The Green Lab

Introduction to the course

Ivano Malavolta

VU VRIJE UNIVERSITEIT AMSTERDAM

LOOKING FURTHER

https://www.youtube.com/watch?v=9bZkp7q19f0

ICT is unsustainable

Total number of views:

4.8b

Total energy per view:

0.2 kWh

Total energy consumed: ~**835 GWh** in less than 7 years

x40,239 for 7 years!

http://shrinkthatfootprint.com/average-household-electricity-consumption

Where does this energy go?

Battery charge efficiency: 90%

CPU: 500 - 2,000 mW

GSM: 800 mW

Display: 400 mW

GPS: 176 mW

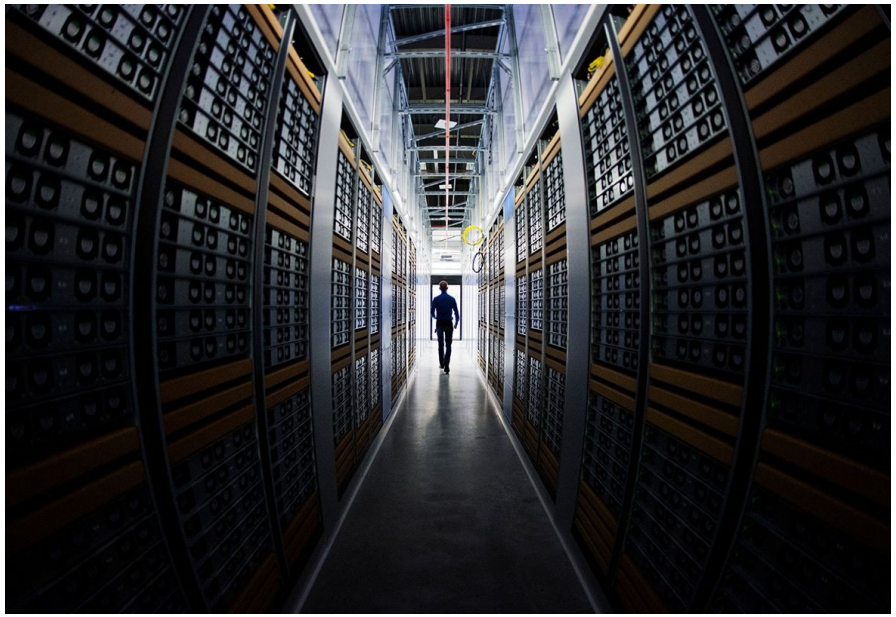
Gyroscope: 130 mW

Microphone: 101 mW

Bluetooth: 100 mW

Accelerometer: 21 mW

Where does this energy go?



Energy loss:

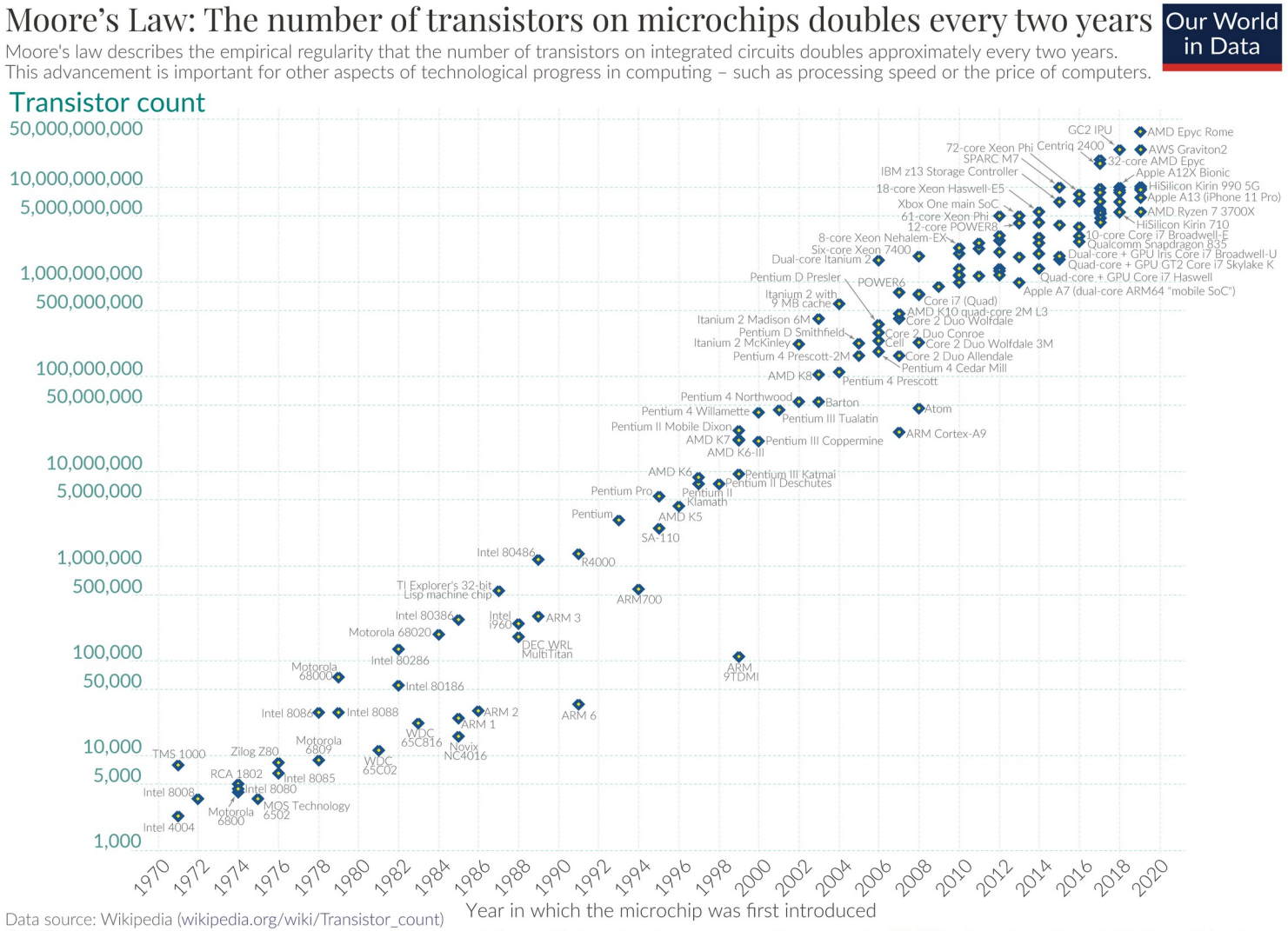
- Low utilization

  Min utilization rate: 10%
  Max utilization rate: 80%
- Cooling
- Lighting

$$\text{PUE} = \frac{\text{Total Facility Energy}}{\text{IT Equipment Energy}}$$

"Good" PUE = 1.4 = **30% loss**

Moore’s law



Data source: Wikipedia (wikipedia.org/wiki/Transistor_count)
OurWorldinData.org – Research and data to make progress against the world's largest problems.

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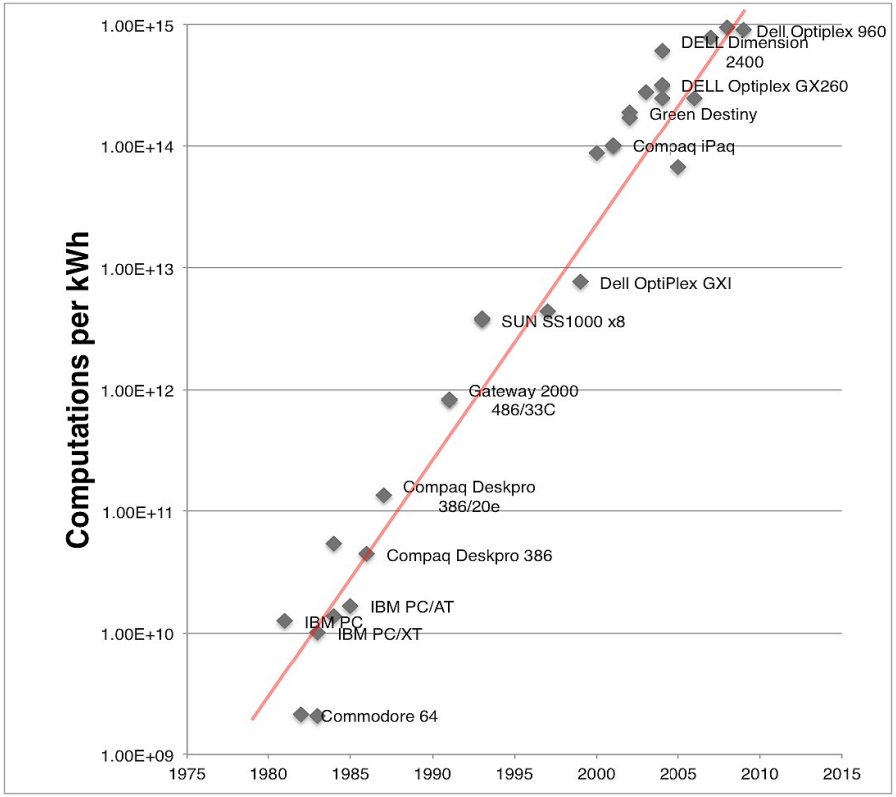
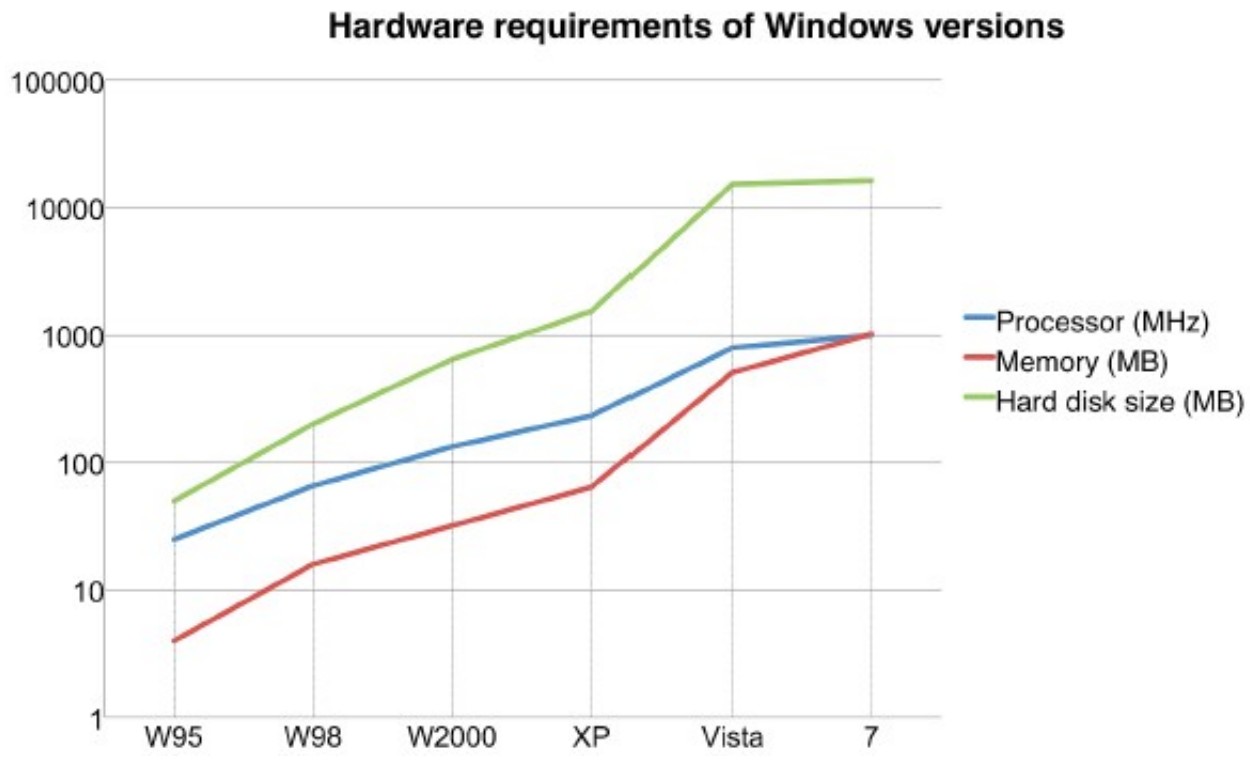
Is hardware energy-efficient?



"The energy efficiency of hardware doubles every 1.5 years"

(Koomey's law)

Ok, so what about **software**?



"Software gets slower more rapidly than hardware gets faster"

(Wirth's law)

Why is software consuming more and more?

1. **Software is a gas**
   Software always expands to fit whatever container it is stored in

2. **Software grows until it becomes limited by Moore's Law**
   The initial growth of software is rapid, like gas expanding, but is inevitably limited by the rate of increase in hardware speed

3. **Software growth makes Moore's Law possible**
   People buy new hardware because the software requires it

4. **Software is only limited by human ambition and expectation**
   We'll always find new algorithms, new applications, and new users

Nathan P. Myhrvold, Microsoft, ACM 1997

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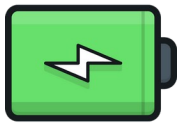
Let’s touch the problem



Battery Drainer

The Green Lab

Code: X_418158

Period: 1 (September-October)

ECTS: 6.0

Language: English

Technically challenging: YES!

What this course is about

- **MAIN GOAL** – to learn about:
  - energy efficiency of software
  - empirical software engineering
    - data-driven
    - the experimental process

- Build a successful experiment in the lab
  - software measurement
  - Data analysis with R
  - Data visualization with R
  - How to write a scientific report

Course schedule

wk		Tuesdays		Fridays	Assignments
1	Tue 05/09 - 11:00 WN-Q112	L1 - Introduction to the course; Example of team project; Intro to empirical software engineering [Ivano]	Fri 08/09 - 9:00 WN-D107	L2 - Experimental Process; GQM [Ivano]	
2	Tue 12/09 - 11:00 WN-Q112	LAB1 - Lab environment, tools, and devices (Android/Experiment Runner) [Radu]	Fri 15/09 - 9:00 WN-D107	L3 - How to design and develop green software [Vincenzo]	GQM (deadline: 15/09 - 23:59)
3	Tue 19/09 - 9:00 HG-02A00	L4 - Experiment planning; Subjects and variable selection; Measurement theory basics [Ivano]			
	Tue 19/09 - 11:00 WN-Q112	L5 - Experiment Design (basics and advanced) [Ivano]			
4	Tue 26/09 - 11:00 WN-Q112	L6 - Data Analysis; Hypothesis Testing [Ivano]	Fri 29/09 - 9:00 WN-D107	LAB2 - R in practice [Theodore]	Experiment design (deadline: 29/09 - 23:59)
5	Tue 03/10 - 11:00 WN-Q112	L7 - Statistical Tests [Ivano]	Fri 06/10 - 9:00 WN-D107	LAB3 - Statistical tests with R [Theodore]	
6	Tue 10/10 - 11:00 WN-Q112	L8 - Data Visualization [Ivano]	Fri 13/10 - 9:00 WN-D107	LAB4 - Data visualization in R with ggplot2 [Theodore]	
7	Tue 17/10 - 9:00 HG-02A00	L9 - Experiment Reporting; Validity evaluation [Ivano]			
	Tue 17/10 - 11:00 NU-4C51 (Theater 9)	**Guest lecture**			
8	FINALIZE PROJECT				Final report (deadline: 20/10 - 23:59)

2 types of lectures

- Theory
- Labs

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A typical lecture

- ~5 minutes
  - discussion about the previous lecture/lab
    - questions about how it went, feeling about the tools, problems, ideas, etc.
- ~1.5 hours
  - lecturing, giving and explaining examples, moderation of possible discussions
- ~5 minutes
  - wrap up, discussion of reading material, look forward to the next phases of the course

Each lecture will be your compass, not your book

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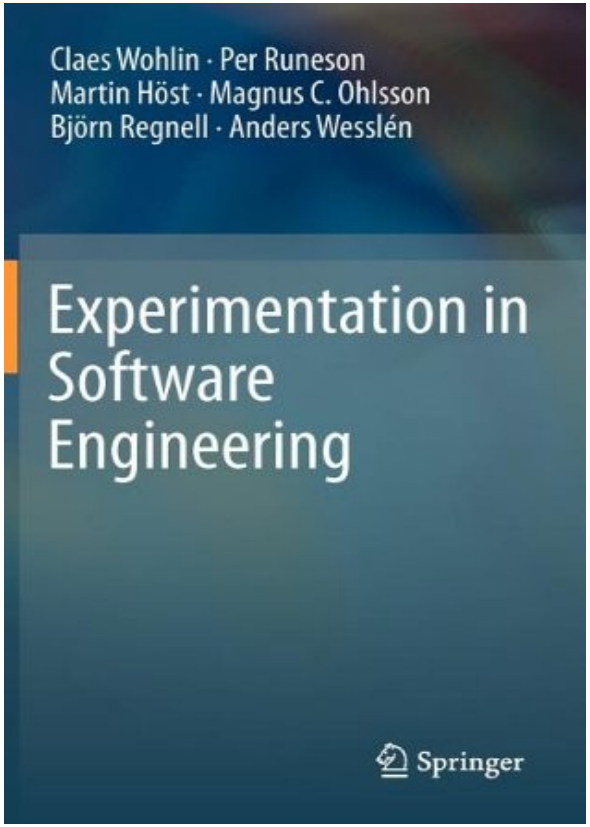
Textbook



Experimentation in Software Engineering

by Anders Wesslén, Björn Regnell, Claes Wohlin, Magnus C. Ohlsson, and Martin Host

http://link.springer.com/book/10.1007%2F978-3-642-29044-2

It is also available on Canvas

Additional books also available on Canvas, use them as manuals

A typical Lab session

- ~5 minutes
  - discussion about the previous lecture
- ~40 minutes
  - the TA shows you how to use the tools
  - explanation of a simple exercise and its execution in an interactive manner
  - the source code of the exercise will be available on Canvas
- ~45 minutes
  - you will work on a small hands-on exercise
  - you can ask questions at any time to the instructor, thus solving your problems "on-demand"
  - bring your own laptop

MANDATORY ATTENDANCE

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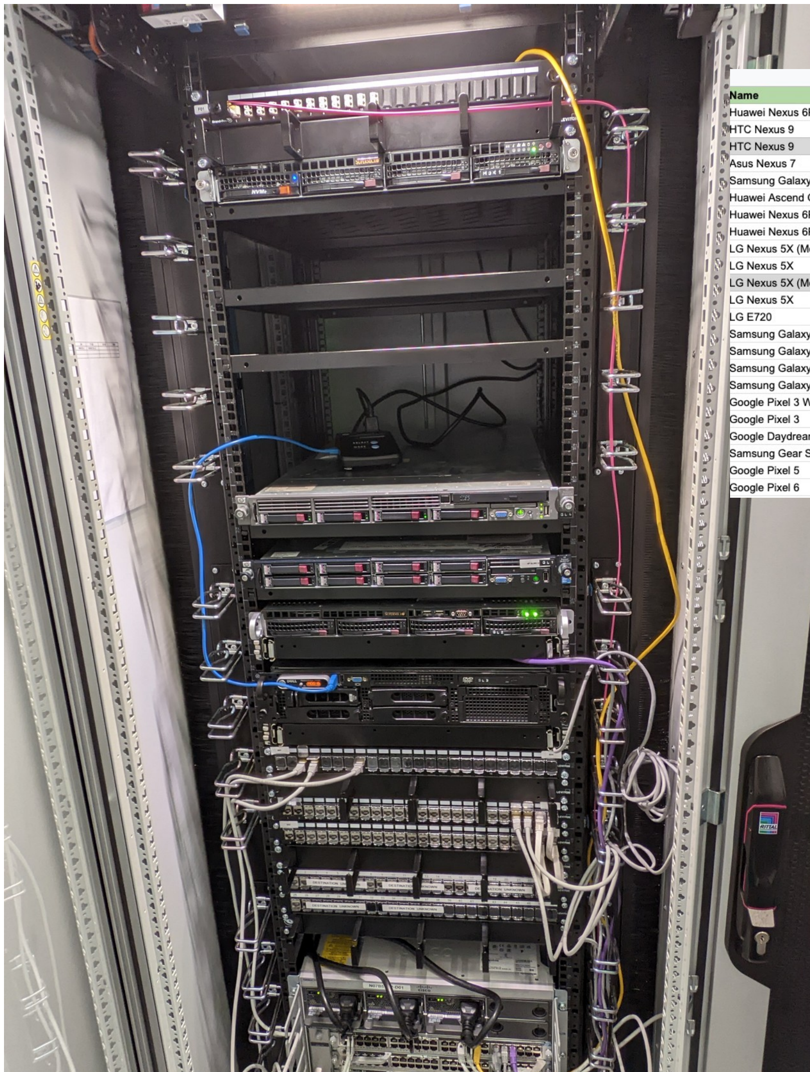
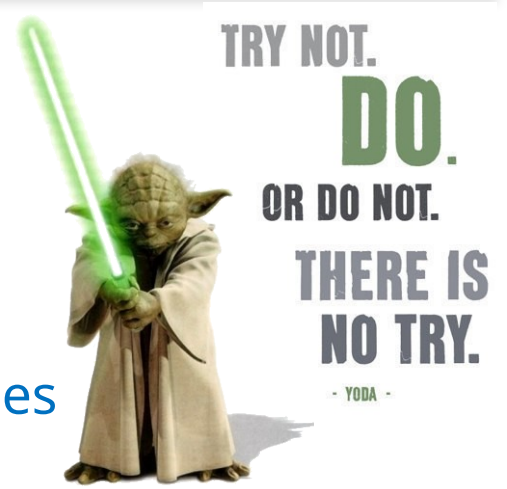
The Green Lab is also a physical place



Name	Type	Technical spec	CPU	Memory	Android	Trepn	Batterystats	Released	Rooted?
Huawei Nexus 6P	Smartphone	http://www.gsmarena.co	Qualcomm MSM8994 Snapdragon 810 - Octa-core 1.5+2.0 GHz	3Gb	6.0.1	Yes	Yes	2015	Yes
HTC Nexus 9	Tablet	http://www.gsmarena.co	Nvidia Tegra K1 - Dual-core 2.3 GHz Denver	2Gb	5.1.1	Yes	No	2014	
HTC Nexus 9	Tablet	http://www.gsmarena.co	Nvidia Tegra K1 - Dual-core 2.3 GHz Denver	2Gb	6.0.1	Yes	No	2014	
Asus Nexus 7	Tablet	http://www.gsmarena.co	Qualcomm Snapdragon S4Pro - Quad-core 1.5 GHz Krait	2Gb	6.0.1	Yes	Yes	2013	
Samsung Galaxy Nexus 3	Smartphone	http://www.gsmarena.co	TI OMAP 4460 - Dual-core 1.2 GHz Cortex-A9	1Gb	4.4.4	No	No	2011	
Huawei Ascend G300	Smartphone	http://www.gsmarena.co	Qualcomm MSM7227A Snapdragon S1 - 1.0 GHz Cortex-A5	512Mb	4.0.3	No	No	2012	
Huawei Nexus 6P	Smartphone	http://www.gsmarena.co	Qualcomm MSM8994 Snapdragon 810 - Octa-core 1.5+2.0 GHz	3Gb	8.1.0	Yes	Yes	2015	
Huawei Nexus 6P	Smartphone	http://www.gsmarena.co	Qualcomm MSM8994 Snapdragon 810 - Octa-core 1.5+2.0 GHz	3Gb	6.0.0	Yes	Yes	2015	
LG Nexus 5X (Monsoon-compatible)	Smartphone	https://www.gsmarena.c	Hexa-core (4x1.4 GHz Cortex-A53 & 2x1.8 GHz Cortex-A57)	2Gb	to check	No	Yes	2015	
LG Nexus 5X	Smartphone	https://www.gsmarena.c	Hexa-core (4x1.4 GHz Cortex-A53 & 2x1.8 GHz Cortex-A57)	2Gb	8.1.0	No	Yes	2015	
LG Nexus 5X (Monsoon-compatible)	Smartphone	https://www.gsmarena.c	Hexa-core (4x1.4 GHz Cortex-A53 & 2x1.8 GHz Cortex-A57)	2Gb	6.0.1	to check	Yes	2015	Yes
LG Nexus 5X	Smartphone	https://www.gsmarena.c	Hexa-core (4x1.4 GHz Cortex-A53 & 2x1.8 GHz Cortex-A57)	2Gb	to check	No	Yes	2015	
LG E720	Smartphone	https://www.gsmarena.c	Qualcomm MSM7227 ARM1136EJ-S (1x600 Mhz)	418Mb	2.2	No	No	2010	
Samsung Galaxy J7 Duo	Smartphone	https://www.gsmarena.c	Octa-core (2x2.2 GHz Cortex-A73 & 6x1.6 GHz Cortex-A53)	4gb	8.0.0	No	Yes	2018	
Samsung Galaxy J7 Duo	Smartphone	https://www.gsmarena.c	Octa-core (2x2.2 GHz Cortex-A73 & 6x1.6 GHz Cortex-A53)	4gb	8.0.0	No	Yes	2018	
Samsung Galaxy J7 Duo	Smartphone	https://www.gsmarena.c	Octa-core (2x2.2 GHz Cortex-A73 & 6x1.6 GHz Cortex-A53)	4gb	8.0.0	No	Yes	2018	
Samsung Galaxy J7 Duo	Smartphone	https://www.gsmarena.c	Octa-core (2x2.2 GHz Cortex-A73 & 6x1.6 GHz Cortex-A53)	4gb	8.0.0	No	Yes	2018	
Google Pixel 3 White	Smartphone	https://www.gsmarena.c	Octa-core (2x2.2 GHz Cortex-A73 & 6x1.6 GHz Cortex-A53)	4gb	8.0.0	No	to check	2018	
Google Pixel 3	Smartphone	https://www.gsmarena.c	Octa-core (2x2.2 GHz Cortex-A73 & 6x1.6 GHz Cortex-A53)	4gb	8.0.0	No	to check	2018	
Google Daydream for smartphone	VR visor	https://vr.google.com/da	-	-	-	-	-	-	-
Samsung Gear S3 42mm WiFi LTE	Smartwatch	https://www.samsung.cc	-	-	-	-	-	-	-
Google Pixel 5	Smartphone	https://www.gsmarena.c	-	8Gb	to check	to check	to check	2020	No
Google Pixel 6	Smartphone	https://www.gsmarena.c	-	8Gb				2021	No

Raspberry Pi Camera Module V2	Module	https://www.raspbe	Locker 14
Raspberry Pi Camera Module V2	Module	https://www.raspbe	Locker 14
Raspberry Pi Powerpack v2.0	Energy Component		Locker 14
Raspberry Pi Powerpack v2.0	Energy Component		Locker 14
Raspberry Pi Powerpack v2.0	Energy Component		Locker 14
Raspberry Pi Powerpack v2.0	Energy Component		Locker 14
Raspberry Pi Powerpack v2.0	Energy Component		Locker 14
Raspberry Pi Powerpack v2.0	Energy Component		Locker 14
TurtleBots			
TurtleBot3 Burger (customized with INA	Robot	https://www.robotis.	Tahsin
RaspberryPi Camera	Module	...	Tahsin
Energy Monitor Device	Device	...	Tahsin
TurtleBot3 Burger	Robot	https://www.robotis.	Locker 13
Energy Monitor Device	Device	...	Locker 13 on TurtleBot
Raspberry Pi Camera Module V2	Module	https://www.raspbe	Locker 13 on TurtleBot
TurtleBot3 Burger	Robot	https://www.robotis.	Locker 13
INA219 DC Current Monitor	Sensor	https://www.adafruit	Locker 13 on TurtleBot
TurtleBot3 Burger	Robot	https://www.robotis.	Locker 13
TurtleBot3 Burger			? Lended ?
Arduino			
Arduino Nano Atmega328	Microcontroller	https://store.arduinc	Tahsin
Arduino Nano Atmega328	Microcontroller	https://store.arduinc	Vincenzo
Arduino Nano Atmega328	Microcontroller	https://store.arduinc	Locker 14
Arduino Nano Atmega328	Microcontroller	https://store.arduinc	Locker 14
Arduino Nano Atmega328	Microcontroller	https://store.arduinc	Locker 14
Arduino Nano Atmega4809	Microcontroller	https://store.arduinc	Locker 14
Arduino Nano Atmega4809	Microcontroller	https://store.arduinc	Locker 14
Arduino Nano Atmega4809	Microcontroller	https://store.arduinc	Locker 14

Grading



- Team project (100% of the final grade)
  - start day-1 with the project work
  - if you are not familiar with the technologies
    - study and practice (A LOT!)
  - teams of 5 students

- Aims:
  - to put in practice what you will learn
  - to develop your technical skills

Start forming teams NOW!

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Schedule and deliverables

- **Deliverable 1** (20% of the final grade)
  - Experiment goal, scope description, and related work
  - Deliverable:
    - written report
  - Deadline: 15 September: 23:59
- **Deliverable 2** (30% of the final grade)
  - Detailed design of the experiment
  - Deliverable:
    - written report
  - Deadline: 29 September: 23:59
- **Deliverable 3** (50% of the final grade)
  - Final report of the experiment
  - Deliverables:
    - written report
    - GitHub repository containing:
      - experiment execution scripts and source code
      - raw data and analysis scripts in R
    - YouTube video presenting your experiment
  - Deadline: 20 October: 23:59

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Grading

To pass the course the following conditions must be met:

- The score of each assignment must be 6.0 or higher
- The final weighted grade of all assignments must be 6.0 or higher
- YouTube video completed
  - ~15 minutes in total, with each team member presenting ~3 minutes

Deadlines and slip days:

- Deadlines are firm
- Violating deadlines means losing slip days
- You have 3 slip days per team
  - You decide how to spend them
- Your assignment will be marked fail if you will use more than 3 slip days

Relationship with lectures and labs

Attendance to all lectures and labs is MANDATORY

Each lecture/lab will correspond to a specific part of your project

→ you can look at how each part should be done
→ you can ask questions interactively
→ you start reasoning concretely on your project

Misinterpreting or not applying what the lecturer/TA teaches will result in failing the course

- for example: using R for data analysis is mandatory

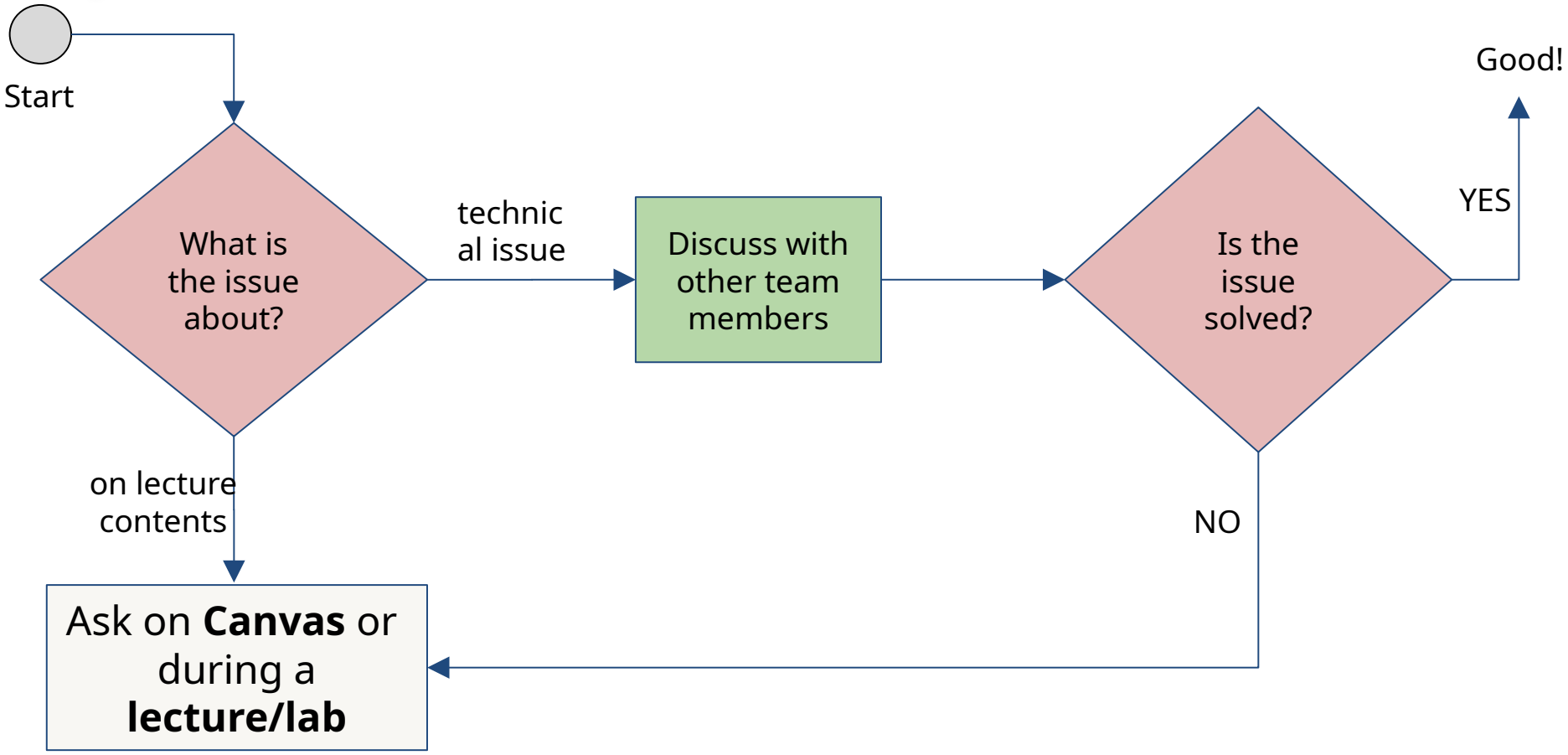
Fraud

Information exchange and collaboration are fully allowed within each single team, cases of plagiarism or inter-team collaboration and assignment contents exchange will be reported to and managed by the official fraud committee.

The use of generative AI to create ready-made content in assignments is considered fraud (*still, you can use it for grammar checks and polishing your English*).

In case of fraud, the consequences of those acts may potentially lead to: formal warning, inclusion of the formal warning in your VU student file, suspension from education and exams for up to one year.

Communication



This course is about opportunities

MOBILE SOFT 2017

4TH IEEE/ACM INTERNATIONAL CONFERENCE ON MOBILE SOFTWARE ENGINEERING AND SYSTEMS

Other publications: https://s2group.cs.vu.nl/pages/greenlab

First action!

- Form your team (by today!)
  - fill this form:
    - https://forms.gle/oroasFK1fkn62uq5A
    - on September 8 I will finalize the teams on Canvas
- Start getting familiar with technologies
  - Experiment Runner
    - https://github.com/S2-group/experiment-runner
  - Android Debug Bridge (ADB)
    - https://developer.android.com/studio/command-line/adb.html
  - Android Runner
    - https://github.com/S2-group/android-runner