The Green Lab

Introduction to the course

Vincenzo Stoico

Announcement about your study plan

Computer Science track Software Engineering & Green IT constrained choice

Description
Students need to choose one course of 6 EC from the Foundations of Computing and Concurrency constrained choices, one course of 6 EC from the Mathematics constrained choices, one course of 6 EC from the...
›More information

Computer Science JD Foundations of Computing and Concurrency constrained choice year 1 and year 2

Computer Science JD Mathematics constrained choice year 1 and year 2

Computer Science JD Programming constrained choice year 1 and year 2

Computer Science JD Societal Perspectives on Computer Science constrained choice

Computer Sciences JD Security constrained choice

CS JD Research Skills constrained choice

Description
Students must complete at least one course of 6 EC from those listed below. Alternatively, students may complete Large Research Project Computer Science XM_0130 (12 EC).
›More information

COURSE NAME	PERIOD	CREDITS	CODE
Literature Study	Ac. Year (sept)	6.00 EC	XM_0131
Research Project Computer Science	Ac. Year (sept)	6.00 EC	XM_0129

Announcement about your study plan

Computer Science pre-approved elective courses

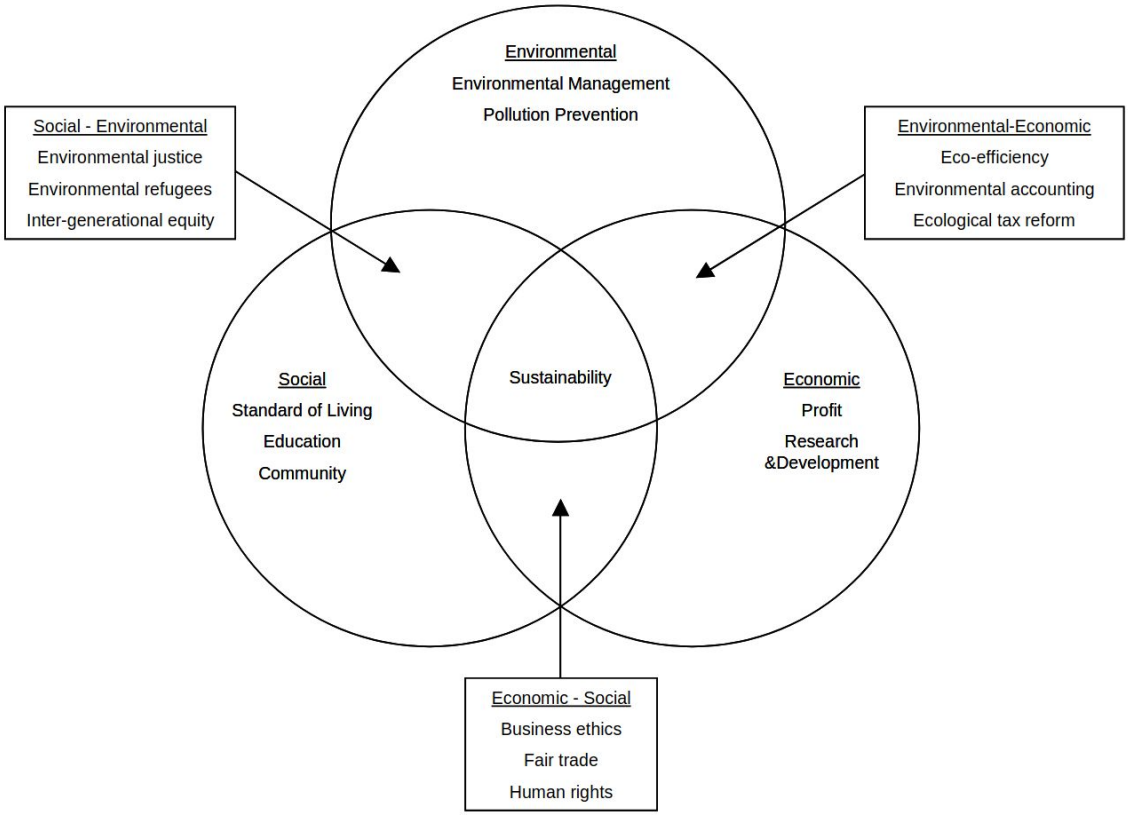
COURSE NAME	PERIOD	CREDITS	CODE
Individual Systems Practical	Ac. Year (sept)	6.00 EC	XM_405088
Industrial Internship	Ac. Year (sept)	6.00 EC	XM_405080
Large Research Project Computer Science	Ac. Year (sept)	12.00 EC	XM_0130

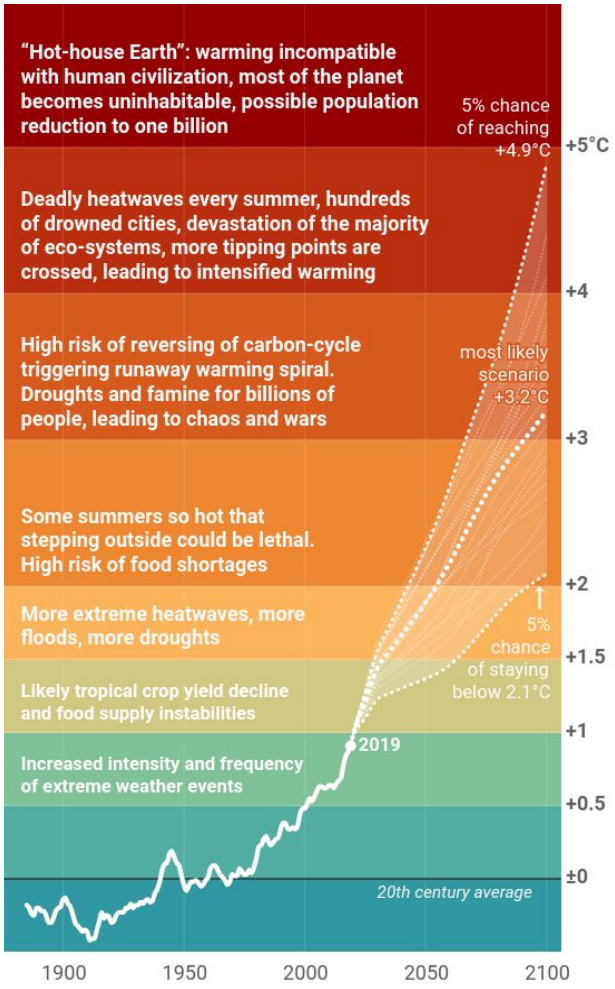
Total of 18 additional ECTs to go DEEPER into a specific research topic!

Our Common Future

"Sustainable development is development that meets the **needs of the present** without compromising the ability of **future generations to meet their own needs.**"

- United Nation, Brundtland Report, 1987





The solid line shows 5-year average of global land and ocean temperature anomalies (NOAA). Dotted lines show different percentiles of warming predictions according to Raftery et.al, 2017. Inspired by The Guardian.

source: https://t.co/2y4fvielXf

Our Common Future

"Sustainable developr
present without comp
meet their own need

- United Nation, E

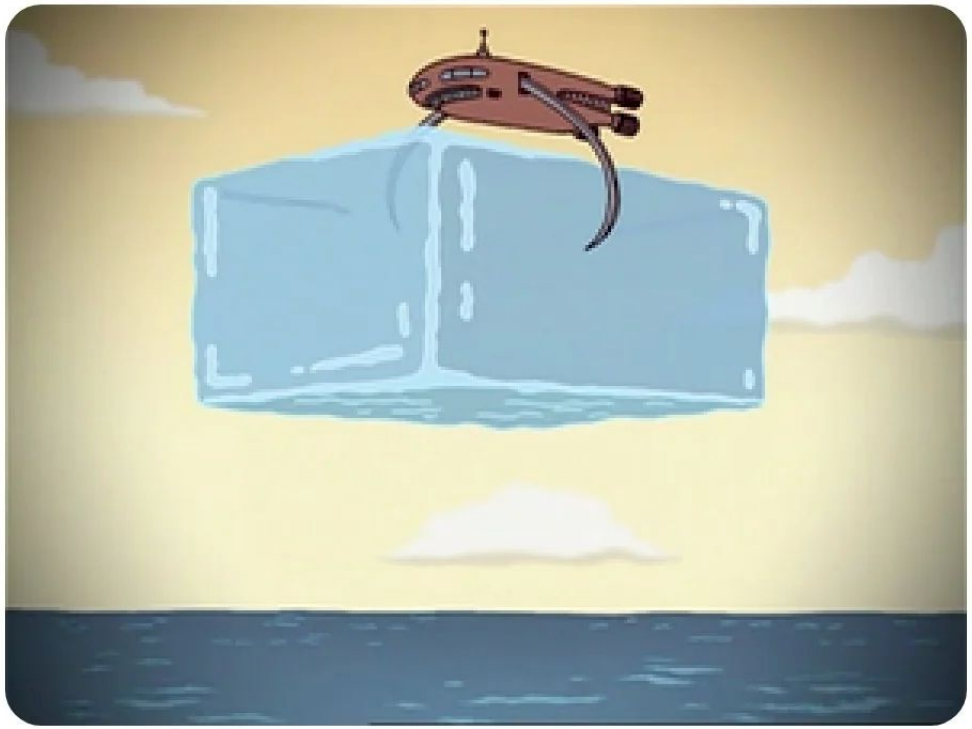
Social - Environmental
Environmental justice
Environmental refugees
Inter-generational equity

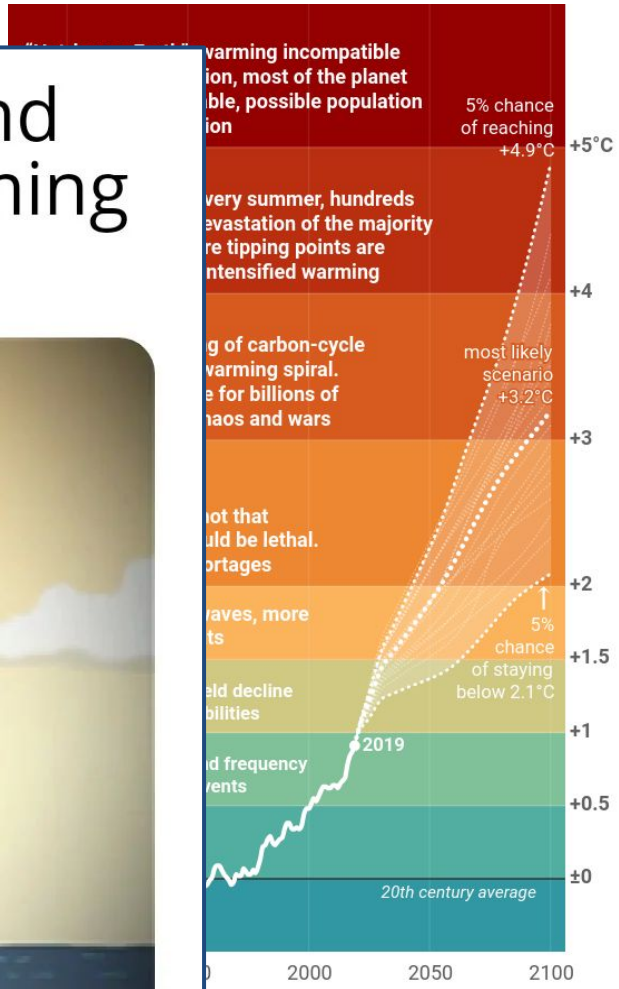
Social
Standard of Livi
Education
Community

Fair trade
Human rights

Scientists: We need to find a solution to global warming

Me:





5-year average of global land and ocean
es (NOAA). Dotted lines show different
g predictions according to Raftery et.al, 2017.

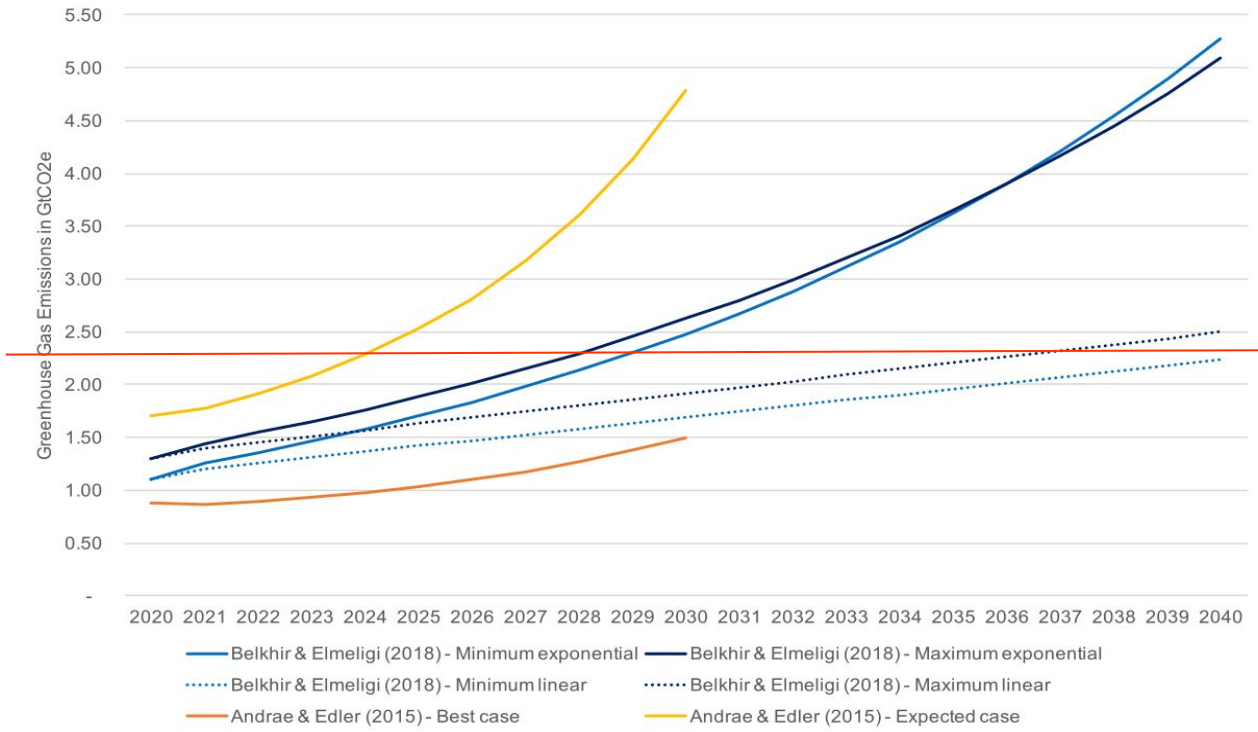
Inspired by The Guardian.

source: https://t.co/2y4fvielXf

Information Communication Technology (ICT) is unsustainable

ICT has growing carbon footprint:

- Embodied (extraction materials, transport, manufacturing)
- Use/Operational
- End-of-Life (disposal)

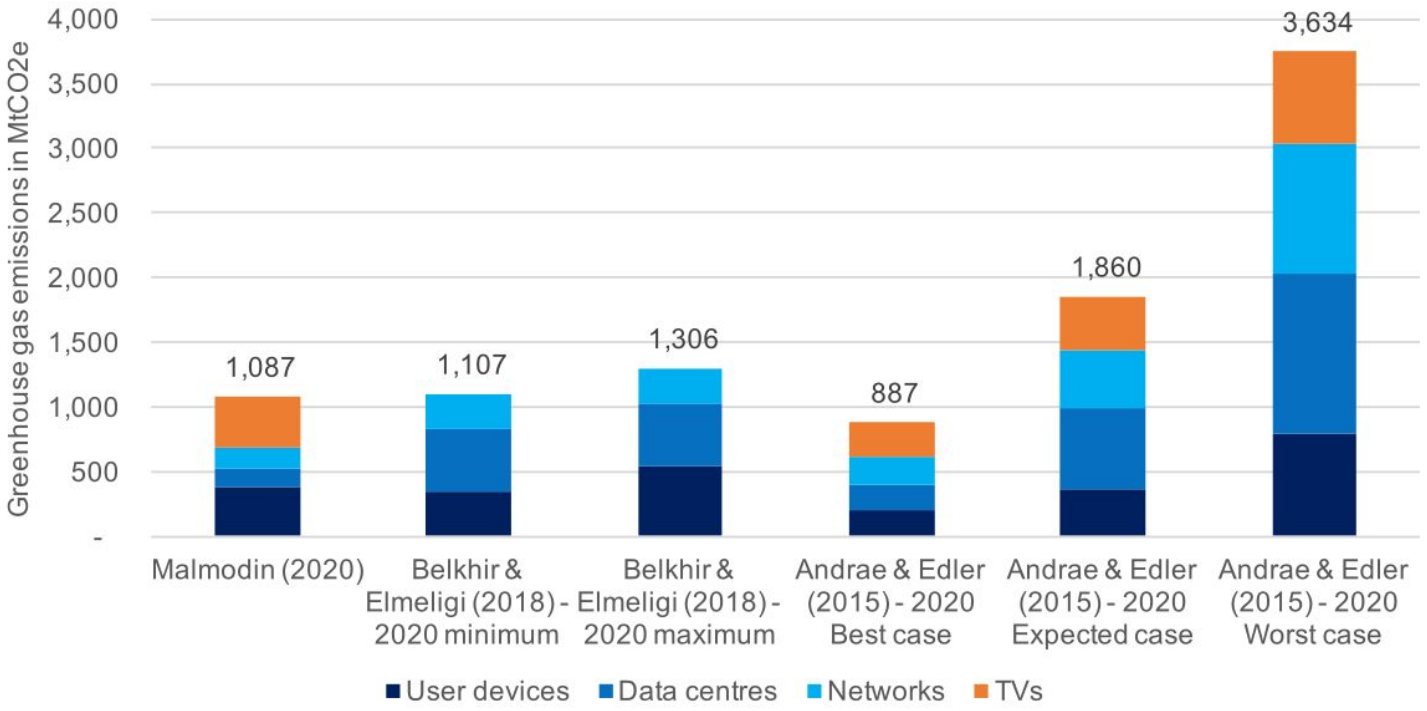


3.9% of global emissions in 2020

Freitag et al. - *"The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations."* Patterns 2, 2021

ICT is unsustainable

- Estimate suffer of “Truncation Error”
- Not accurate but useful drivers (30% Embodied, 70% Use)

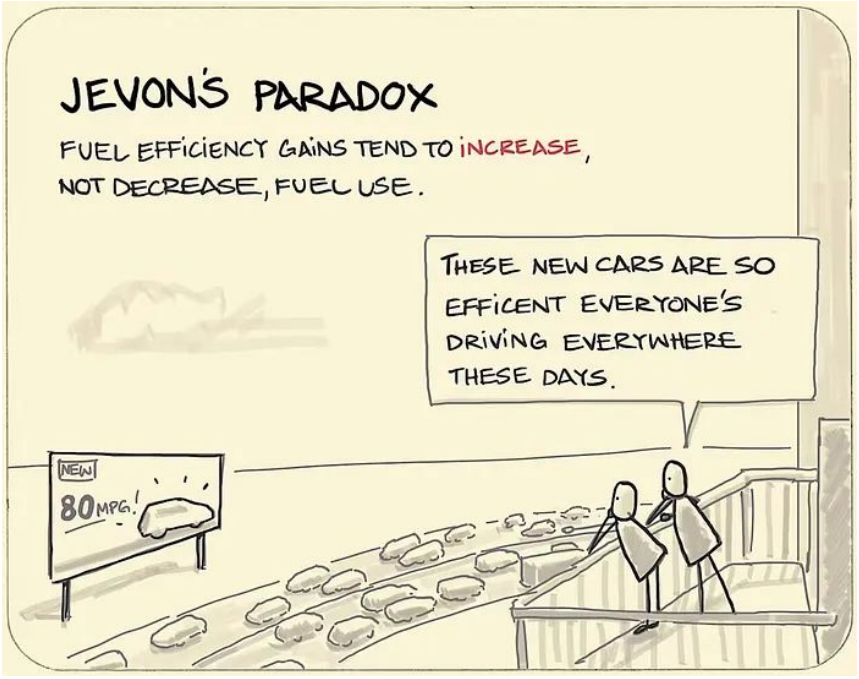


Freitag et al. - *"The real climate and transformative impact of ICT: A critique of estimates, trends, and regulations."* Patterns 2, 2021

Rebound Effects

A *rebound effect* happens when improved resource efficiency leads to higher consumption, offsetting the expected benefits.

- *Direct* rebound:
  - *Cloud Computing*: Increased energy expenditure due to easy access to cloud resources
- *Indirect* rebound:
  - *Food Delivery Apps*: Increased transportation and packaging waste
- *Economy-Wide* rebound:
  - *Fashion Delivery Apps*: Increased consumption of clothes and production

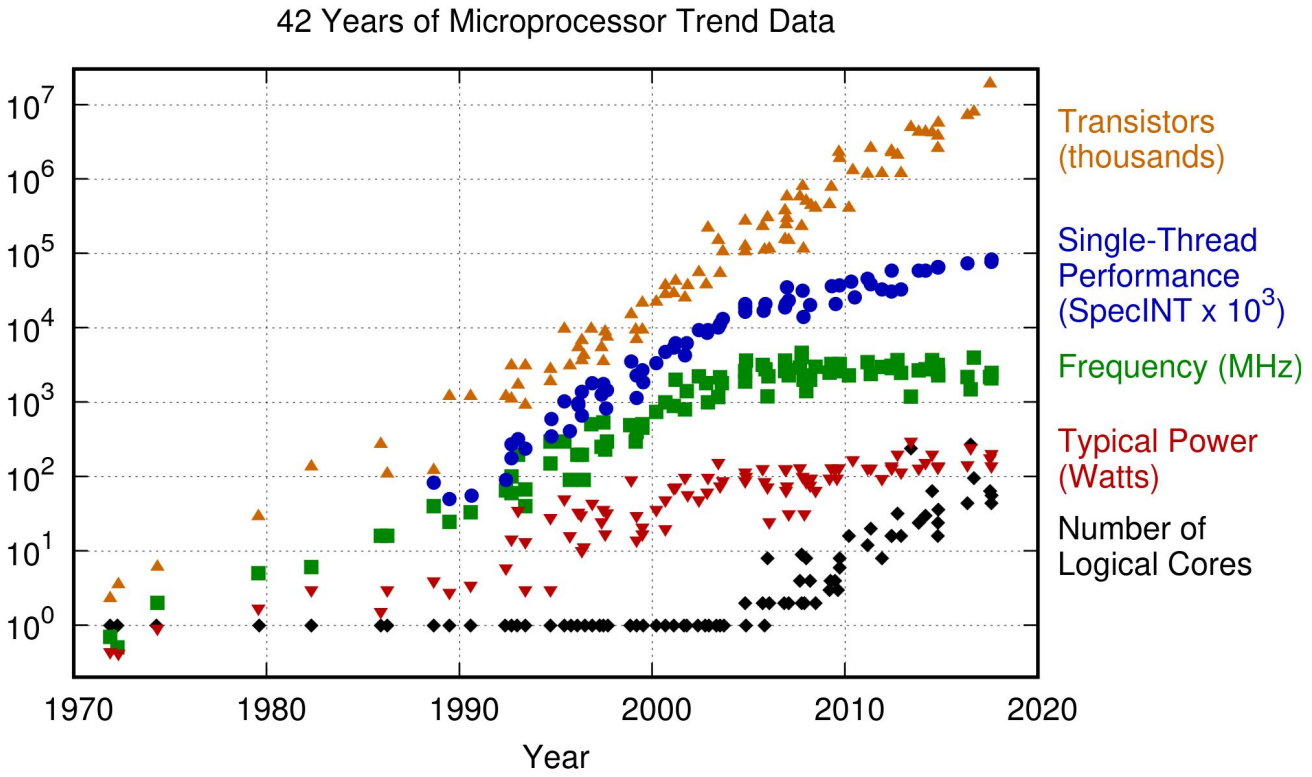


Source: https://rb.gy/fd7sdf

Gossart, *Rebound effects and ICT: a review of the literature. ICT innovations for sustainability*, 2015

Moore's law

- The number of transistors on a microchip doubles about every two years, while the cost halves
- System complexity over chip density



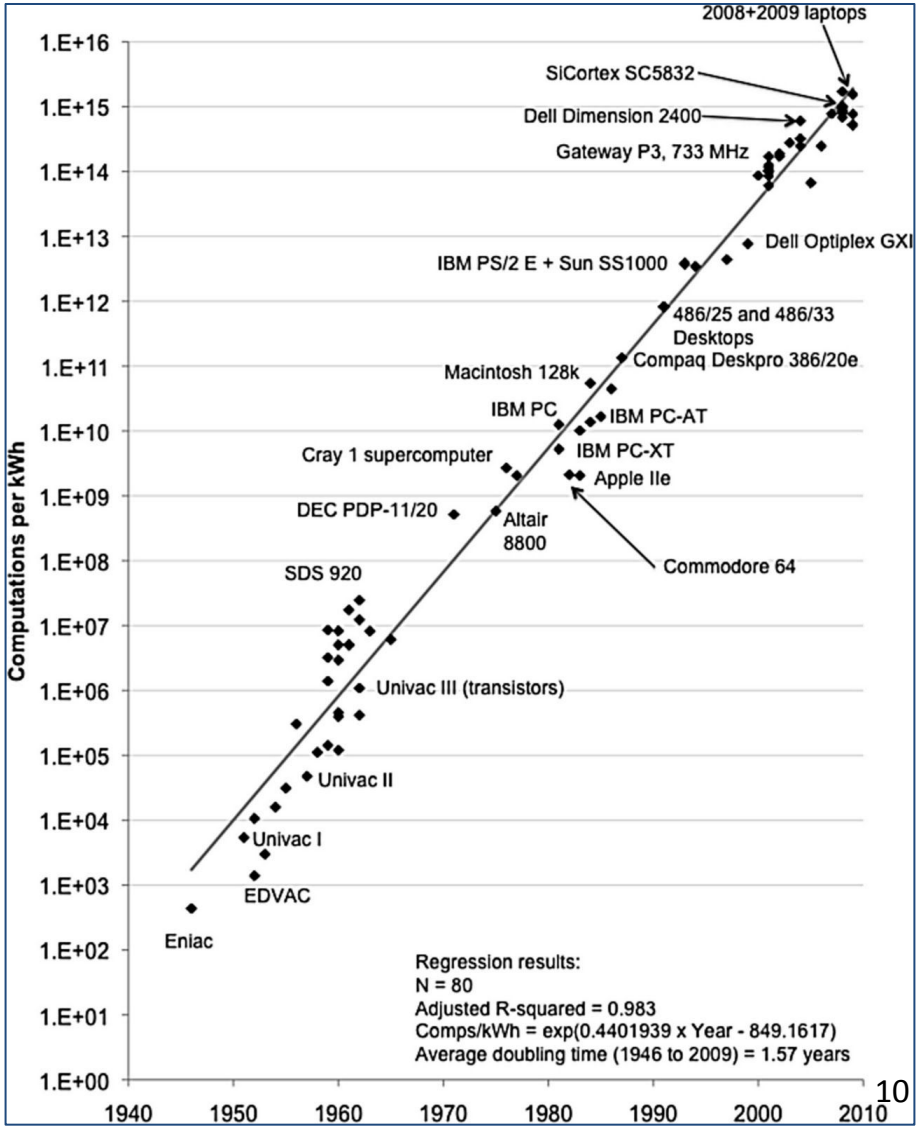
Original data up to the year 2010 collected and plotted by M. Horowitz, F. Labonte, O. Shacham, K. Olukotun, L. Hammond, and C. Batten
New plot and data collected for 2010-2017 by K. Rupp

Is hardware energy-efficient?

Koomey's Law: peak output *energy efficiency of hardware* doubles every 1.5 years

After 2000, the doubling time increased to about 2.6 years

- not accurate since it refers to the energy efficiency at full load
- wasted by inefficient software



Source: https://bitly.cx/qm1N

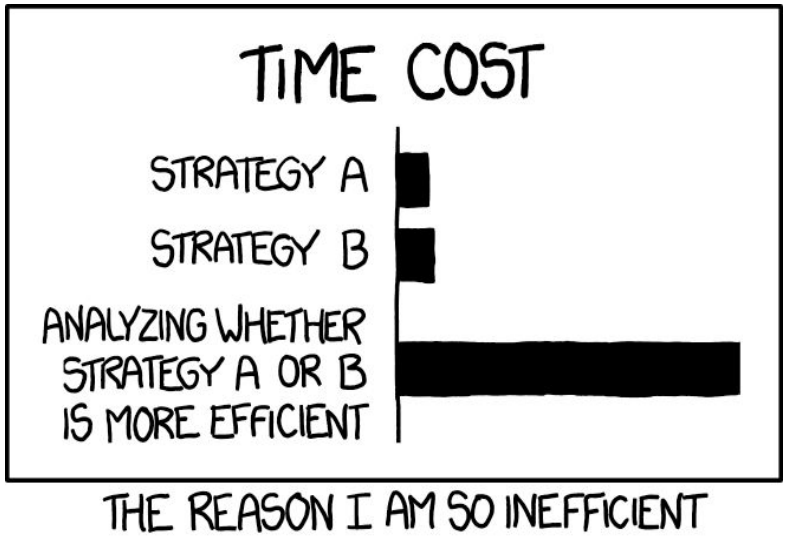
In this course

ICT has growing carbon footprint:

- Embodied (extraction materials, transport, manufacturing)
- Use/Operational
- End-of-Life (disposal)

Software Energy Consumption:

- Correlated
- Measurable



Source: https://xkcd.com/1445/

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

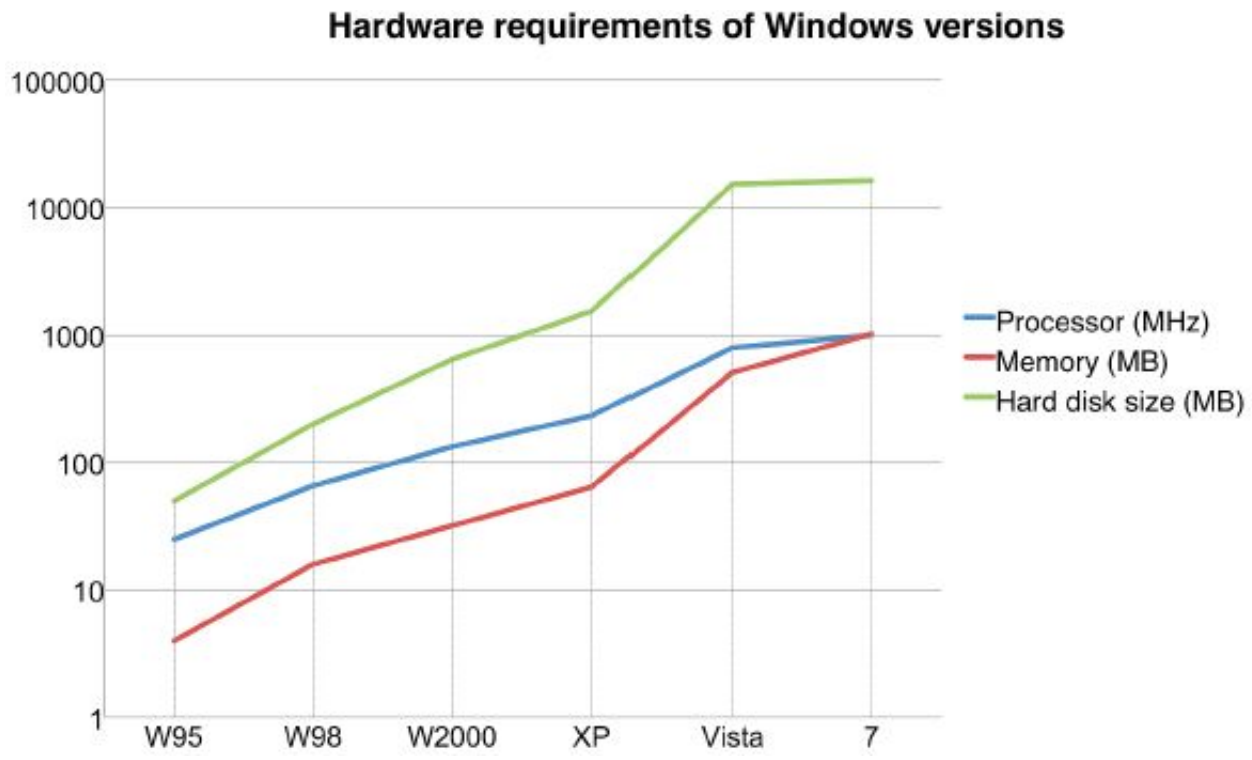
Min utilization rate: 10%
Max utilization rate: 80%

- Cooling
- Lighting

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

"Good" PUE = 100000 kW / 80000 kw = 1.25 = **80% is used**

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

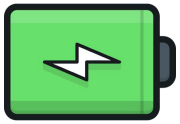
2. **Software grows until it becomes limited by Moore's Law**
   The initial growth of software is rapid, like gas expanding, but is inevitably limited by the rate of increase in hardware speed

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

Let’s touch the problem



Battery Drainer

The Green Lab

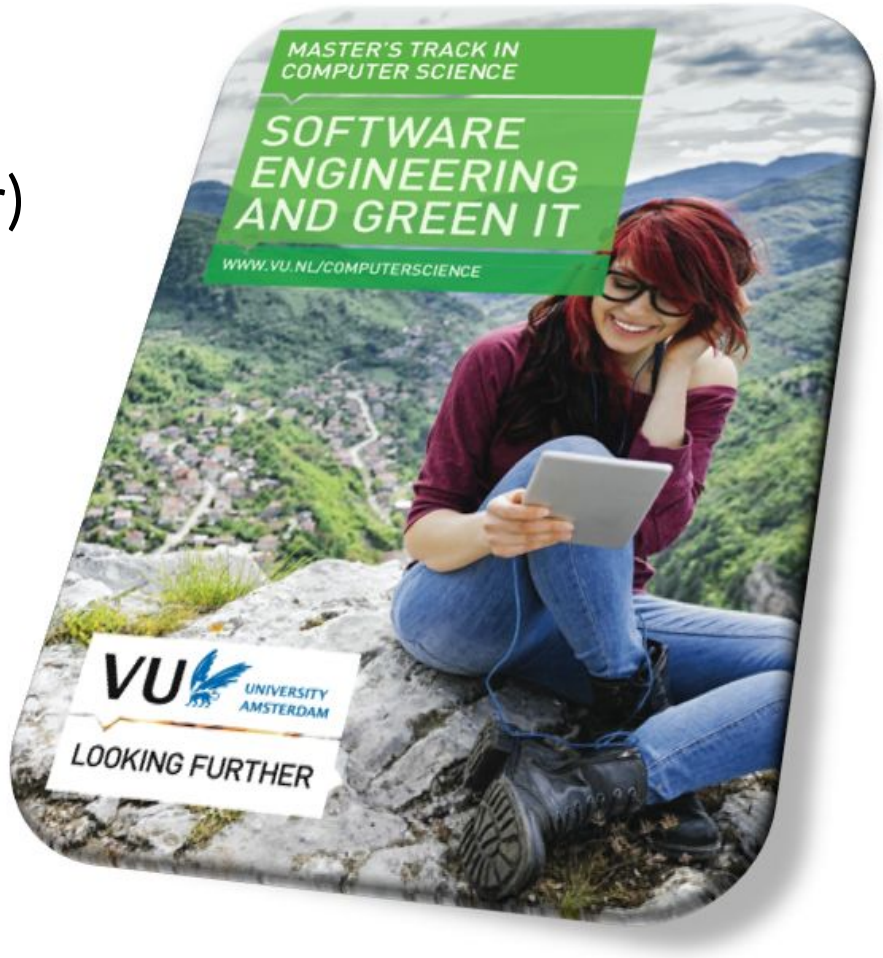
Code: X_418158

Period: 1 (September-October)

ECTS: 6.0

Language: English

Technically challenging: YES!



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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

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Who is who

- Ivano Malavolta
  - i.malavolta@vu.nl
  - Room 10A-33 – NU building

Coordinator

- Vincenzo Stoico
  - Measurement tools – Cloud/IoT
  - General support on experiments

Lecturer and support

- Radu Apsan, Serein Li, Arturo Abril Martinez
  - Measurement tools
- Italo Rossi del Aguila, Chiara Zambianchi, Jakub Frąc
  - R + R Studio
  - Statistical analysis with R
  - Data visualization with R

Teaching assistants

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Course schedule

wk		Tuesdays		Fridays	Assignments
1	Tue 03/09 - 11:00 Theater 2 (NU-C745)	L1 - Introduction to the course; Example of team project; Intro to Energy and Green IT [Vincenzo]	Fri 06/09 - 9:00 HG-KC07	L2 - How to design and develop green software [Vincenzo]	
2	Tue 10/09 - 11:00 Theater 2 (NU-C745)	L3 - Experimental Process; GQM; Construct threats to validity [Ivano]	Fri 13/09 - 9:00 MF-BK37, MF-BK43, MF-BK50	LAB1 - Lab environment, tools, and devices (Android/Experiment Runner) [Radu, Serein, Arturo]	GQM (deadline: 13/09 - 23:59)
3	Tue 17/09 - 9:00 Theater 2 (NU-C745)	L4 - Experiment planning; Subjects and variable selection; Measurement theory basics; External threats to validity [Ivano]	Fri 20/09 - 11:00 HG-KC07	L5 - Experiment Design (basics and advanced); Internal threats to validity [Ivano]	
4	Tue 24/09 - 11:00 Theater 2 (NU-C745)	L6 - Data Analysis; Hypothesis Testing; Conclusion threats to validity [Ivano]	Fri 27/09 - 9:00 MF-BK37, MF-BK43, MF-BK50	LAB2 - R in practice [Chiara, Italo, Jakub]	Experiment design (deadline: 27/09 - 23:59)
5	Tue 01/10 - 11:00 Theater 2 (NU-C745)	L7 - Statistical Tests [Ivano]	Fri 04/10 - 9:00 MF-BK37, MF-BK43, MF-BK50	LAB3 - Statistical tests with R [Chiara, Italo, Jakub]	
6	Tue 08/10 - 11:00 Theater 2 (NU-C745)	L8 - Data Visualization; Experiment Reporting [Ivano]	Fri 11/10 - 9:00 MF-BK37, MF-BK43, MF-BK50	LAB4 - Data visualization in R with ggplot2 + QA [Chiara, Italo, Jakub]	
7	Tue 15/10 - 9:00 Theater 2 (NU-C745)	L9 - Software Carbon Intensity; Final QA [Ivano]	Fri 18/10 - 9:00 HG-KC07	**Guest lecture**	
8	FINALIZE PROJECT				Final report (deadline: 25/10 - 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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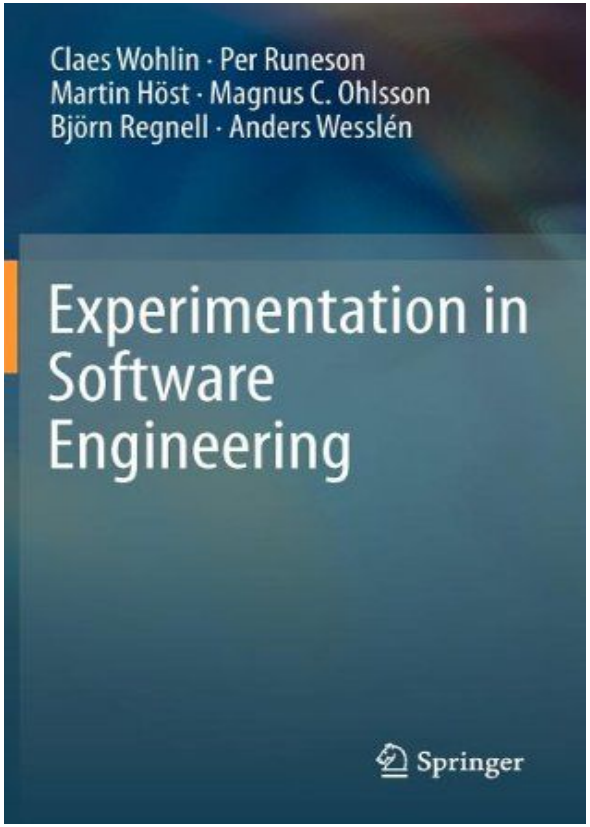
Textbook



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

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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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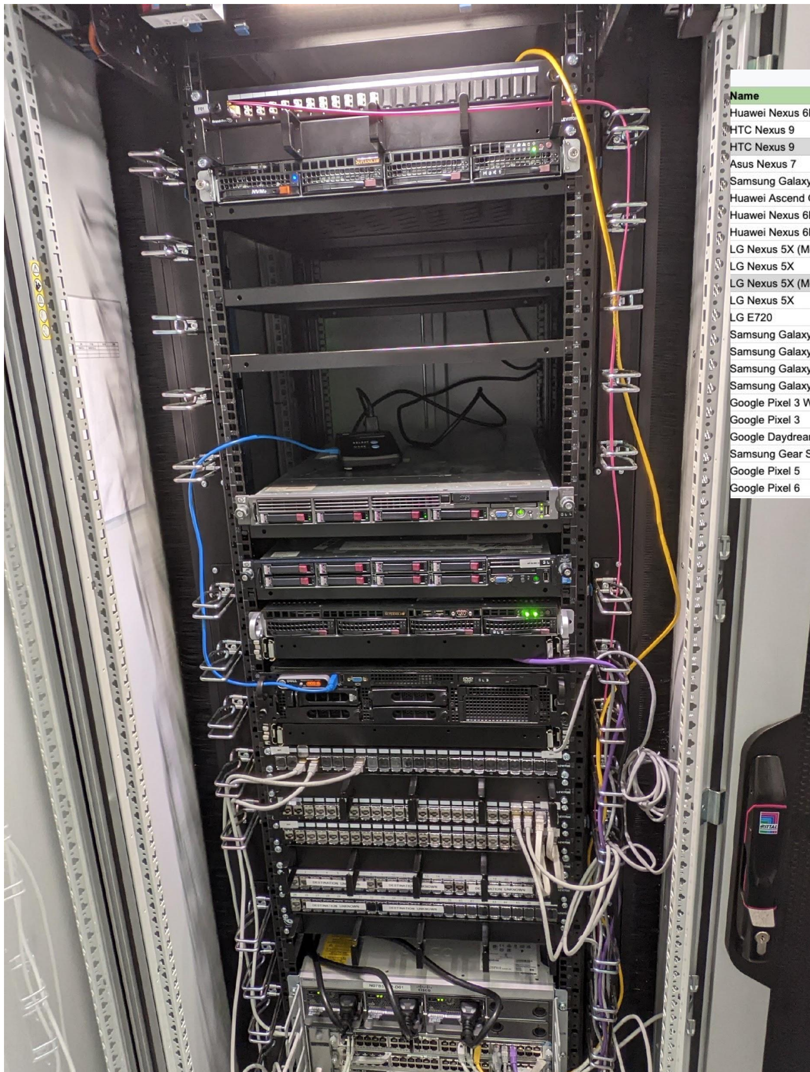
The Green Lab is also a physical place



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 IN/	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: 13 September: 23:59
- **Deliverable 2** (30% of the final grade)
  - Detailed design of the experiment
  - Deliverable:
    - written report
  - Deadline: 27 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
    - video presenting your experiment
  - Deadline: 25 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
- Recorded video completed
  - ~15 minutes in total, with each team member presenting ~3 minutes

Deadlines are firm!

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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

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What we expect from you

This is a **6 credits** course

- we ask you to invest approximately 150 hours for passing the exam

Your estimated average time per week is as follows:

- Attending lectures and lab sessions: 3 hours
- Studying literature and lecture material: 7 hours
- Working on your team project: 8 hours

TOTAL: 18 hours

- **Total study time: 18 hours x 7 weeks =** 126 hours
- Final push: 150 – 126 = 24 hours

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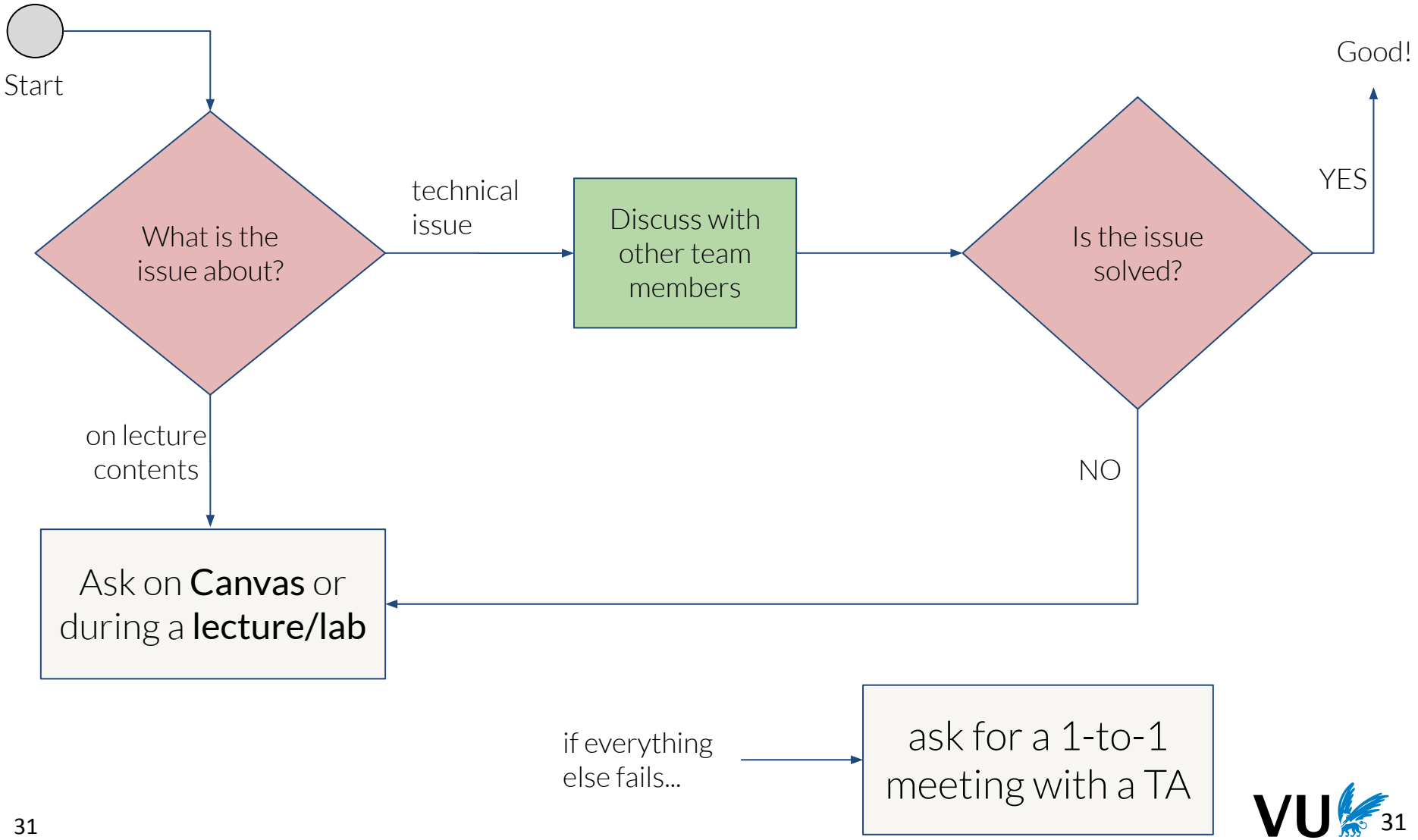
Fraud

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



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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

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First action!

- Form your team (by tomorrow!)
  - fill this form:
    - https://forms.gle/yc54gEoqEJJy7wt6A
    - on September 6 we will finalize the teams on Canvas

- Start getting familiar with technologies
  - Experiment Runner
    - https://github.com/S2-group/experiment-runner
  - Android Runner
    - https://github.com/S2-group/android-runner

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