Low Cost Computer Platforms for Environmental Monitoring
The case of the AgroComp Project

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Abstract. Nowadays human activities and the uncontrolled exploitation of natural resources take place all over the planet. The resulting environmental degradation is evident in a variety of forms (global warming, extreme weather events, atmospheric pollution etc.). As a result, today it is more important than ever, for scientists to gather and analyze environmental data using various methods in order to solve environmental problems. A new and innovative data collection methodology is based in the creation and deployment of computerized networks dedicated in Environmental monitoring and protection. These computer networks can monitor, locate and inform scientists continuously regarding a variety of parameters automatically correlate them and provide a solid background for a better understanding of the causes of environmental degradation. This paper aims at presenting a series of computer platforms which have the capability to network, connect with a variety of sensor arrays and can be reprogrammed in order to fulfill new or evolving needs. The usage of commercial hardware and software under the GNU/GPL license for their implementation makes these platforms reliable and low cost.

Keywords: Sensors, Environmental Monitoring, computer platform.

1 Introduction

During the last 20 years there is a constant increase in environmental awareness. This is mainly caused because societies during these years have witnessed a series of extreme weather events (rains, drought, extreme temperatures, etc.). These phenomena have triggered other secondary disasters like forest fires, crop

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destruction, floods, etc. (Harvey, 2016; Hammill et al, 2016; Kumar, 2016; Ioannou et al, 2010).

A lot of solutions have been suggested for environmental monitoring however all these solutions are costly and additionally lack the capability to monitor large and remote areas. For example, Ciabatta et al, use microwave observations for daily precipitation estimation, Wafi et al, 2015 use image processing in order to create a disaster surveillance system, Zhang, 2015 uses a combination of sensors and software for creating an early warning system. Additionally, the economic crisis has reduced the budget for the environment, leading to services with limited capabilities both in human resources and in hardware (Cruz-Castro and Sanz-Menendez, 2016, Burns and Tobin, 2016).

This paper aims at presenting three very popular computer platforms that can be used for environmental monitoring. These platforms (and their variations, let's call them flavors) can be purchased at a very low cost, use an Operating System and Programming Languages compatible with the GNU/GPL License and include input and output ports that can be easily reprogrammed by scientists.

Additionally, they also include build in network capabilities, allowing end users to easily create and deploy computer networks on remote areas. Finally, we will create a comparison table comparing the most interesting features (processor architecture, RAM, speed, etc.).

2 Material and Methods

2.1 The Arduino platform

Arduino is an open-source platform used for building electronics projects. Arduino consists of both a physical programmable circuit board (often referred to as a microcontroller) and a piece of software, or IDE (Integrated Development Environment) that runs on your computer, used to write and upload computer code to the physical board.

The Arduino platform has become quite popular with people just starting out with electronics. Unlike most previous programmable circuit boards, the Arduino does not need a programmer in order to load new code onto the board. Additionally, the Arduino IDE uses a simplified version of C++, making it easier to learn to program. Finally, Arduino provides a standard form factor that breaks out the functions of the micro-controller into a more accessible package.

Arduino boards came in many different versions and include an Atmel CPU with 8, 16 or 32-bit architectures. The boards are not capable of running an operating system, therefore a computer is needed for programming in C++. Arduino uses single-row pins or female headers for facilitating connections for programming and incorporation into other circuits. (www.arduino.cc)

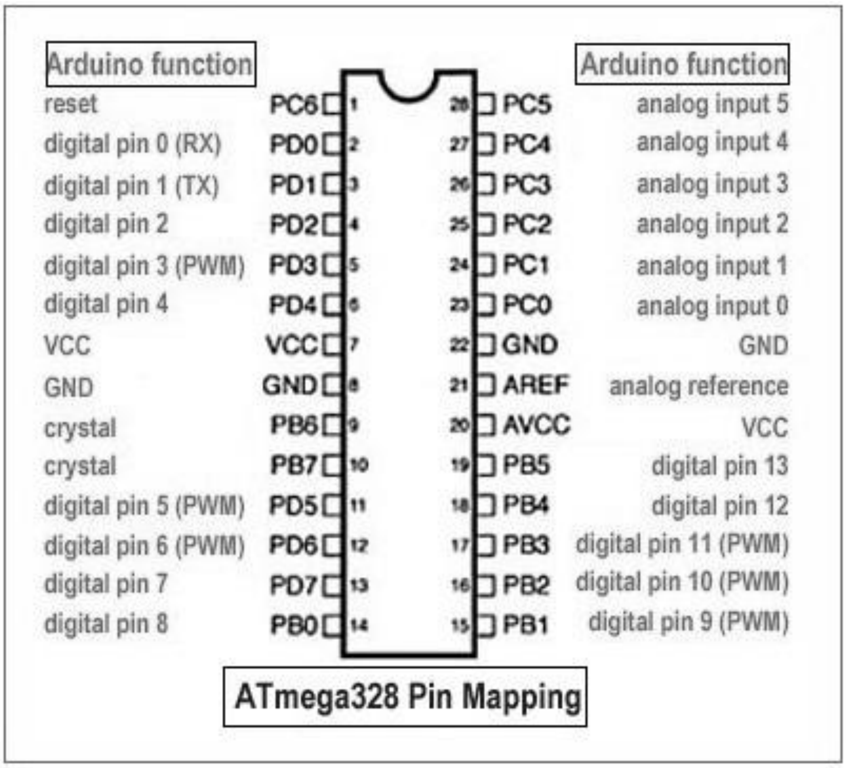

Fig. 1. Arduino Uno I/O pinout (www.arduino.cc)

2.2 The Raspberry Platform (wiki)

The Raspberry Pi is a series of low cost single board computers developed in the United Kingdom by the Raspberry Pi foundation as a tool for teaching basic computer science in schools and developing countries. The initial model didn't incorporate a network port. The first model to do so was Raspberry Pi Model B, which was released in 2012 and was capable of networking. All Later models however included wired and many wireless network capabilities. The entire range of models include is based on ARM compatible Central Processing Unit (CPU), with different architectures starting from an ARMv6 32bit architecture for the initial model to an ARM Cortex A53 64-bit quad core CPU architecture for the most recent model (ARM processors).

All Raspberry Pi boards are capable of using Linux as Operating System. The Raspberry Pi foundation has created a special Linux Distribution called Raspbian, which is available for download free of charge from their site.
Another alternative Operating System for the platform which is also distributed free of charge is a special version of Microsoft Windows called Windows 10 Internet of thing Core Edition.

All Raspberry versions include a General Purpose Input Output (GPIO) bus. General-purpose input/output (GPIO) is a generic pin on an integrated circuit or computer board whose behavior including whether it is an input or output pin—is controllable by the user at run time.

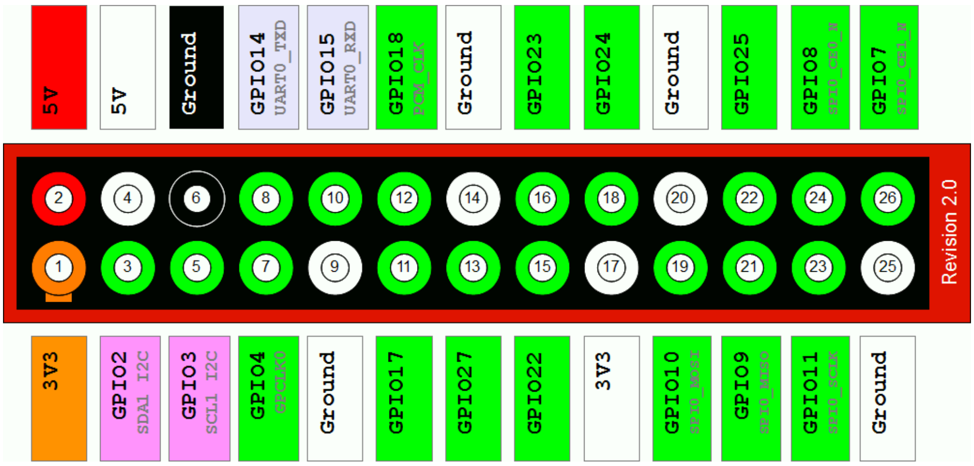

Fig. 2. The initial GPIO pinout of Raspberry Pi Model A (Raspberry Pi Foundation)

The number of pins initially was 20 but increased in later version to. The board can supply power (3.3 Volts and 5 Volts) through the pins connect to external devices, etc.

2.3 Pine A64 Platform (pine64.org)

Pine 64 is a family of single board computers initially funded through kicks starter crowd funding site. The platform is powered from a Quad Core ARM Cortex A53 64-bit CPU similar to the one found in Raspberry Pi. The operating system used is also compatible with the GNU/GPL License and is based on Linux Kernel. Microsoft has also released a Windows IoT version of its operating system. The platform also supports a Raspberry Pi 2 compatible bus, a platform specific Euler Bus and many other peripheral devices interface for makers to integrate with sensors and devices. Finally, the platform also includes wired and wireless networking capabilities.

3 Results

All three platforms share common characteristics; however, they are also characterized from fundamental differences. We will try to create a comparison table depicting their similarities and most striking differences. Table 1 contains the detailed information regarding all Raspberry Pi platforms currently available, the four more typical Arduino boards and the Pine A64+ boards which are considered as a more advanced version of the Raspberry boards at a fraction of the Raspberry cost.

Table 1. Detailed Platform Comparison

	CPU	Architecture	Memory	Lan Ports	WiFi	GPIO	Operating System
Raspberry Pi Model A	700 MHz single-core ARM1176JZ F-S	ARMv6Z (32 -bit)	256 MB (shared with GPU)	N/A	N/A	8× GPI O	Linux, windows 10 IoT
Raspberry Pi Model B	700 MHz single-core ARM1176JZ F-S	ARMv6Z (32 -bit)	512 MB (shared with GPU) as of 4 May 2016. Older boards had 256 MB (shared with GPU)	10/100 Mbit/s Ethern et	N/A	8× GPI O	Linux, windows 10 IoT
Raspberry Pi Model B2	900 MHz 32-bit quad-core ARM Cortex-A7	ARMv7-A(32-bit)	1 GB (shared with GPU)	10/100 Mbit/s Ethern et	N/A	17× G PIO	Linux, windows 10 IoT
Raspberry Pi Model B3	1.2 GHz 64-bit quad-core ARM Cortex-A53	ARMv8-A (64/32-bit)	1 GB (shared with GPU)	10/100 Mbit/s Ethern et,	802,11 n	17× G PIO	Linux, windows 10 IoT
Raspberry Pi Zero	1 GHz single-core ARM1176JZ F-S	ARMv6Z (32 -bit)	512 MB (shared with GPU)	N/A	N/A	40× G PIO	Linux, windows 10 IoT
Arduino Uno	ATmega328P	8bit	2KB	N/A	N/A	14*1	6*2
Arduino Leonardo	Atmega32U4	8bit	2,5KB	N/A	N/A	20*1	7*2
Arduino Micro	ATmega32U4	8bit	2,5KB	N/A	N/A	20*1	7*2
Arduino Nano	ATmega328 (ATmega168 before v3.0	8bit	0,5KB	N/A	N/A	14*1	6*2
Pine A64+	1.152 GHz quad-core ARM Cortex-A53	ARM 64-bit	0.5/1/2GB	1	802,11 bgn	Euler Bus Expans ion Bus PI-2 Bus	Debian, Ubun tu, Android, RemixOS

*1: Digital I/O
*2: Digital I/O with PWM
*3: Analog Input (pins)

From Table 1 it is evident that all platforms share a common characteristic, the General Purpose Input Output ports (G.P.I.O.). These ports are using sets of pings in order for the boards to communicate with the environment. GPIO pins have no predefined purpose, they can be used both as input and output ports and receive analog and digital signals. However only the Arduino platform is capable of receiving directly analog input from external sensors without the need for an Analog to Digital converter. All the boards we study have this capability, but the number of pins varies between the various models and the makers. For example, the initial raspberry pi board had only 20 pins (Picture 1) while the last version incorporates 40. The number of pins varies between the various Arduino versions, while in the Pine A64 platform there are a total of 80 pins. Another usage for these ports is the expansion of the board's capabilities by using an add-on, which is called "shield" or "hat". These add-ons are essentially sensor arrays designed specifically for each platform. They can be added to the GPIO bus and provide additional characteristics to the platform. For example, the sense HAT is an add-on board specifically designed for the Raspberry Pi platform in order to be used by the Astro-Pi mission launched to ISS in December 2015. This hat provides the following characteristics to an existing Raspberry board. A gyroscope, an accelerometer, a magnetometer, temperature sensors, barometric pressure and humidity sensors (astro-pi.org).

Although the boards share same similar characteristics, considerable differences can be found on their processing performance, i.e. the amount of work accomplished in each time unit.

Essentially we have two completely different categories, the first is the Arduino platform, which is very limited performance-wise and therefore it cannot support an operating system. If performance is an issue, then users must select one of the later versions of Raspberry pi (Model B2 or Model B3) or the PineA64 board. These platforms incorporate a quad core CPU with frequencies ranging from 900 MHz to 1.152 GHz and 32 or even 64 bit architectures, allowing the end user to use a specialized operating system with graphic environment. Additionally, these platforms also provide a lot of memory for programming purposes and have multitasking capabilities allowing the simultaneous usage of multiple programing codes and therefore are ideal to measure real data from various sensors. A classic performance indicator is the ability of the processor to calculate prime numbers. For this reason, we used the same operating system (Debian Linux) in a Raspberry Pi 2 (quad core) and Pine A64 (quad core) for computing prime numbers in the range from 1 to 1000 using custom Python code (Picture 1). The results showed that it took 1.9542 seconds for the Raspberry platform to calculate all the prime numbers in the given range, while it took only 0.1962 seconds for the Pine platform. For comparison reasons we also calculated the prime numbers in the same range using the same OS and and Intel i5-5200 processor. In this case the CPU needed only 0.1142 seconds for the calculation (Table 2).

```python
def is_prime(n):
i = 2
while i < n:
if n%i == 0:
return False
i += 1
return True


n = int(raw_input("What number should I go up to? "))

p = 2
while p <= n:
if is_prime(p):
print p,
p=p+1

print "Done"
```

Fig. 3. The Python Custom code used

Of course the prime number test used can act only as an indicator. Real world performance can significantly vary and relies in many parameters including the optimization level of the code used.

Table 2. Prime Number Results

Platform	Time (seconds)
Raspberry Pi 2	1.9542
Pine A64	0.1962
Intel I5-5200	0.1142

The AgroComp Project

In the framework of the Niarchos Fellowships we are currently developing the project AgroComp. The main aim of the project is the development of a methodology that will allow field scientists and researchers to create and deploy large computer networks in rural areas. The project is implemented around the Raspberry Pi platform.

Although it is not the fastest implementation this platform includes an operating system based on Linux (Raspbian) and many tools for writing and deploying custom code.

Contrary to the more powerful Pine platform it also embeds WiFi and Bluetooth communication capabilities, allowing easy networking with other Raspberries in the area. Additionally, the power requirements of this platform are low and can be easily covered using photovoltaic panels.

Currently we use the Pi 2 platform, however after the finalization and the optimization of the programing code we will also use the orange Pi version which uses far less energy and is cheaper.

Parallel to the development of the computation platforms we will also use a methodology already proposed in order to locate the best possible installation locations based on the end user needs. For doing so we must at first determine the criteria affecting the location of the platforms. Subsequently we must determine the weight coefficients of the criteria. Next each study area will be divided in a pre-determined raster with specified dimensions and each of them will be assigned with a value using the following formula.

$$\text{Raster Value, RV} = \sum_{i=1}^{n} W_i * X_i \qquad \textbf{(1)}$$

Where W is the calculated weight coefficient and X is the value of the raster cell (criteria value). After the application of the Equation 1, each raster will receive a value based on its suitability for sensor installation. More suitable for platform installation areas, should receive a higher rating compared with areas with lower suitability.

The results of this equation should also be expressed in a map showing the installation locations. Of course the end user will determine the exact positions based on the fact that the wireless communication technologies supported by the platforms have a limited communication range.

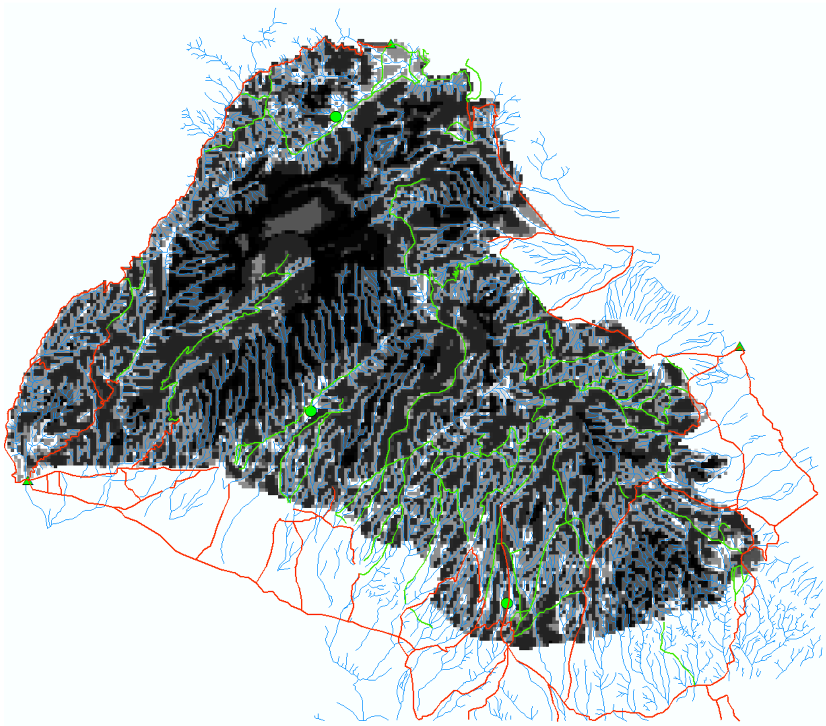

Fig. 4 A map depicting the installation locations.

Having georeferenced properly the entire area, the user can also determine the exact coordinates of each installation point, in a variety of projection systems.

4 Discussion

Today computers can be found in every aspect of our life and society. The usage of computers for research purposes is common ground, however there are some scientific fields where computers cannot be easily used for field research mainly because the solutions provided are expensive and use proprietary equipment both in terms of hardware and software.

Recently a new type of computing platforms has emerged. These platforms can be programmed and used for a variety of applications and at the same time provide the end user with enough processing power to support a graphical user interface, wireless communications, database management etc.

This paper demonstrates the capability to use this type of hardware for creating and deploying computer networks in remote and rural areas using the Raspberry Pi platform.

Additionally, we introduce an innovative methodology for locating the optimal installation sites based on the criteria and the weight coefficients calculated by the end user.

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