Micropython at Applied Physics

Assignments, purpose, examples and more

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Today?

- Why (micro)Python
- Our curriculum (HHS)
- Assignments, grading as feedback?
- Learning (for us and our students)

Who am I

- Lecturer at the Applied Physics department (THUAS)
  - Teaching computational related physics courses
  - Python and micropython
- Researcher at the Smart Sensor Systems research group
  - Extracting the right data at the right time from sensors
  - In various fields (agriculture, predictive maintenance, well-being)
  - Using micro-controllers (with quite often micropython)

Background - programming in Python

Previous decade

Programming in C(++)and Labview, no applications in other courses.

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Moved to Python

- Data-analyses
- Data-visualization

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Now and the future

Adding micropython instead of Labview

- Control hardware with the same language as analysing the data
- Automate experiments

But why?

Micropython

High-level programming on a microcontroller

https://www.inkl.com/news/micropython-1-20-brings-raspberry-pi-pico-w-support-lightweight-package-manager

But why?

Micropython

High-level programming on a microcontroller

- Simple is better than complex (one language for everything)
- There should be one– and preferably only one –obvious way to do it.
- Now is better than never.

Python at HHS

1st year

- S2 Basic Python
- S2 Generating nice graphs
- S2 First data analysing

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- S2 Automation in the lab
- S2 Numerical modelling with Python

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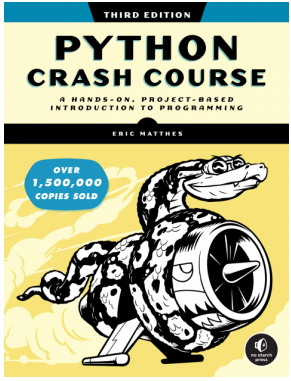
3rd, 4th year: applying skills and knowledge

Python at HHS - 1st year

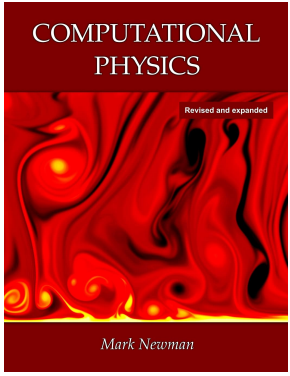
https://nostarch.com/python-crash-course-3rd-edition



- The Dutch version
- All the basics of Python
- Including object oriented programming, unit-tests
- Focus on documentation and readability
- Applied at Medical Physics course after the introduction course
- Time-based data-analysing

Python at HHS - 2nd year

https://public.websites.umich.edu/~mejn/cp/index.html



- Linear Algebra using the computer (using Jupyter)
- Working with and creating solvers for Differential Equations
- And controlling hardware

How does a class look like

1st year

- 16 students per class
- 1 teacher
- 3 contact hours per week
- 10 weeks
- Working on assignments during classes
- This year 4 parallel classes, 3 teachers.

(And a lectur for all students in the first 4 weeks, total 8 hours)

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Grading

- Compulsary assignments, Done/Not Done mark
- 2 Projects
  - Game (Object Oriented, large code base)
  - Visualisation of data

Both need a passing mark.

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During the class

- Short lectures, just in time teaching
- Working on assignments
- Grading and feedback

What do you need to automate an experiment?

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- Sensors
  - ADC
  - temperature
  - luminosity
  - magnetic probes
  - ...
- Actuators
  - Motors (DC, stepper)
  - Heating
  - Pumps
  - DAC
  - ...
- Protocols
  - I^2C
  - SPI
  - PWM
  - 1-wire
  - UART
  - Serial, Modbus, VISA

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Students need to be prepared...

- Where will they apply their knowledge?
- What technology will be available?

Micro-controllers - Where to start

(final) Learning objective

The student is capable of designing, building and validating a combined project where sensors and actuators interact; using the provided hardware.

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Micro-controllers - Where to start

(final) Learning objective

The student is capable of designing, building and validating a combined project where sensors and actuators interact; using the provided hardware.

(but in Dutch at THUAS)
This implies

- The student knows how to connect a sensor/actuator
- The student understands when to use which sensor
- The student can connect the device and program the microcontroller

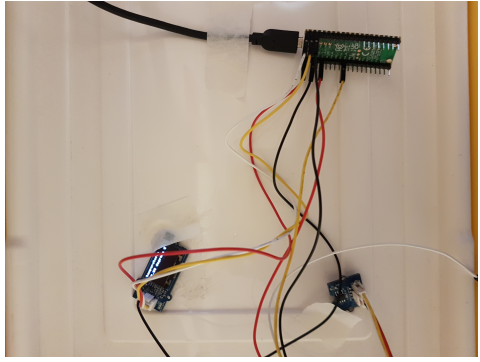
(small print: minimum requirements listed in rubrics)

Thats all!

```python
import machine
from ssd1306 import SSD1306_I2C
import time
import math

if __name__ == "__main__":
    i2c = machine.I2C(0, sda=0, scl=1)
    ssd = SSD1306_I2C(128, 64, i2c)
    adc = machine.ADC(0)
    B = 4250;  R0 = 100e3

    running = True
    while running:
        try:
            R = R0*((2**16-1)/adc.read_u16() - 1)
            temp = 1/(math.log(R/R0)/B + 1/298.15)-273.15
            ssd.fill(0)
            ssd.text('temperature:', 0, 0)
            ssd.text('%2.2f degrees C' %(temp), 0, 15)
            ssd.show()
            time.sleep(2)
        except KeyboardInterrupt:
            running = False
```



Live demonstration...

What if the span of the sensor is not matching?
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Aligned classes

Same time: designing electronic circuits for amplification, reduction, etc

- apply knowledge immediately
- create a purpose
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Apply problem solving skills in almost real situations
Intrinsic motivation?

And the lab?

Digital Multi-Meters, Power supplies

Many DMMs and power supplies in various labs...

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Analog Programming (DAC) for power supplies

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Many DMMs and power supplies in various labs...

Analog Programming (DAC) for power supplies

https://www.bensel ectronics.nl/usb-n aar-rs232.html

- DMMs: RS232, high voltage protocol
- Tricky and high risk of damage
- USB-connector with 'normal' python

But code missing, and we do not train computer-scientists!

DMMs

Balance

- Students should *USE* code
- Students should *ADAPT* code
- Not all students want to program

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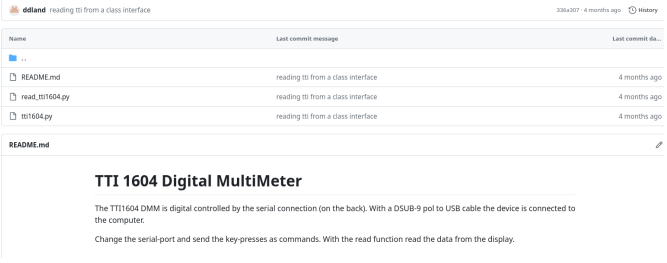

Already advanced versions created by students, even some forks!

Grading - Inclusive

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grading per learning objective

- 4 learning (sub)goals
- Assessments during contact hours
- 1 retake allowed (sub goal, students own choice)
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All active students pass the class...

Grading - during class

Rubrics per learning goal

- (short) oral assessment with all students
- individual questions
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Students prepare with their own solution...
minimal requirements provided but

- How do they know it is sufficient?
- How do we asses fair?

Rubrics per learning objective

Rubrics with 5 criteria

- 20 points per criteria
- Minimal grade per objective: 4.5
- Clear description of the requirements

Assessment provides already feedback...

Grading - Assessment

- Why did you do this?
- Can you explain the need for this line of code?
- Can you measure your quantity with your sensor?
- How much more headroom does your setup have?
- Is your code / solution understandable for a fellow student?
- Can you re-use your implementation without too much effort?
- How would you improve your code if you had to do it again?

Feedback

Oral evaluations (previous year)

- Half of the class enjoyed it
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We were pleased with the feedback but...

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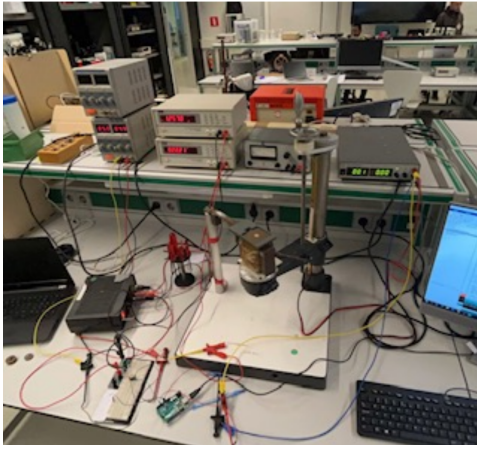
- Have more often cross-classroom (teacher) assessments
- As teacher you need to understand and know how to apply the sensors
  We are lacking the on-boarding time/preparation
- Apply the same grading system to more courses
  But this will require lots of effort from the team

Nice to haves:
student assistants...

Results

Images from automated experiments, after the basic course:



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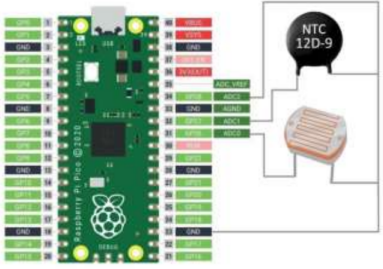

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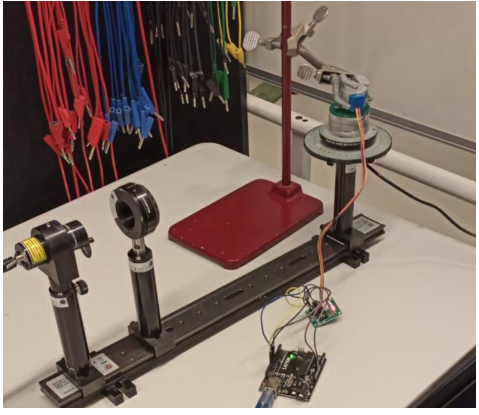
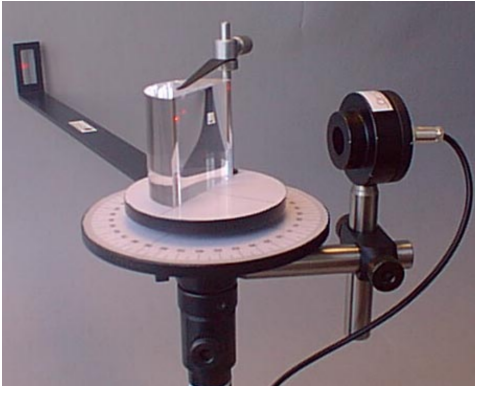
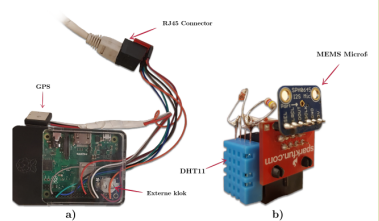




Results

And beyond the courses



Ontworpen meetsysteem

- Automazation at internships:
  - Rewriting Labview to Python for Electron Microscope at Leiden University Lab
  - Automatic measure traffic-noise with a Raspberrypi at DGMR
  - Measure leaf-area-index with capacitive sensors (wireless) at Smart Sensor Systems
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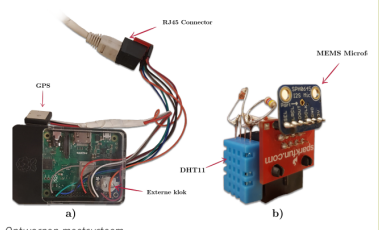

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  - ...
  - Almost all students use Python / MicroPython at internships

Students feel confident and can deliver!