Teaching in Sub-Saharan Africa

Academic Training Lectures
October 2018

Lecture 1

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Formally CERN BE/BI

now “retired”

Once upon a time ...

Came to CERN as a doctoral student in Nov. 1978

Worked on one of the first LEAR experiments measuring X-rays from anti-protonic atoms.

Data rate at a PS secondary beam line: 2 p/s with 10^5 pions
Data rate at LEAR: 2000 p/s with no pions
Data acquisition was done with Europe's first VME boards and mini-computers

Later worked on Linac-1 and Linac-2 which was also controlled by a mini-computer

A mini-computer

A “normal” computer was a mainframe machine costing several 100kCHF
Cost for a mini-computer was “only” ~ 60 – 100 kCHF

Typical specs:

- 16 bit CPU
- 128 kBytes RAM
- 600 Mbytes hard disk
- RS232 terminal
- Camac interface

… a revolution started

Arrival of microprocessors
Cost for the chip: 360 US$
Chip had

- 8 bit CPU, 1 MHz
- 16 bit address bus
- only external memory
- only external peripherals

Development board with

- 128 bytes of RAM
- 2kBytes EPROM
- 16 bit parallel interface

I took ½ year Technical Training course to learn about this exiting

Abdus Salam proposes a course

Prof. Abdus Salam was director of ICTP Trieste

He proposed a course on micro-processors for developing countries.

Finding computing lecturers ok!

Finding people to setup and run a computer lab for programming exercises: problem!

ICTP asks CERN to help with the lab.

This is how I started lecturing. The course continued and was regularly updated to the latest technology for 35 years!

The ICTP course crew

… a few years later

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Nii Quaynor

From Wikipedia, the free encyclopedia

For the Ghanaian rapper whose full name is Nii Addo Quaynor, see Tinny (musician).

Prof. Nii Narku Quaynor is a scientist and engineer who has played an important role in the introduction and development of the Internet throughout Africa.

Nii Narku Quaynor

Prof. Nii Narku Quaynor

Born	Nii Narku Quaynor
Occupation	Computer Scientist
Known for	Developing telecommunications and Internet in Africa
Title	Professor

Contents [hide]

Biography [edit]

Prof. Quaynor graduated in engineering science from Dartmouth College in 1972 and received a Bachelor of Engineering degree from the Thayer School of Engineering there in 1973. He then studied Computer Science, obtaining an M.S. from the State University of New York at StonyBrook in 1974 and a Ph.D. from the same institution in 1977. He attended Kinbu, Adisadel College(citation needed) and Achimota School in Ghana

He is one of the founding members of the Computer Science Department at the University of Cape Coast in Ghana, and continues to hold a professorship there.[1] He is also a member of the Council of the University of

Can you help?

A Skype call from Shanghai: Could you help us in at the University of Cape Coast (UCC) ?

- Contact with the department head DCSIT (Department of Computer Science and Information Technology, Jojo Eghan
- Counseling over the Internet: did not work!
- Could you come?

  For 3 weeks?

  Better for a month?

  Even better for a full semester?

What does UCC need?

The Deal

My job:

- Do a market survey to find most suited devices for the laboratory
- Test the devices and prepare a prototype station
- Prepare the course (Lecture slides, exercises, solutions, doc)

UCC's job

- Order the lab material
- Provide the flight ticket
- Provide accommodation an living expenses

The design of the Lab

To be found:

- A widely supported micro-controller system with access to external devices. Best: a bread board
- A kit with different kinds of sensors and actuators:
  - Temperature, humidity, air pressure, color, light intensity ...
  - LEDs, LCD displays, relays, stepping motors ...
  - Different types of instrumentation interfaces:
    - GPIO
    - I2C

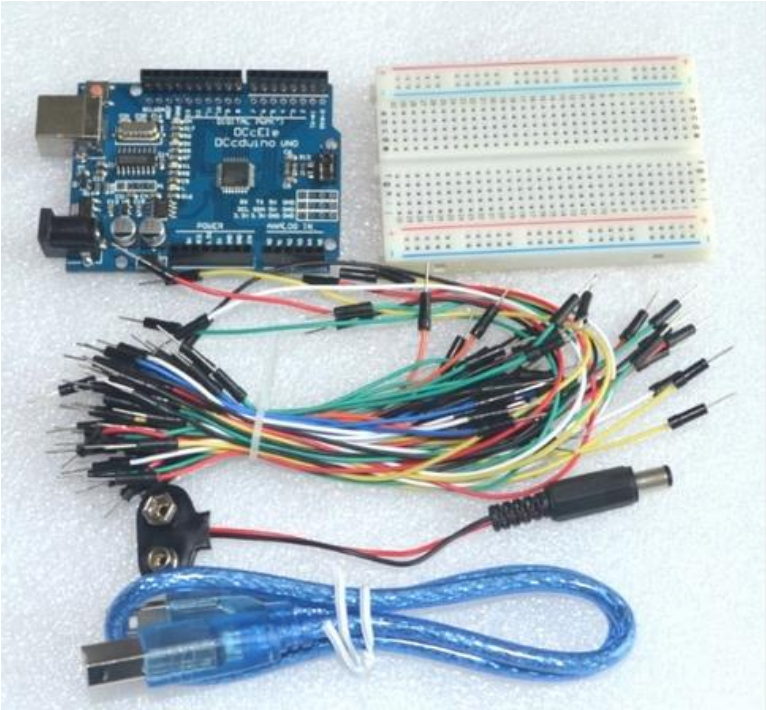
Which processor board?

The most expensive solution
(80 Euros): **Raspberry Pi**
Advantages:

- Very powerful CPU (64 bit ARM, quad core)
- Kit contains everything that is needed
- Huge user base (10 million boards sold)
- Runs Linux operating system with desktop on 32 Gbyte micro SD cards
- Has Ethernet and WiFi network connections
- Native software development using gcc or Python

The Arduino

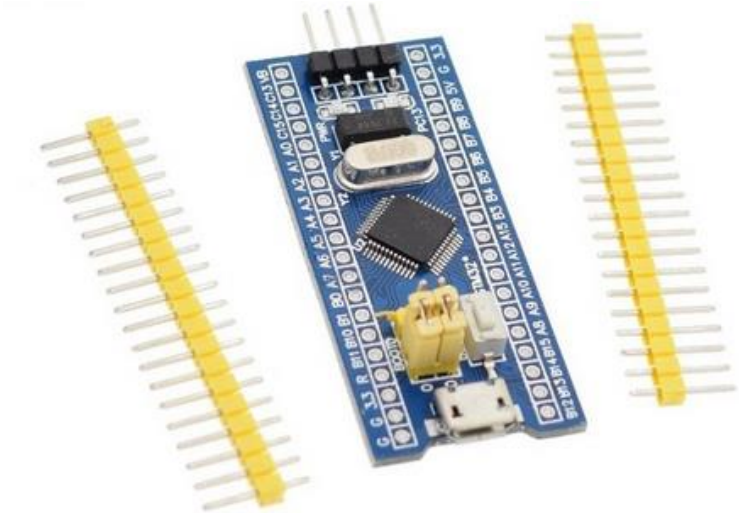
The Arduino exists in several varieties and is substantially cheaper than the RPi (8.50 Euros):



Advantages:

- Huge user base
- Has free Integrated Development Environment
- Drivers for virtually all sensors on the market exist.

The cheapest solution



STM32F103C8T6
Advantages

- Price: 1,61 Euros (including shipping)
- IDE using Eclipse + plugin + ST supplied STM32CubeMX application, creating a program template
- ST supplied Hardware Abstraction Layer (HAL) library

Disadvantages:

- Smaller user base

Comparison of processors

Motorola 6800

- Cost: 360 US$
- CPU 8 bits 1 MHz
- Just the chip
- No memory, no peripherals

STM32F103C8T6

- 1,61 Euros (including shipping)
- ARM Cortex, 32 bits, 72 MHz
- 20 kBytes RAM
- 64 (128) kBytes flash
- 2 12 bit ADCs
- DAC
- I2C, SPI interfaces, 2 UARTs
- DMA

Decision: Raspberry Pi

We went for the luxury version!
Specs:
SOC: Broadcom BCM2837
CPU: 4x ARM Cortex-A53, 64 bits, 1.2 GHz
RAM: 1 GB LPDDR (900 MHz)
Networking: 10/100 Ethernet, 2.4 GHz 802.11n wireless
Bluetooth: Bluetooth 4.2 Classic, Bluetooth Low Energy
Storage: microSD
GPIO: 40-pin header, populated
Ports: HDMI, 2.5mm analogue audio-video jack, 4xUSB 2.0
Ethernet, Camera Serial Interface (CSI), Display Serial Interface

The sensor kit

Contains 37 different types of sensors and actuators

Types of sensors and actuators

Standard LED
2 color LED
7 color flash LED
RGB LED
Laser
Active and passive buzzer
Relay
Hall sensor
Infrared tracking sensor
Push button switch
Reed switch

Shock detector

Heart beat detector

Analogue temperature sensor

Digital temperature and humidity sensor

1-wire digital temperature sensor

Photo resistor

Ball switch

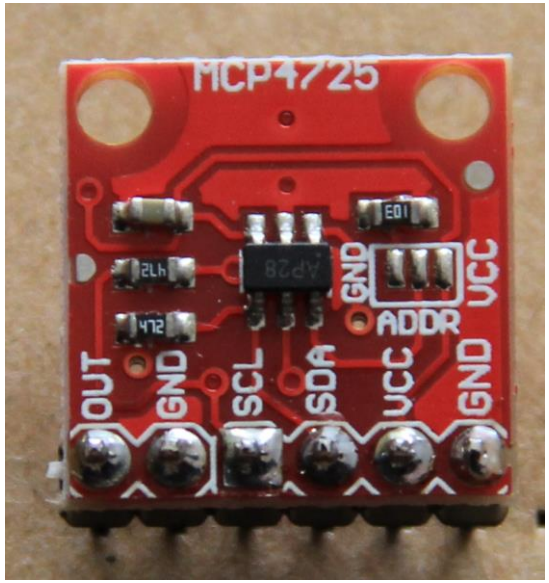
Rotary encoder

Infrared receiver and transmitter

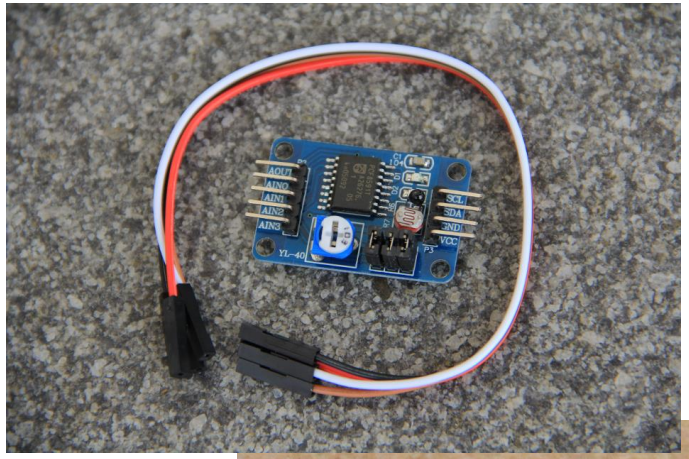
Touch sensor

Infrared avoidance monitor

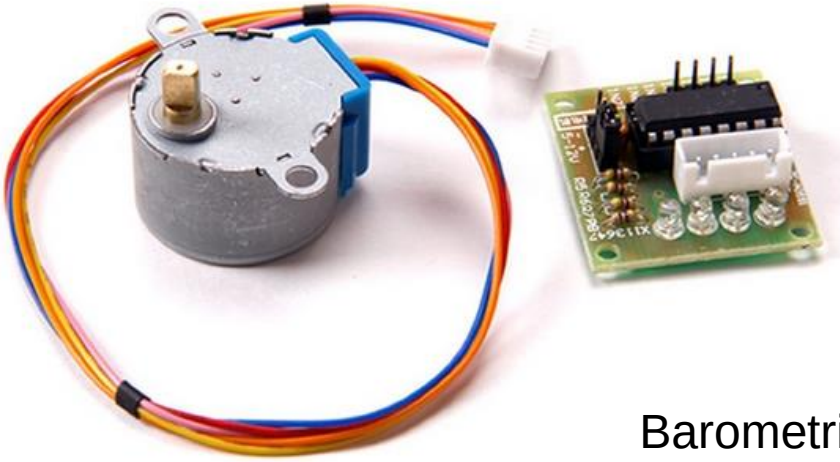
Additional devices



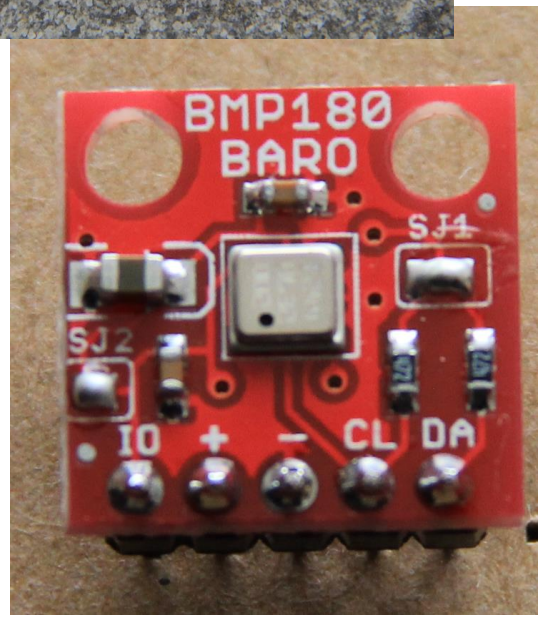
Digital to Analogue Converter



Analogue to Digital Converter



Stepping motor



Barometric pressure sensor

Shopping list

Shopping list was sent to UCC in December 2016
I buy one set for testing on my personal budget
My Ghanaian colleague Ike buys one set on his personal budget

Advantage to order clones in China

- Price!

Problems with devices ordered in China: quality control and documentation!

- Best: You find documentation on the net where someone has figured out how to make the device work (you find it sometimes for the Arduino, sometimes for the RPi)
- Average: there is documentation translated from Chinese with Google translate. The result is just as “Chinese” as the original to me.

Documentation

The course should be visible to anybody not only UCC.
Documentation must go onto the WEB
We set up a Twiki server which allows to store and easily update the course documentation

- Installation of Ubuntu Linux on an external PC hard drive and how to make the disk bootable.
- Description of the Raspberry Pi and how to install its OS onto the microSD card
- Results from reverse engineering of the sensor PCBs
- Demonstration programs on how to use the sensors. These become solutions to the exercises

Re-organisation

The department head changes (actually twice), Jojo was promoted.

2 weeks before departure I send my flight details such that I can be picked up at the airport by UCC staff.

I get an email saying that all my arrangements are wrong and that the stay should be limited to two months. Since the lab is still not ordered this makes no sense.

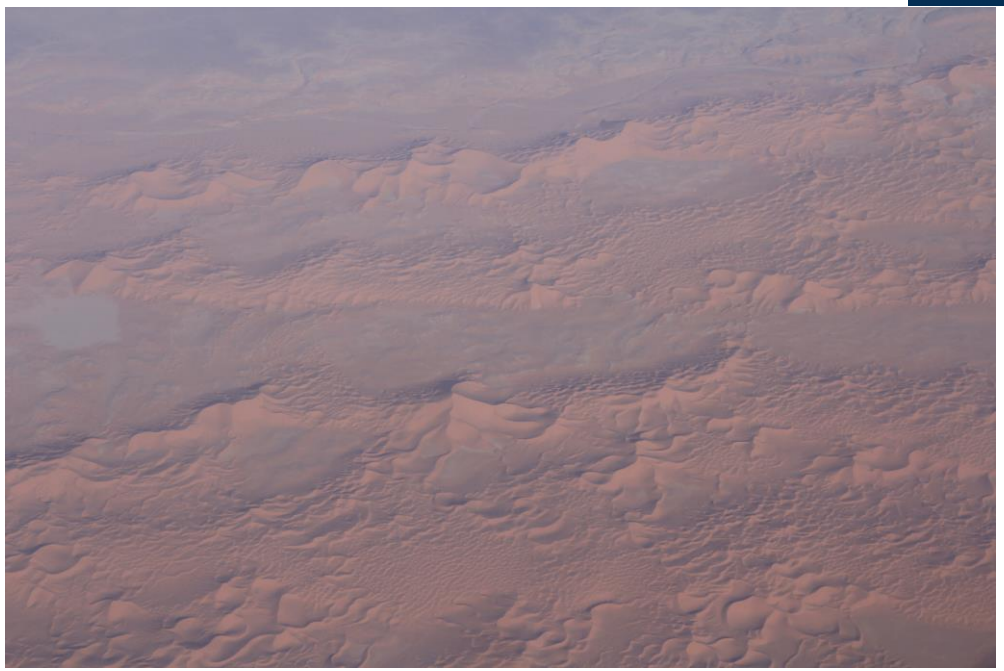
I contact Jojo who initially organized my stay.

The affair goes up to the highest level at the university. The department head and the dean of the school meet the university vice chancellor.

Where is Cape Coast?

Departure

This is **not Mars**! It is the Sahara as seen from the airplane



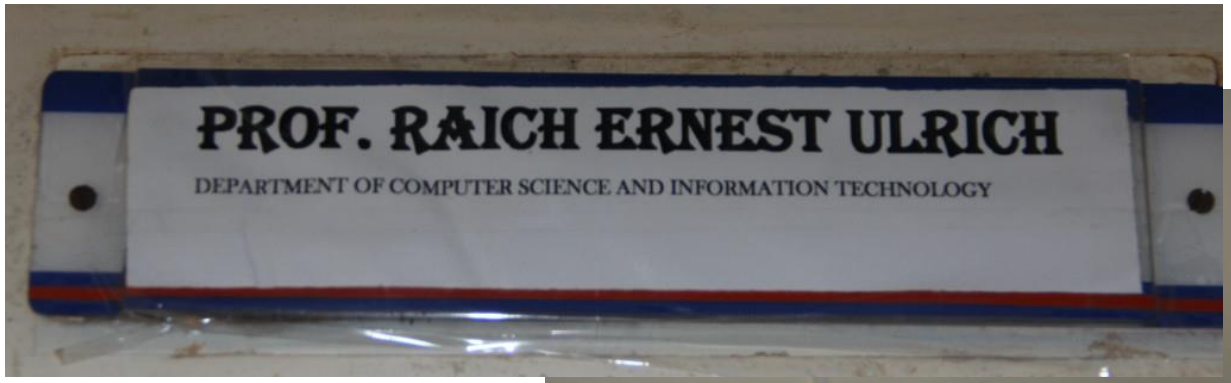
End of August: Departure for Ghana even though the lab material is still not ordered

Picking up works! My Ghanaian colleague and his wife welcome me at the airport with a driver from UCC. I stay one night in the UCC guest house in Accra, meet my friend Nii the next day before leaving for Cape Coast.

Accommodation was not arranged in Cape Coast. I am set up in the university guest house.

The department

The office


PROF. RAICH ERNEST ULRICH
DEPARTMENT OF COMPUTER SCIENCE AND INFORMATION TECHNOLOGY

First work

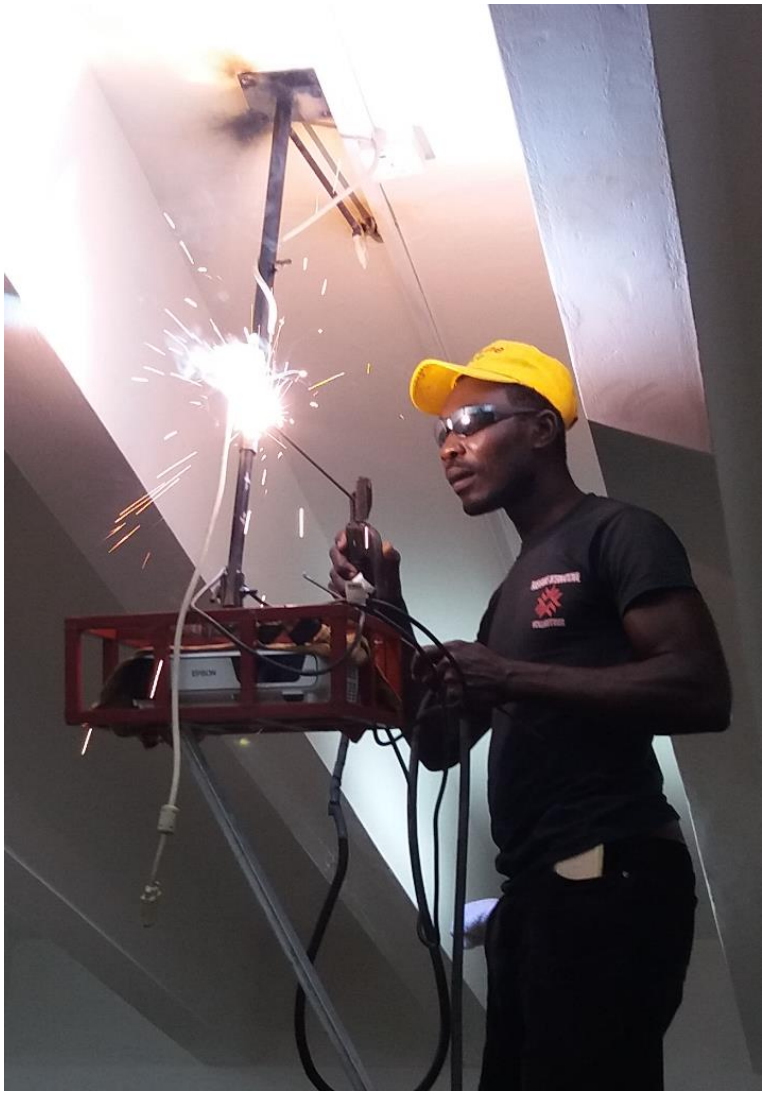
A lab of 15 PCs with heterogeneous operating systems but are allowed to erase the disks.
Installation of Ubuntu Linux on all machines
The OS on the Raspberry Pi is Raspbian, a Linux OS very similar to Ubuntu
Try to get the budget for the laboratory Raspberry Pis and the sensors unblocked
Setup the network
Prepare slide projector and screen for the lectures

Ike preparing the lab

The Slide Projector

Installing a slide projector is also slightly different from the way we do it!

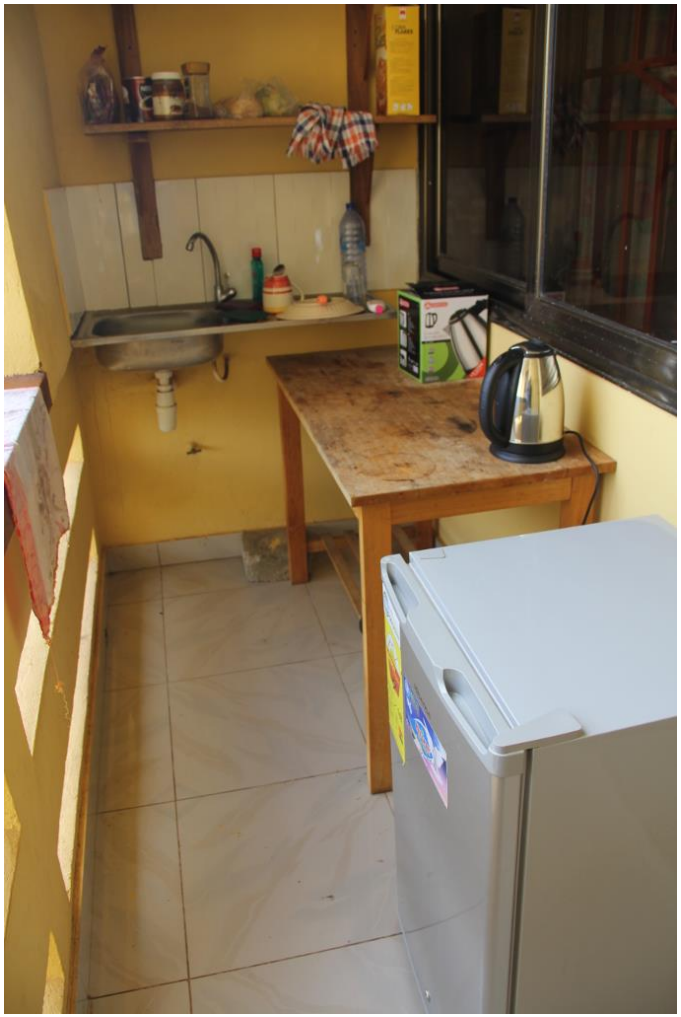
With this the lecture hall is ready!



The Oguaa Fetu Afahye Festival

The guest house is booked and I have
to leave.

My appartment



The room: a bed, a table and chair, a cupboard, a fan and a cold shower.

The kitchen with a fridge!

Mama Area's palace

First 3 lectures

Introduction to the course:

- Basics of Linux
  - bash shell
  - stdin/stdout, I/O redirection
  - file system
  - file permissions
  - octal and hex mathematics
  - Valid for the PC and the Raspberry Pi
- C- programming

Students had a 1 semester C++ course.

The micro-controllers and sensors

After the first week we still have no lab! With Ike's and my devices we can equip 2 stations.

The physics department has 5 Raspberry Pis but no power supplies for them! We can borrow them but the Physics department wants another course for its students! This doubles my work load.

A CERN friend sends me this advice:

No matter how tremendous an obstruction may appear at a distance, you will find that if you go on in a certain way, it will disappear as you approach it, or that a way over, though, or around

The Miracle

After a week and over a beer
Nii promises 1000 US $ to start the lab.

The next day the university releases the budget for the lab.

The supplier in China can deliver immediately and 2 weeks later we have the material.

The lab material

Bringing up Raspbian

The operating system distribution is named **Raspbian**, a Debian based Linux distribution for the ARM processor

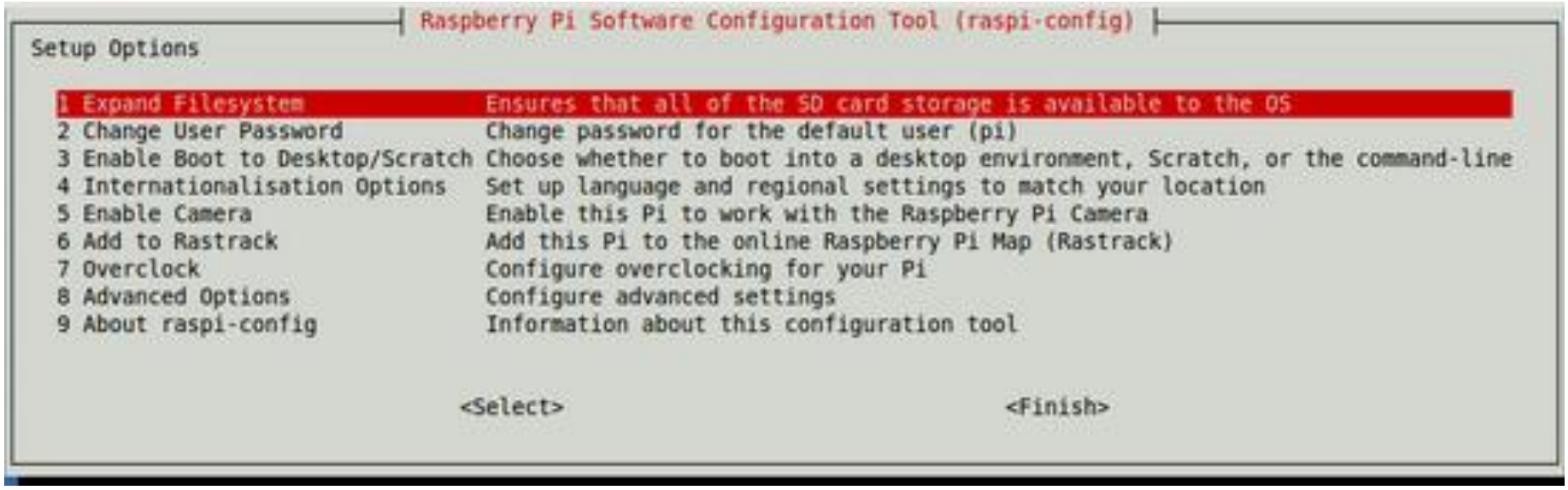
- The system is distributed in zip format
- Download to the PC and unzip → binary image with 2 partitions
- Copy the image to a micro SD card using Unix *dd*
- Install the micro SD card in the slot on the RPi
- Boot the system
- Upgrade the system to its latest revision with *apt* (Advance Package Tool)
- Run the configurator *raspi-config to* enable drivers for
  - GPIO, I2C, SPI, camera

Lab Preparations

The local area network is available but there are too few network connections to accommodate the Raspberry Pis.

- The switches are available but new network plugs and cables must be installed. Done over the weekend in 2 days!
- The Raspberry Pis need fixed IP addresses to be easily accessible from any PC.
- Raspberry Pis are accessible through ssh or through the remote desktop
- We were working on the configuration literally until seconds

The configuration tool



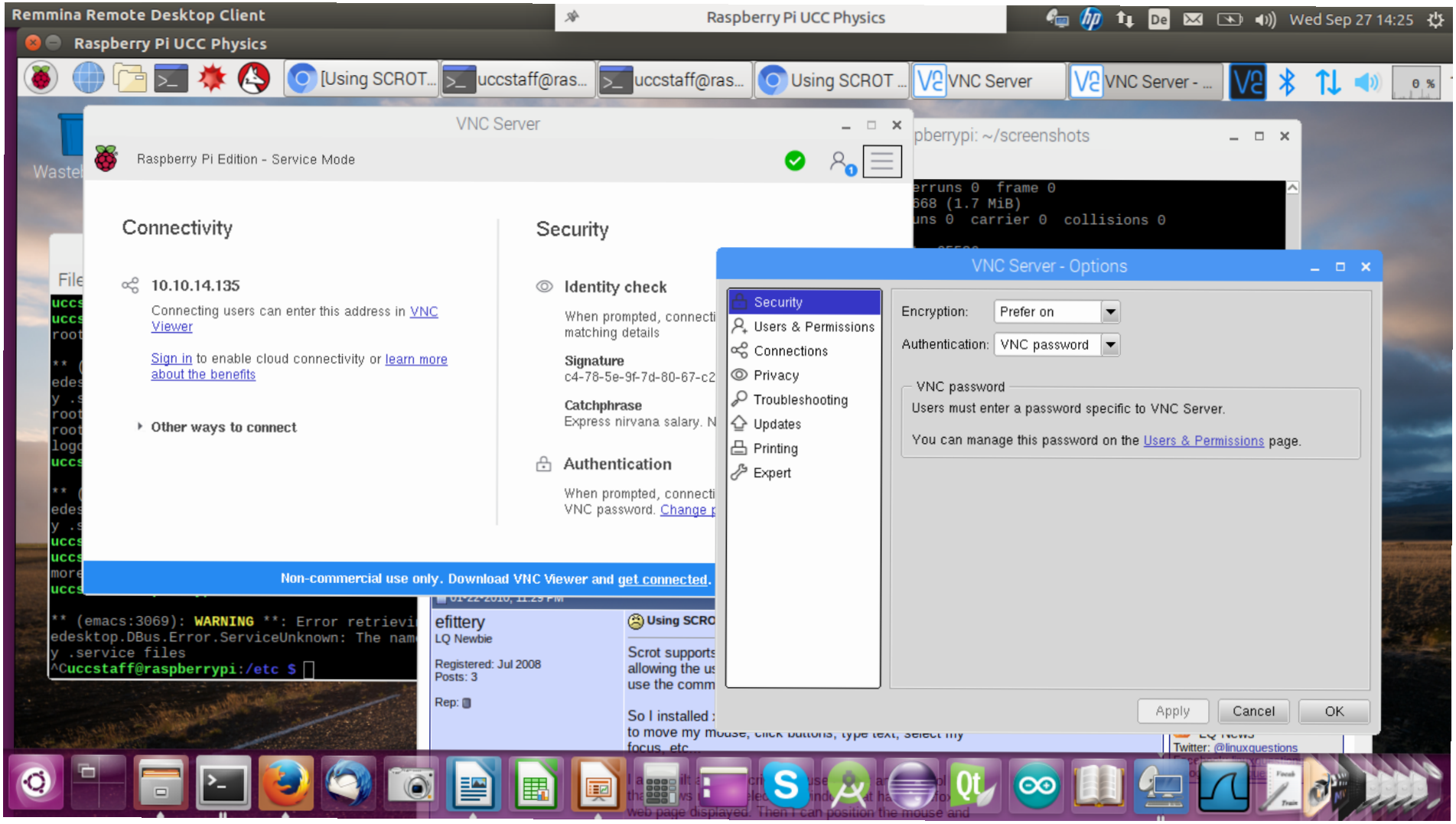
Accessing the Raspberry Pi remotely

Of course we can access the RPI through its screen, keyboard and mouse but this needs a lot of equipment.

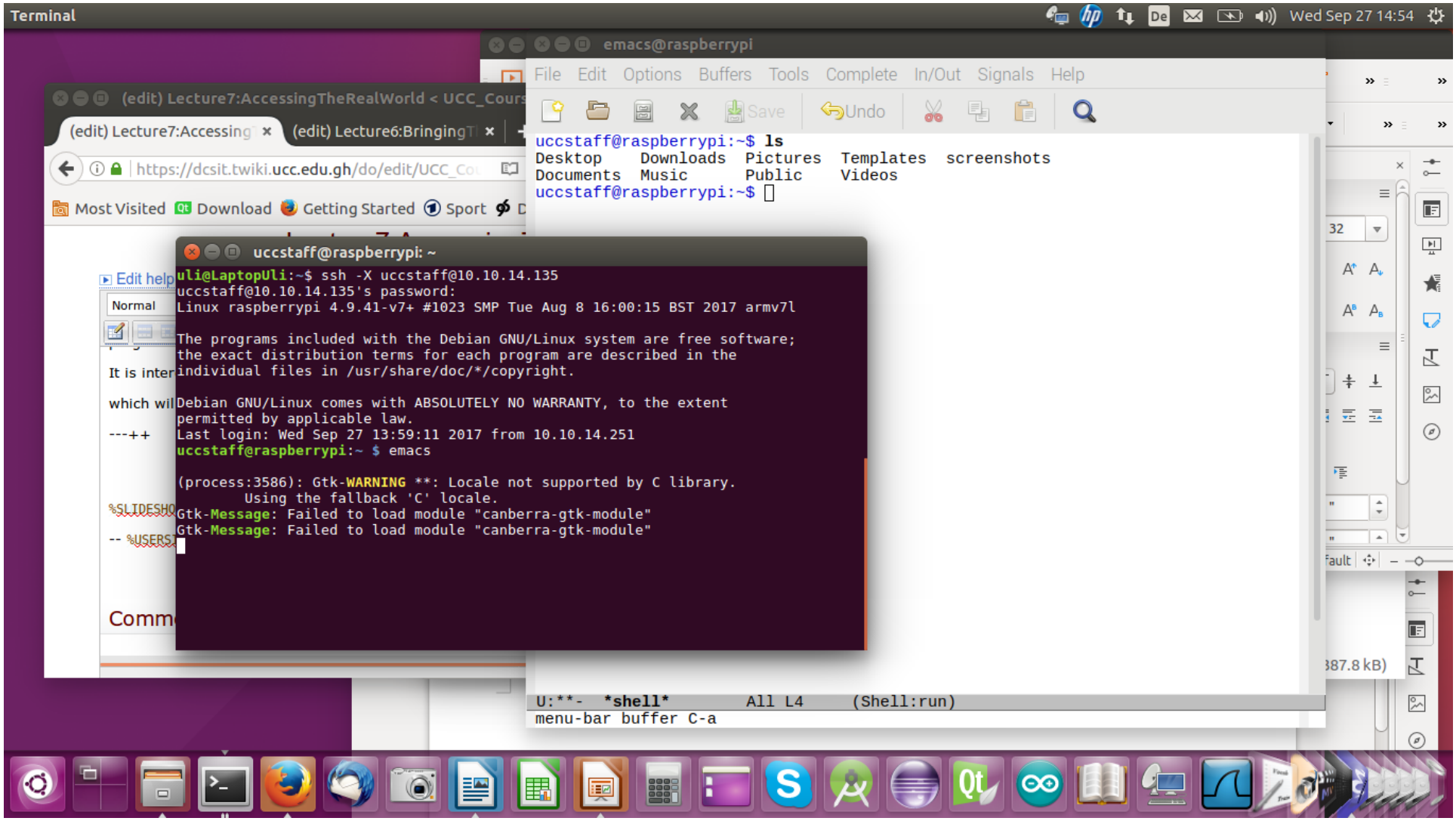
There are several ways to access the RPi remotely:

- Enabling the RPi VNC or RDP server and configuring them allows you to access the RPi with a remote desktop client on the PC
- The secure shell ssh allows you to create a remote terminal on the RPi. With the option ssh -X you enable the X forwarding and you can use the PC as an X-terminal

The remote desktop



An ssh example



First exercise on the RPi

The OS on the RPi looks very similar to Ubuntu on the PC

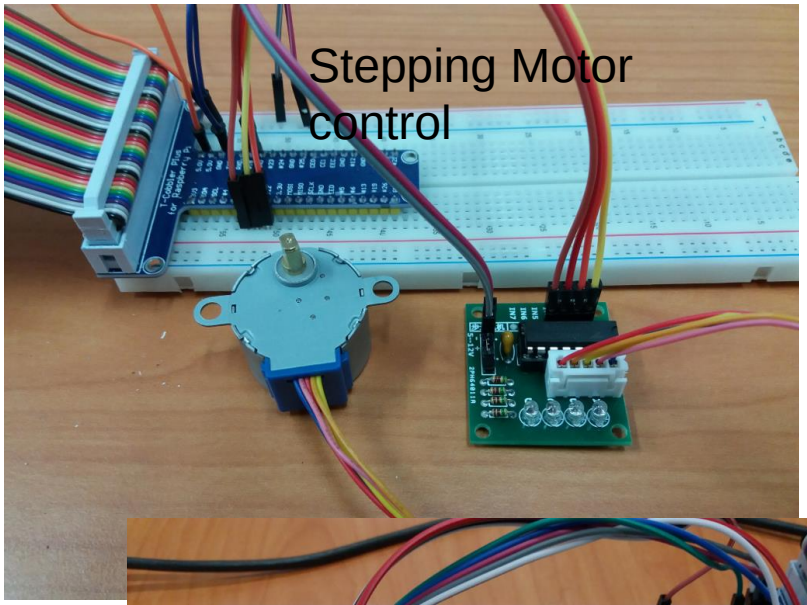
- The students compile and try their programs on the RPi
- When copying the binary to the RPi is does not run, why?
- Native vs cross compilations (both are possible on our system)

The UCC Open Day

The university organizes an Open Day where the students show off projects prepared in the department
The department head asks me to prepare a few presentations
We have:

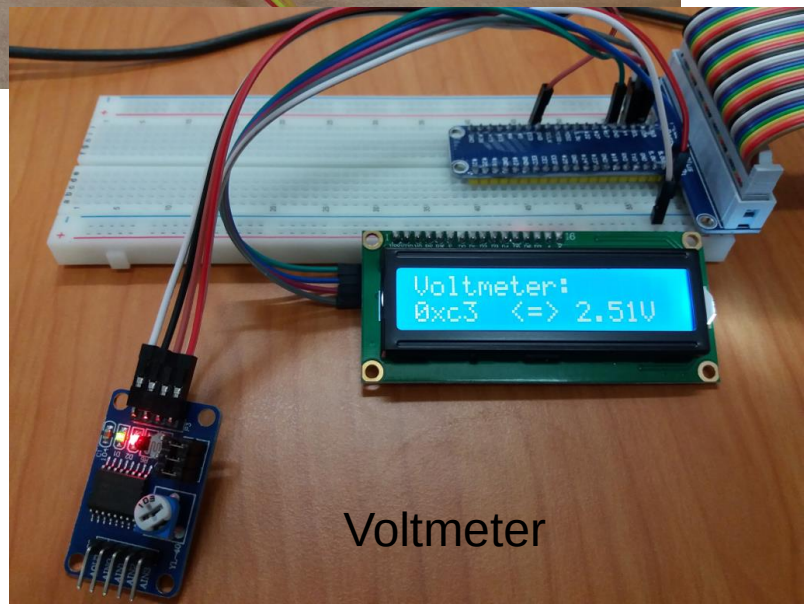
- A traffic light simulator using LEDs
- Name display: A visitor types his name which is then displayed in a welcome message on an LCD screen attached to the Rpi.
- A stepping motor control program
- A voltmeter
- A small meteorological station measuring
  - Temperature· air pressure, humidity
- A simple obstacle avoiding robot

Open Day Projects

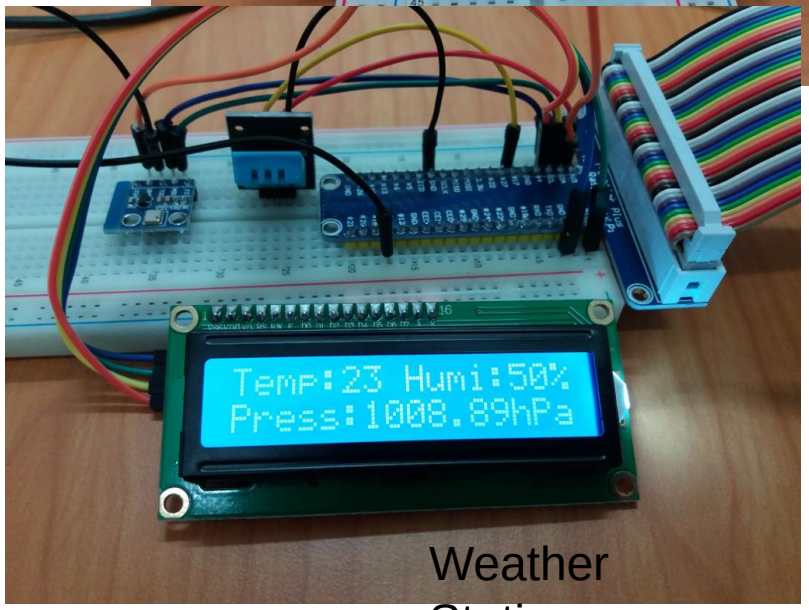


Stepping Motor control

Name Display



Voltmeter



Weather Station

Photo from the Open Day

Tomorrow

- A demonstration of how to access external hardware (with demonstration)
- Different instrumentation buses
- An introduction to the Internet of Things (IoT)
- A 2 day workshop on IoT sensor at the AIS (African Internet Society) workshop 2018 in Dakar
- An IoT project with long range wireless communication (LoRaWan)
- Possible extensions to the course
- How to go on?