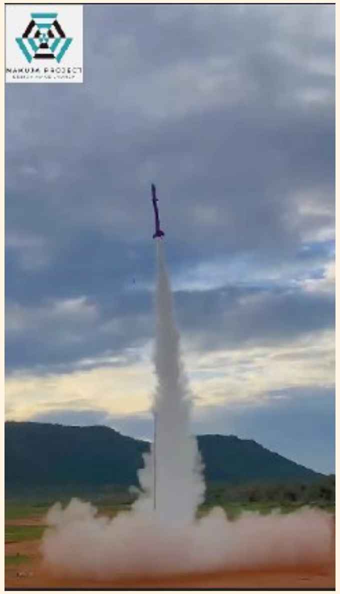
Robotics Dojo:
To drive robotics research in Kenya

Dr. Shohei Aoki

Jomo Kenyatta University of Agriculture and Technology (JKUAT)

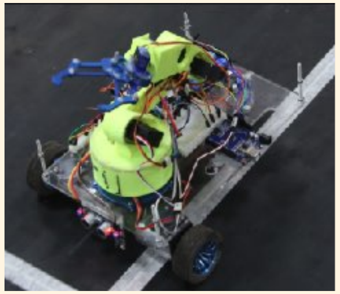
Nakuja Project (nakujaproject.com)



NAKUJA PROJECT
DESIGN.MAKE.LAUNCH

KSA
KENYA SPACE AGENCY
Possibilities beyond our skies

Robotics Dojo (roboticsdojo.github.io)



Jibebe (jibebe-jkuat.github.io)

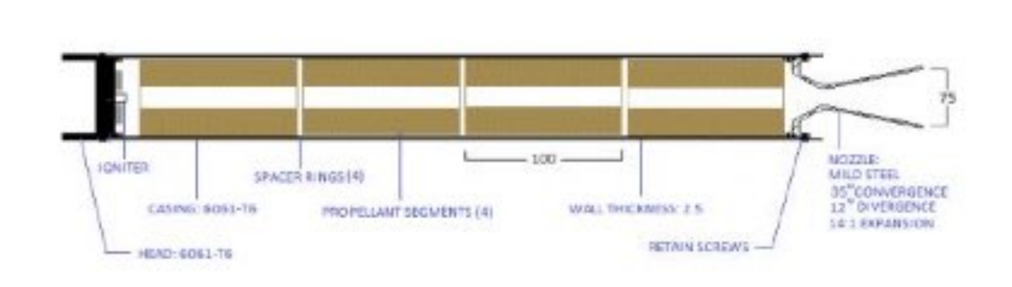
Electric Tricycle Presentation at JKUAT

Drone group(drone.jkuat.ac.ke)

Nakuja project

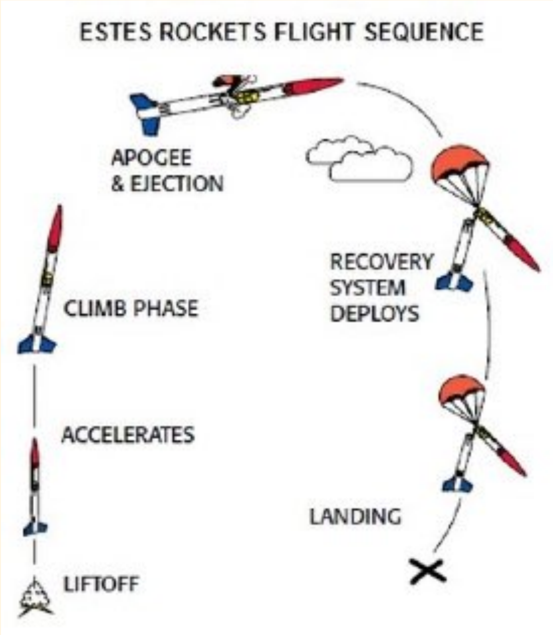
Solid propulsion team

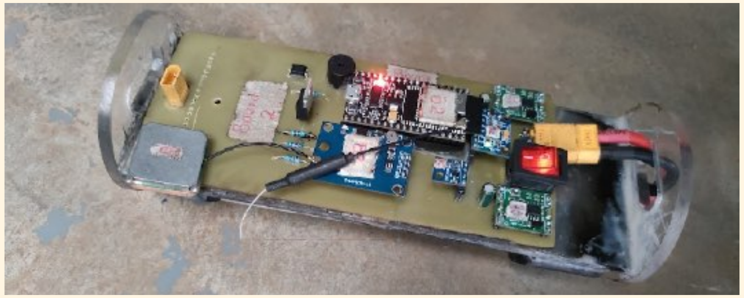
- Develop solid rocket motor
  - Grain, casing, nozzle, bulkhead
- Static test
  - Fire the motor on the ground
  - Measure the thrust curve

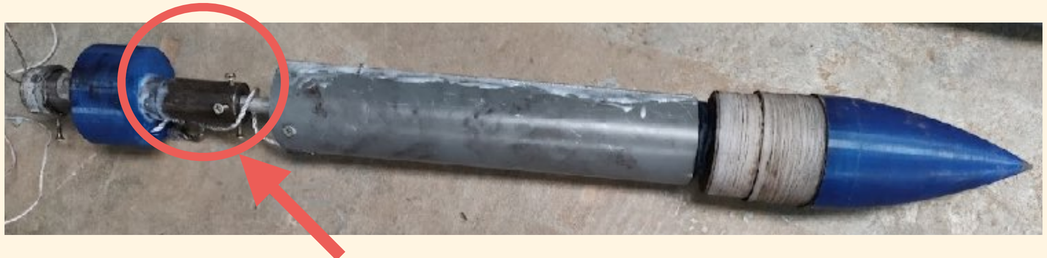


Recovery team

- Flight computer (sensor)
- Ejection mechanism
- Telemetry
- Payload (camera)



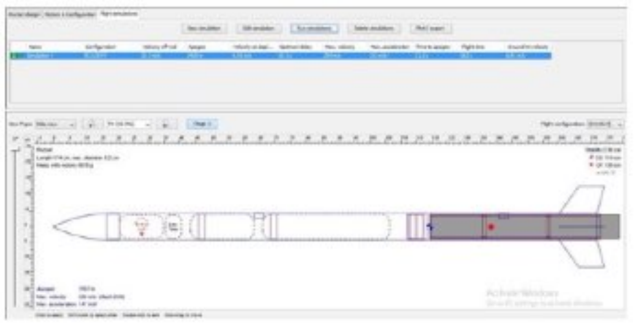




Crimson powder

Airframe team

- Design and fabrication
  - Nose cone
  - Body tube
  - Fin
  - Launchpad
- Simulation
  - OpenRocket
  - CFD
- Material testing
  - Tensile test

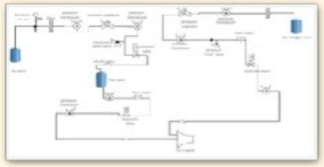


Liquid propulsion team

2022 Final projects

Combustion Chamber

Pintle injector



2023
Attachment + Final projects

Ignitor

Movie

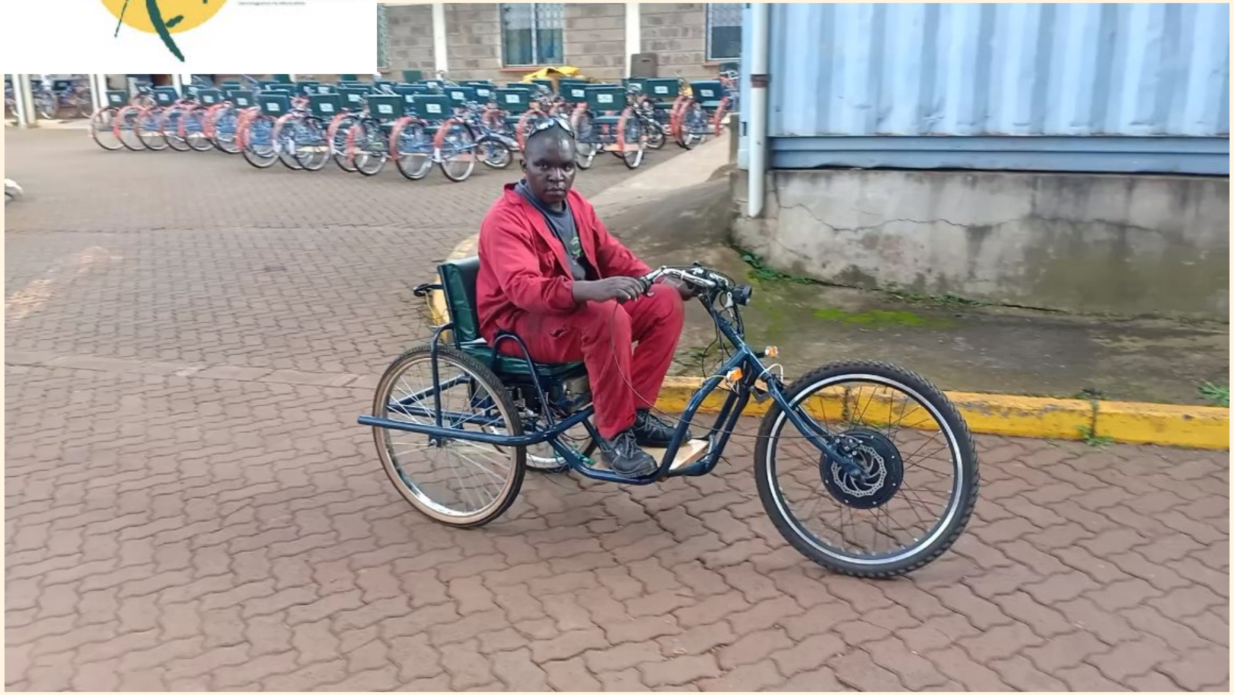
2024
Attachment + Final project

- Water test
- Integration of subsystems

  injector, ignitor, chamber, test stand

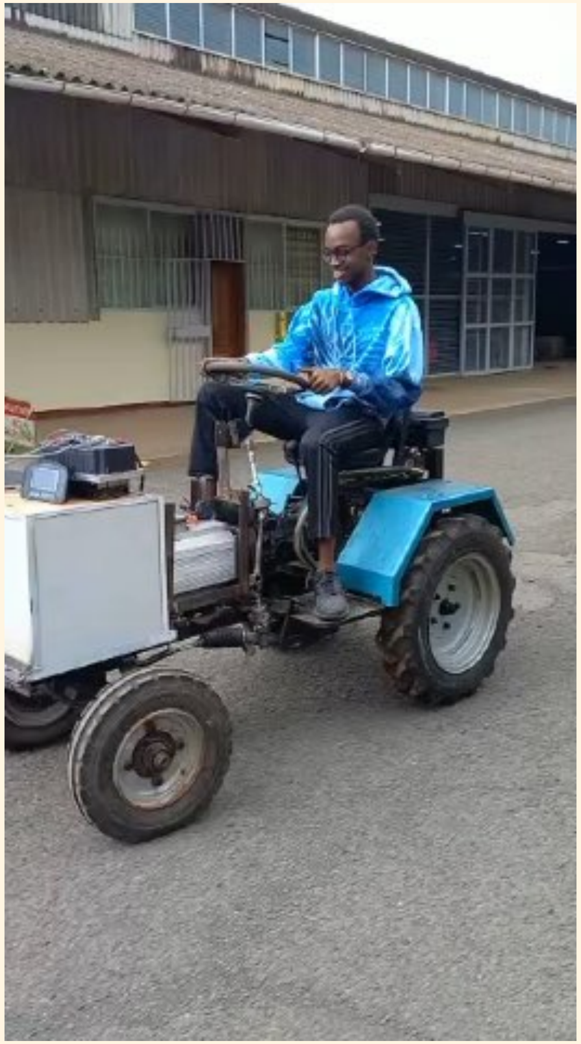
Jibebe

Development of Electric Vehicle (EV)



E-tricycle

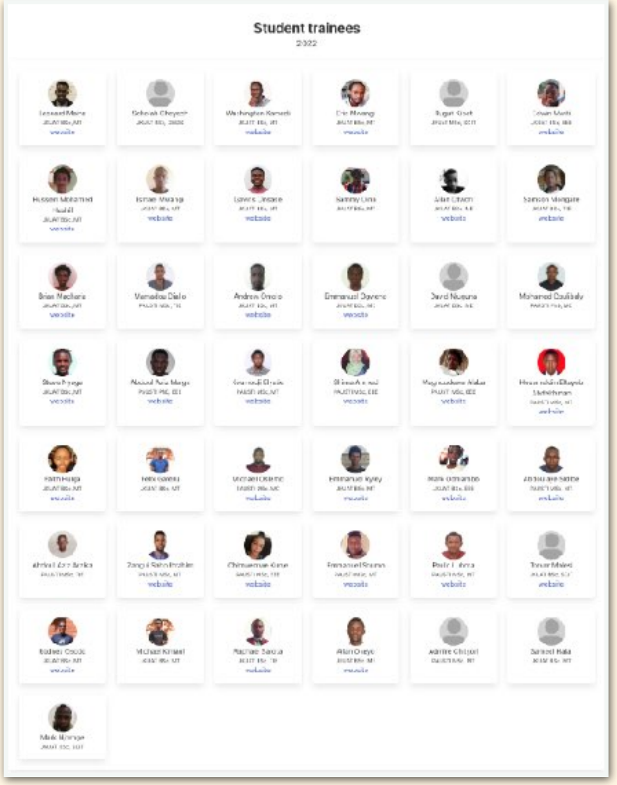
(Collaboration with **APDK**)



E-tractor

Robotics Dojo

- Encourage robotics research in JKUAT
- Train students on robotics
- Organize robotics competition



Student trainees

2022

Leonard Maina
JKUAT BSc, MT
website

Deborah Cheyech
JKUAT BSc, [illegible]

Washington Kamadi
JKUAT BSc, MT
website

Eric Mwangi
JKUAT MSc, MT
website

[illegible]
JKUAT MSc, [illegible]

Edwin Mathi
JKUAT BSc, EEE
website

Hussein Mohamed Hadafi
JKUAT BSc, MT
website

Ishmael Mwangi
JKUAT BSc, MT
website

Lewis [illegible]
JKUAT BSc, MT
website

Sammy [illegible]
JKUAT BSc, MT

Allan [illegible]
JKUAT BSc, EE
website

Samson Mangare
JKUAT BSc, TIE
website

Brian Macharia
JKUAT BSc, MT
website

Mamadou Diallo
PAUSTI MSc, TE

Andrew Orodo
JKUAT BSc, MT
website

Emmanuel Oyvere
JKUAT BSc, MT
website

David Nuguna
JKUAT BSc, EE

Mohamed Coulibaly
PAUSTI PhD, MC

Steve Nyaga
JKUAT BSc, MT
website

Abdoul Aziz Manga
PAUSTI PhD, EE
website

[illegible]
PAUSTI MSc, MT
website

[illegible]
PAUSTI MSc, EEE
website

[illegible]
PAUSTI MSc, EEE
website

[illegible]
[illegible]
PAUSTI MSc, MT
website

Faith [illegible]
JKUAT BSc, MT
website

Felix [illegible]
JKUAT BSc, MT

Michael [illegible]
PAUSTI MSc, MC
website

Emmanuel [illegible]
JKUAT BSc, MT
website

Mark [illegible]
JKUAT BSc, EEE
website

Abdoulaye [illegible]
PAUSTI MSc, MT
website

[illegible]
PAUSTI MSc, TE

Zangui Saho Ibrahim
PAUSTI MSc, MT
website

[illegible]
PAUSTI MSc, EE
website

Emmanuel [illegible]
PAUSTI MSc, MT
website

[illegible]
PAUSTI MSc, MT
website

[illegible]
JKUAT BSc, [illegible]
website

[illegible]
JKUAT BSc, MT
website

Michael Kimani
JKUAT BSc, MT

Rachael [illegible]
JKUAT BSc, TE
website

Allan [illegible]
JKUAT BSc, MT
website

[illegible]
PAUSTI MSc, MT

Samuel [illegible]
JKUAT BSc, MT

Mark Njoroge
JKUAT BSc, EEE

First trainees
in 2022 (JKUAT/PAUSTI)

Competition 2022

Competition 2023

Let's design Robotics Competition in JKUAT

- Start from scratch
  - No experience to organize competition

- **Criteria**
  - **Feasibility** (cost and complexity)
  - Gameplay (= **Fun** to watch)
  - **Educational** aspect (learn robotics skills)

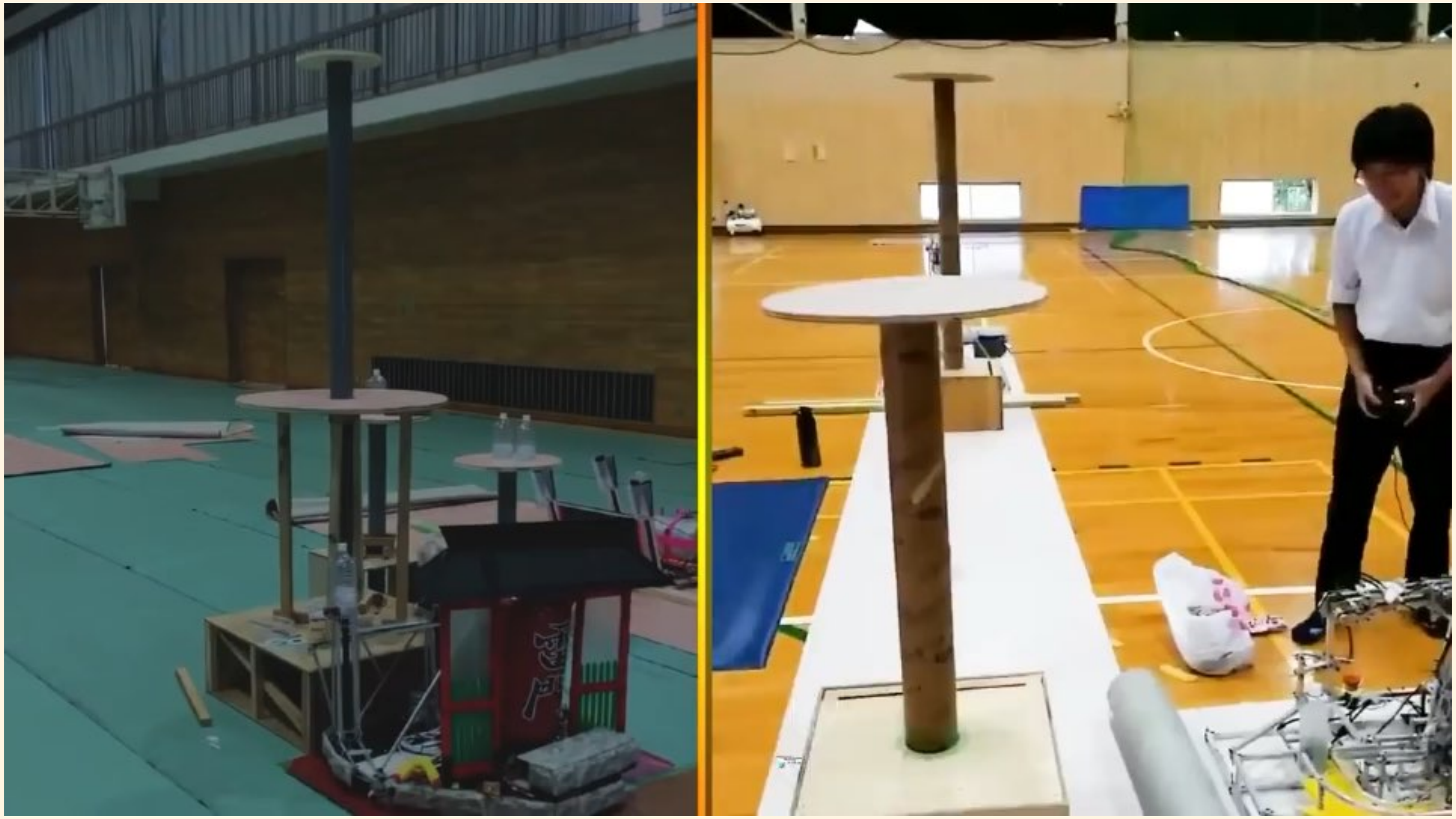
- **Benchmarked** several robotics competitions

ASABE Robotics Student Design Competition

ASABE: American Society of Agricultural and Biological Engineers

- Agricultural robot can be sales point of JKUAT
- Majority of the feedback: Not fun 😂
  - Gameplay is important to attract audience

Kosen ROBOCON since 1988



- Most popular in Japan (nationwide TV broadcast)
- Too much **complicated** for beginners
    - Cost and team capacity are beyond the scope

ET Robocon

- Focuses on **software** programming
  - Ordinary competition focuses on **hardware**
    - **No time** to refine **software**

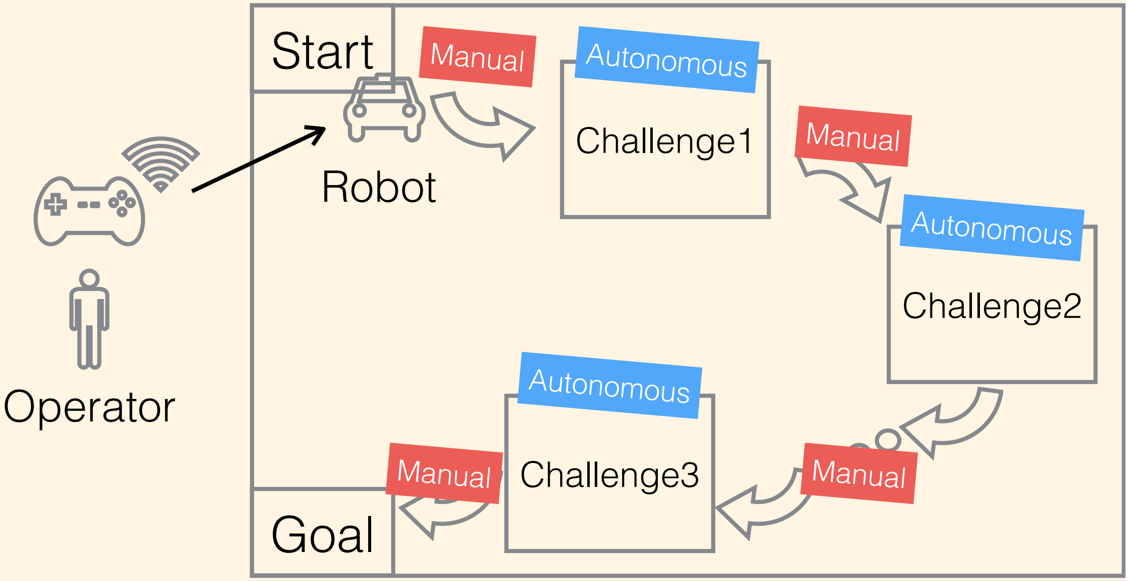
Preliminary design of Dojo competition

Referring to ET Robocon, **incorporate multiple tasks**

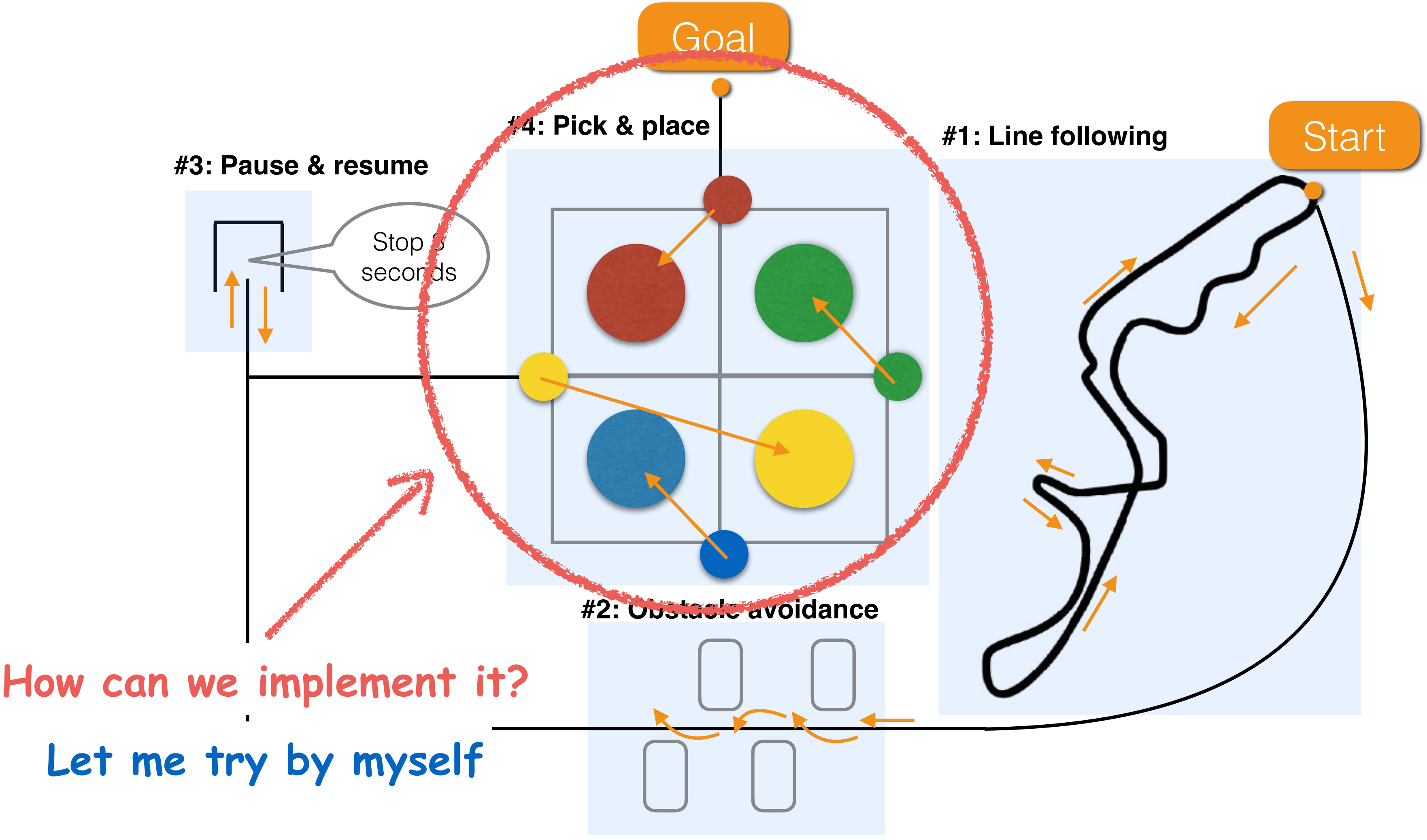
Tasks **proposed by students**

- **Line tracer**
- **Computer vision** (e.g., segmentation)
- **Manipulation** by robotic arm
- **Obstacle avoidance**

- **Hybrid control** of manual/autonomous?
    - **Manual**: movement between challenges
    - **Autonomous**: each challenge



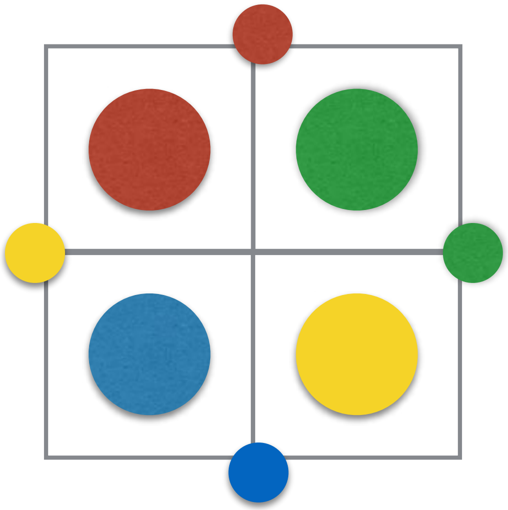
The first idea of Gamefield



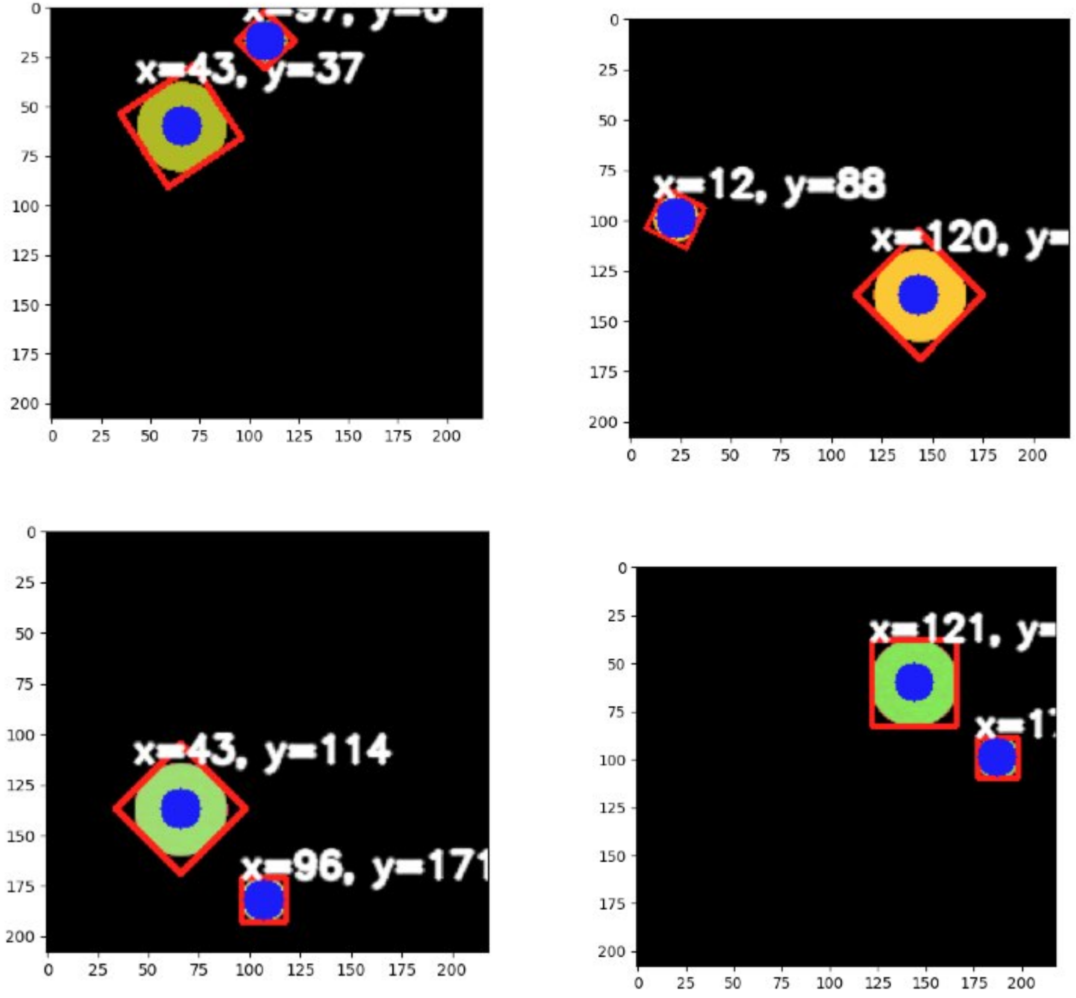
How can we implement it?

Let me try by myself

The control is fully autonomous



OpenCV implementation

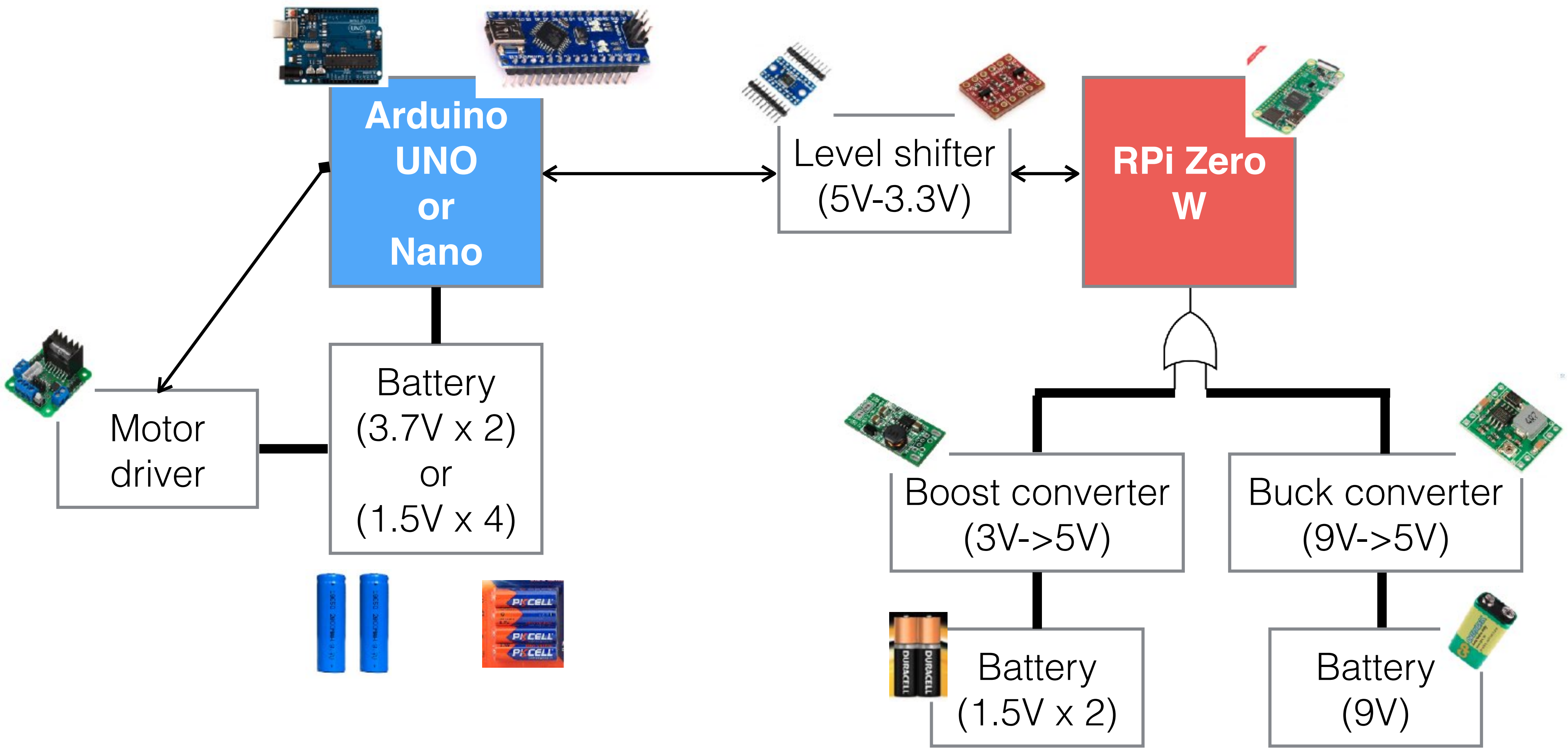


Use computer vision to detect the object color (e.g. OpenCV)

↔ signal

— power

Typical hardware architecture



Arduino UNO or Nano

Level shifter (5V-3.3V)

RPi Zero W

Motor driver

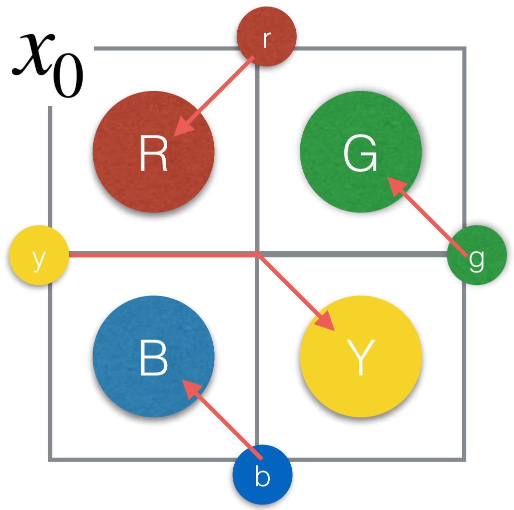
Battery (3.7V x 2) or (1.5V x 4)

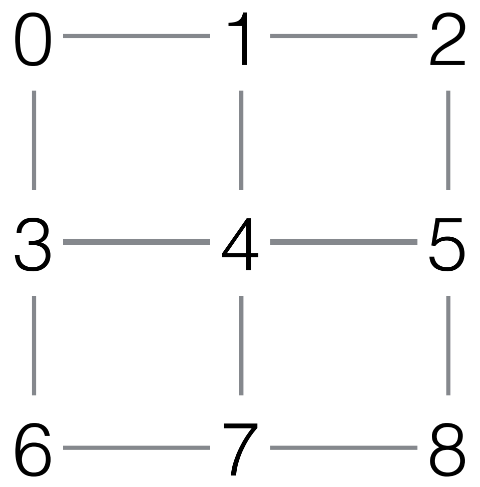
Boost converter (3V->5V)

Buck converter (9V->5V)

Battery (1.5V x 2)

Battery (9V)





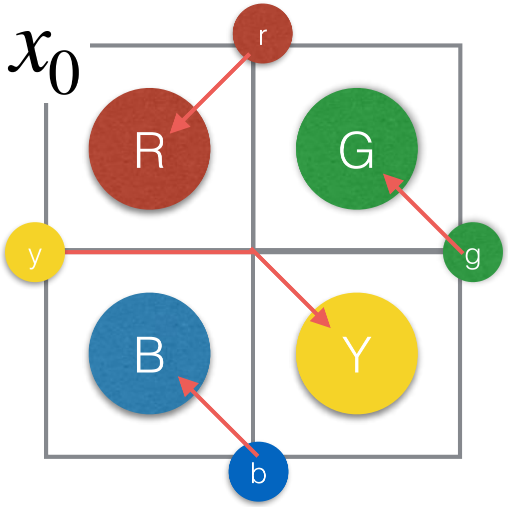
Reference implementation

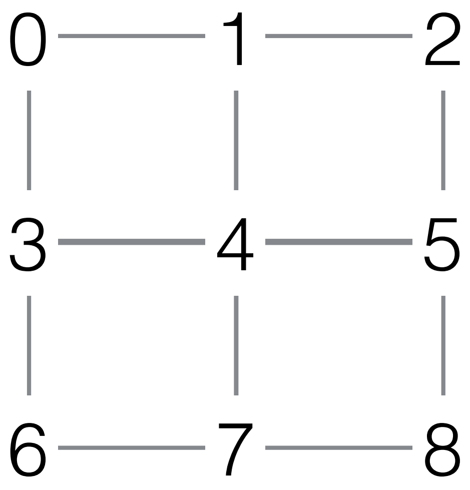
1. Detect the location of the targets
   {r: 1, g: 5, b: 7, y: 3}
2. Detect the carrying path
   {r: ↙, g: ↖, b: ↖, y: →↘}
3. Generate the path between neighbors

{[0,1], '→'},{[0,3], '↓'}
{[1,2], '→'}, {[1,4], '↓'}, {[1,0], '←'}
{[2,5], '↓'}, {[2,1], '←'}
{[3,4], '→'}, {[3,6], '↓'}, {[3,0], '↑'}
{[4,5], '→'}, {[4,7], '↓'}, {[4,1], '↑'}, {[4,3], '←'}
{[5,2], '↑'}, {[5,4], '←'}, {[5,8], '↓'}
{[6,7], '→'}, {[6,3], '↑'},
{[7,8], '→'}, {[7,4], '↑'}, {[7,6], '←'}

4. Decide the order to carry the targets
   {r → g → b → y}

5. Generate the paths to pass the targets
   [0, r, g, b, y, 0]
   ⟹ [0, **1, 5, 7, 3,** 0]
   ⟹ [0, **1,** 2, **5**, 8, **7**, 6, **3,** 0]
   ⟹ [0, **1**, ↙+back, 2, **5**,↖+back,
   8, **7**,↖+back, 6, **3**,→↘+back, 0]





6. Generate path by expanding the path between neighbors

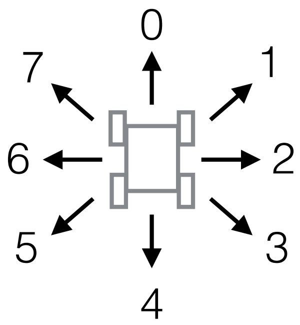
[0, 1, ↙b, 2, 5,↖b, 8, 7,↖b, 6, 3,→↘b, 0]

⟹ [0,→, ↙b, →, ↓,↖b, ↓, ←,↖b, ←, ↑,→↘b, ↑, 0]

7. Complete the movement

[0(↓),→, ↙b, →, ↓,↖b, ↓, ←,↖b, ←, ↑,→↘b, ↑, 0]

⟹[L90F, R135F, B, L135F, R90F, R135F, B, L135F, R90F, R45F, B, L45F, R90F, R90F, R45F, B, L45B, L90F]



0: forward (F)
1: turn-right-45deg and forward (R45F)
2: turn-right-90deg and forward (R90F)
3: turn-right-135deg and forward (R135F)
4: turn-right-180deg and forward (R180F)
5: turn-left-135deg and forward (L135F)
6: turn-left-90deg and forward (L90F)
7: turn-left-45deg and forward (L45F)

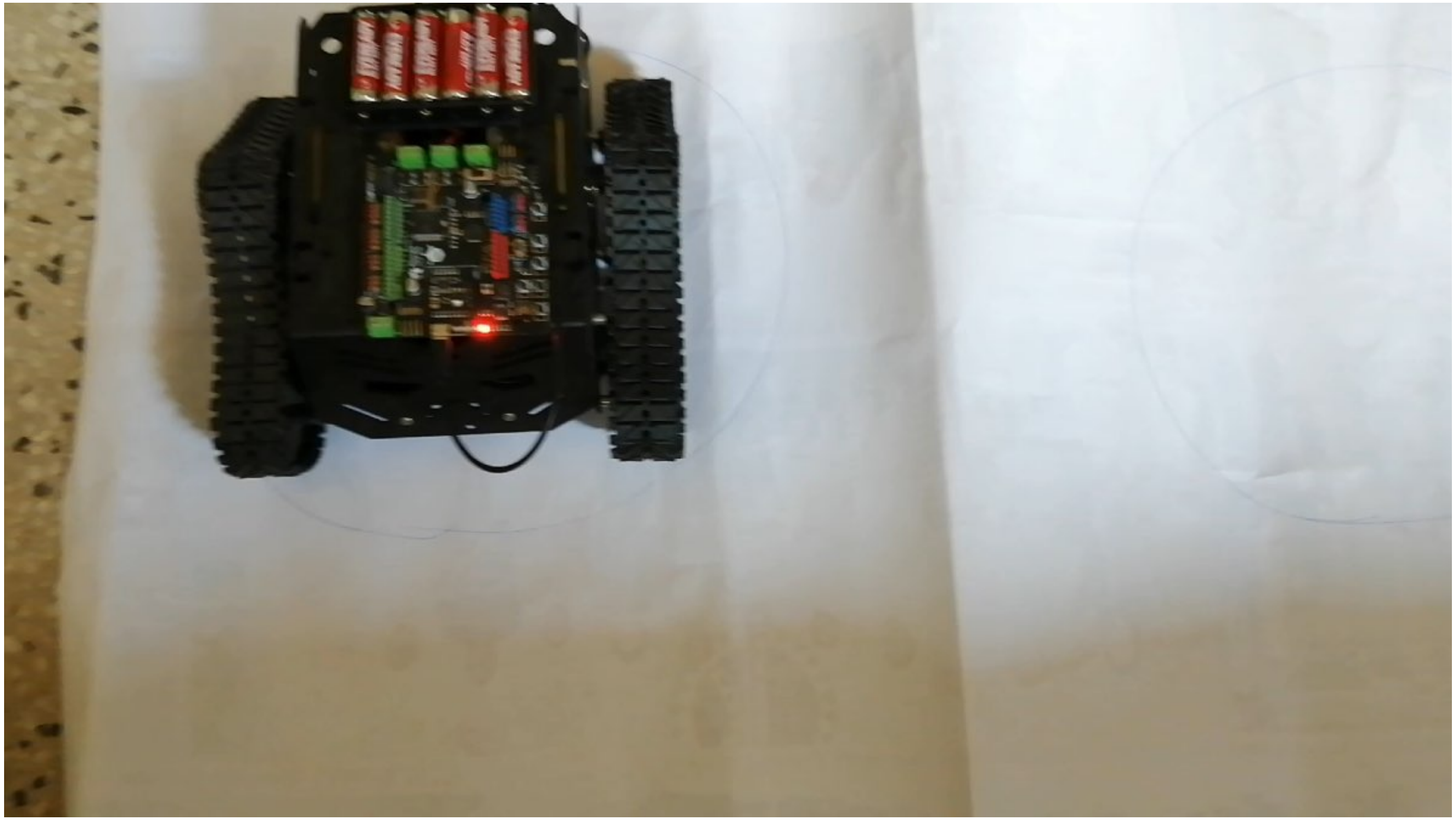
previous	next	command
↑	↑	F
	↗	R45F
	→	R90F
	↘	R135F
	↓	R180F
	↙	L135F
	←	L90F
	↖	L45F
↗	↑	L45F
	↗	F
	→	R45F
	↘	R90F
	↓	R135F
	↙	R180F
	←	L135F
	↖	L90F

previous	next	command
→	↑	L90F
	↗	L45F
	→	F
	↘	R45F
	↓	R90F
	↙	R135F
	←	R180F
	↖	L135F
↘	↑	L135F
	↗	L90F
	→	L45F
	↘	F
	↓	R45F
	↙	R90F
	←	R135F
	↖	R180F

previous	next	command
↓	↑	R180F
	↗	L135F
	→	L90F
	↘	L45F
	↓	F
	↙	R45F
	←	R90F
	↖	R135F
↙	↑	R135F
	↗	R180F
	→	L135F
	↘	L90F
	↓	L45F
	↙	F
	←	R45F
	↖	R90F

previous	next	command
←	↑	R90F
	↗	R135F
	→	R180F
	↘	L135F
	↓	L90F
	↙	L45F
	←	F
	↖	R45F
↖	↑	R45F
	↗	R90F
	→	R135F
	↘	R180F
	↓	L135F
	↙	L90F
	←	L45F
	↖	F

Implementation of the sequence on hardware

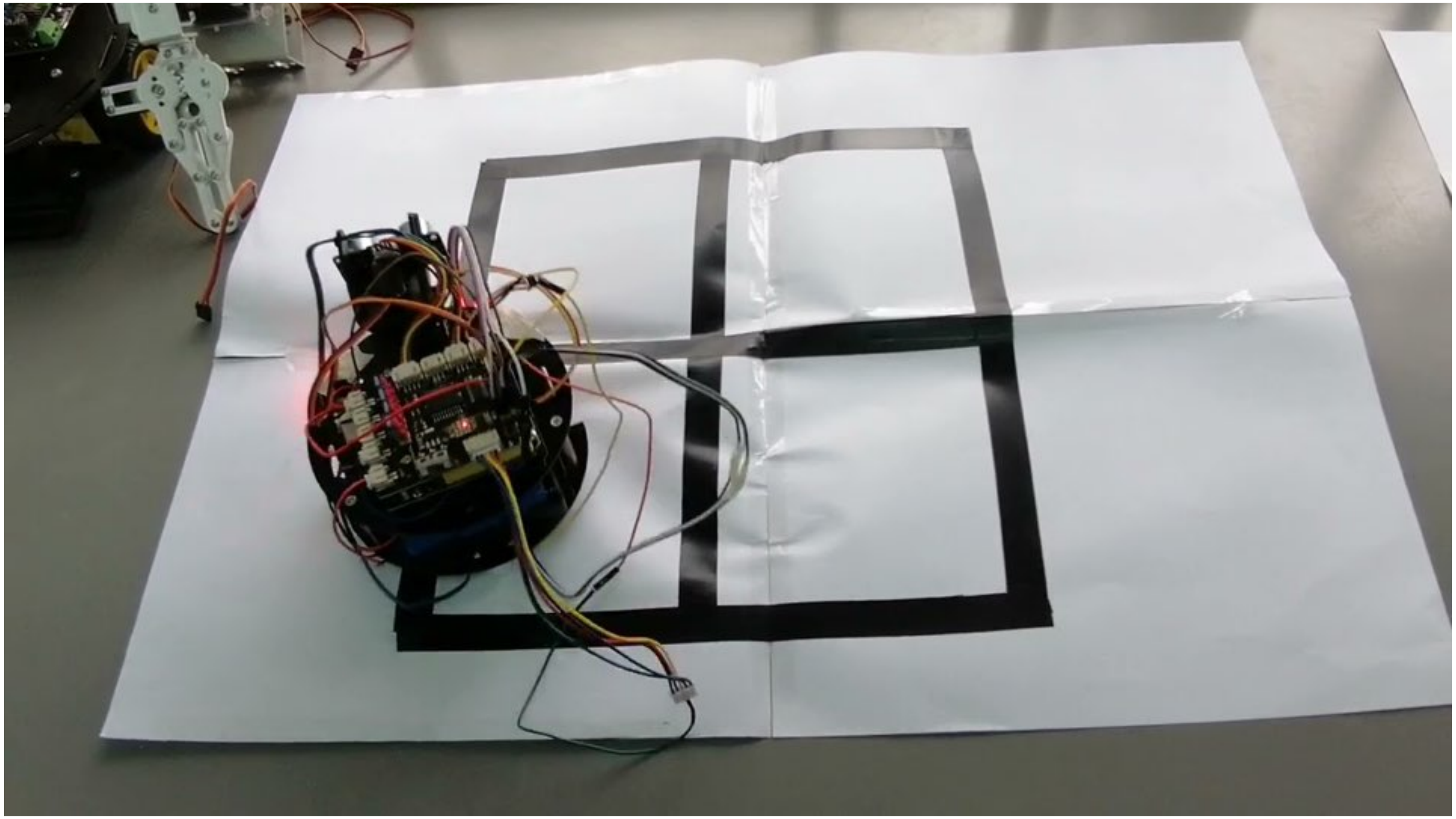


https://www.youtube.com/watch?v=REDNsu_Z2yo

There was a large motion error by slipping

- Better to have a **guide** → line following

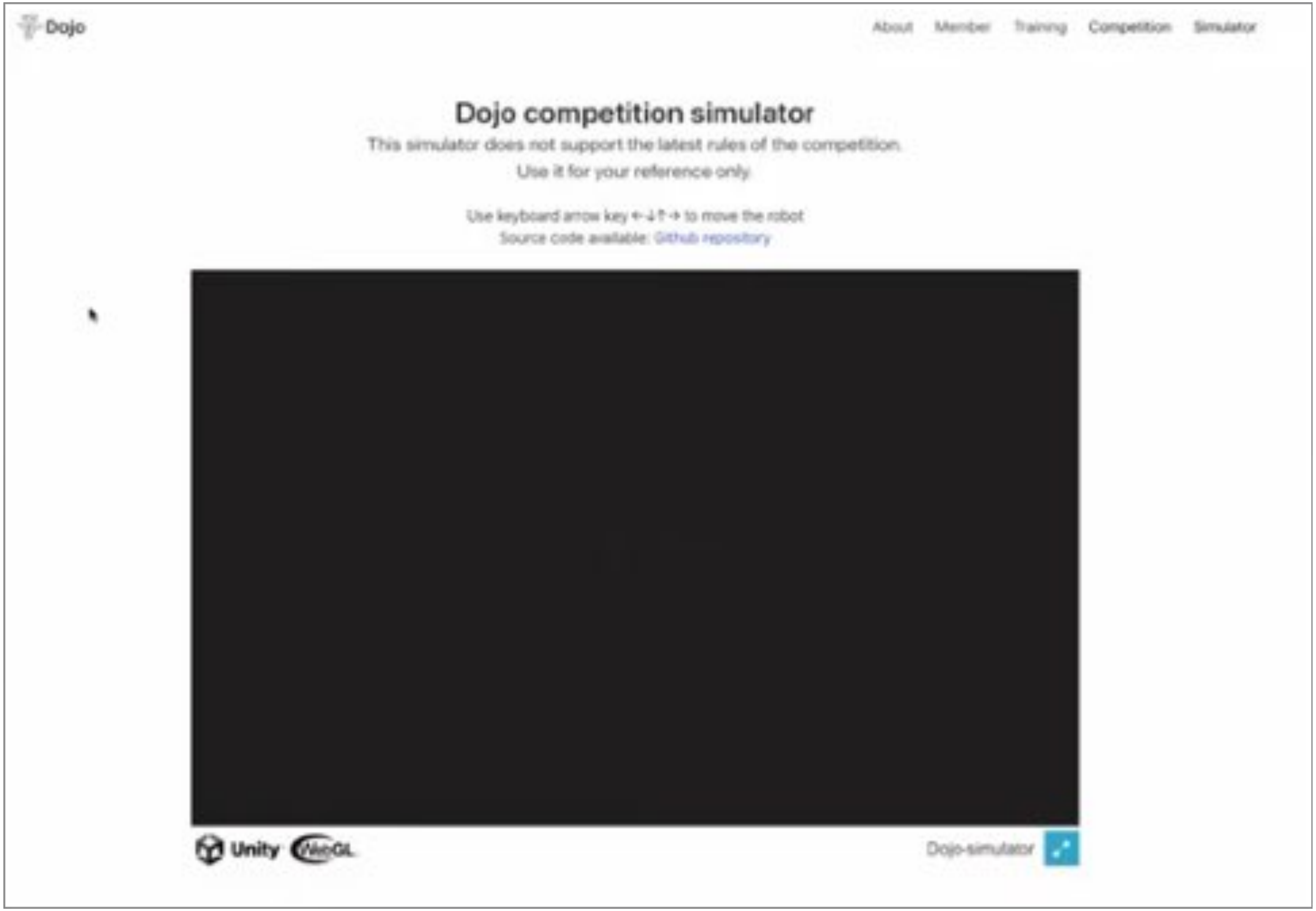
Line following version



https://github.com/shohei/line_follower

https://www.youtube.com/watch?v=hlZUGrfDYE8

Dojo simulator powered by Unity & ROS



Dojo competition simulator

This simulator does not support the latest rules of the competition.

Use it for your reference only.

Use keyboard arrow key ←↓↑→ to move the robot

Source code available: Github repository

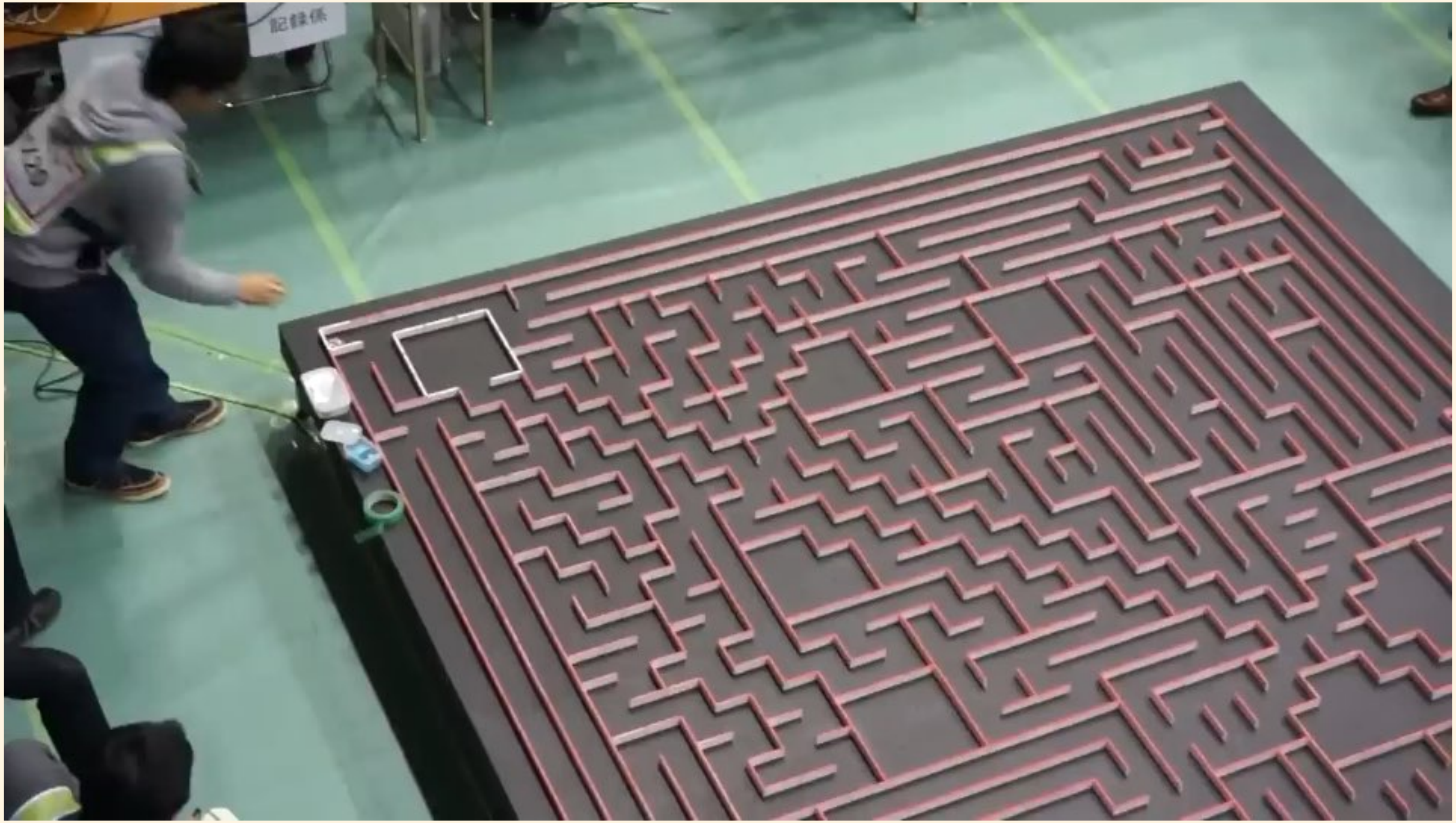
https://roboticsdojo.github.io/simulator/

https://www.youtube.com/watch?v=XQmicl2z_go

What I learned…

- Pick and place task would be **too difficult** for students!
    - Probably no time to integrate manipulator
- Any alternatives?

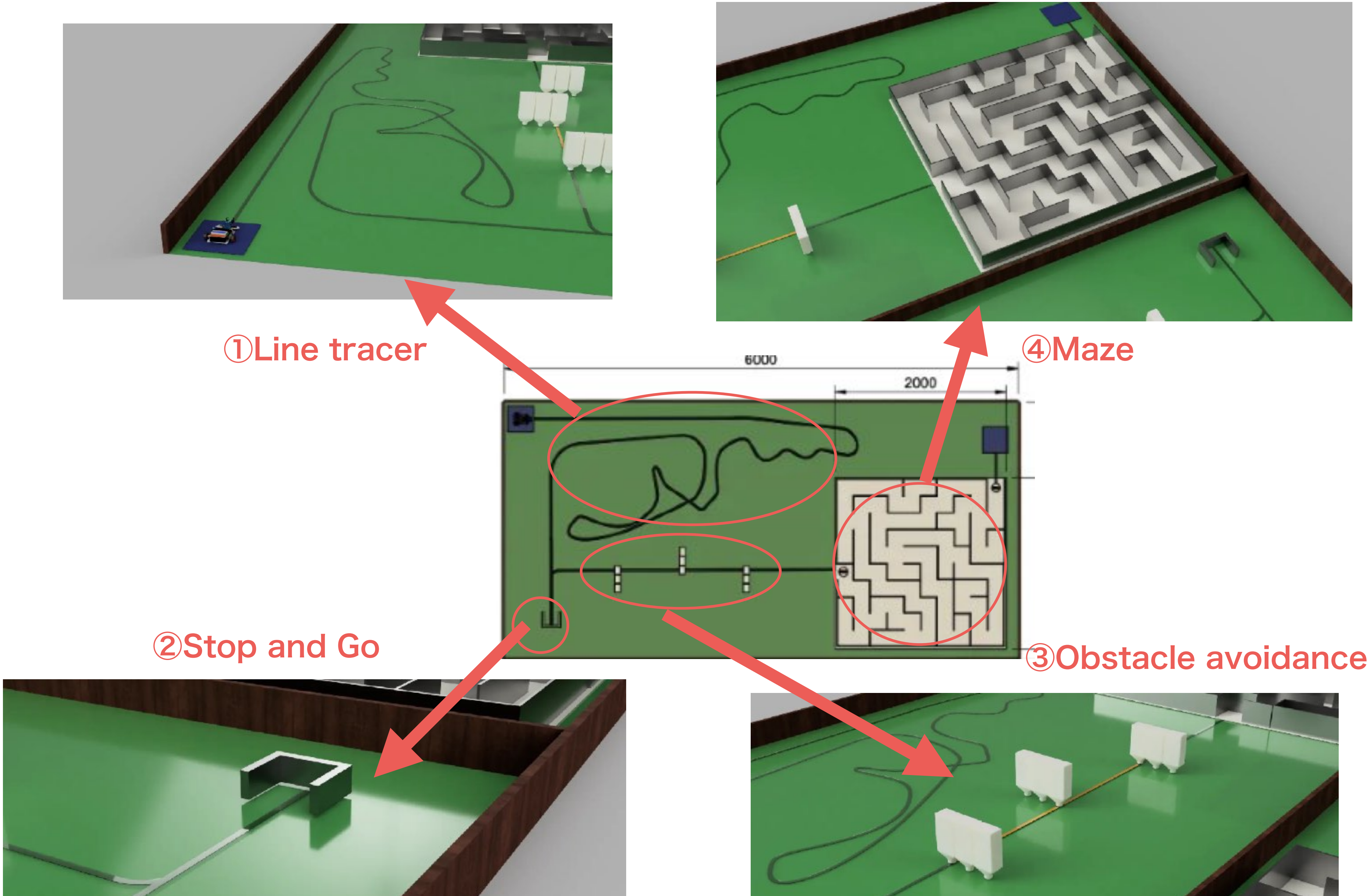
Micromouse



- Technically interesting!
- Fun to watch!

Let's incorporate Maze

Final gamefield Dojo 2022 competition



①Line tracer

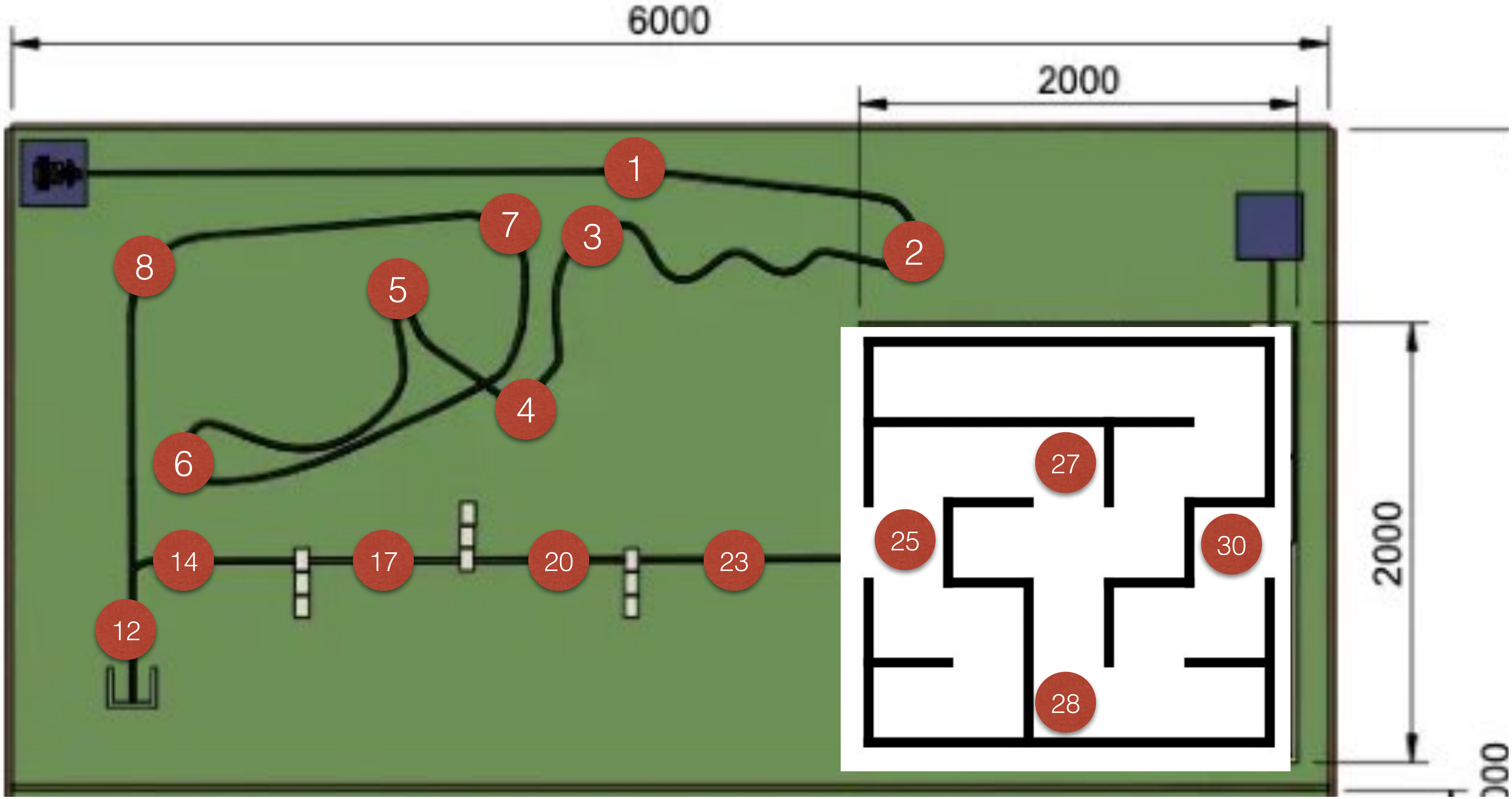
④Maze

②Stop and Go

③Obstacle avoidance

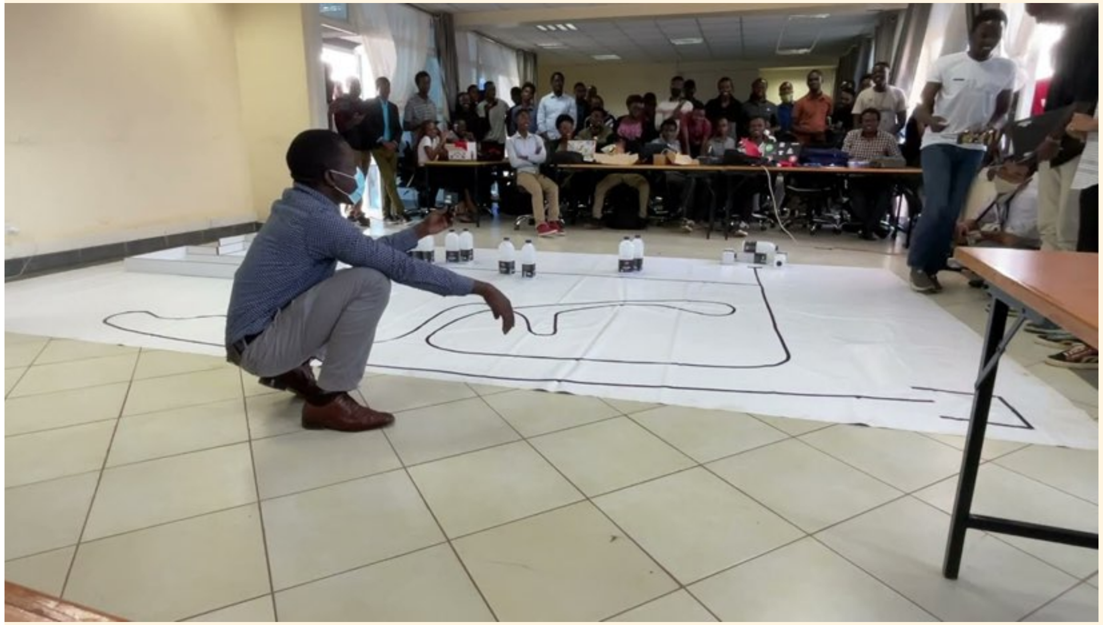
Scoring rule

Checkpoint and points

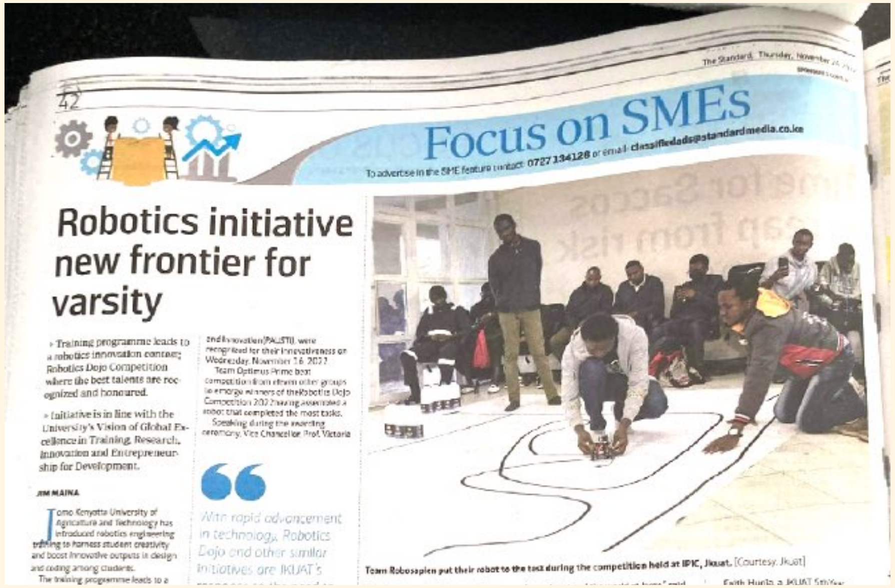


Maze was simplified

Success of 1st competition in 2022



長崎大学
NAGASAKI UNIVERSITY



The Standard, Thursday, November 24, 2022

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Focus on SMEs

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Robotics initiative new frontier for varsity

- Training programme leads to a robotics innovation contest; Robotics Dojo Competition where the best talents are recognized and honoured.
- Initiative is in line with the University's Vision of Global Excellence in Training, Research, Innovation and Entrepreneurship for Development.

JIM MAINA

Jomo Kenyatta University of Agriculture and Technology has introduced robotics engineering training to harness student creativity and boost innovative outputs in design and coding among students.

The training programme leads to a

and Innovation (PAUSTI), were recognised for their innovativeness on Wednesday, November 16, 2022.

Team Optimus Prime beat competition from eleven other groups to emerge winners of the Robotics Dojo Competition 2022 having assembled a robot that completed the most tasks.

Speaking during the awarding ceremony, Vice Chancellor Prof. Victoria

With rapid advancement in technology, Robotics Dojo and other similar initiatives are JKUAT's

Team Robosapien put their robot to the test during the competition held at IPIC, Jkuat. [Courtesy: Jkuat]

Faith Hunja, a JKUAT 5th Year

Plan for the next year 2023

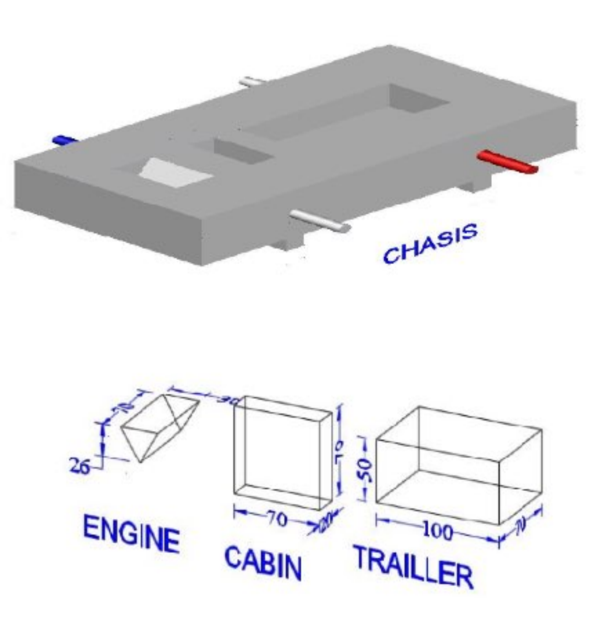
- Alignment to **ROBOKEN 2023**
    - Line trace
    - Manipulator

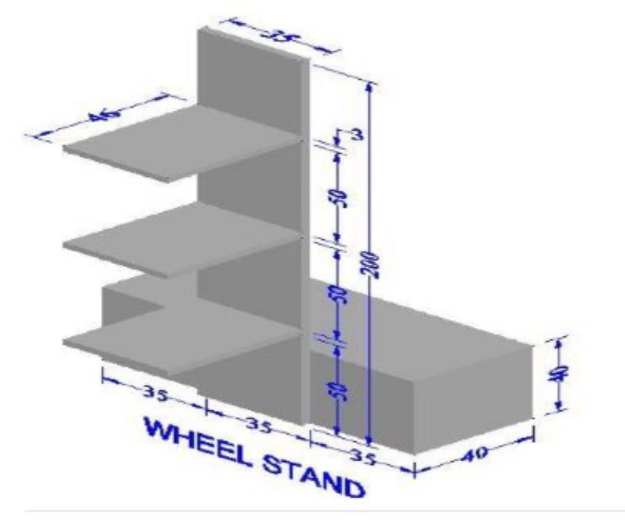
MINISTRY OF EDUCATION

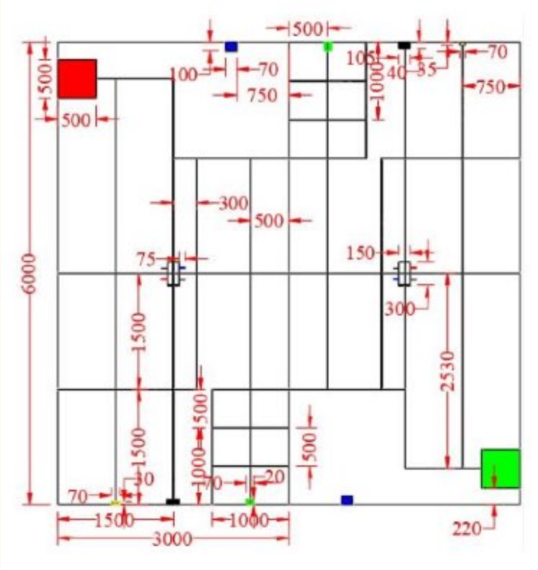
THE STATE DEPARTMENT TECHNICAL VOCATIONAL EDUCATION AND TRAINING

ROBOKEN 2023 RULES

ROBOTS IN MANUFACTURING



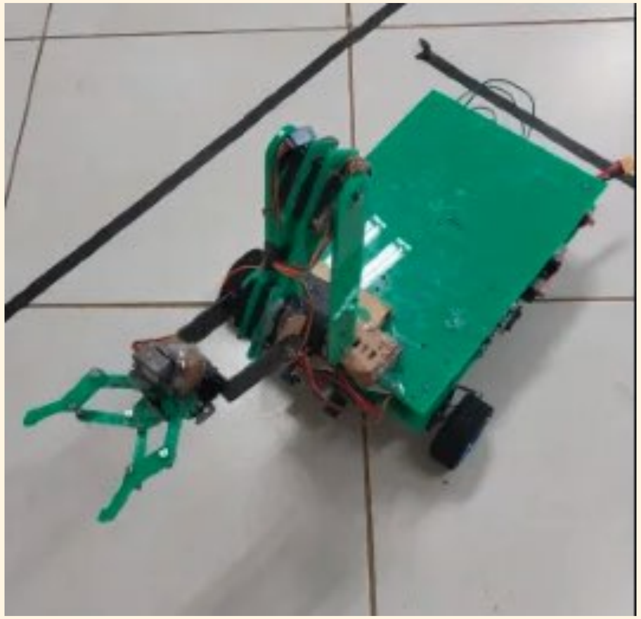


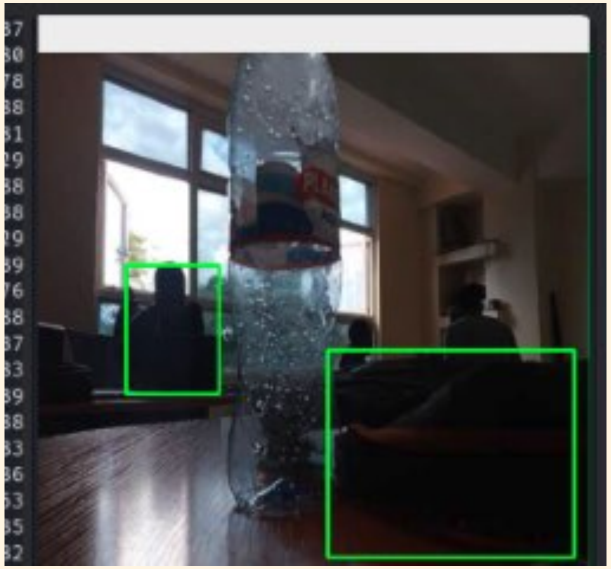


The assembly of the parts (wheel, engine, cabin, trailer) seemed complex... Let's try.

Dojo interns

2023 May - July

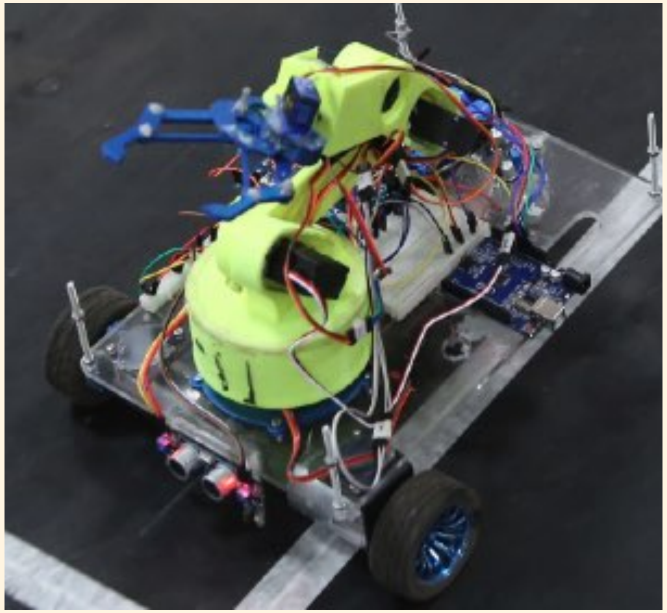




Mission of the interns

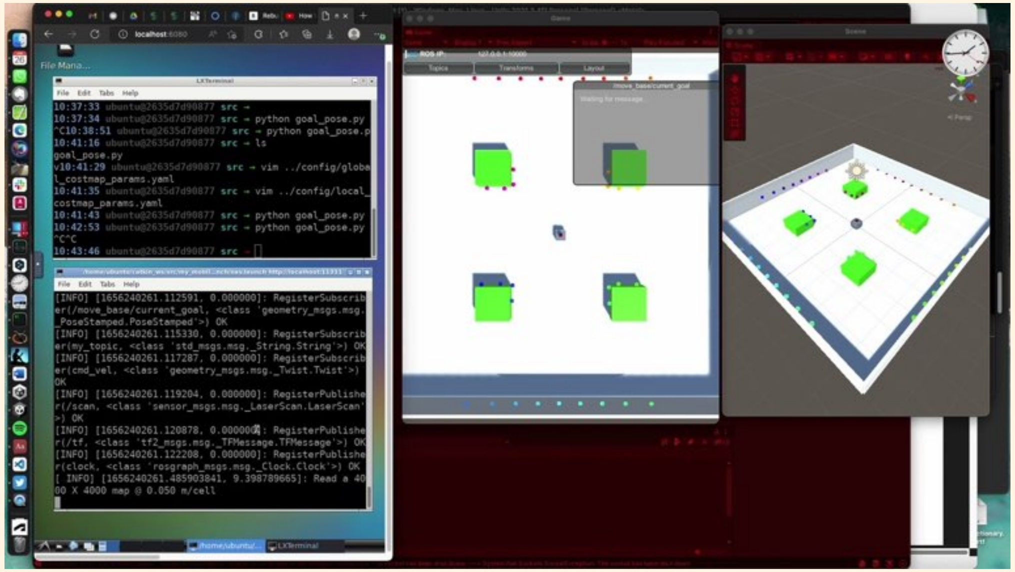
- Develop a **model robot**
- Become a **mentor** of other students

Dojo competition 2023



Toward Robotics Dojo 2024

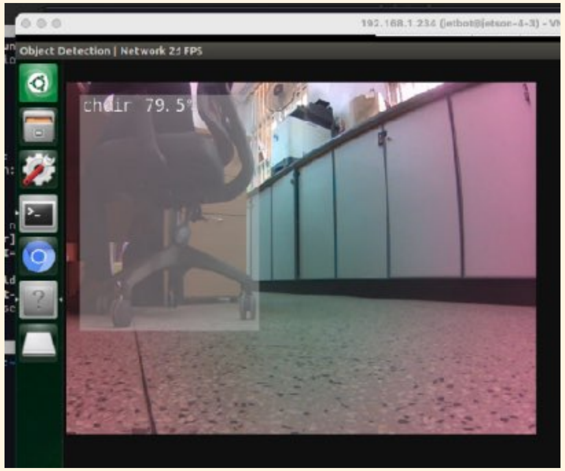
- Lesson learned from Dojo 2023
  - Time was not sufficient to complete
  - Use the **same rule** and perfect the tasks
- Encourage to use **ROS**
  - Leave software asset for future teams
  - Can utilize ROS packages (= library)



```
10:37:33 ubuntu@2635d7d90877 src →
10:37:34 ubuntu@2635d7d90877 src → python goal_pose.py
^C10:38:51 ubuntu@2635d7d90877 src → python goal_pose.p
10:41:16 ubuntu@2635d7d90877 src → ls
goal_pose.py
v10:41:29 ubuntu@2635d7d90877 src → vim ../config/globa
l_costmap_params.yaml
10:41:35 ubuntu@2635d7d90877 src → vim ../config/local_
costmap_params.yaml
10:41:43 ubuntu@2635d7d90877 src → python goal_pose.py
10:42:53 ubuntu@2635d7d90877 src → python goal_pose.py
^C^C
10:43:46 ubuntu@2635d7d90877 src →
```

```
[INFO] [1656240261.112591, 0.000000]: RegisterSubscrib
er(/move_base/current_goal, <class 'geometry_msgs.msg.
_PoseStamped.PoseStamped'>) OK
[INFO] [1656240261.115330, 0.000000]: RegisterSubscrib
er(my_topic, <class 'std_msgs.msg._String.String'>) OK
[INFO] [1656240261.117287, 0.000000]: RegisterSubscrib
er(cmd_vel, <class 'geometry_msgs.msg._Twist.Twist'>)
OK
[INFO] [1656240261.119204, 0.000000]: RegisterPublishe
r(/scan, <class 'sensor_msgs.msg._LaserScan.LaserScan'
>) OK
[INFO] [1656240261.120878, 0.000000]: RegisterPublishe
r(/tf, <class 'tf2_msgs.msg._TFMessage.TFMessage'>) OK
[INFO] [1656240261.122208, 0.000000]: RegisterPublishe
r(clock, <class 'rosgraph_msgs.msg._Clock.Clock'>) OK
[ INFO] [1656240261.485903841, 9.398789665]: Read a 40
00 X 4000 map @ 0.050 m/cell
```

Mobile robot navigation using ROS


192.168.1.234 (jetbot@jetson-4-3) - VN
Object Detection | Network 2x FPS
chair 79.5%

Jetbot

Joystick

Combination of YOLO object detection,
& joystick control on Robot car

By the way...

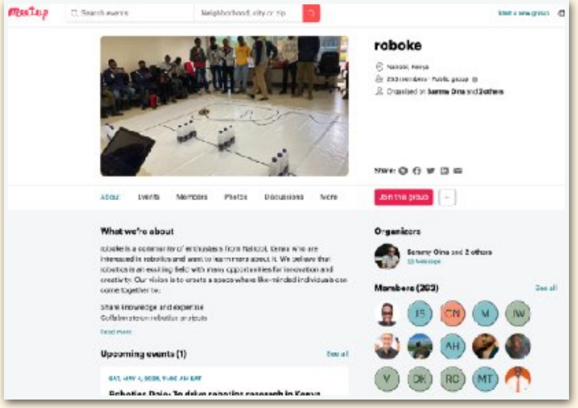
Making of the gamefield is always a lot of work

Future collaboration

Seek collaboration with other robotics competitions

Domestic

ROBOKEN



roboke

Nairobi, Kenya

[illegible] members · Public group

Organized by Sammy Oina and 2 others

What we're about

roboke is a community of enthusiasts from Nairobi, Kenya who are interested in robotics and want to learn more about it. We believe that robotics is an exciting field with many opportunities for innovation and creativity. Our vision is to create a space where like-minded individuals can come together to:

Share knowledge and expertise

Collaborate on robotics projects

Read more

Upcoming events (1) See all

[illegible]

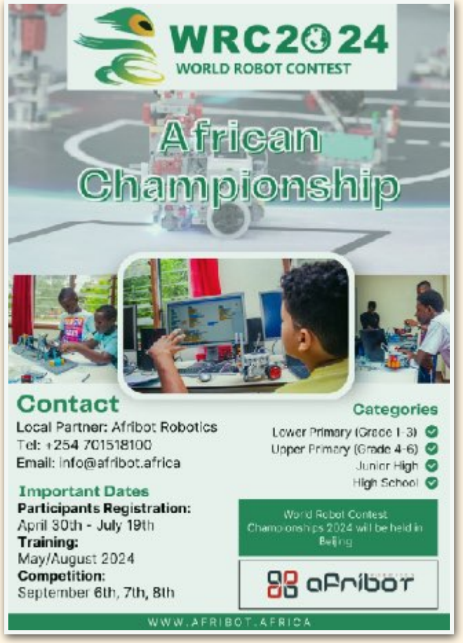
Robotics Dojo: To drive robotics research in Kenya

Organizers

Sammy Oina and 2 others

Members (263) See all

roboke



WRC2024
WORLD ROBOT CONTEST

African Championship

Contact

Local Partner: Afribot Robotics
Tel: +254 701518100
Email: info@afribot.africa

Important Dates

Participants Registration:
April 30th - July 19th
Training:
May/August 2024
Competition:
September 6th, 7th, 8th

Categories

- Lower Primary (Grade 1-3) ✓
- Upper Primary (Grade 4-6) ✓
- Junior High ✓
- High School ✓

World Robot Contest Championships 2024 will be held in Beijing

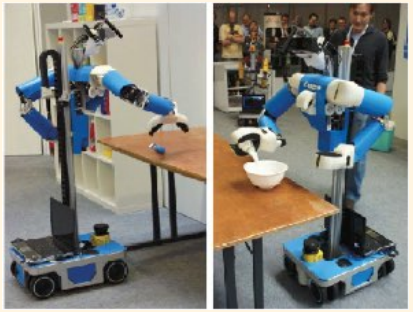
afribot

WWW.AFRIBOT.AFRICA

WRC (Afribot)

International

RoboCup



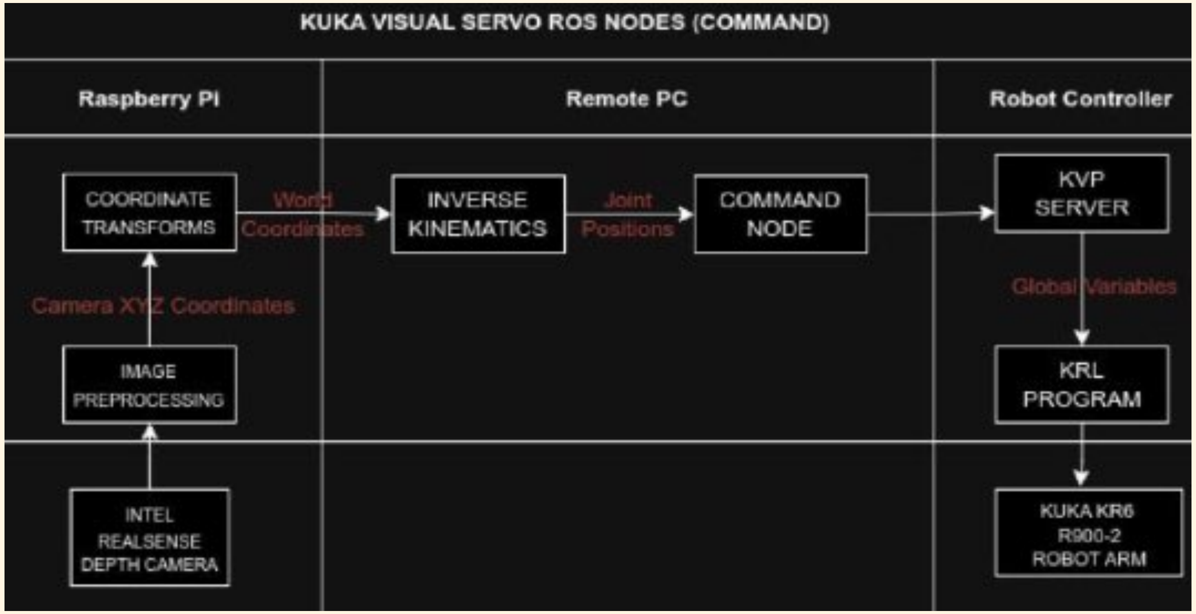
RoboCup @Home

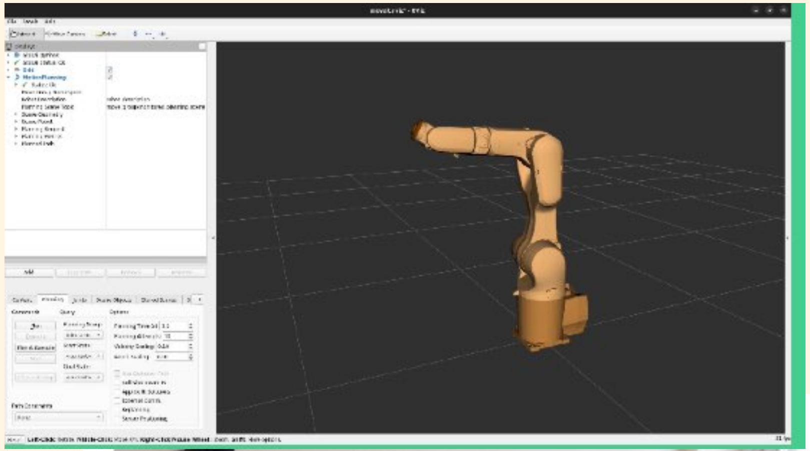
Pan-African robotics competition (PARC)

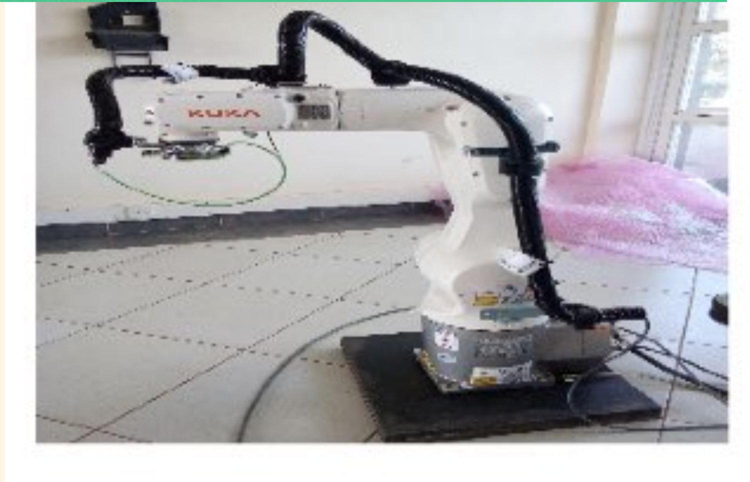
Past research on robotics

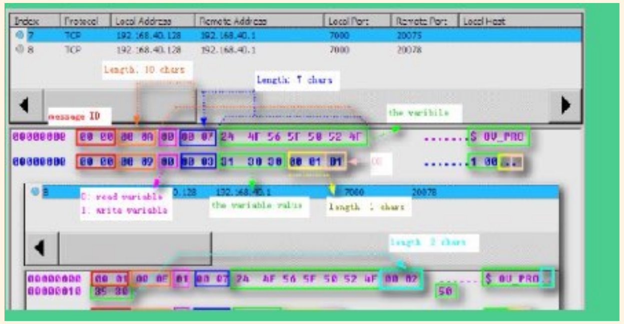
- Control of KUKA using ROS
  - Reverse engineering of communication protocol
  - Work by **Lenny Ng'ang'a** (JKUAT Physics)
- Disease detection using deep learning
  - Detect blight disease from leaf image
  - Work by **Emmanuel Soumo** (PAUSTI Mechatronics)
- Integration of Arduino and FPGA
  - Migrate Arduino code on PYNQ MicroBlaze CPU
  - Work by Aoki

Control of KUKA using ROS









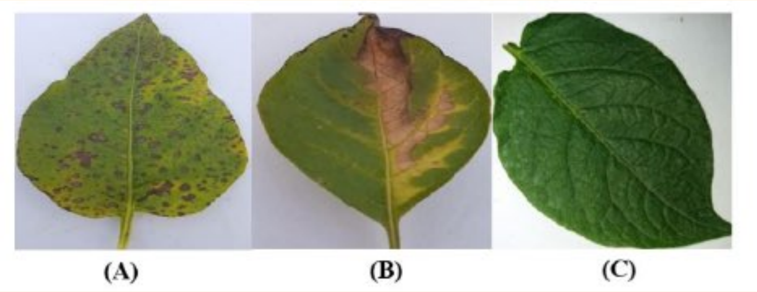
Index	Protocol	Local Address	Remote Address	Local Port	Remote Port	Local Host
7	TCP	192.168.40.128	192.168.40.1	7000	20075	
8	TCP	192.168.40.128	192.168.40.1	7000	20078	

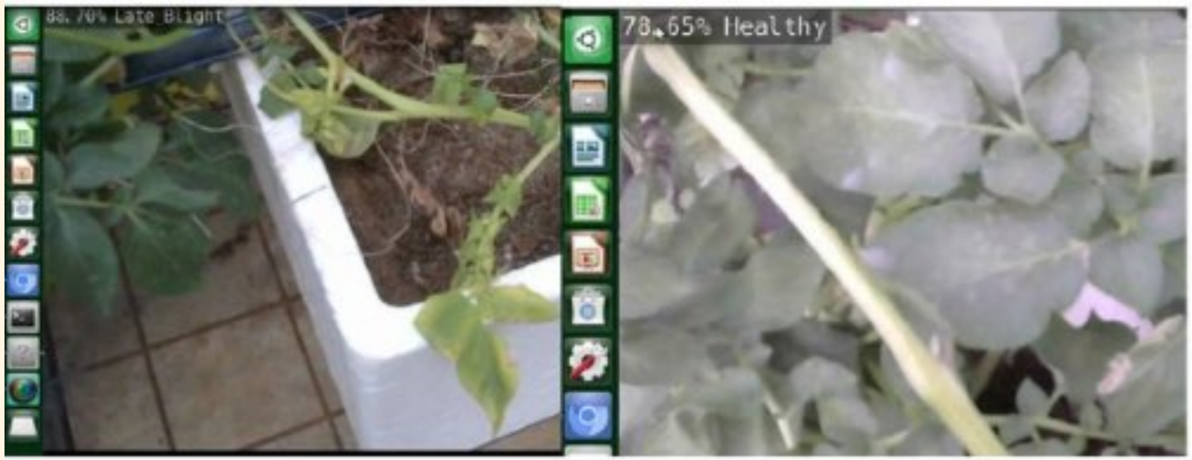
```
00000000  00 00 00 0A 00 00 07 24 4F 56 5F 50 52 4F   .......$ OV_PRO
00000000  00 00 00 09 00 00 03 31 30 30 00 01 01      .......1 00..
```

```
00000000  00 01 00 0F 01 00 07 24 4F 56 5F 50 52 4F 00 02   ......$ OV_PRO.
00000010  35 30                                             50
```

- Can program KUKA robot arm with ROS
  - Reverse engineering of communication protocol

Potato disease detection

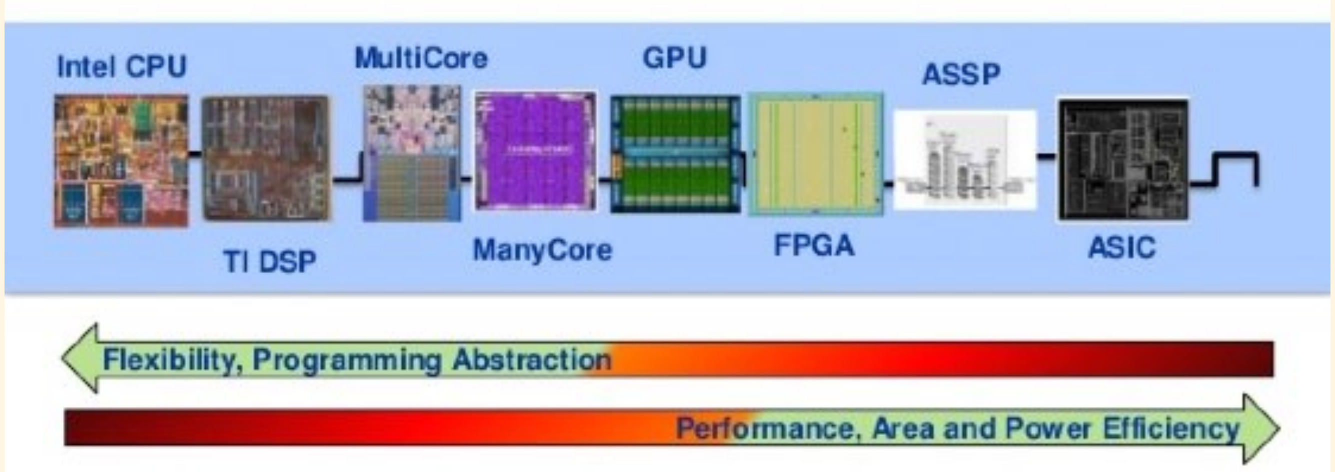



88.70% Late Blight

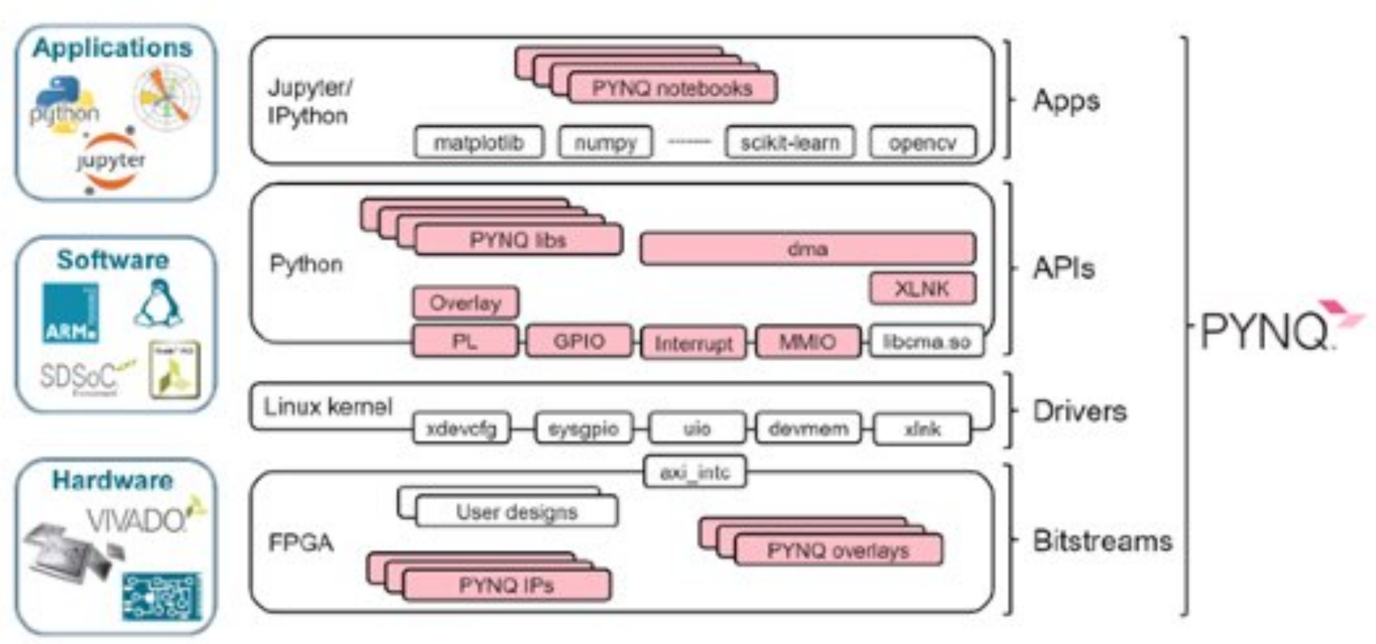
78.65% Healthy

- Can classify the leaves into 3 categories using DNN
  - Early blight, Late blight, healthy

Integration of Arduino and FPGA


Intel CPU
MultiCore
GPU
ASSP
TI DSP
ManyCore
FPGA
ASIC
Flexibility, Programming Abstraction
Performance, Area and Power Efficiency

3D Printing using PYNQ



- Aimed to computer vision on FPGA and realtime control on Arduino (MicroBlaze CPU)

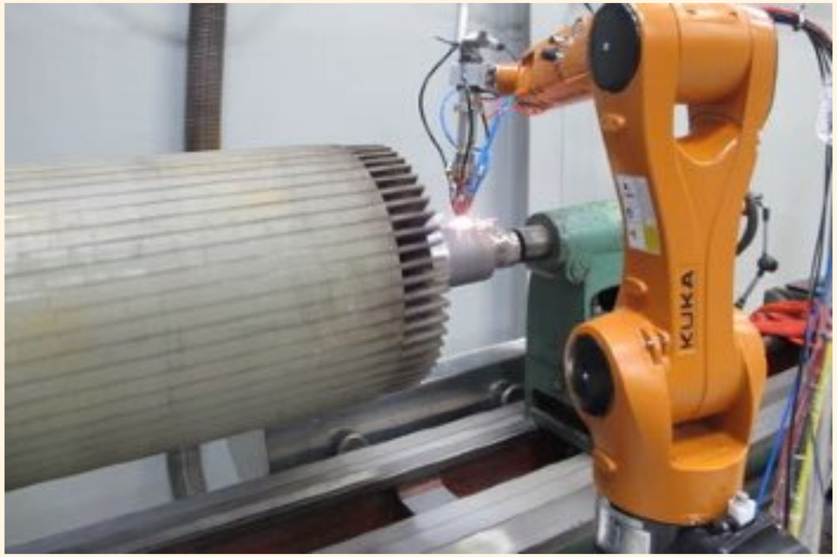
Necessary robotics research in Kenya

- Agriculture
- Manufacturing

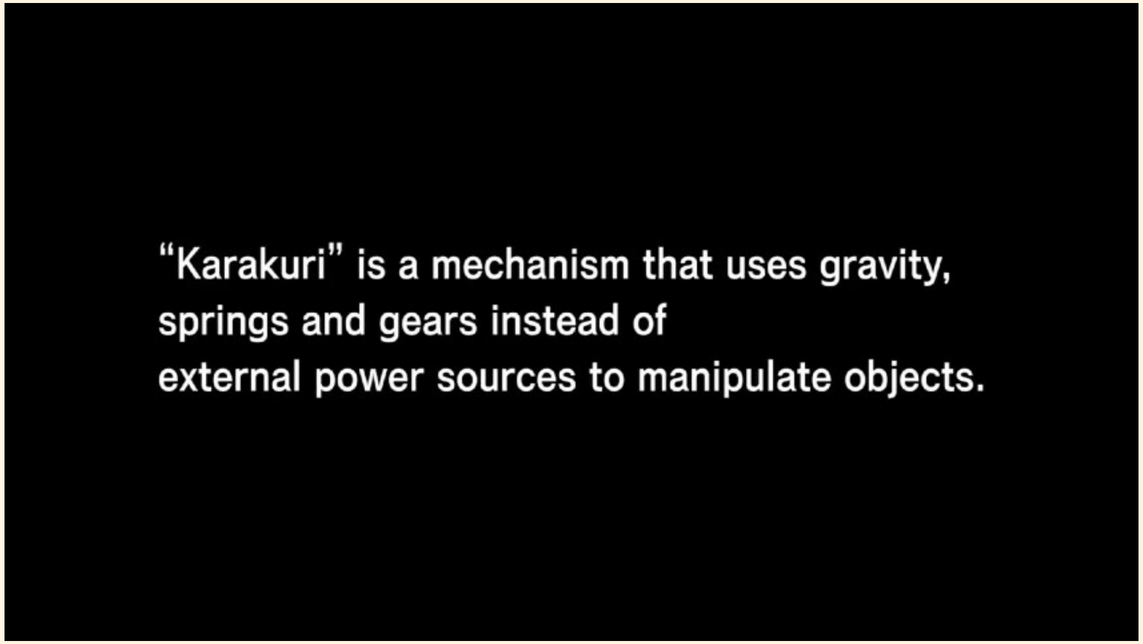
Robotics for Agriculture

- JKUAT Potato value chain project since 2019
  - Test farm in Nyandarua county
  - Mechanization and ICT are included
- Remote sensing w/ satellite&drone
  - **Soil map**
  - **Delineation** of land parcel
- Production of "Smart Fertilizer"
  - Adsorb K/Ca/Zn on Clay particle

Robotics for manufacturing



- Laser cladding with robotic arm
  - i.e. Metal 3D printing



"Karakuri" is a mechanism that uses gravity,
springs and gears instead of
external power sources to manipulate objects.

- **Karakuri** for factory

Thank you for your attention

- Contact
  - aoki@jkuat.ac.ke