The F1/10 simulator

Real-Time Embedded System - The F1tenth autonomous racing

UNIMORE
UNIVERSITÀ DEGLI STUDI DI MODENA E REGGIO EMILIA

High Performance Real Time Lab

Course outline

- Intro course + basics of AD
- Hardware platform
- ROS2: Installation and profiling
  - Ex: ROS2 to HiL, open a bag
- Navigation: FTG, FTW, Pure pursuit
  - EX: navigation HiL
- Perception: scan matching, PF, LIO?
  - Ex: perception (PF with PThreads)
- Build the car

I do <u>not</u> cover all aspects of AD!!!

- Systems and control theory => Prof. Falcone
- Platforms and algorithms for autonomous systems => Prof. Sanudo & Prof. Falcone
- High-Performance Computing => Prof. Marongiu (FIM)
- Machine Learning => Cucchiara's

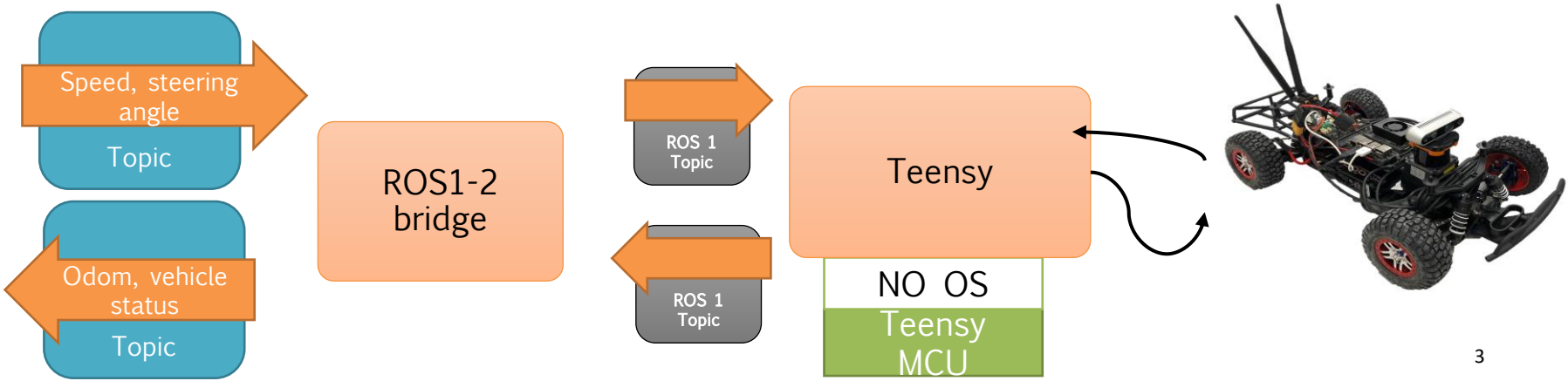
«Teensy» ROS node

Teensy is the microcontroller that controls the brushless engine

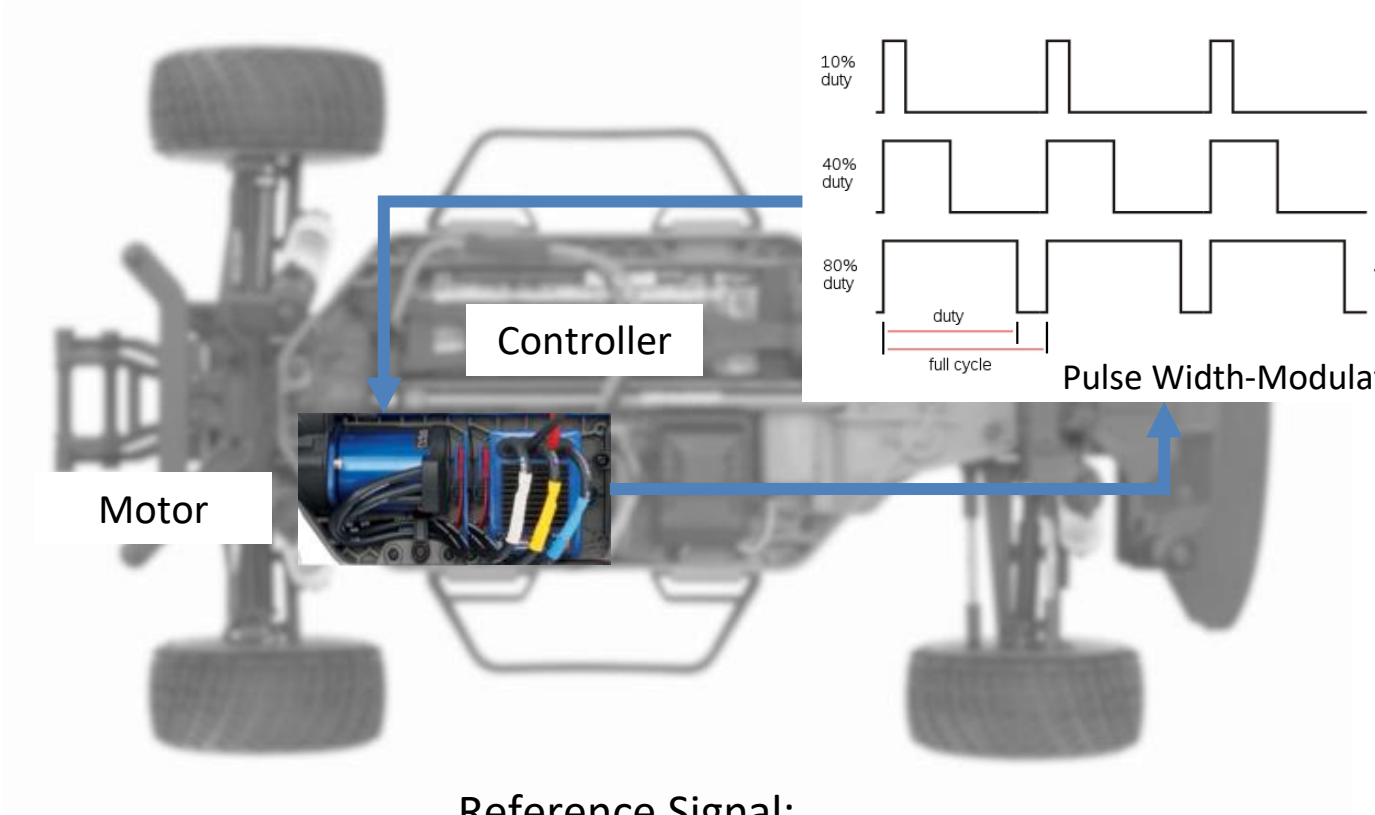
› Typical scenario, also real cars have legacy actuator ECUs!

Note written in ROS1 (teensy has no OS!)

› ROS1-to-ROS2 bridge



Actuation circuit



Pulse Width-Modulated signals

Reference Signal:
“60 RPM”

PWM - D/A conversion (recap..?)

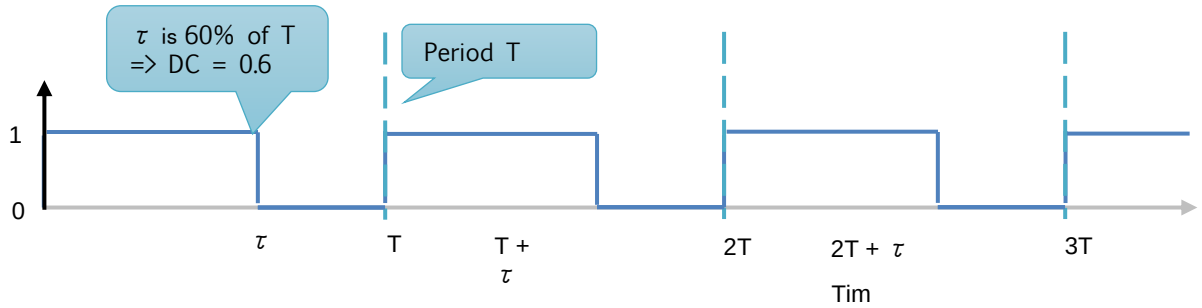
Generate a tension corresponding to a digital value stored in a register

› Not easy! Use Pulse-Width Modulation (PWM)
  – (Almost) fully implementable in SW!

How it works

DC = τ / T

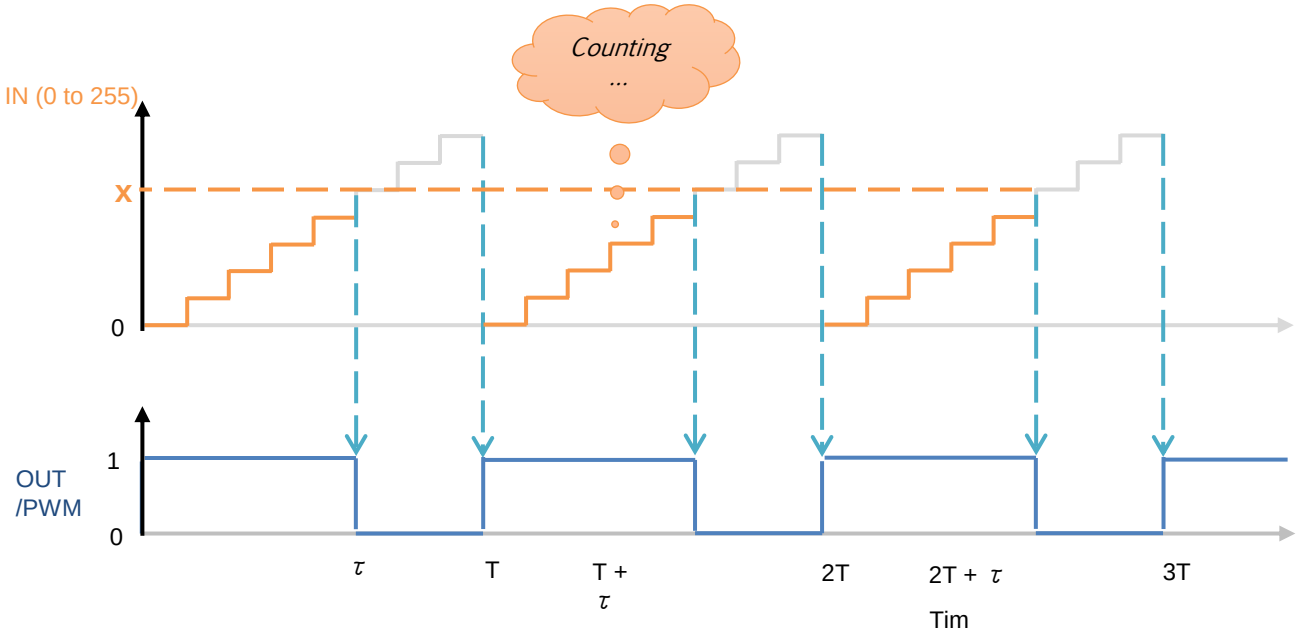
1. Generate a periodic signal of amplitude 1 whose **duty cycle** is proportional to the digital value we want to convert
2. Give it to a low-pass filter, to average (such as Resistor-Capacitor - RC circuit)
3. ..and enjoy your analog signal! ☺



PWM (recap..?) – step 1

We need

- A register that counts from 0 to 255 (8-bit)
- An output port (bit) set to '1' and becoming '0' when input value matches the one of the register

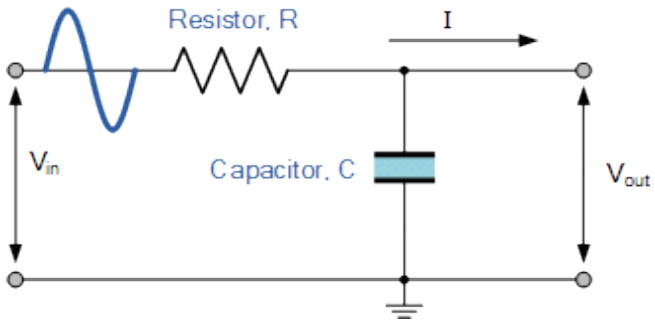


RC low-pass filter (recap..?)

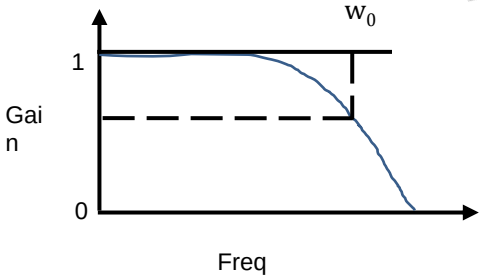
Simple electric circuit with a Capacitor and a Resistance

› "Averages" the IN value

$$|V_{out}| = |V_{in}| \times \frac{1}{\sqrt{1 + w^2 R^2 C^2}}$$



Frequency domain



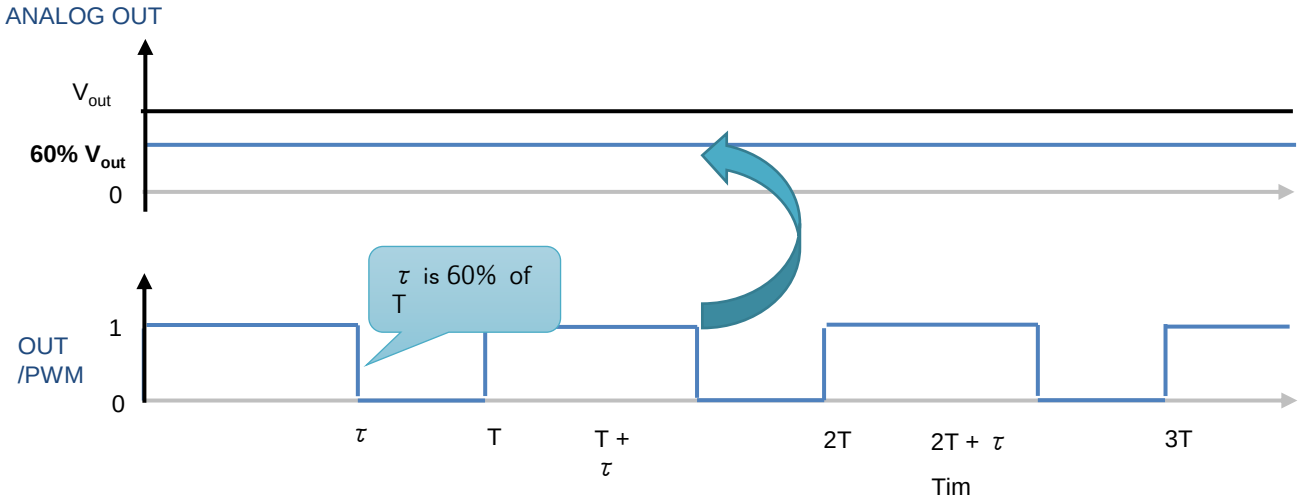
Cutoff freq $w_0 = \frac{1}{RC}$

PWM (recap..?) – step 2

Now, compute the average for every T

- Using a low-pass filter
- Plug it to output port
- *Et voilà*

Extremely useful in engine controls



Electronic Speed Controller – (V)ESC

Manages the brushless engines of the car

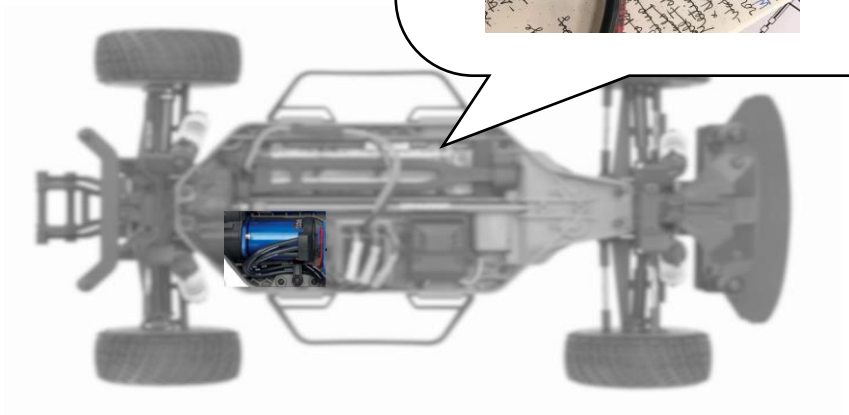
Programmed via a tool

› Once-for-all

Accepts ROS1 commands for lat/lng control

› Acceleration & steering

https://vesc-project.com/



Actuation system W/VESC

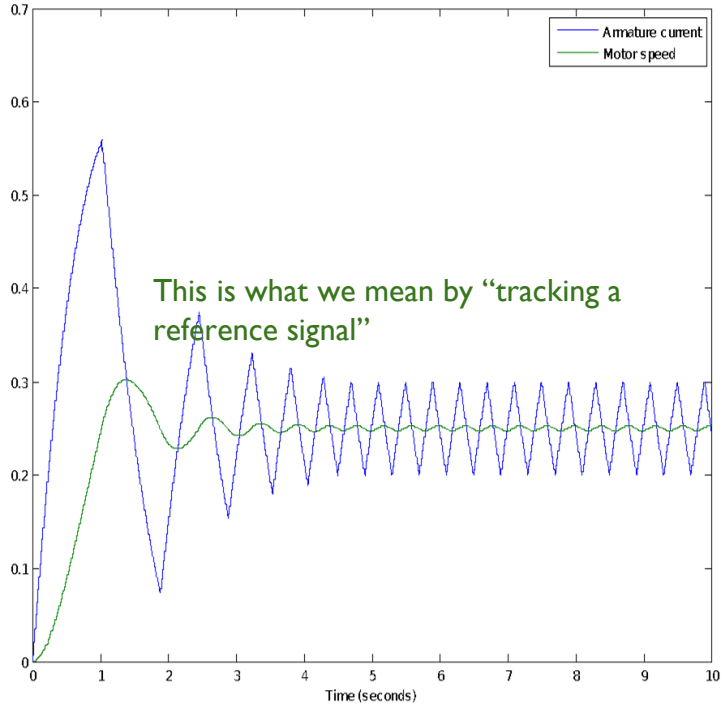
Reference
r(t)
("60rpm")

CONTROLLER

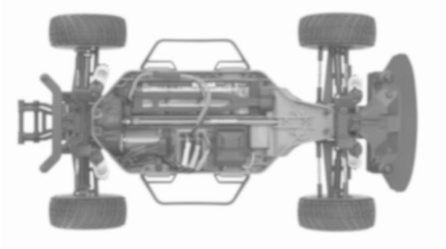
PLANT

Output x(t)
(angular velocity)

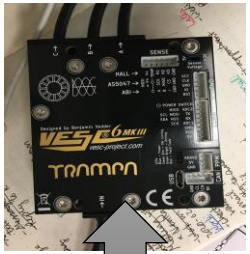
Control input
u(t)
(electric current)



Actuation timings



- LiDAR publishes @40Hz (25ms)
- Teensy loop @?? Hz
  - We don't care! If we don't send a signal, it holds the previous one
- Our pipeline must meet 25ms deadline…incl. ROS delays!



Point cloud

ROS

Urg

Delay

ROS

Perc/Loc

Delay

ROS

Plan+ Ctrl

Delay

ROS

Teensy

ROS2

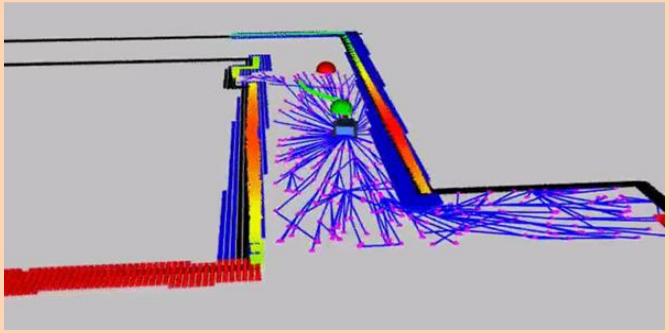
GNU/Linux

NVIDIA Jetson NX

µkernel

Teensy

Actuation in simulator (HiL)



Point cloud

ROS

Urg

Delay

ROS

Perc/Loc

Delay

ROS

Plan+ Ctrl

Delay

ROS

ROS2

GNU/Linux

NVIDIA Jetson NX

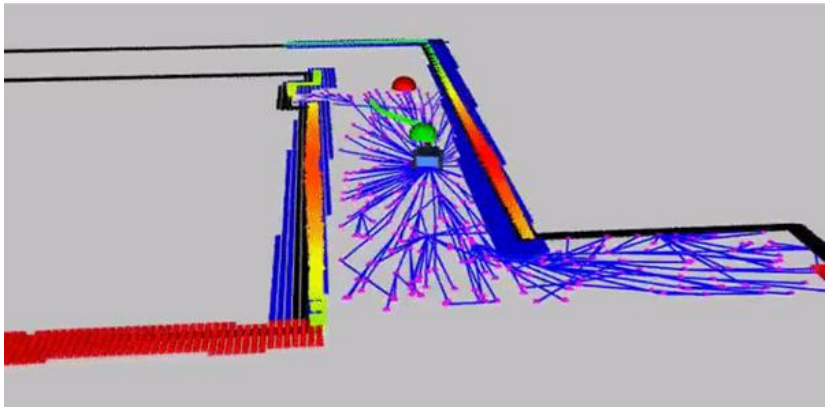
Your-OS

Your-Laptop

F1/10 simulator

F1TENTH Gym:

- Lightweight 2D simulator built in Python
- Asynchronous
- Faster than real-time execution (30x realtime)
- Realistic vehicle simulation and collision
- Runs multiple vehicle instances
- Publishes laser scan and odometry data
- Built for fast prototyping



Exercise

Let's code!

Build and run the pub/sub examples that come with in ROS2

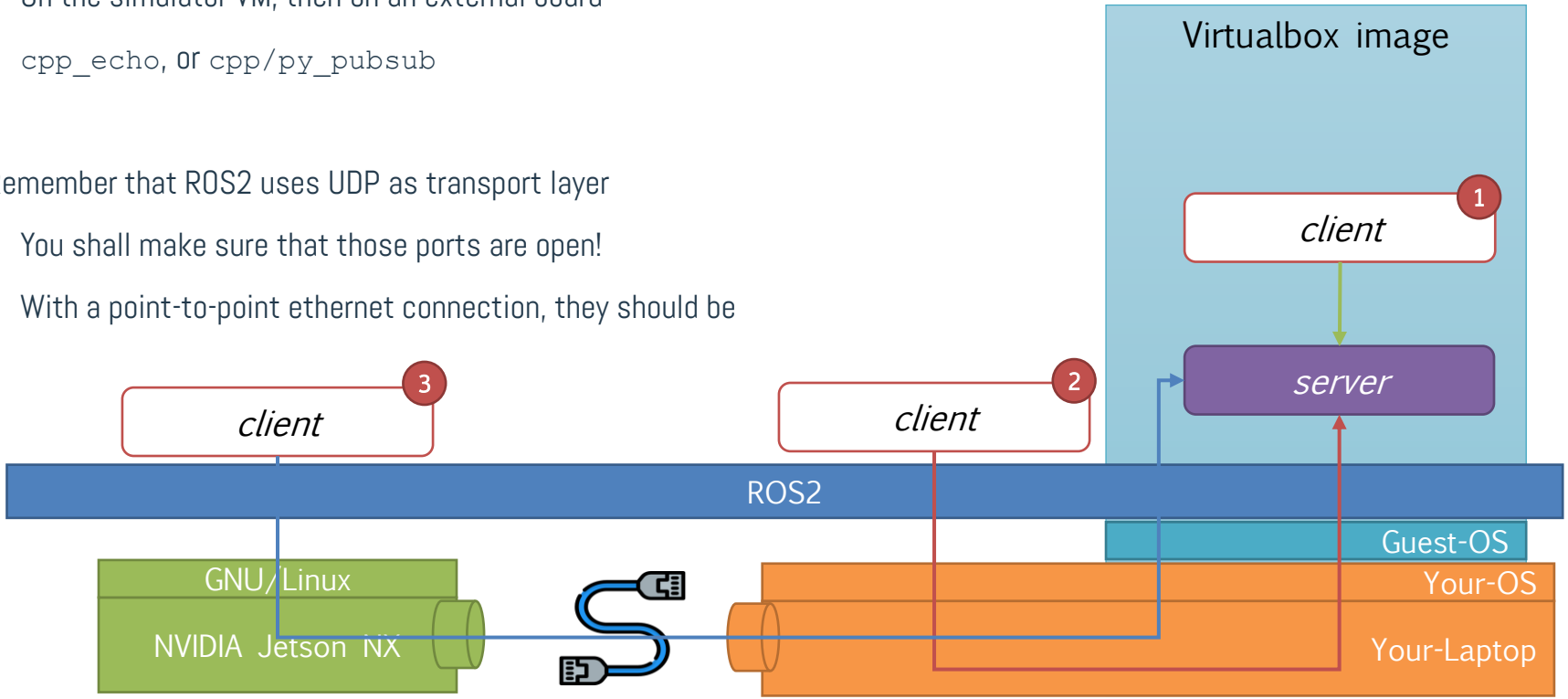
› On the simulator VM, then on an external board

› `cpp_echo`, or `cpp/py_pubsub`

Remember that ROS2 uses UDP as transport layer

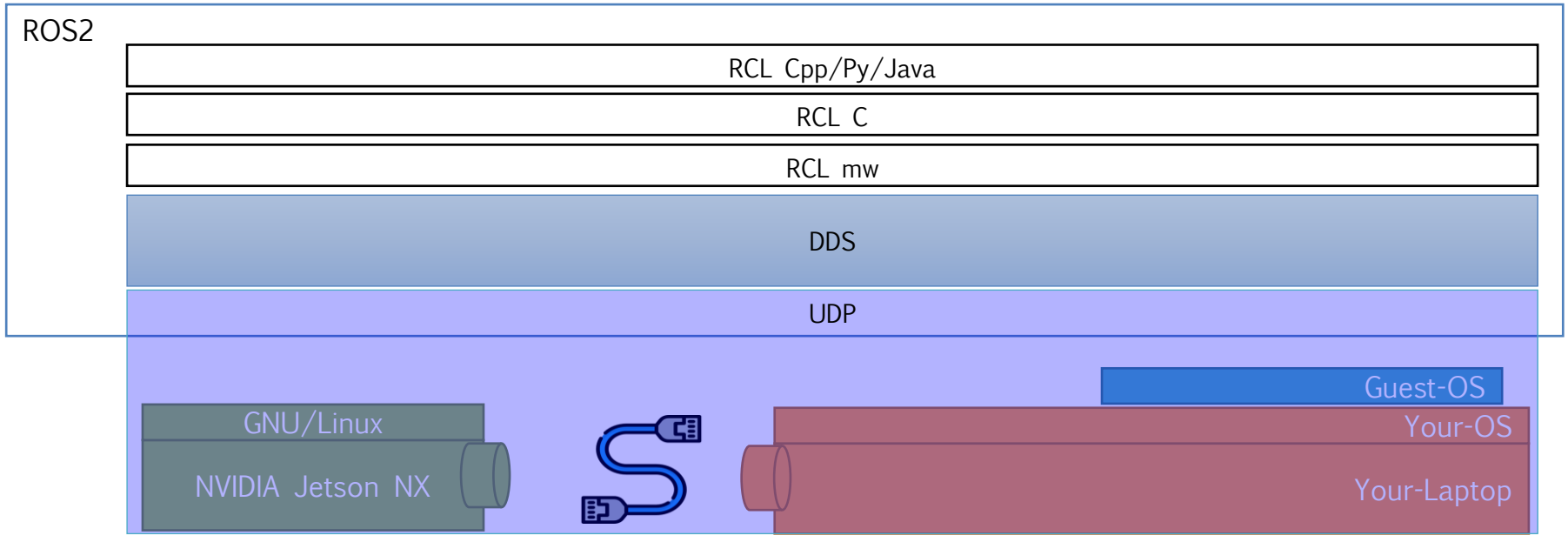
› You shall make sure that those ports are open!

› With a point-to-point ethernet connection, they should be



ROS_DOMAIN_ID and ROS2 ports

- ROS_DOMAIN_ID groups communication onto sub-nets [0-101] – Default 0
- Each domain has an associated port for discovery and (2x) communication
- Example: Domain ID 1 uses port 7650 and 7651 for multicast, then 7660/1 on for comms



Networking

Let's code!

The three machines should be able to “speak” to each other

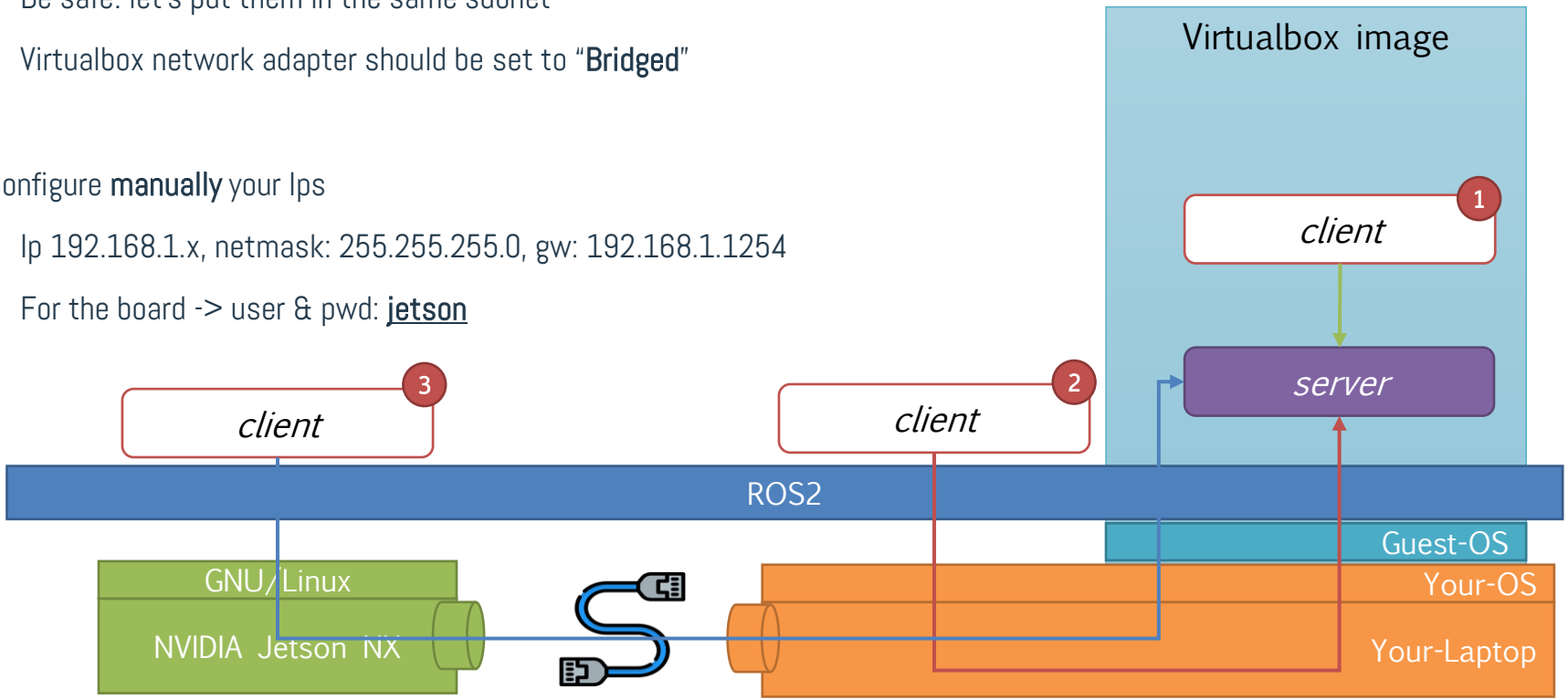
› Be safe: let’s put them in the same subnet

› Virtualbox network adapter should be set to “**Bridged**”

Configure **manually** your Ips

› Ip 192.168.1.x, netmask: 255.255.255.0, gw: 192.168.1.1254

› For the board -> user & pwd: **jetson**



Network map

Let's code!

We already set up reserved addresses for the boards

#408: *192.168.1.2*

#410: *192.168.1.3*

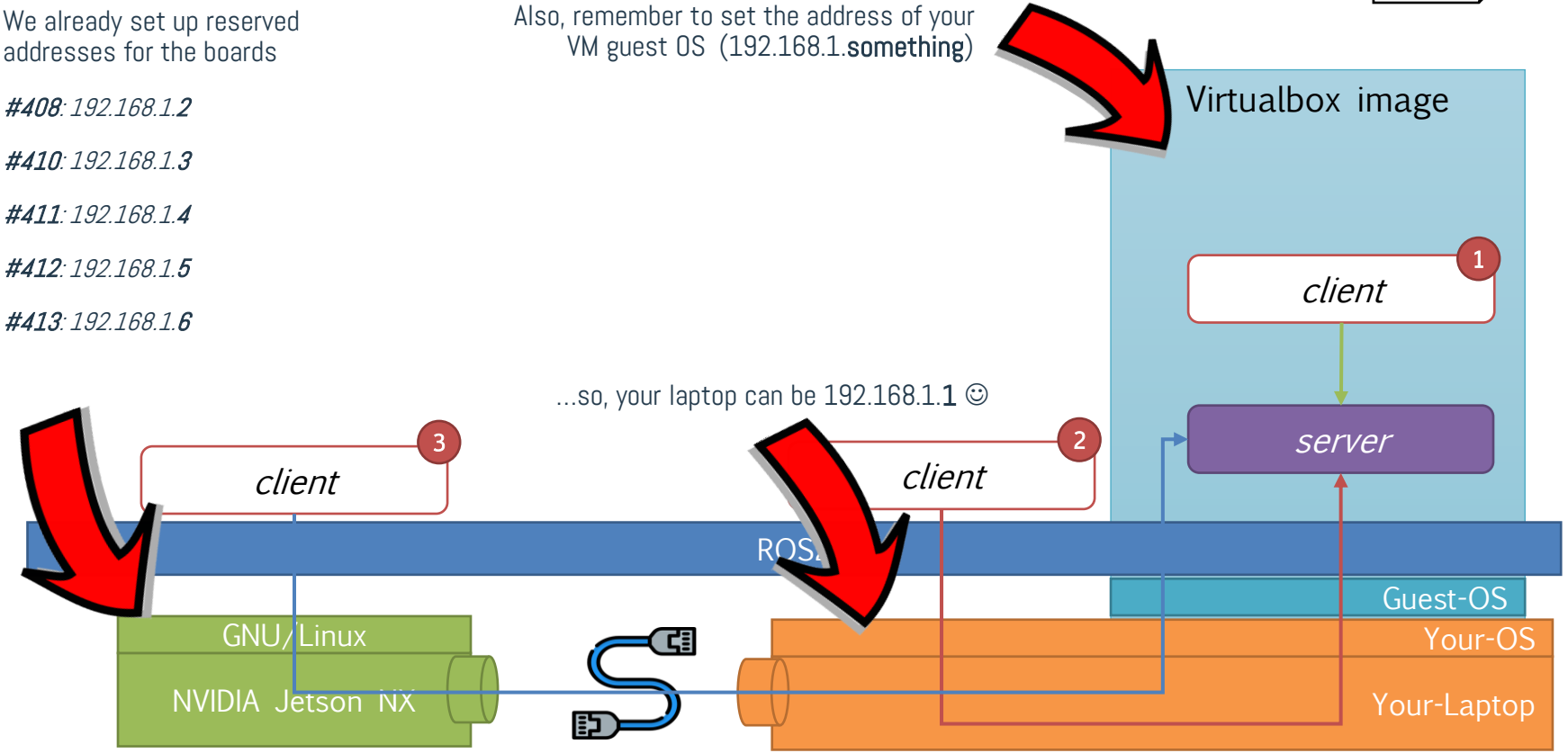
#411: *192.168.1.4*

#412: *192.168.1.5*

#413: *192.168.1.6*

Also, remember to set the address of your VM guest OS (192.168.1.**something**)

...so, your laptop can be 192.168.1.**1** ☺



Exercise

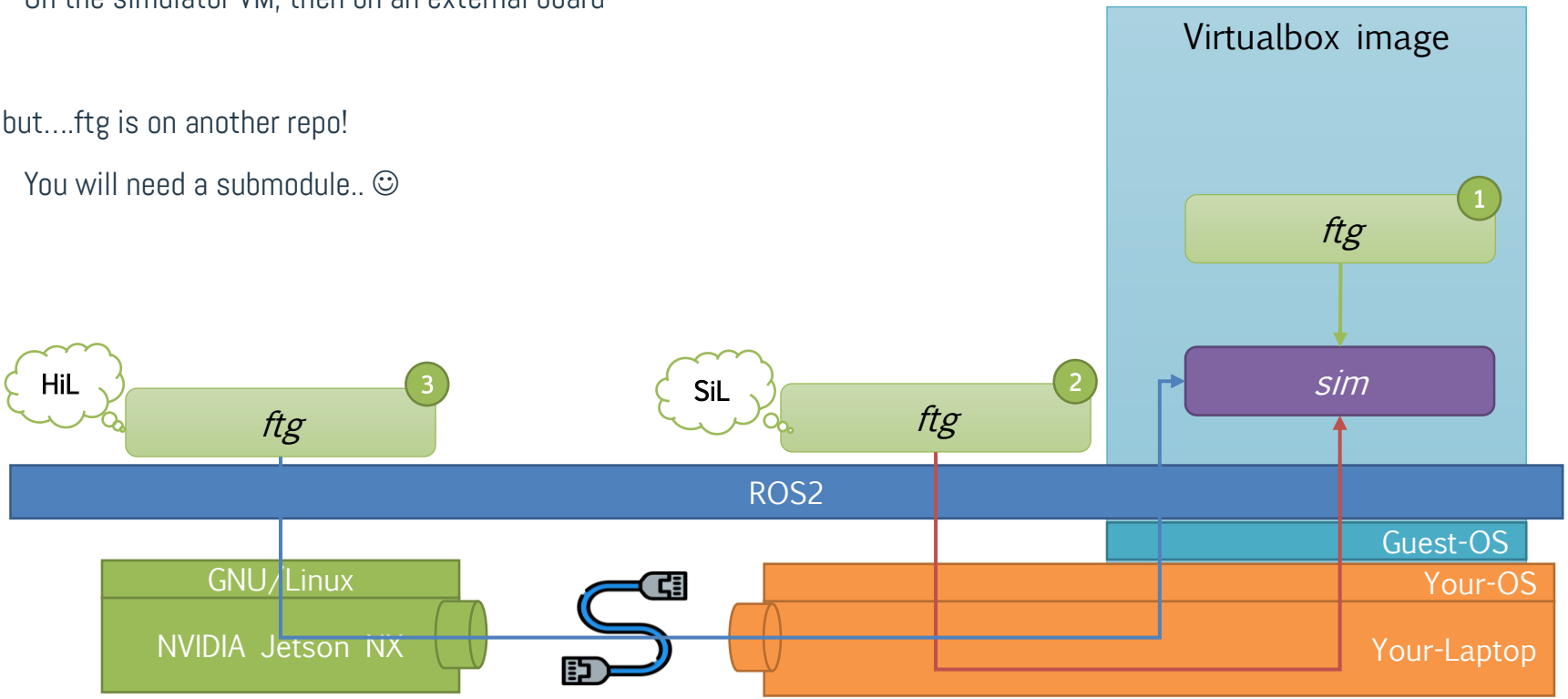
Let's code!

Build and run the Follow-the-Gap *ftg* node and the F1tenth-Gym simulator

› On the simulator VM, then on an external board

..but….ftg is on another repo!

› You will need a submodule.. ☺



References

Course website

- http://personale.unimore.it/rubrica/contenutiad/markober/2023/71846/N0/N0/10005
- https://github.com/HiPeRT/F1tenth-RTES
  - Online resources/preview

My contacts

- paolo.burgio@unimore.it
- http://hipert.mat.unimore.it/people/paolob/

Resources

- https://github.com/HiPeRT/F1tenth-RTES/blob/master/Code/ros2/LAB_CHEAT_SHEET.md
- A "small blog"
  - http://www.google.com