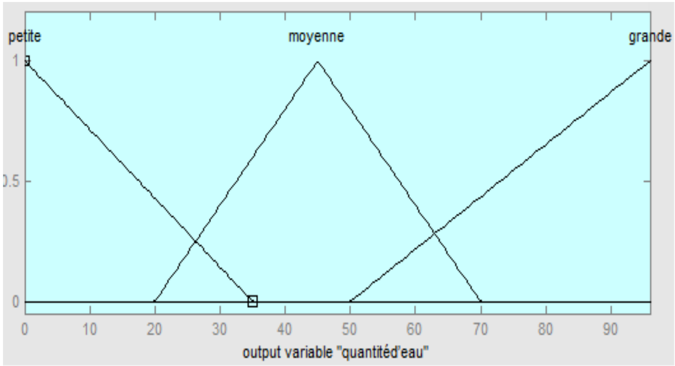

Fig.8. Membership function of the output variable

2.3.3.ANN controller

The irrigation system explained herein feat by a closed control loop. The control unit continuously receives feedback from various sensors on the ground [4].

The control unit decides is what we will or not to irrigate based on data from sensors and preset parameters (soil type, nature of the plant, number of the day in the year ...)

2.3.4.ANN Controller architecture:

This is a model for the irrigation system using the ANN
(Artificial Neural Network).

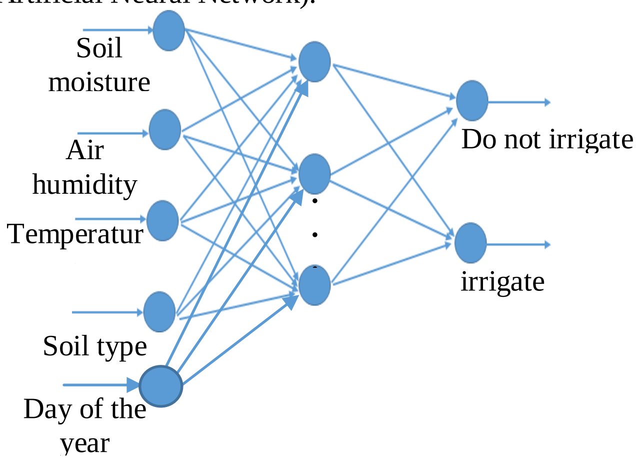

Fig.9. Modeling of the irrigation system

ANN Controller is implemented using the following:

- **Topology:** Distributed Time Delay Neural Network is used.
- **Training Function:** Bayesian Regulation function is used for training.
- **Performance:** Sum squared error is taken as performance measure.
- **Goal:** The set goal is 0.0001.
- **Learning Rate:** The learning rate is set to 0.05

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2.4. Experimental Result

2.4.1. Fuzzy rules

To fix fuzzy rules we try many combinations of the input parameters to find the most optimized output has our system [7].

The table below summarizes all rules and logical relationships between the sub- functions of input and output.

Table 1.rules and logical relationships between the sub- functions of input and output.

If Soil moisture =	And Air humidity=	And Temperature =	then amount of water =
Dry	Low	Cool	Average
Dry	Low	Normal	Big
Dry	Low	Warm	Big
Dry	Medium	Cool	Average
Dry	Medium	Normal	Average
Dry	Medium	Warm	Big
Dry	High	Cool	Little
Dry	High	Normal	Average
Dry	High	Warm	Average
Average	Low	Cool	Little
Average	Low	Normal	Little
Average	Low	Warm	Average
Average	Medium	Cool	Little
Average	Medium	Normal	Little
Average	Medium	Warm	Average
Average	High	Cool	Little
Average	High	Normal	Little
Average	High	Warm	Little
Average	Low	Cool	Little
Wet	Low	Normal	Little
Wet	Low	Warm	Little
Wet	Medium	Cool	Little

Wet	Medium	Normal	Little
Wet	Medium	Warm	Little
Wet	High	Cool	Little
Wet	High	Normal	Little
Wet	High	Warm	Little

2.4.2.Comparison between the two controllers

An experiment was carried out to compare between our controllers at quantity of irrigated water and have an idea on economization provided by these two algorithms.

We chose to plant two rows of the pumpkin the first line is irrigated using the fuzzy logic controller and the second line with the ANN controller. Experience has unrolled for 11 days, for each 24 calculates the quantity of water for each controller based on the output of the pump and the irrigation time.
Pump flow rate = 0.3 L/min.
Number of plants per line = 3.
Irrigated area = 1800 mm^3

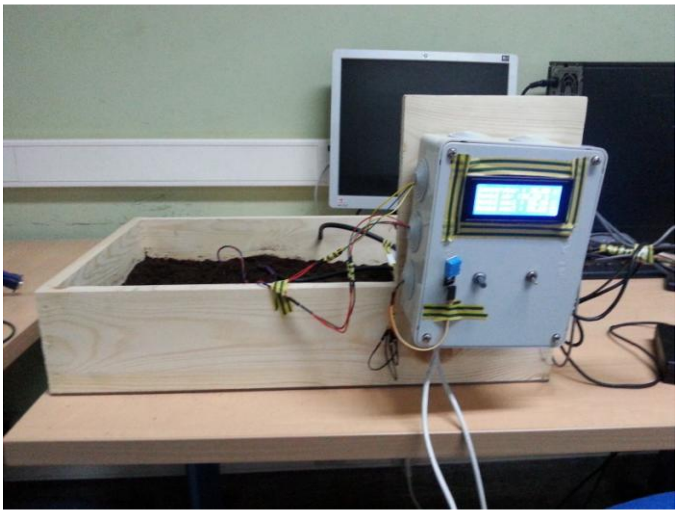

Fig.10. Final prototype

Note in Figure 11 ANN controller uses an average of 0.68L / day unless the fuzzy logic controller using 0.83L / Days.

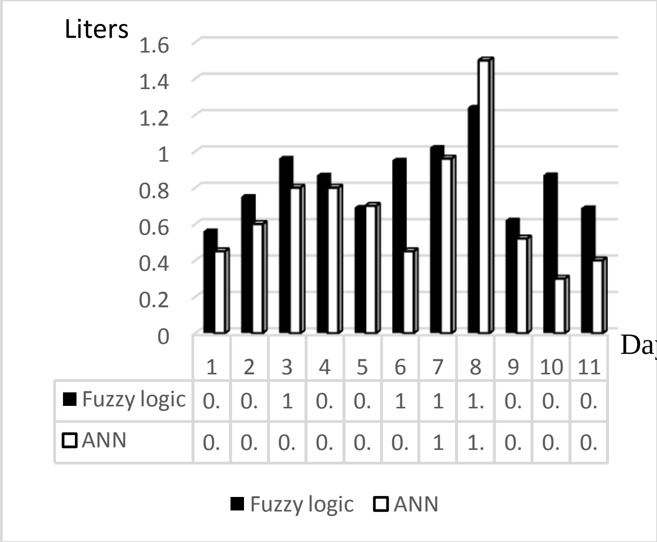

Fig.11. Comparison between the controllers at the amount of water irrigated

It was assumed that for manual mode that irrigates one liter of water per day. Figure 11 shows that the fuzzy logic controller input irrigated water reduction of 16.08% compared to manual mode and ANN controller 32%.

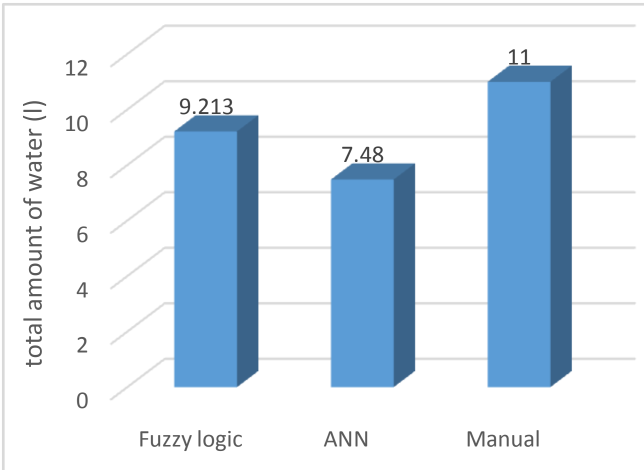

Fig.12. Total irrigation water quantity for each controller

Certainly our system requires a lot of improvement in order to adapt to the real environment; among these modification: the achievement of a wireless acquisition card that contains our entire sensor to the duplicated on the entire field to have the maximum information on the state of the environment [8], [9].

Finally the results of our system encourages us to continue to help farmers and encourage them to use green energies for maximize their income. Our next focus will be on implementation and calibration of the system in a fruit tree field to validate our prototype [10].

3. DIGITAL ELECTRONIC PRACTICAL WORK

3.1. Implemented Architecture

The design is based on a client-server architecture using open source software and low-cost embedded systems that allow the student,instructor or manager to access remotely to the practical work (Fig.13).

The server part is equipped using PcDuino v3 board. It provides for the user a full environment for development based on embedded Linux as operating system.
The pcDuino is connected to the Internet through integrated Wi-Fi. This architecture usesmore less peripherals and sophisticated materials.

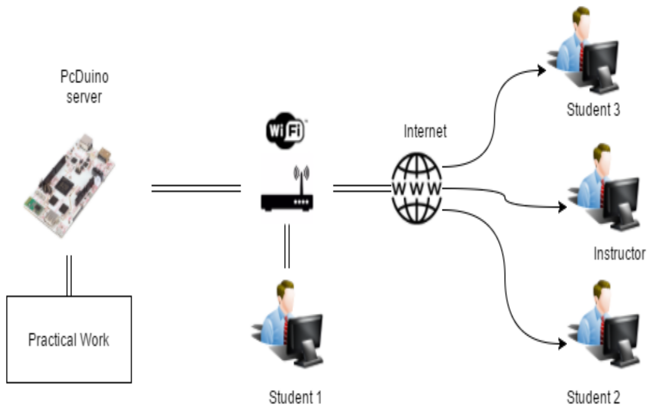

Fig.13. General used architecture

3.2. Hardware Description

The principal hardware used in this architecture is the PcDuino v3 that is a high performance board computer[13]. It runs operating systems such as Linux. PcDuino3 has several outputs and inputs:

- HDMI: interface to show the graphic desktop screen.
- Ethernet: to connect to the internet through RJ45 cable.
- Wi-Fi
- Audio out
- LCD : with a LVDS connector
- IR receiver : receive infra-red signals
- Camera : CSI
- SATA host socket to connect it to external hard drive.
- USB: 1 USB host and 1 USB OTG.
- Power: 5V and 2A.
- Arduino Headers : The PcDuino3 is 100% compatible with original Arduino shield and has the same pin :
- 14 GPIO : General Purpose In/Out Digital pins
  - 6 Analog Inputs connected to an ADC (Analog to Digital Converter) module.
  - 2 PWM : Pulse Width Modulation
  - 1 UART , 1 SPI and 1 I2C

Also, Pcduino3 has a CPU AllWinner A20 1GHz ARM cortex, a DRAM with 1GB and a Onboard storage 4GB flash.

3.3. Practical work description

In this Practical Works destined to the 3rd year bachelor class of Electronics, students achieve and familiarized with integrated logic circuit such as AND, NAND and NO (Fig.14).

They command the Input ports of the logic gate in order to get the truth table of each of them, also, they measure the voltage and current of LOW and HIGH state in the output using the ADC of PcDuino.

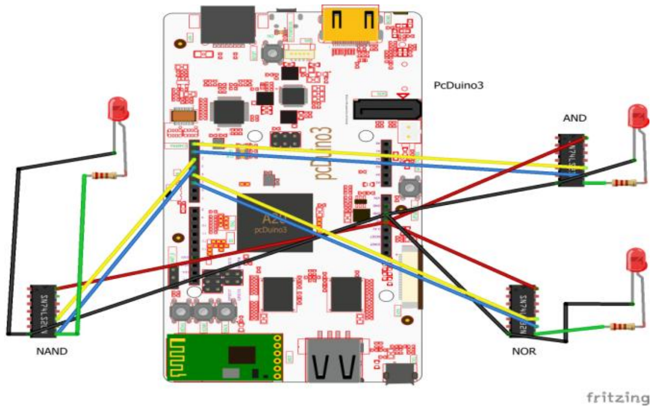

Fig.14. Electronic schema of the experimentation

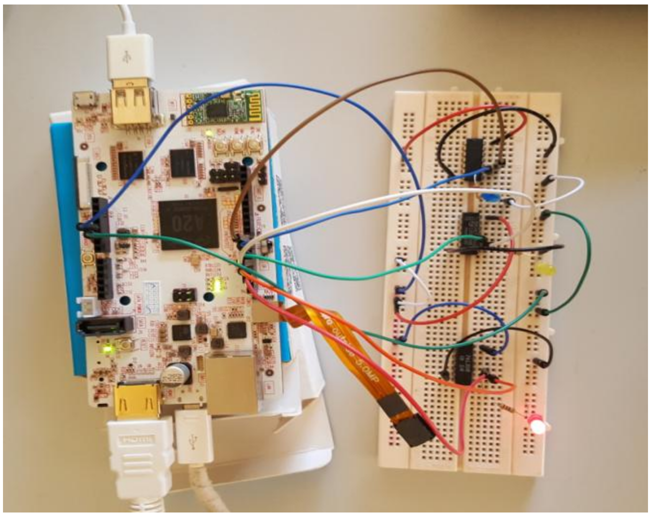

Fig.15. Hardware of the practical work

3.4. Software description

The development environment is based on python programming language

3.4.1.Python programming language

We used python as script to communication with the GPIO and system files of PcDuino. Python provides a huge number of scientific libraries that make of it a robust server programming language.

To facilitate the execution of functions related Pcduino we use an open source project PyDuino [13] to code programs using this library to send and get orders to and from GPIO, file system and multimedia.

3.4.2.PyQT4

In order to develop our interface we chose Pyqt4, a design language based on python. In the first step we design the window interface using Qt designer tool, after we get a python file.

We will have 2 files :

- PwMain.py : contains the main code to communicate with GPIO and import the design code from the second file.
- Pw.py : contains the design code.

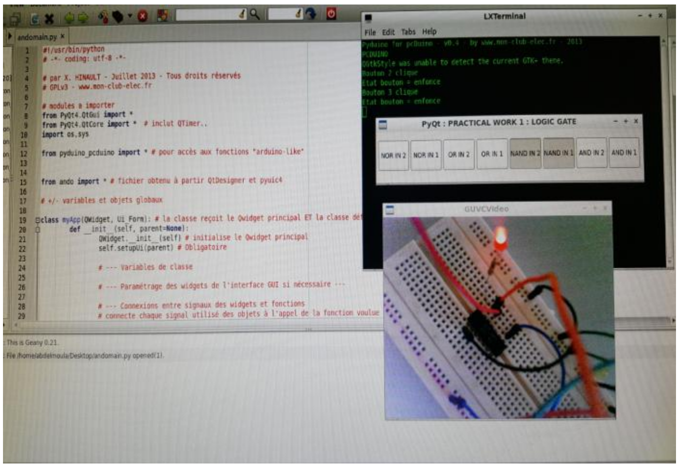

Fig.16. User interface

The Figure 16 shows the Qt application, part of the code and live video from the installed webcam module with pcDuino.

This work is also in progress and under test, for this reason we use Virtual Network Connect (VNC) to connect to the PcDuino for executing the PW.

4. CONCLUSION

This work was done as a solutionto the real need for theteaching of practical work, especially in the open-access

Faculties. In this work, we proposed two practical works in renewable energy and electronic 3rd year bachelor classes. The approach was to use low-cost, high performance embedded systems as PcDuino and using free open source tools. Student uses VNC to connect to the practical work. We develop the first manipulation to show that the system is extensible to industrial use.

In this paper we built a smart irrigation system used as remote practical work for bachelor on renewable energy that is based on two closed loop controllers, the inputs of the first fuzzy logic controller is temperature, soil moisture and air humidity and the output is the amount of water to be irrigated, this denier has given satisfactory results because the use of water devoid of 16.08%. The second controller is based on the algorithms of the latter neural networks inputs such as temperature, soil moisture, air humidity, soil type and day of the year; the output is the decision to start irrigation or not irrigated, the results obtained by this controller are very satisfactory as it saves water consumption to 32%.

The second work in progress is a remote practical work for electronic bachelor. its objective is to manipulate the logic gate and get the truth table and measure physical quantities.

References

[1] J. García-Zubía, I. Angulo, L. Rodríguez-Gil, P. Orduna and O. Dziabenko, "Boole-WebLab-Deusto: Integration of a remote lab in a tool for digital circuits design," *2013 IEEE Frontiers in Education Conference (FIE)*, Oklahoma City, OK, 2013, pp. 848-854. doi: 10.1109/FIE.2013.6684945.

[2] AbdessamadMalaoui, Kamal Quotb, Khalid Auhmani, Mohamed Ankrim, Mohamed Benhayoun, "An accurate electronic device for ultrasonic measurements using a microcontroller". IEEE International Conference on Industrial Technology, Vol.3, pp. 1432-1437, December 2004.

[3] MalaouiAbdessamad. "Low cost pedagogic device for Practical Works using embedded system". 12th ACS/IEEE International Conference on Computer Systems and Applications (AICCSA'2015), November 2015. unpublished.

[4] Ioslovich, I., P. Gut man and I. Seginer, 2006. A non linear optimal greenhouse control problem with heating and ventilation. Optimal Control Applications and Met hods, 17: 157-169.

[5] AbdessamadMalaoui, "Implementation and tests of an automatic system to improve electrical energy in photovoltaic installations," International Journal of Innovation and Applied Studies, vol. 8, no. 1, pp. 328–340, September 2014.

[6] Gericota, M. ; Barataud, D. ; Andrieu, G. ; De Craemer, R. ; Cristea, M.; Benachenhou, A. ; Ankrim, M. ; Bouchlaghem, K. ; Ferreira, P. "The EOLES project remote labs across the Mediterranean", 11th International Conference on Remote Engineering and Virtual Instrumentation (REV) . pp.211 – 216, 2014.

[7] AbdessamadMalaoui, Mohamed Ankrim, Kamal Quotb, Mohamed AbderrahimFichouch. "Modelling and realization of a programmable thermic regulator using fuzzy logic algorithm: comparison with PI Controller". *Association for the Advancement of Modelling & Simulation Techniques in Entreprises (A.M.S.E) Journal*, Vol.64, N°1-2, 2009.

[8] G.Vellidis, M.Tucker,C.Perry, C.Kvien, C.Bednarz, A real-time wireless smart sensor array for scheduling irrigation, computers and electronics in agriculture 61(2008)44–50.

[9] Vories, E.D., Glover, R.E., Bryant, K.J., Tacker, P.L., 2003. Estimating the cost of delaying irrigation for mid-south cotton on clay soil. In: Proceedings of the 2003 Belt wide Cotton Conference National Cotton Council, Memphis, TN, USA, pp. 656–661.

[10] A. Kobry, A. Eliamani. L'irrigation localisée dans les périmètres de grande hydraulique, atouts et contraintes dans le périmètre du Tadla au Maroc. Ali Hammani, Marcel Kuper, AbdelhafidDebbarh. Séminaire sur la modernisation de l'agriculture irriguée, 2004, Rabat, Morocco. IAV Hassan II, 11 p.

[11] C. A. Matarrita and S. Beatriz Concari, "Remote laboratories used in physics teaching: A state of the art," *2016 13th International Conference on Remote Engineering and Virtual Instrumentation (REV)*, Madrid, 2016, pp. 385-390.

[12] Luís Gomes, Seta Bogosyan,"Current Trends in Remote Laboratories", *IEEE TRANSACTIONS ON INDUSTRIAL ELECTRONICS*, VOL. 56, NO. 12, DECEMBER 2009.

[13] www.mon-club-elec.com