Using Raspberry Pi Computers in Education

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Abstract - This paper describes the ideas of using Raspberry Pi computers in high schools and higher education. Raspberry Pi is a powerful computer in a size of a credit card. It was created by the Raspberry Pi Foundation charity, whose primary goal was the re-introduction of computer skills learning among students. The Raspbian operating system is based on Linux and offers an excellent working environment for students, as it includes software solutions designed to expand students' knowledge of computer science in an interesting way. Besides computer science knowledge, it is also suitable for acquiring basic knowledge in electronics. It is also very important to have the possibility of interconnecting such acquired knowledge. Our students have adopted the knowledge how to install and use the Raspbian operating system, how to network and connect to the Internet, how to write programs using the Python programming language, and how to develop hardware-based projects. From our own experience in Raspberry Pi we can conclude that this is an ideal platform for students to acquire new knowledge and competences in the field of computer science and electronics.

Keywords - Raspberry Pi; Education; Raspbian; Python

I. INTRODUCTION

The Raspberry Pi is a brand of tiny single-board computers developed by the United Kingdom. It was originally designed as an educational tool for promoting teaching of basic computer science in schools. However, it quickly became very popular as a cheap general purpose computer without any peripherals. Nevertheless, there are various official and unofficial accessories available [1].

Raspberry Pi organisation is divided into Raspberry Pi Trading that develops the technology, and the Raspberry Pi Foundation - an educational charity that promotes computer science teaching and learning, especially in the developing countries.

Five million units of Raspberry Pi computers were sold by 2015, making it the best selling British computer. In March 2018 the cumulative sales of Raspberry Pi reached 19 million units and it became one of the best selling general purpose computers worldwide [1].

II. RASPBERRY PI HARDWARE IN TEACHING

Why do we choose Raspberry Pi and not the Arduino platform for out teaching purposes? Raspberry Pi is a complete functional mini computer, while Arduino is basically a microcontroller. There are also several other reasons. Using RPI students can familiarize themselves with Linux OS, they have the ability to program in Python, and they still can control the world the same as with microcontroller in Arduino platform.

For our teaching purposes we have chosen Raspberry Pi 3 B, as it is the latest iteration of the world’s most popular single board computer. The biggest change that has been enacted with the Raspberry Pi 3 B is an upgrade to a next generation main processor and improved connectivity with Bluetooth Low Energy (BLE) and Wi-Fi on board. Additionally, the Raspberry Pi 3 has improved power management, with an upgraded switched power source up to 2.5 A, to support more powerful external USB devices. Also, the performance of the Pi 3 is roughly 50-60% faster than the Pi 2 which means it is ten times faster than the original Pi [2].

Built specifically for the new Raspberry Pi 3 B, the Broadcom BCM2837 system-on-chip (SoC) includes four high-performance ARM Cortex-A53 processing cores running at 1.2GHz with 32kB Level 1 and 512kB Level 2 cache memory, a VideoCore IV graphics processor, and is linked to a 1GB LPDDR2 memory module on the rear of the board.

The Raspberry Pi 3’s four built-in USB ports provide enough connectivity for a mouse, keyboard, or anything else we need for our teaching purposes, and if it is not enough we can still use a USB hub. Powering the Raspberry Pi 3 is easy, just plug any USB power supply into the micro-USB port [3].

The Raspberry Pi 3 B features the same 40-pin General-Purpose Input-Output (GPIO) as previous versions. It offers several standards of serial communication: UART (Universal Asynchronous Receiver / Transmitter), SPS (Serial Peripheral Interface) and I2C Interface (Integrated Circuit) and the ability to control each of the eight GPIO
pins that can be programmed as inputs or outputs (for sensors, relays and other non-standard peripherals), the feature is very important for our teaching purposes.

There’s no need to connect an external antenna to the Raspberry Pi 3 B. Its radios are connected to this chip antenna soldered directly to the board, in order to keep the size of the device to a minimum. Despite its diminutive stature, this antenna is more than capable of picking up wireless LAN and Bluetooth signals – even through walls, that was important issue for our school, which has wireless LAN installed on all floors.

III. RASPBERRY PI SOFTWARE IN TEACHING

It is recommended to install Raspbian operating system on Raspberry Pi. Raspbian is a free operating system based on Debian distribution of Linux and optimized for the Raspberry Pi hardware. An operating system is the set of basic programs and utilities that make Raspberry Pi run. However, Raspbian provides more than just an OS: it comes with over 35,000 packages, pre-compiled software bundled in a nice format for easy installation on Raspberry Pi [4].

The initial build of over 35,000 Raspbian packages, optimized for best performance on the Raspberry Pi, was completed in June of 2012. However, Raspbian is still under active development with an emphasis on improving the stability and performance of as many Debian packages as possible. Raspbian is not affiliated with the Raspberry Pi Foundation. Raspbian was created by a small, dedicated team of developers (mainly Mike Thompson and Peter Green) that are fans of the Raspberry Pi hardware, the educational goals of the Raspberry Pi Foundation and, of course, the Debian Project.

There are several versions of Raspbian including Raspbian Stretch and Raspbian Jessie. Since 2015 it has been officially provided by the Raspberry Pi Foundation as the primary operating system for the family of Raspberry Pi single-board computers. Raspbian OS is highly optimized for the Raspberry Pi ARM CPUs [5].

Raspbian Stretch uses PIXEL, Pi Improved X-Window Environment, Lightweight as it’s main desktop environment as of the latest update. It is composed of a modified LXDE desktop environment and the Openbox stacking window manager with a new theme and few other changes [6].

The distribution is shipped with a copy of computer algebra program Mathematica and as well as a lightweight version of Chromium as of the latest version.

Raspberry Pi 3 also supports many other operating systems such as Ubuntu Mate, Windows 10 IoT Core or Android Things. For our teaching purposes we have chosen Raspbian Stretch (Debian 9) version as it suits best to our teaching requirements. Debian 9 distribution is very simple, so it’s an excellent choice for our teaching with Raspberry Pi.

IV. APPLICATION OF RASPBERRY PI IN THE FIRST TECHNICAL SCHOOL TESLA

Raspberry Pi 3 computers are used at laboratory exercise course at the First Technical School Tesla, Zagreb, Croatia, in the fourth grade in the electrical and computer technicians program. Laboratory exercises are organized in small groups of students (maximum 10 students) so that every week one part of the class comes to the Laboratory for 3 school hours. There are a total of 9 exercises devoted to the Raspberry Pi 3 B computer. They are divided into two main parts. The first part refers to getting started with Raspberry Pi 3 B computer and to become familiar with its design, its hardware components and also the Raspbian operating system. In the second part of this laboratory exercises students do some practical electronic projects. They combine various electronic components and write code in the Python programming language to control them [7] [8] [9].

Here is a brief description of these laboratory exercises:

A. Lab. 1: Introduction to Raspberry Pi 3 single board computer

B. Students get acquainted with all of the Raspberry Pi 3 hardware components, especially details of the GPIO connector (functions and pinout).

C. Lab. 2: Install Raspbian Stretch OS

Students learn how to download the right version of Raspbian from Internet and install it on SD card. They learn and understand the characteristics of the Raspbian operating system and modify some settings. They master different Raspbian interfaces.

Figure 1. Instaling OS on Raspberry Pi
From "www.raspberrypi.org/downloads/raspbian/" students download the Raspbian operating system and they install Raspbian on a microSD card that will be used by Raspberry Pi.

After downloading the file containing Raspbian OS students have to unpack it, and then set the operating system to the memory card. First they format the card appropriately with the use of SD Formatter.

After unpacking the Raspbian OS students get an .img file that contains the operating system. To install the operating system on the card students use Win32 Disk Imager.

Now students are ready to run the Raspberry Pi device, insert a micro SD card into the card slot, the keyboard and mouse plug into the USB ports, and the monitor to the HDMI port.

D. Lab 3: Working in Raspbian OS and the GNU nano

Students learn to apply basic Raspbian commands, adopt the function of GNU nano text editor and apply basic commands in the GNU nano text editor.

-E Students learn how to get help with Linux Commands, how to work with directories and files and how to change the user rights.

E. Lab 4: Connecting Raspberry Pi 3 and remote computer

Students are introduced to different protocols and connecting programs. Students master different protocols and programs for connecting and working on a remote computer.

- Students connect Raspberry Pi to the network and they dont know exactly which IP address the Raspberry Pi will get. Raspberry Pis network name is set to "raspberry pi" by default. So, after students connect Raspberry Pi to the network, they try to ping it over the network name with "ping raspberrypi". In our laboratory students find out the IP address and it reads 192.168.178.26.

- After students have managed to find out the IP address they can start connecting to Raspberry Pi via SSH protocol. On our laboratory computer students use the Windows 10 operating system, and Windows systems do not have a built-in SSH client. That's why we use Putty, a free SSH client that students download from http://www.putty.org/.

F. Lab 5: Controlling Light Emitting Diodes (LED) with Raspberry Pi 3

Students learn how to write the code in Python to control LEDs on output pins of the GPIO connector. They learn how to connect the electronic elements according to the given scheme.

Example of the code:
```python
#!/usr/bin/python
from time import sleep # import the time function from the sleep library
import RPi.GPIO as GPIO # import our GPIO library
GPIO.setmode(GPIO.BCM) # set the board numbering system to BCM
# setup our output pins
GPIO.setup(17,GPIO.OUT)
GPIO.setup(27,GPIO.OUT)
# Turn LEDs on
print "lights on"
GPIO.output(17,GPIO.HIGH)
GPIO.output(27,GPIO.HIGH)
sleep(1) # sleep for 1 second
# Turn LEDs off
print "lights off"
GPIO.output(17,GPIO.LOW)
GPIO.output(27,GPIO.LOW)
sleep(1)
# Turn LEDs on
GPIO.output(17,GPIO.HIGH)
GPIO.output(27,GPIO.HIGH)
sleep(1)
# Turn LEDs off
print "lights off"
GPIO.output(17,GPIO.LOW)
GPIO.output(27,GPIO.LOW)
GPIO.cleanup()
```

G. Lab 6: Controlling the servomotor with Raspberry Pi 3

Students learn how to write the code in Python to control the power-operated servomotor SG90 on output pins of the GPIO connector. They also learn how to connect the
power-operated servo motor SG90 according to the given scheme.

Students control the servomotor by sending the PWM signal over the control wire. It is one of the PWM pins on Raspberry Pi. Depending on the length of the impulse the rotor rotates to the desired position. SG90, as well as most servomotors, has a 90 degree rotation in both directions, total 180 degrees.

**Example of the code:**

```python
import RPi.GPIO as GPIO
import time

GPIO.setmode(GPIO.BOARD)
GPIO.setup(12, GPIO.OUT)
p = GPIO.PWM(12, 50)
p.start(7.5)

try:
    while True:
        p.ChangeDutyCycle(7.5)#turn towards 90 degree
time.sleep(1) # sleep 1 second
        p.ChangeDutyCycle(2.5)# turn towards 0 degree
time.sleep(1) # sleep 1 second
        p.ChangeDutyCycle(12.5)# turn towards 180 degree
time.sleep(1) # sleep 1 second
except KeyboardInterrupt:
p.stop()
GPIO.cleanup()
```

**Figure 3. Controlling the servomotor SG90**

H. Lab. 7: Controlling temperature and humidity sensors with Raspberry Pi 3

Students learn how to write the code in Python to control temperature and humidity sensors DHT11 on input pins of the GPIO connector. They learn how to connect these electronic elements according to the given scheme.

DHT11 is the simplest temperature and humidity sensor on the market. It connects to Raspberry Pi with just one pin, and returns two variables - temperature and humidity. There is no need for calibration, students simply connect it and use.

**Example of the code:**

```python
import RPi.GPIO as GPIO
import dht11
import time
import datetime

# initialize GPIO
GPIO.setwarnings(False)
GPIO.setmode(GPIO.BCM)
GPIO.cleanup()

# read data using pin 17
instance = dht11.DHT11(pin=17)
while True:
    result = instance.read()
    if result.is_valid():
        print("Last valid input: " + str(datetime.datetime.now()))
        print("Temperature: %d C" % result.temperature)
        print("Humidity: %d %%" % result.humidity)
        time.sleep(1)
```

**Figure 4. Controlling the sensors for temperature and humidity**

I. Lab. 8: Distance measurement sensor with Raspberry Pi 3

Students learn how to write the code in Python to control distance measurement sensor HC-SR04 on input pins of Raspberry Pi 3.
the GPIO connector. They learn how to connect these electronic elements according to the given scheme.

Figure 5. Controlling distance measurement sensor

HC-SR04 uses ultrasonic waves to determine the distance from the subject. The two basic modules on which the work principle is based are trig (switch) and echo (reflection). With Raspberry Pi, we send 5V to the trigger module lasting at least 10 microseconds. In this way, we activate an ultrasonic transducer that emits eight 40 kHz impulses and waits for their reflection. When the sensor registers the reflected pulse, it sends the data back to Raspberry Pi via the echo pin. These data are actually the duration of the reflected pulse, from 150 micro to 25 milliseconds. If "echo" lasts longer than 35 milliseconds, the sensor registers that the subject is out of reach.

Example of the code:

```python
import RPi.GPIO as GPIO       #Import GPIO library
import time                   #Import time library
GPIO.setmode(GPIO.BCM)        #Set GPIO pin numbering
TRIG = 23                     #Associate pin 23 to TRIG
ECHO = 24                    #Associate pin 24 to ECHO
print "Distance measurement in progress"
GPIO.setup(TRIG,GPIO.OUT)     #Set pin as GPIO out
GPIO.setup(ECHO,GPIO.IN)      #Set pin as GPIO in

while True:
    GPIO.output(TRIG, False) #Set TRIG as LOW
    print "Waiting For Sensor To Settle"
    time.sleep(2)              #Delay of 2 seconds
    GPIO.output(TRIG, True)    #Set TRIG as HIGH
    time.sleep(0.00001)        #Delay of 0.00001 sec
    GPIO.output(TRIG, False)   #Set TRIG as LOW

    while GPIO.input(ECHO)==0: #Check if ECHO LOW
        pulse_start = time.time() # Saves the last LOW time

    while GPIO.input(ECHO)==1: #Check if ECHO HIGH
        pulse_end = time.time()  # Saves the last HIGH time

    pulse_duration = pulse_end - pulse_start
    #Get pulse duration to a variable
    distance = pulse_duration * 17150
    #Multiply pulse duration by 17150 to get distance
    distance = round(distance, 2)
    #Round to two decimal points

    if distance > 2 and distance < 400: #Check whether the distance is within range
        print "Distance: ",distance - 0.5,"cm"
    else:
        print "Out Of Range"  #display out of range
```

J. Lab. 9: Connecting and programming LCD display

Students learn how to write the code in Python to control the mini LCD display RG1602A on output pins of the GPIO connector. They also learn how to connect the mini LCD display RG1602A according to the given scheme.

V. APPLICATION OF RASPBERRY Pi IN VSITE - COLLEGE FOR INFORMATION TECHNOLOGIES

VSITE - College for Information Technologies regularly organizes one day workshops for technical schools and other secondary schools students. The topics are always cutting edge IT technologies. The last was held on April 19, 2018 and the topic was Raspberry Pi [10].

The main goal of this new workshop was to teach the students how to measure the physical quantities, like temperature and pressure, store them in the Raspberry Pi 3 B, allow any computer from outside to connect to the network and use the web browser to monitor the current status and history of the measurement results. It was also intended to demonstrate technology that can capture measured data on a remote network server and be able to simultaneously monitor the results of all measurements of all workshop participants.

Figure 6. Connecting the sensors to Raspberry Pi 3 B
In the introductory part of the workshop participants were briefly introduced to Raspberry Pi 3 B, its hardware design and compare its capabilities with some of the most powerful computers at the time. Lecturers from College for Information Technologies introduced the participants with the most practical details and challenges of using Raspberry Pi 3 B single-board computer and showed examples of professional solutions from their own practices. There was also a team of experienced IT professionals (Linux experts, Web developers and hardware experts) that were at the service to assist the students and trainees throughout the workshop if something gets stuck.

At the workshop there were involved altogether 72 students from 16 different schools and organized in 24 teams. In addition to high school students that were sitting in the benches of College for Information Technology, there was also a 9 year old elementary school pupil who participated in the workshop on a total equal footing. The workshop was successful and Raspberry Pi 3 B single-board computer was awarded for every participant so they could develop and improve the acquired knowledge in their schools.

VI. CONCLUSION

This paper presents how the idea of using Raspberry Pi computers in education was implemented in the First Technical School Tesla, and in VSITE - College for Information Technologies, both from Zagreb, Croatia. The students are taught through examples and are encouraged to combine different disciplines to successfully solve problems. Theory is complemented by demonstrations and, finally, by the practical work of students. We conclude that Raspberry Pi single-board computer is an ideal platform for students to acquire new knowledge and competences not only in the field of computer science but also electronics and many other related fields. As students were encouraged to use Raspberry Pi computers during their schooling and studies, many of them now want to do their finishing and graduating works in projects involving Raspberry Pi.

REFERENCES

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[10] https://www.vsite.hr