Mutation Testing for Physical Computing

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Physical Computing

Wearable

Smart Home

Robotics

Accidents in Physical Computing

Tesla Says Autopilot Was Engaged in Fatal Crash Under Investigation in California

Vehicle's system shows driver had hands off the wheel for six seconds before striking highway divider

A Tesla equipped with automated-control system crashed last week near Mountain View, Calif. **PHOTO:** PUBLISHED CREDIT: KTVU FOX 2/REUTERS.

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Accidents in Physical Computing

Worker killed by robot in welding accident at car parts factory in India

The man was reportedly stabbed by a metal arm and electrocuted

Lizzie Dearden | @lizziedearden | Thursday 13 August 2015 15:02 | 1 comment

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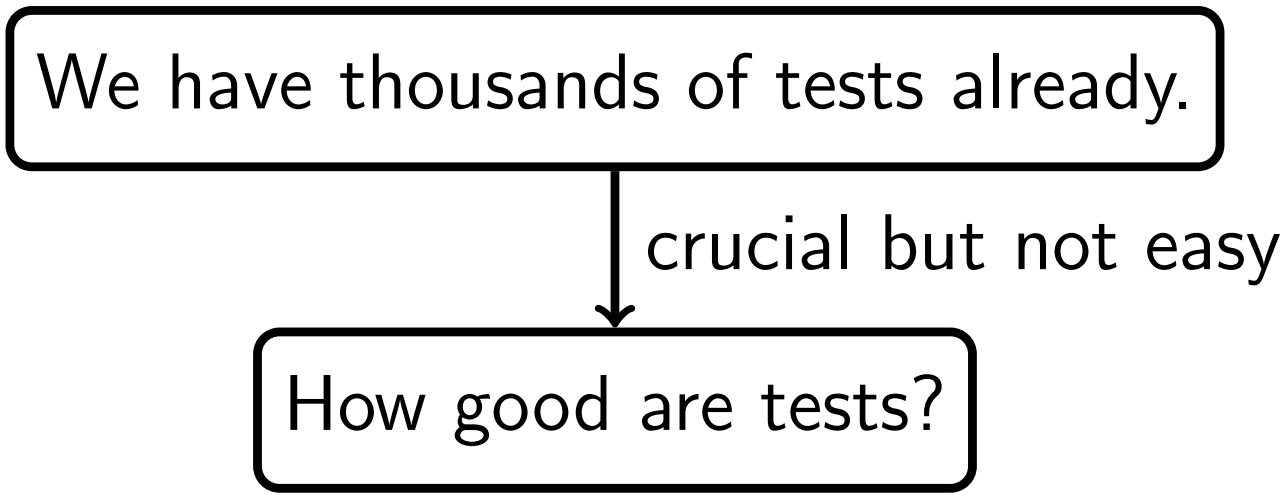
Challenges in Testing Cyber-Physical Systems

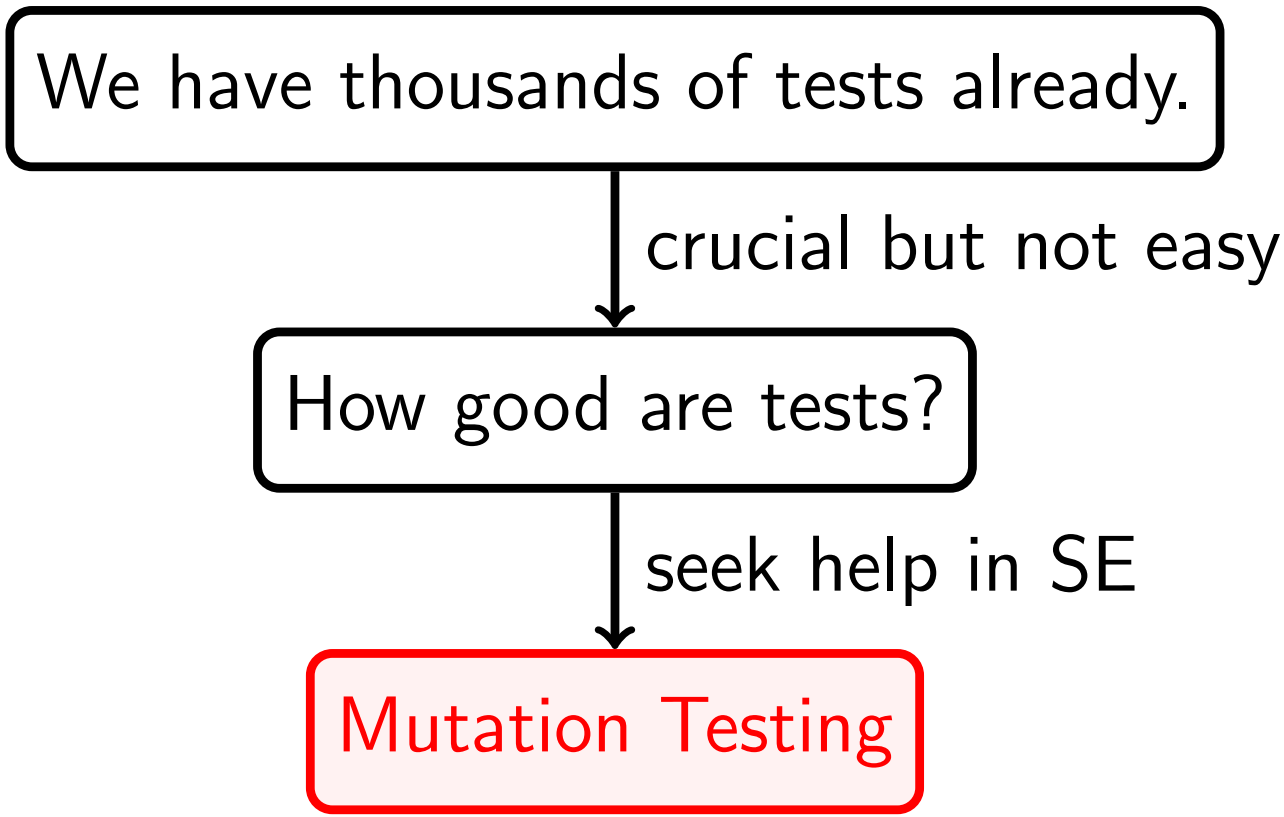
Challenges in Testing Cyber-Physical Systems

We have thousands of tests already.

Challenges in Testing Cyber-Physical Systems



Challenges in Testing Cyber-Physical Systems



Mutation Testing

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An actively investigated field since 1970s

- **Main idea:** small syntactic changes $\rightarrow$ test suite quality
- **Benefit:**
  - better fault exposing capability
  - a good alternative to real faults

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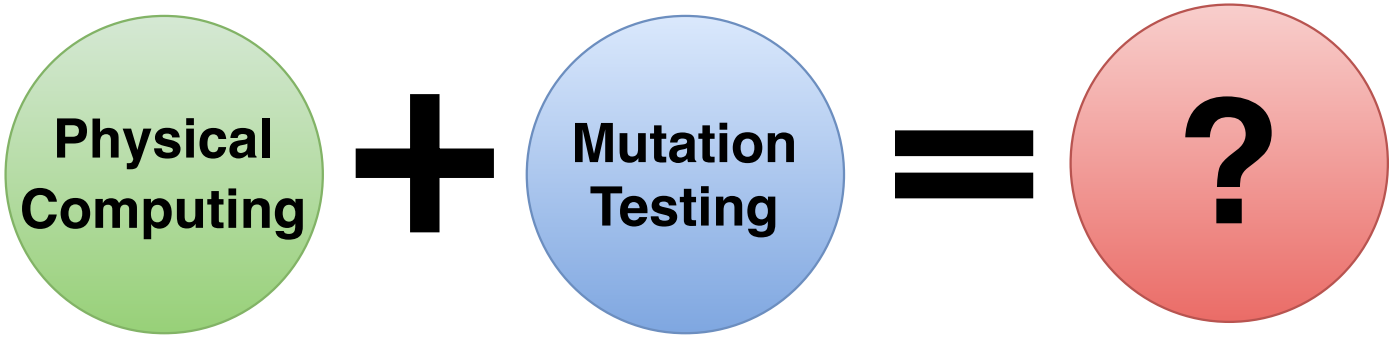
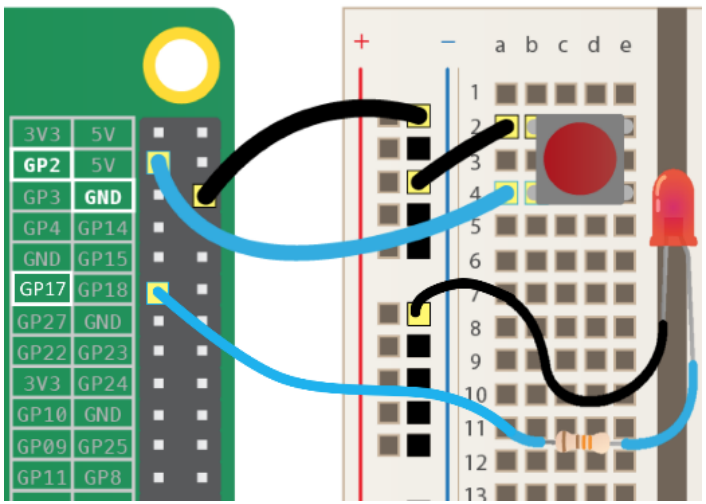


LED example




```
from RPi import GPIO
from time import sleep

pbutton = 2
pled = 17

def setup():
    GPIO.setmode(GPIO.BCM)
    GPIO.setup(pled,GPIO.OUT,initial=GPIO.LOW)
    GPIO.setup(pbutton,GPIO.IN,pull_up_down=GPIO.PUD_DOWN)
    GPIO.add_event_detect(pbutton, GPIO.RISING, bouncetime=200)

def on():
    GPIO.output(pled,1)

def off():
    GPIO.output(pled,0)

# main
setup()
while (True):
    if GPIO.event_detected(pbutton):  # Check to see if button has been pushed
        activate = True
        while (activate is True):    # Execute this code until the button is pushed again
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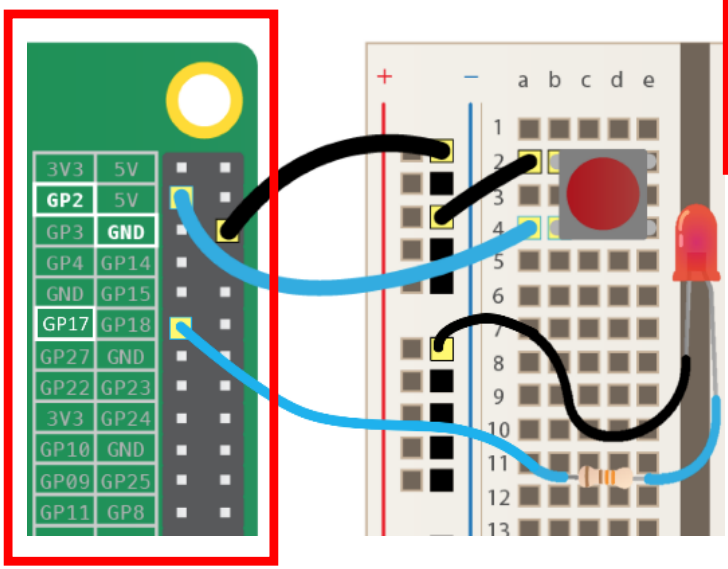


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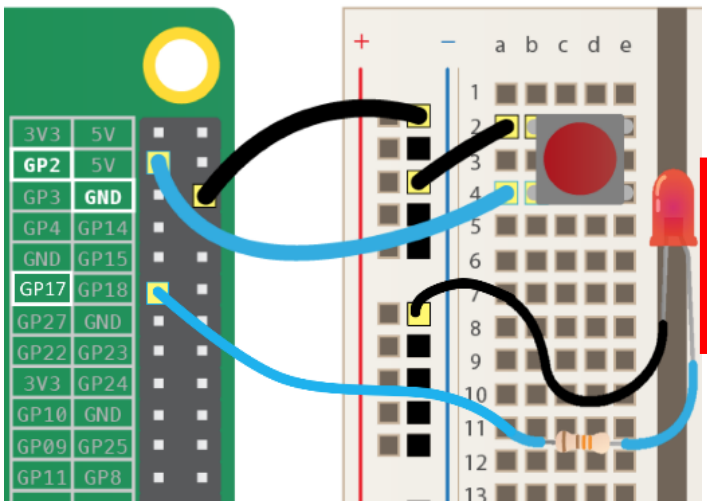


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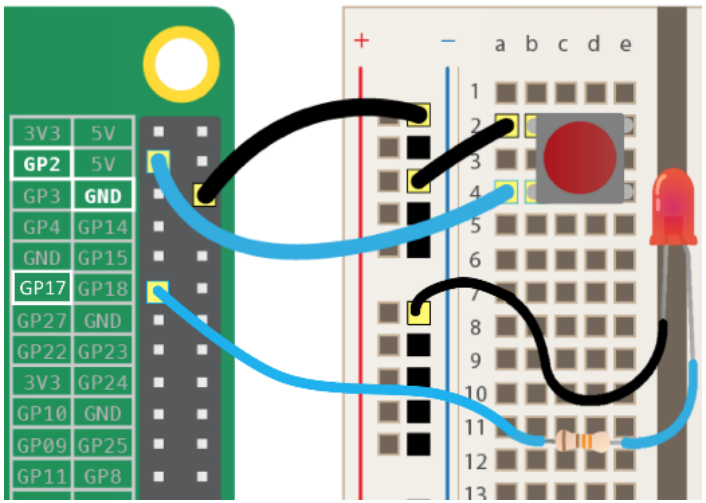
LED example with one mistake

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    GPIO.add_event_detect(pbutton, GPIO.RISING, bouncetime=200)

def on():
    GPIO.output(pled,0)

def off():
    GPIO.output(pled,0)

# main
setup()
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1 **output value errors:** *OutputValueReplacement (OVR)*

Mutation Operators for Physical Computing

1 output value error	1 OutputValueReplacement (OVR)
2 output setting omissions	2 OutputValueReplacement (OVR)
3 pin number errors	3 PinNumberReplacement (PNR)
4 input value errors	4 InputValueReplacement (IVR)
	5 EdgeDetectionReplacement (EDR)
5 I/O pin mode errors	6 I/OModeReplacement (IOMR)
6 initial setup value errors	7 SetupInputReplacement (SIR)
	8 SetupOutputReplacement (SOR)
	9 SetupValueRemoval (SVR)
6 common mistakes	**9 mutation operators**

Empirical Evaluation

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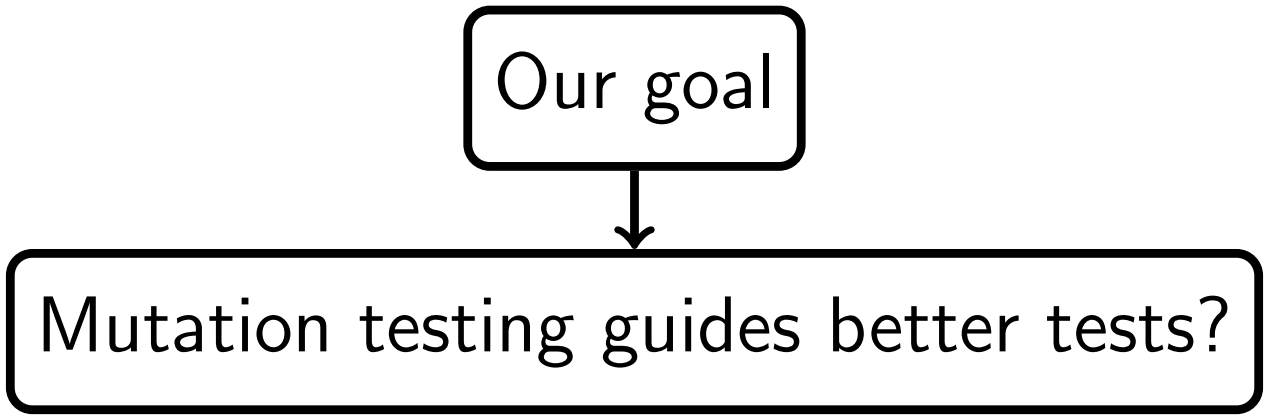
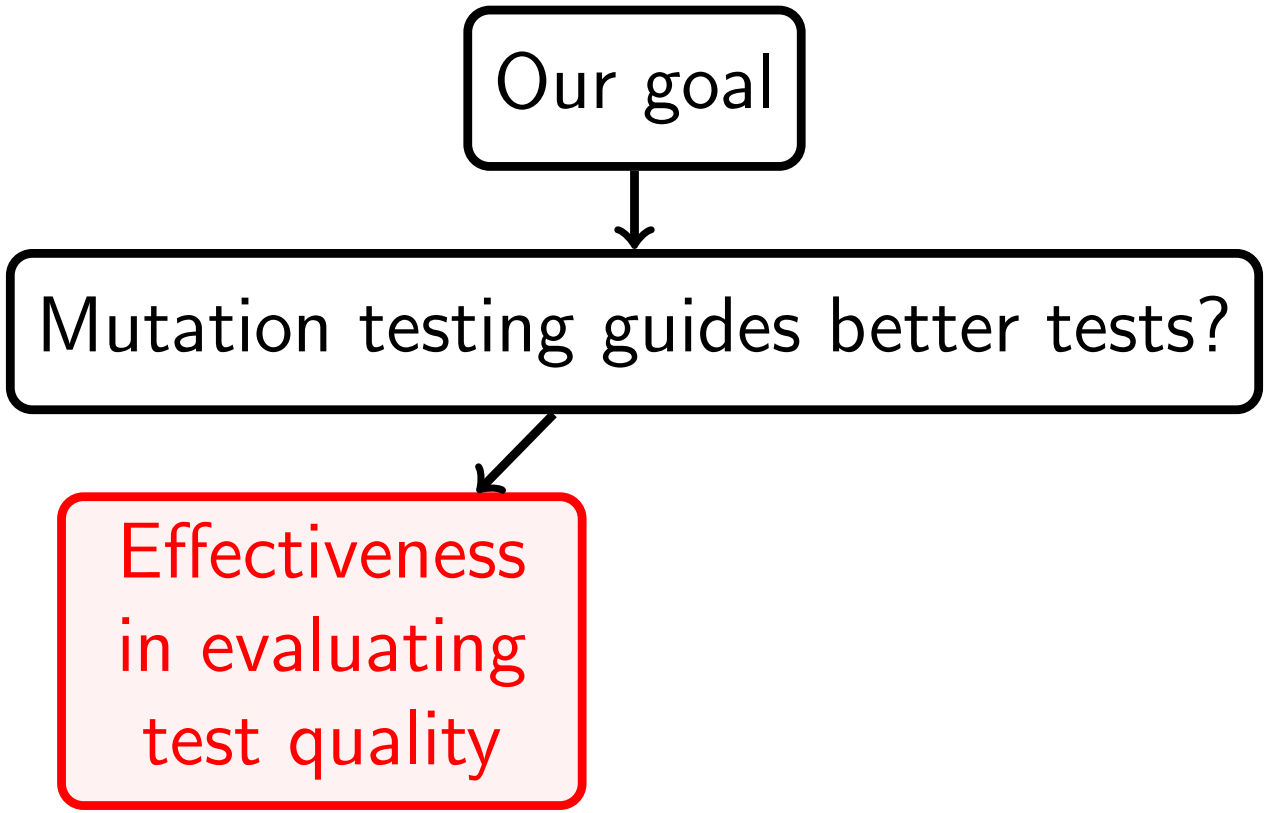
Our goal

Empirical Evaluation



Empirical Evaluation



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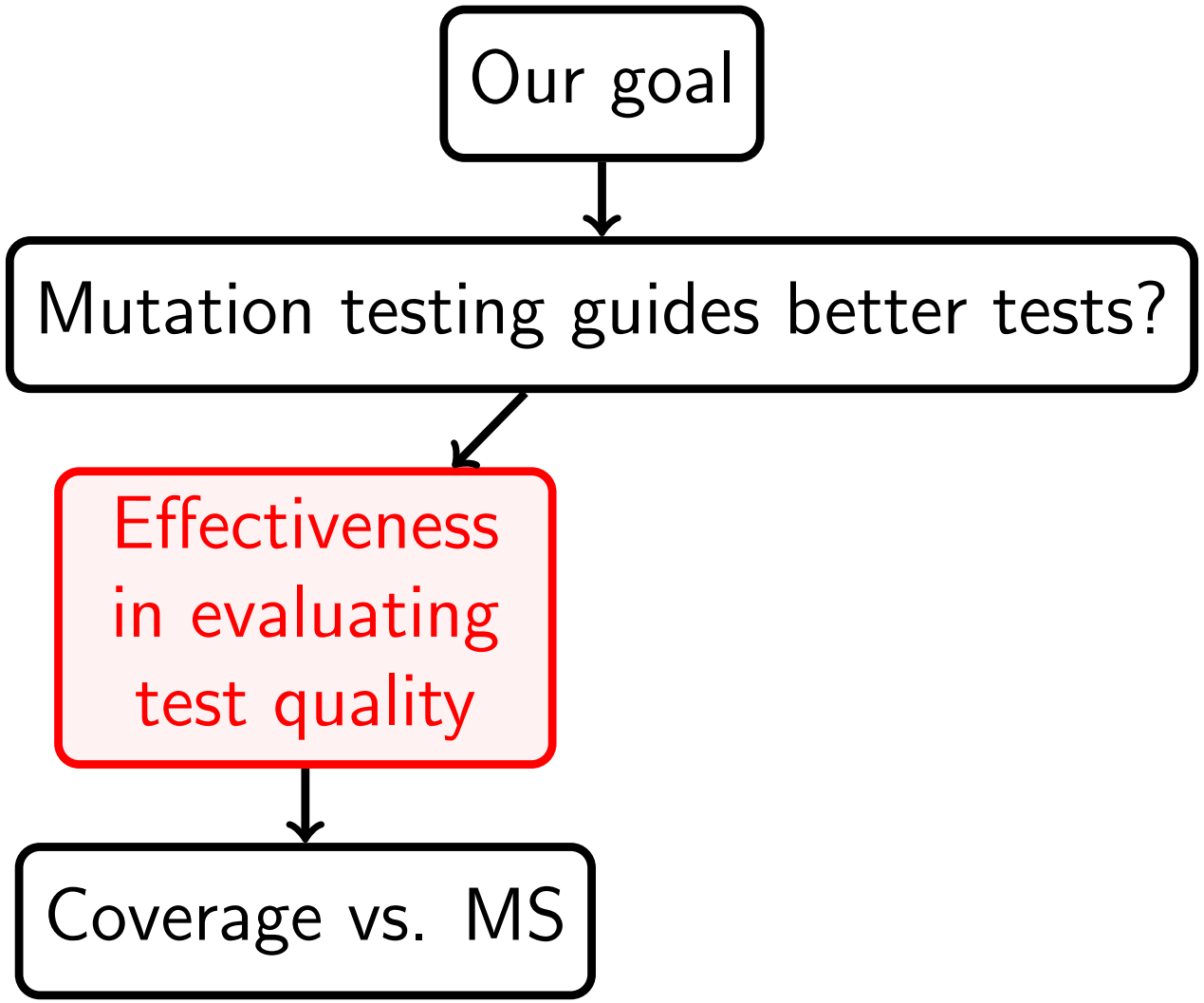

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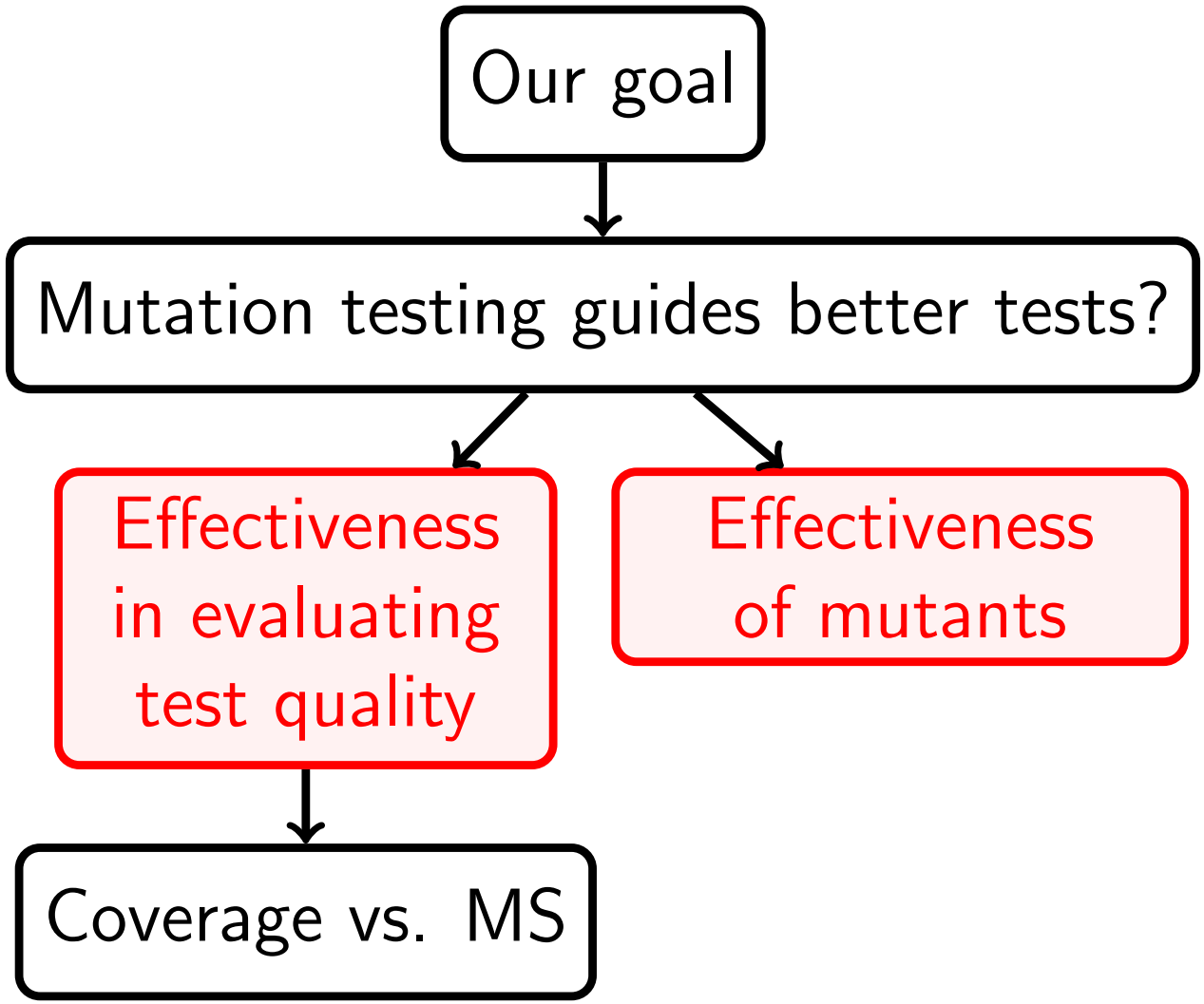

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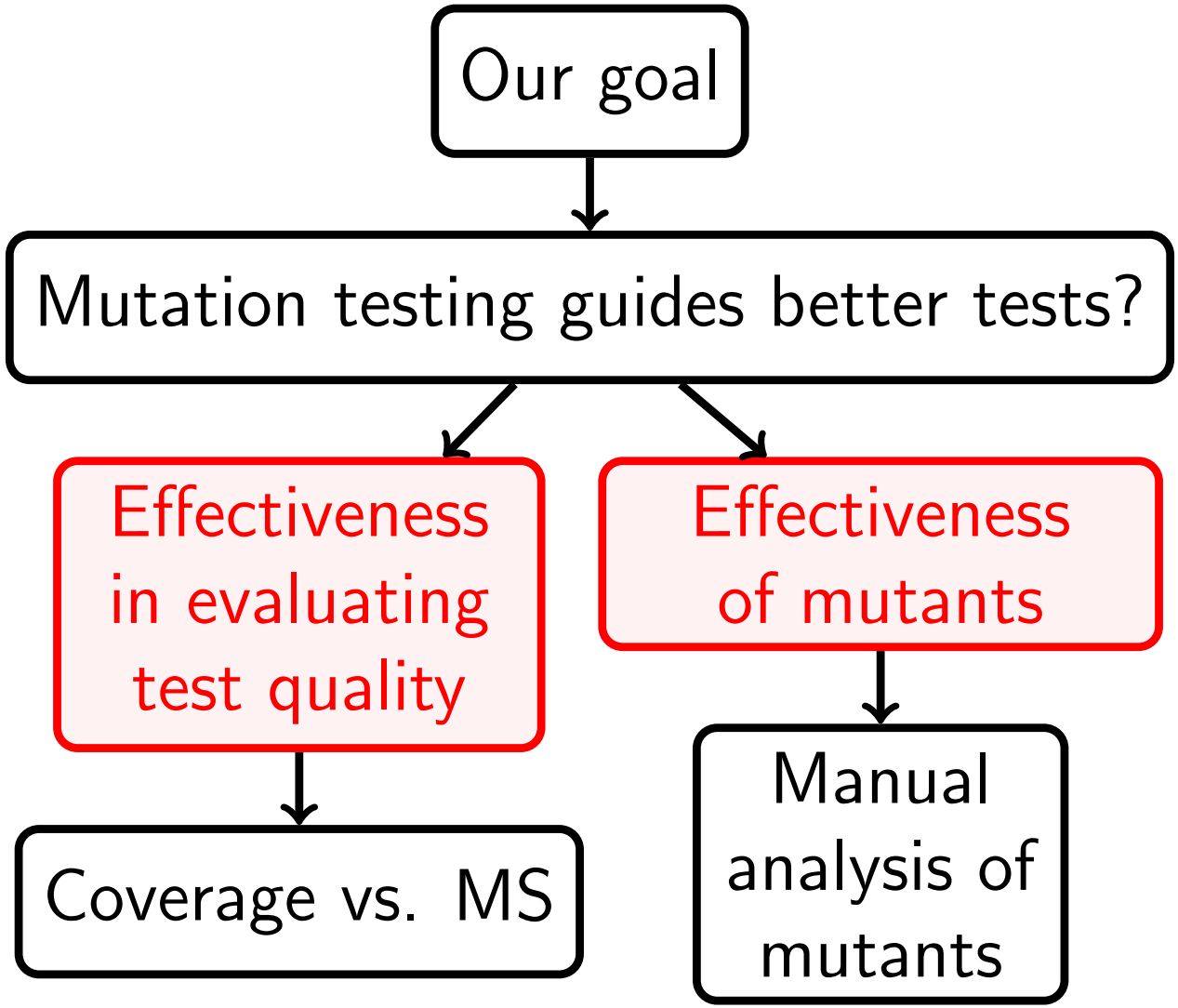
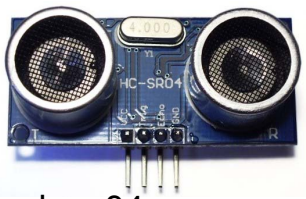


Empirical Evaluation

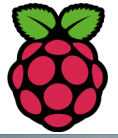
- **Subjects:** 9 cyber-physical systems

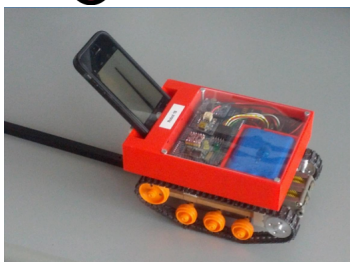

jean-pierre

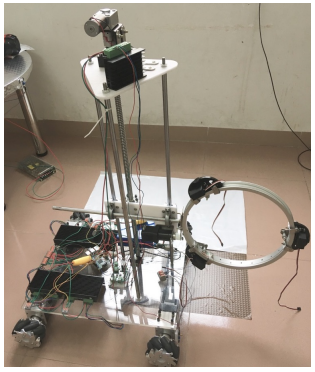
RPLCD



hcsr04sensor


gpiozero


line-follower (4 projects)


four-wheel robot

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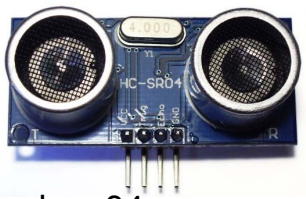

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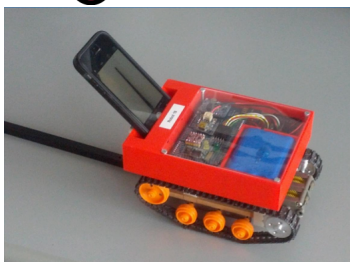
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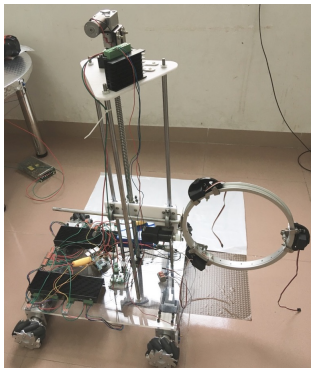
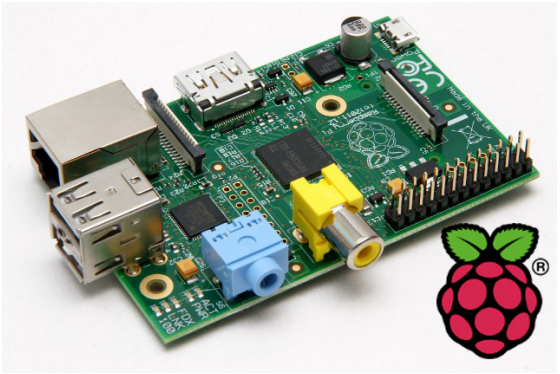
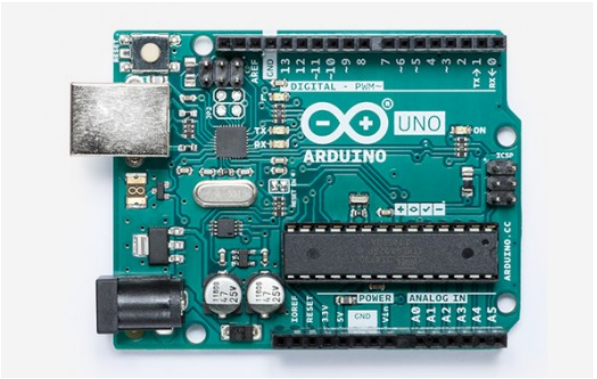

four-wheel robot

- **Platforms:** Raspberry Pi & Arduino





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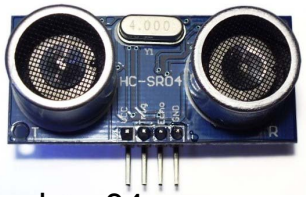

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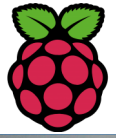
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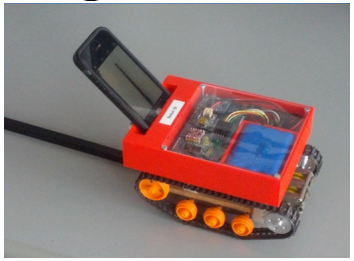
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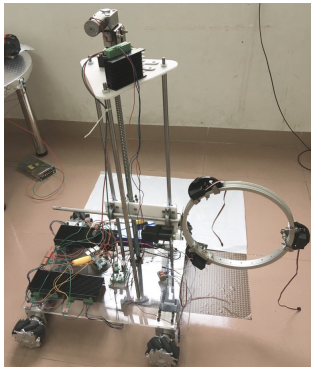
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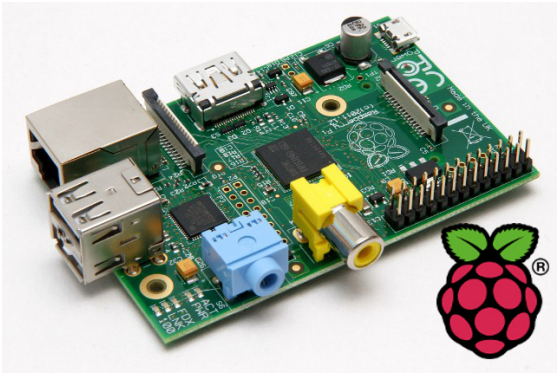
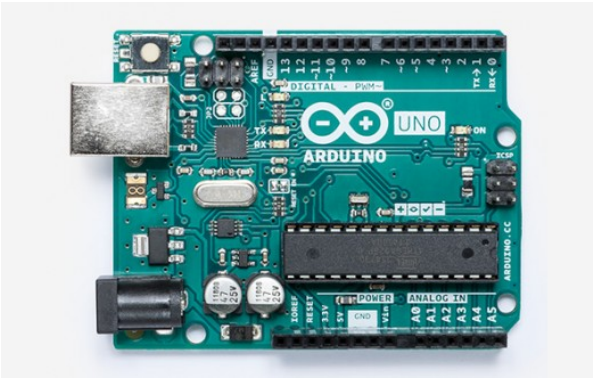
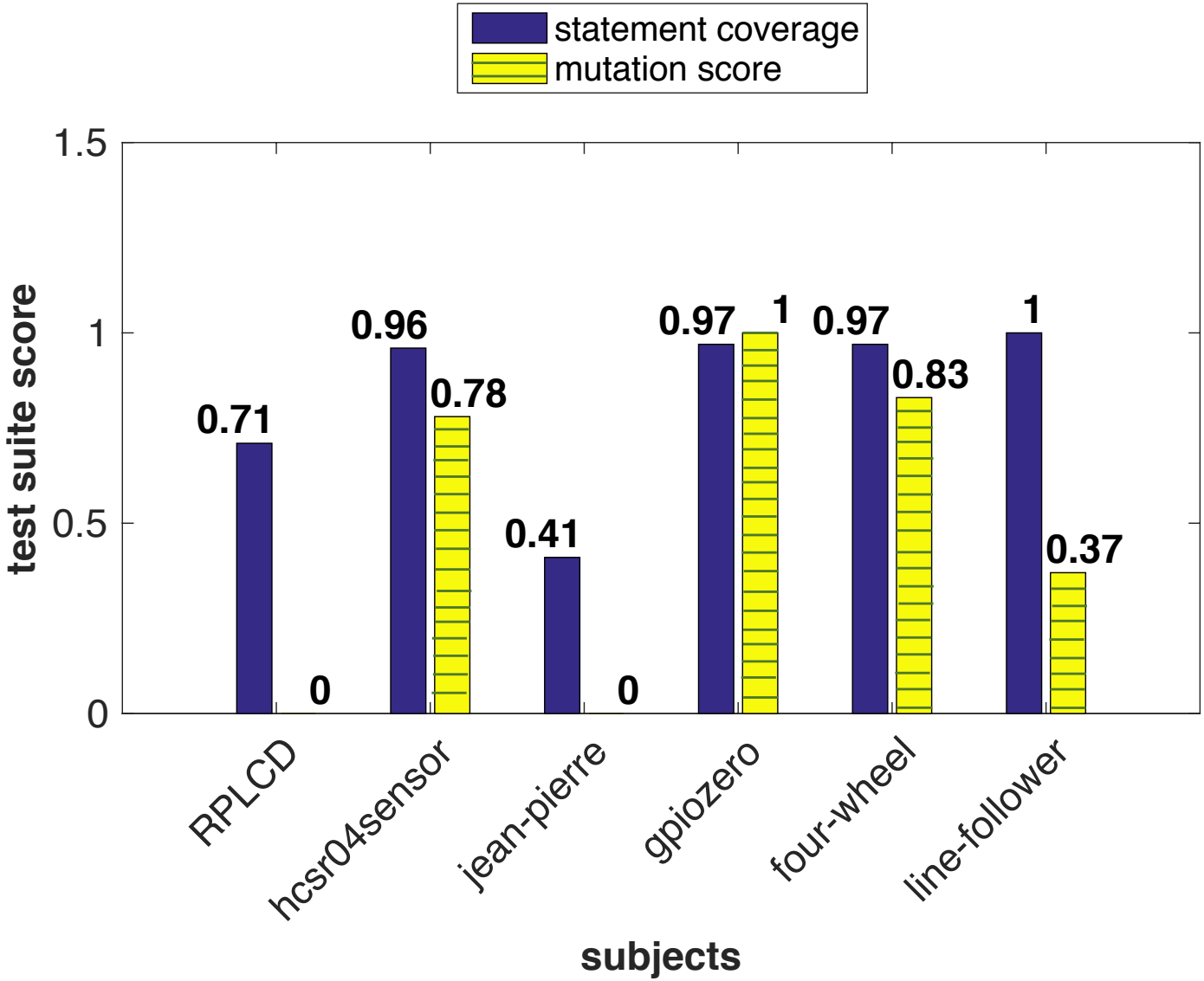




- **Languages:** Python & C/C++

Results

- **Effectiveness in evaluating test suites**



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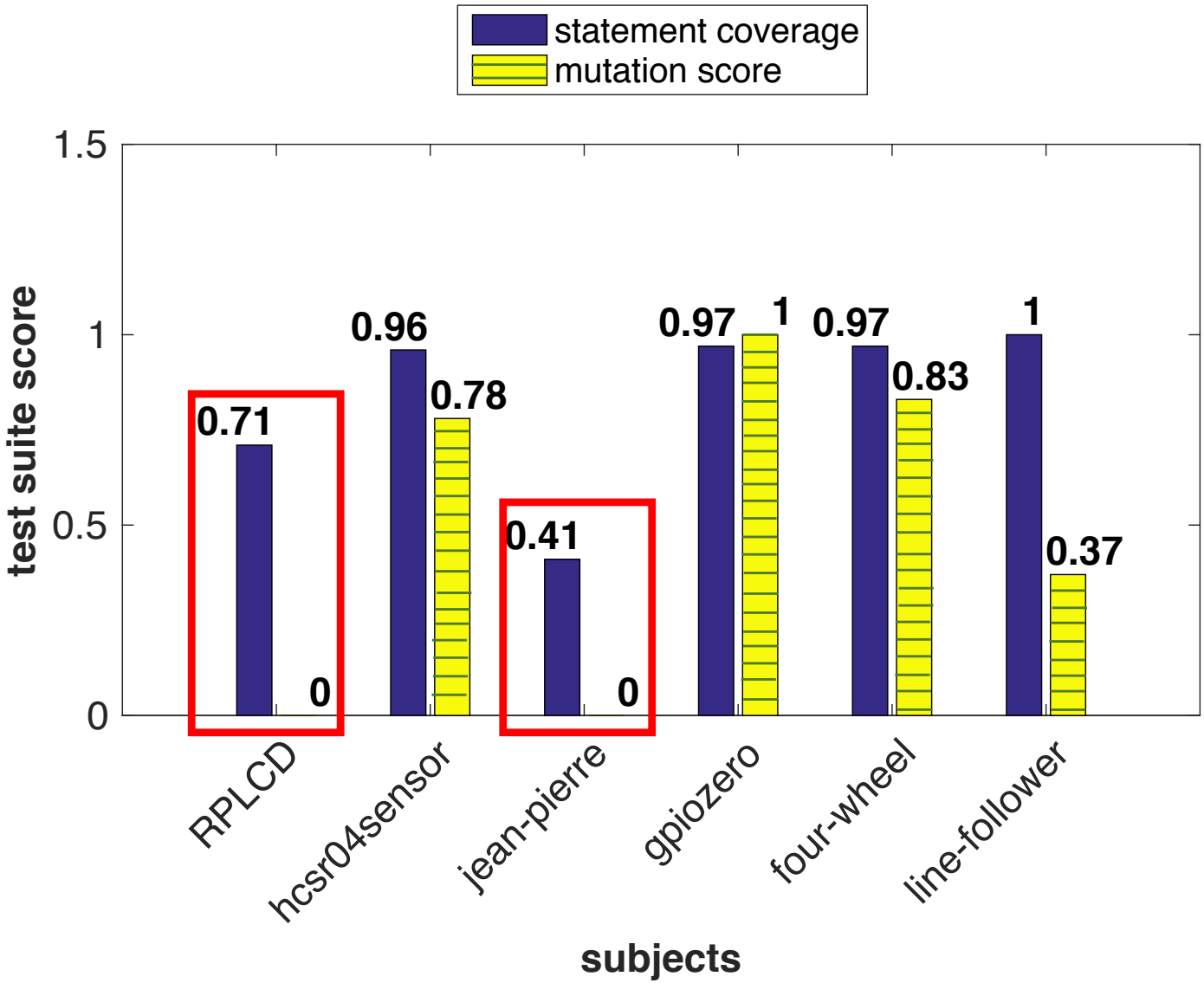

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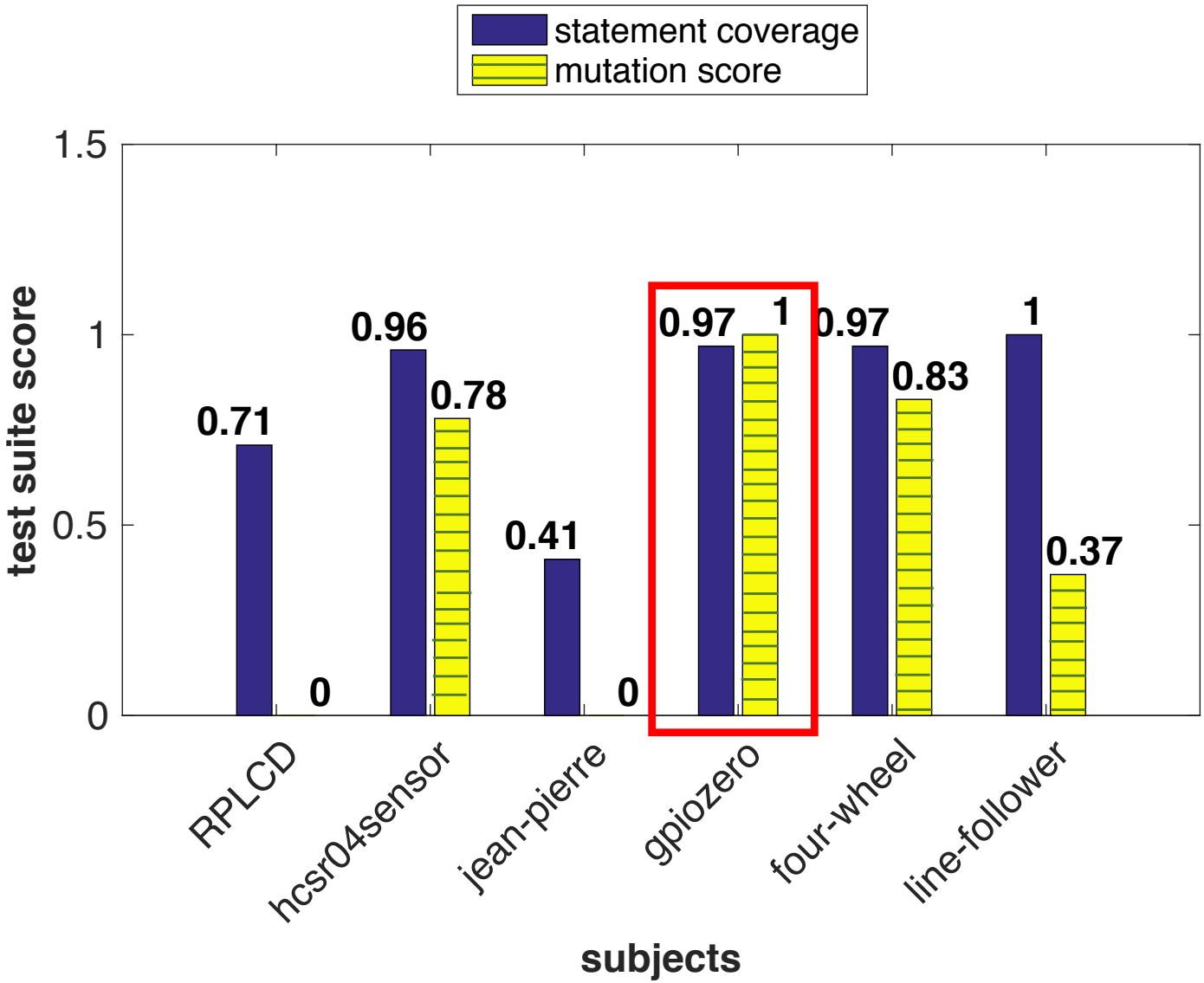

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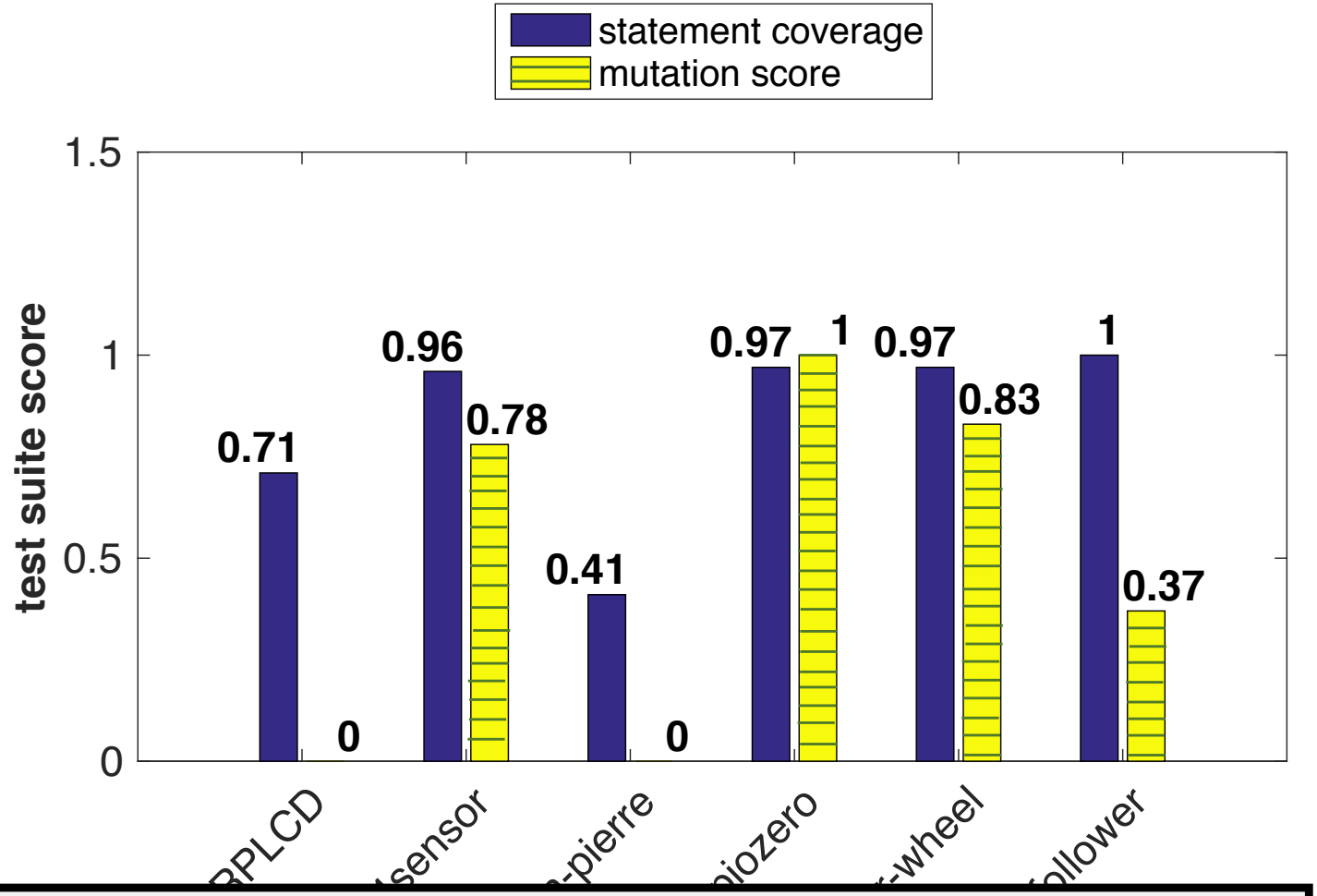

■ integration part: mutation score > statement coverage

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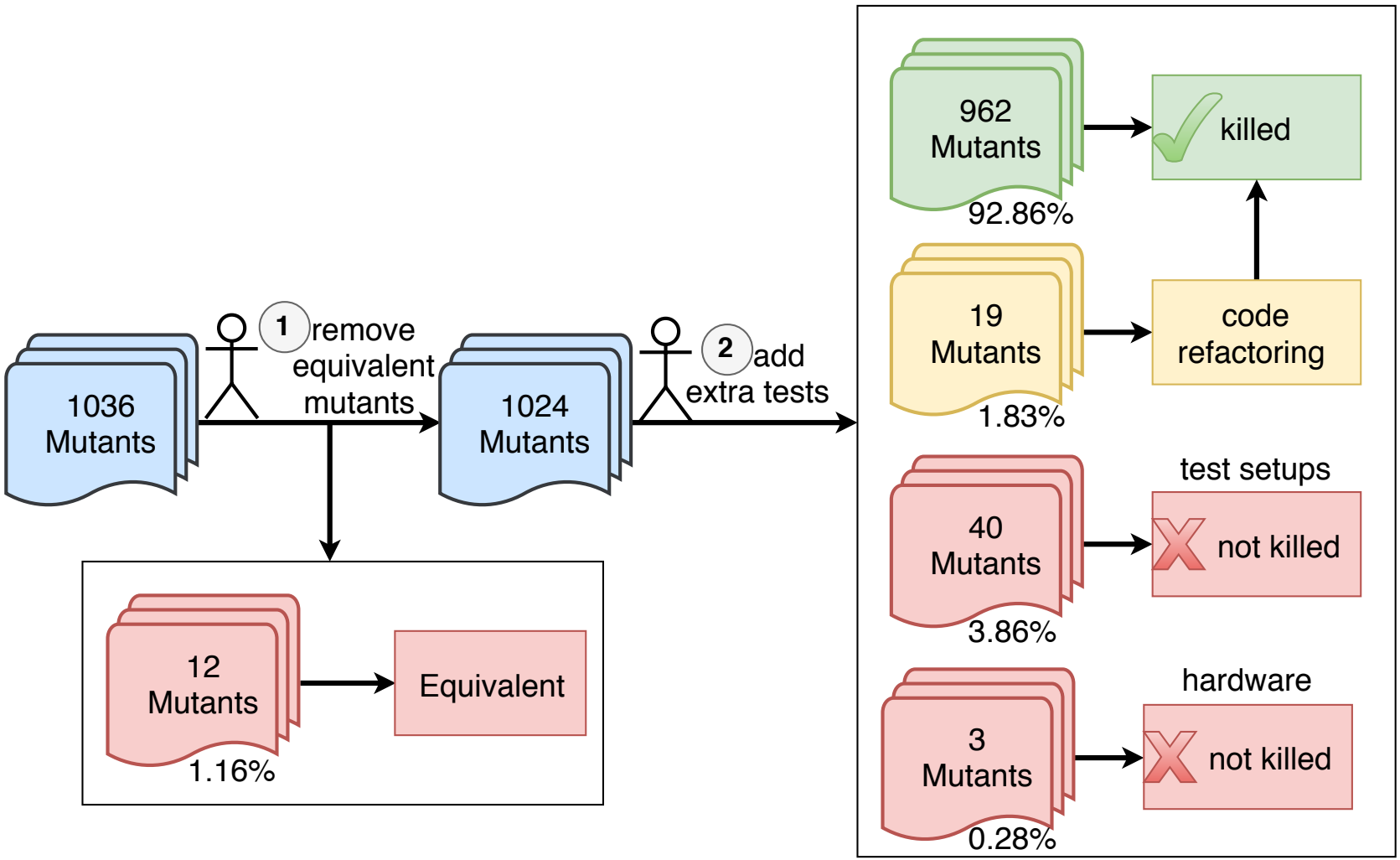

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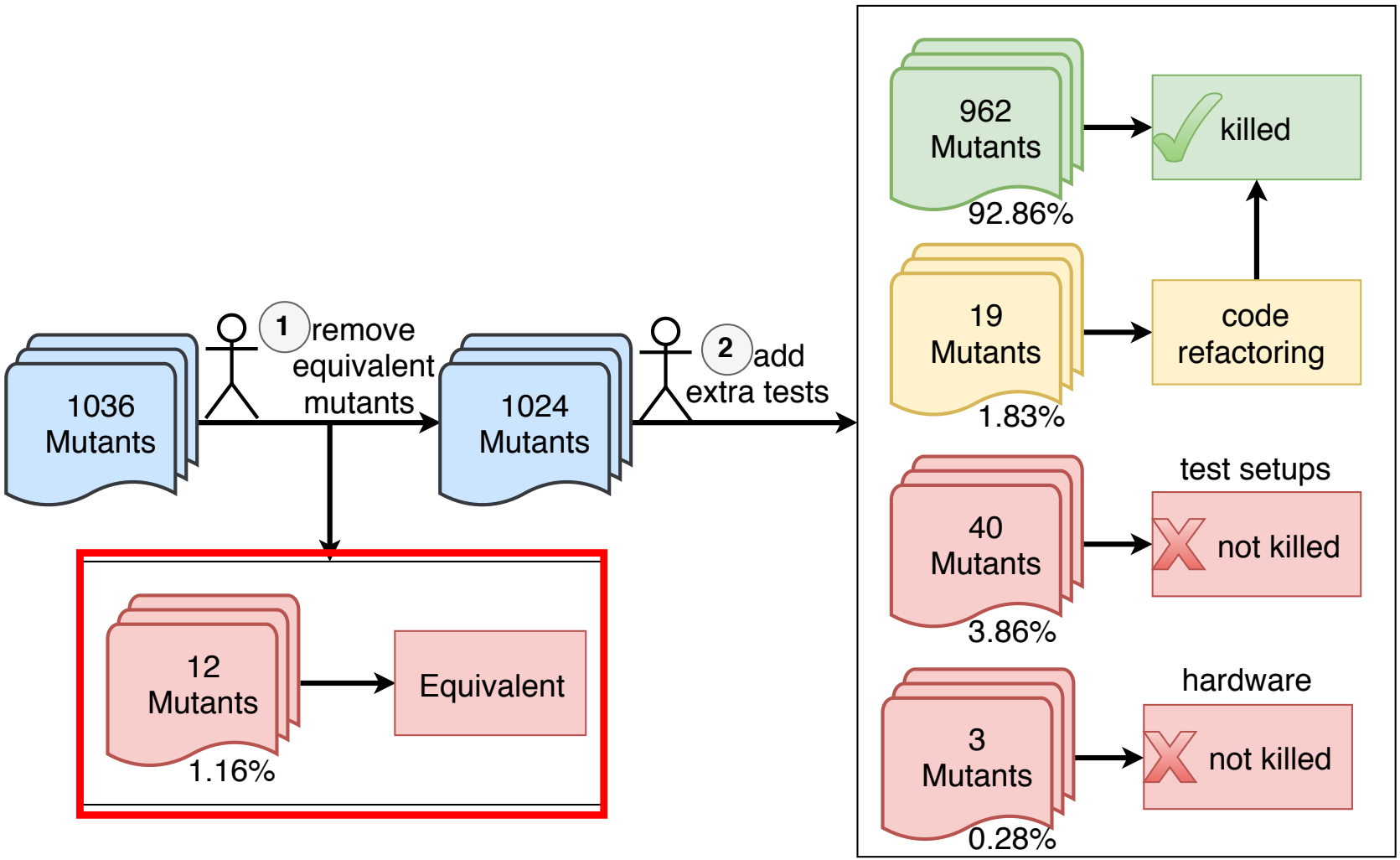

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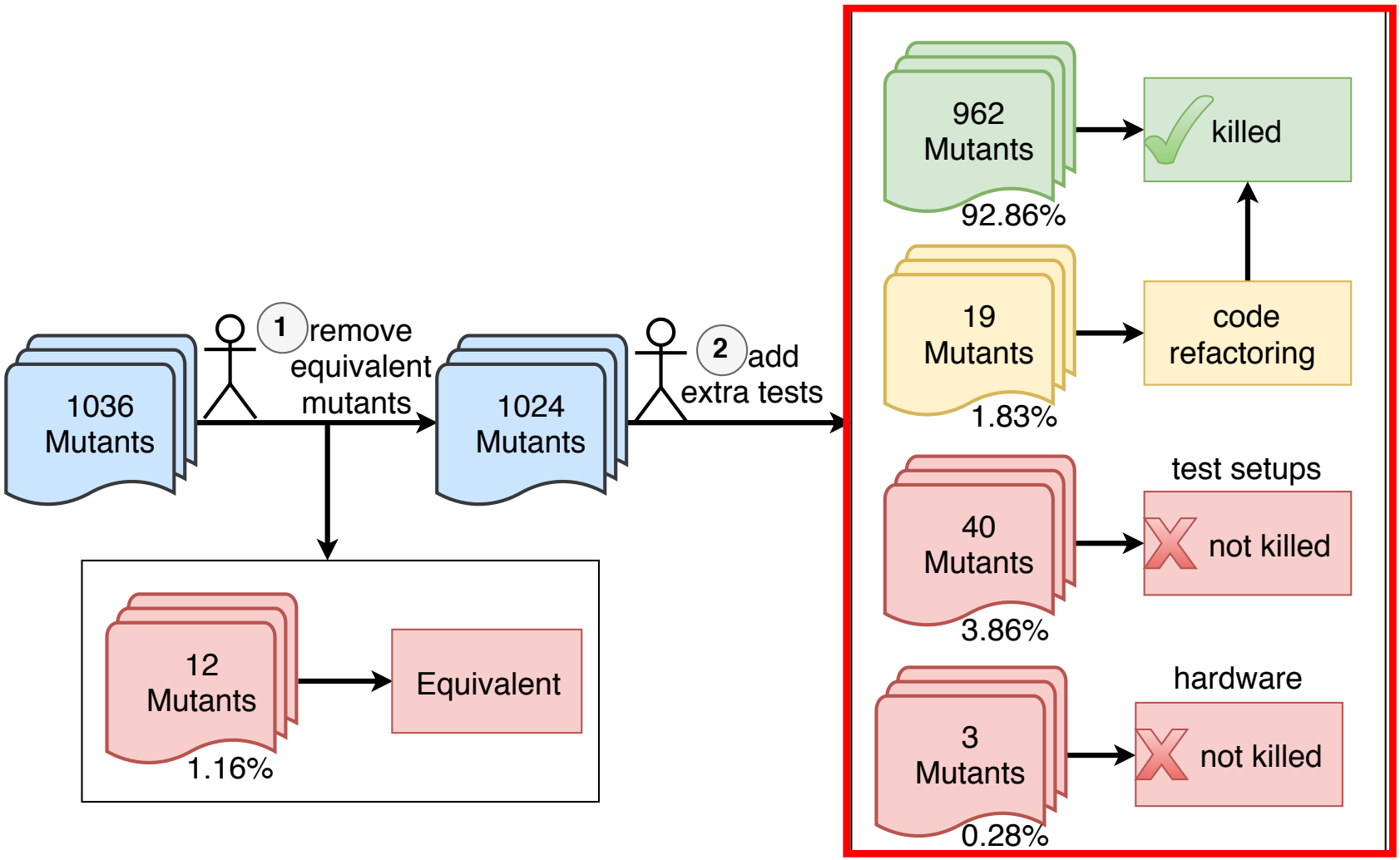
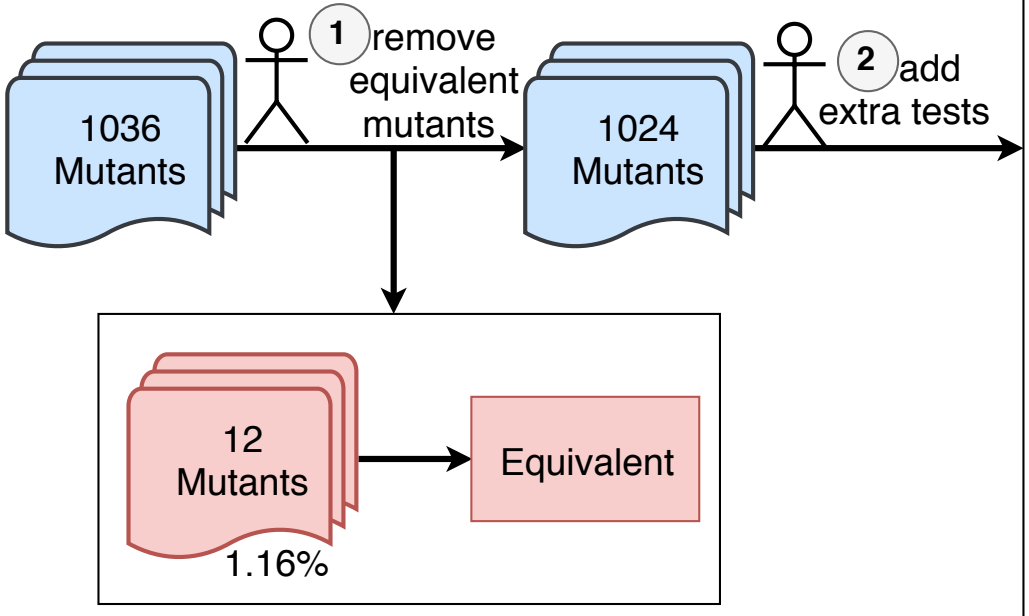
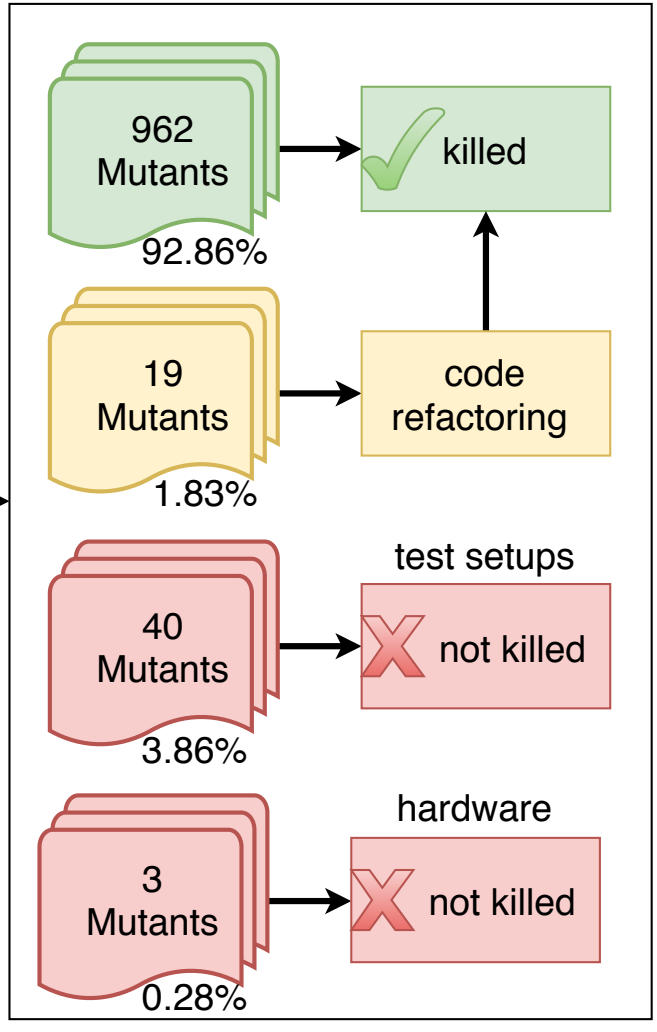


Results

- **Effectiveness of mutants**

- 94.69% mutants → effective
- mutation score ≠ test quality
- non-killable ⊆ equivalent?





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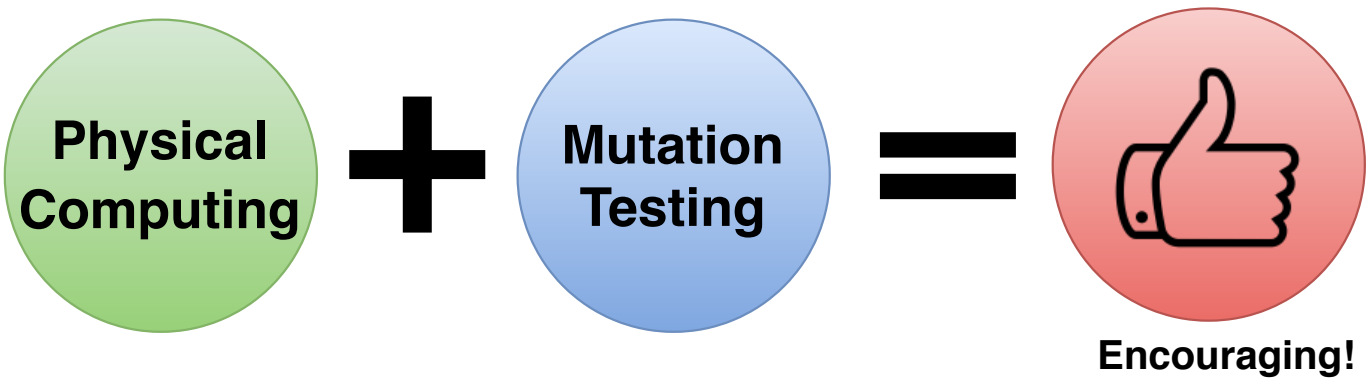
- **What we have learned:**



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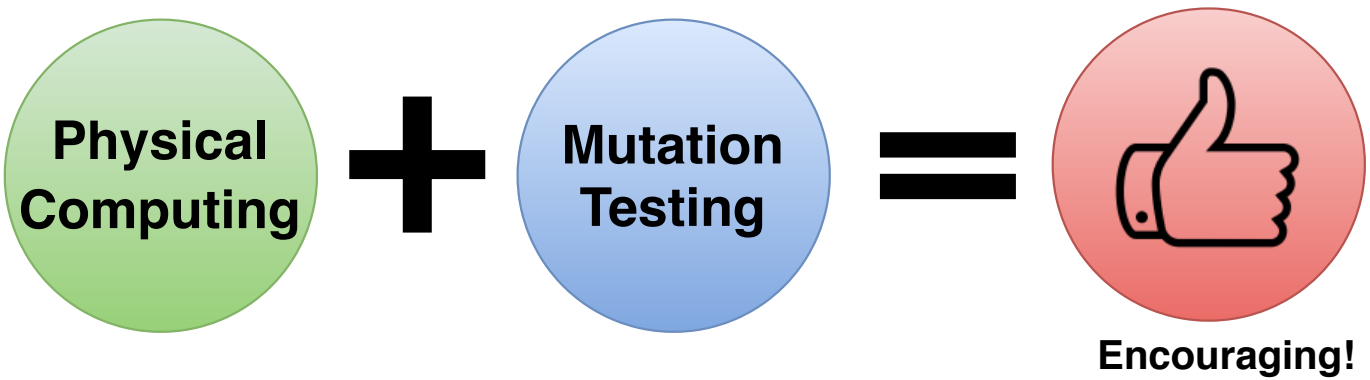


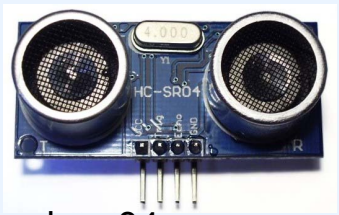
- **What we plan to do:**
  - more case studies
  - traditional mutation operators **vs.** ours
  - fault-finding ability **vs.** mutation score

Case studies with Raspberry Pi

- **Test environment:**
  Raspberry Pi → one-chip computer, mutation testing tool
- **Subjects:**


jean-pierre

gpiozero



hcsr04sensor

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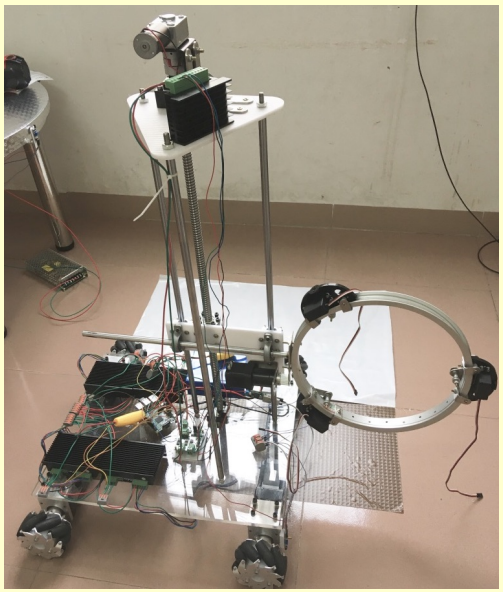
four-wheel robot

GitHub

Kompline
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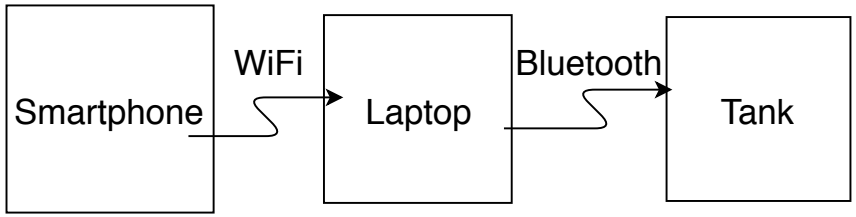
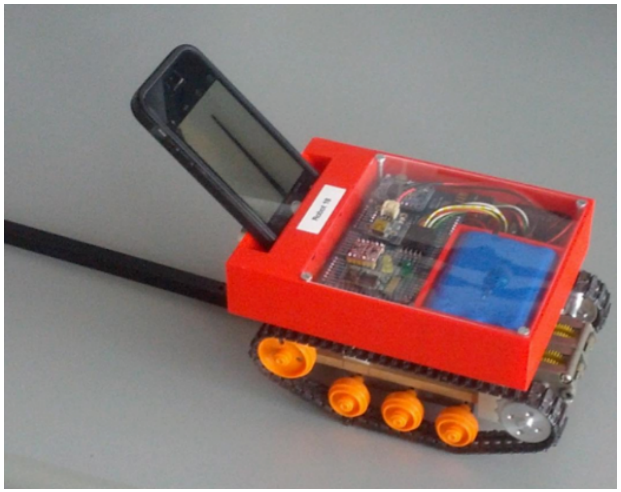
Case studies with Arduino

- **Subject:** line-follower robot





- **Test environment:** hardware monitor