Stand-off Control of Collaborative Robots

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icenine
ROBOTIC SOLUTIONS

SONY

Meet the Team

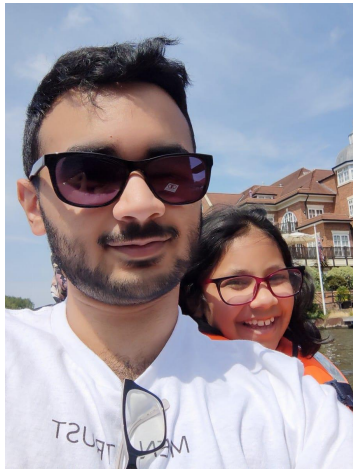
Luka

Qin Le

Sofia

Trajche

Petros



Abu

State of Robot Control

[1]

[2]

Ground Control Stations

Control Strategies

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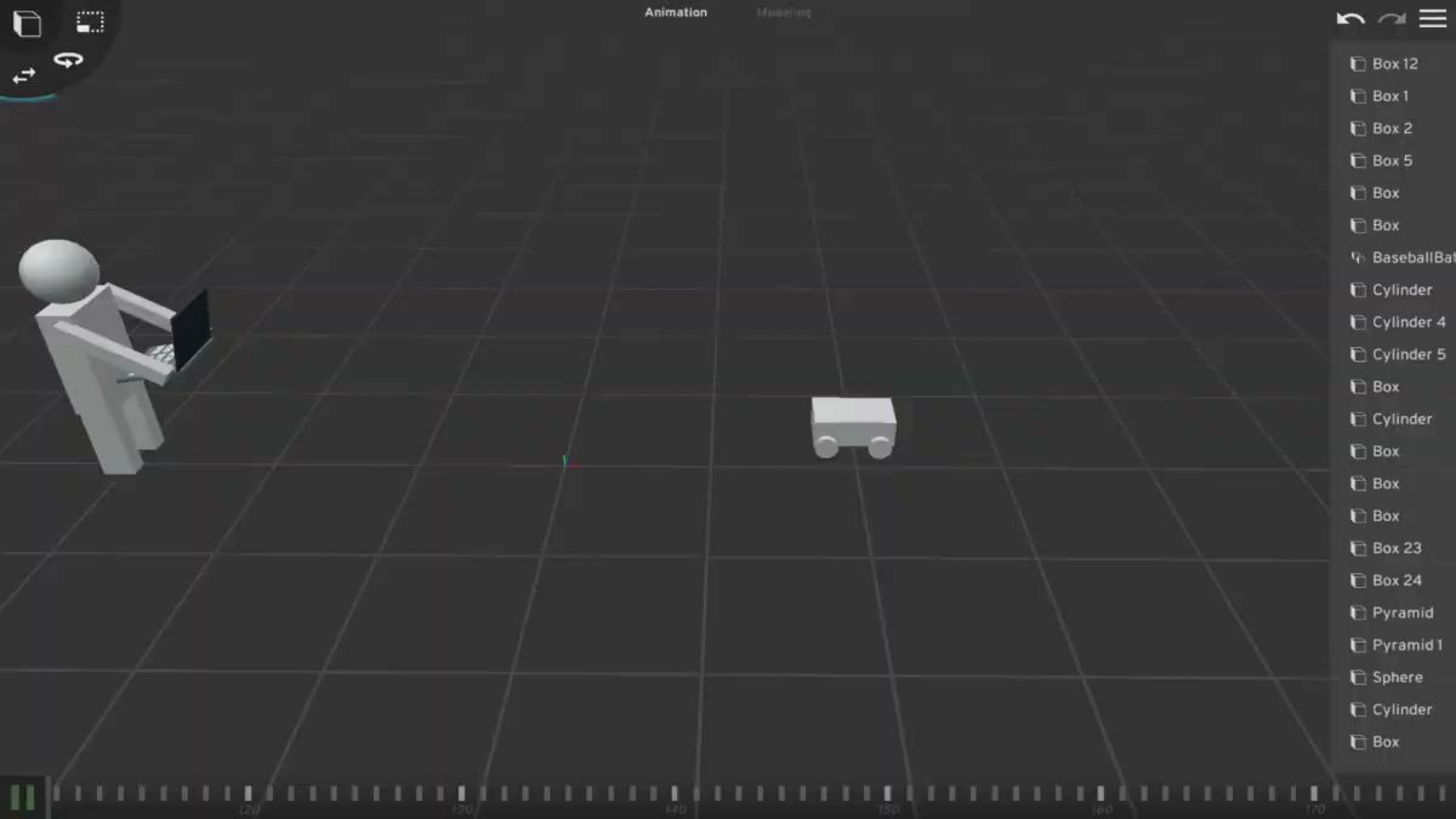
Direct

[3]

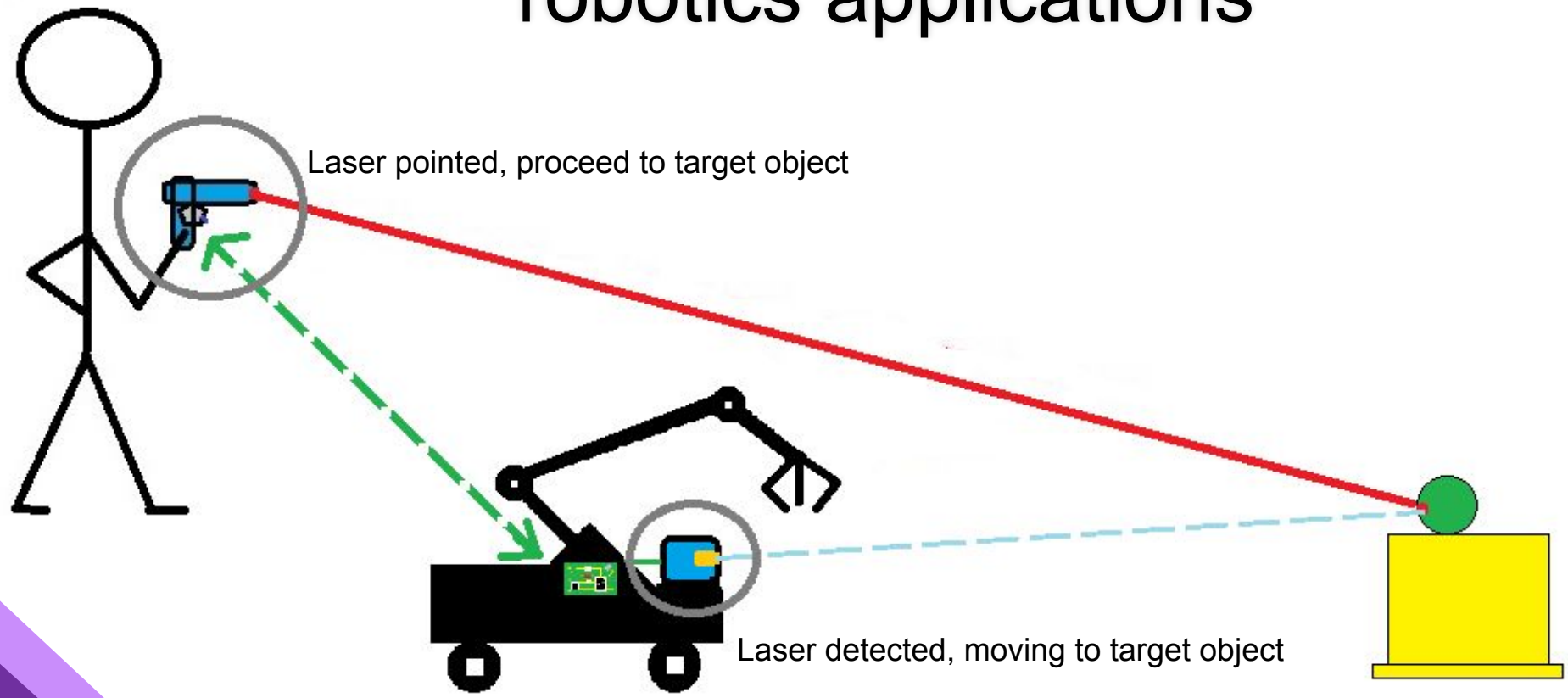
Autonomous

[4]


Animation
Box 12
Box 1
Box 2
Box 5
Box
Box
BaseballBat
Cylinder
Cylinder 4
Cylinder 5
Box
Cylinder
Box
Box
Box
Box 23
Box 24
Pyramid
Pyramid 1
Sphere
Cylinder
Box

Project Vision

Create a **universal** human robot interaction (HRI) system that is compatible with a broad range of robotics applications



Project Motivation

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- Simplified control & interaction between human and robot.
- Bridge the gap between teleOp and autonomous robot control.
- Allow utilisation of robots in new industries
- Create an unified controller that could link with any Robot Operating System (ROS)-enabled robot system.

Semi-Autonomous Control

- Combines direct and autonomous control
- Allows operator to easily direct the robot in close proximity
- Interfaces include touchscreen, voice/gesture control, laser pointing etc.
- Laser Pointer chosen for target designation

[5]

Review of Existing Solutions

- El-E assistive robot

[6]

- DJI Avata video drone

[7]

Aims

- Develop a handheld device for intuitive control via wireless connection
- Implement pointing at locations/objects to send commands for semi-autonomous execution
- Enable compatibility with any ROS-enabled mobile robot
- Foster accessibility to users across various fields with minimal training

Objectives

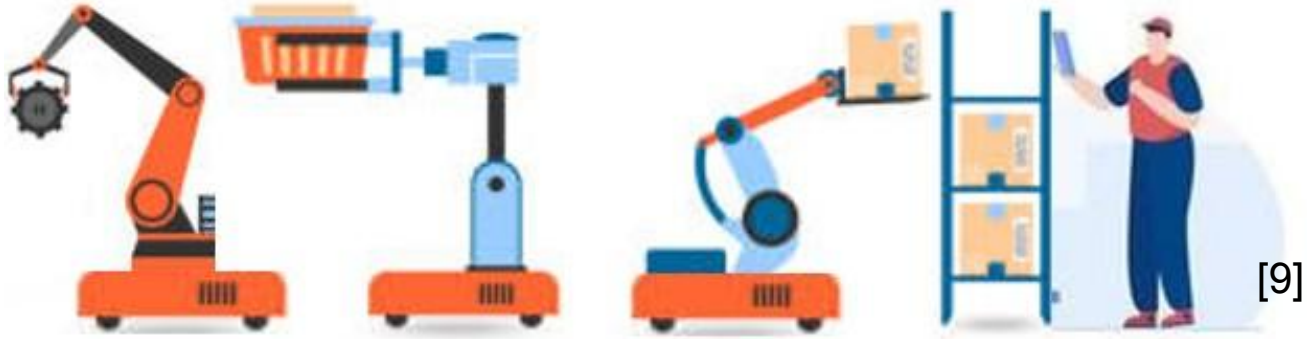
- Manufacture a custom PCB and 3D printed chassis for a handheld device
- The handheld device can generate a laser and send commands to the robot
- Robot can identify where in 3D space the laser is pointing and navigate to it
- The robot can inform the user if a command cannot be executed
- A “route” (multiple commands / waypoints) can be created, stored, and later executed

Potential Applications

- Irrespective of environment
  - Unmapped
  - Unstructured
  - Hazardous

- A variety of industries
  - Mineshaft exploration & Mineral collection
  - Mobility impairment support
  - Item delivery
  - Construction

[8]



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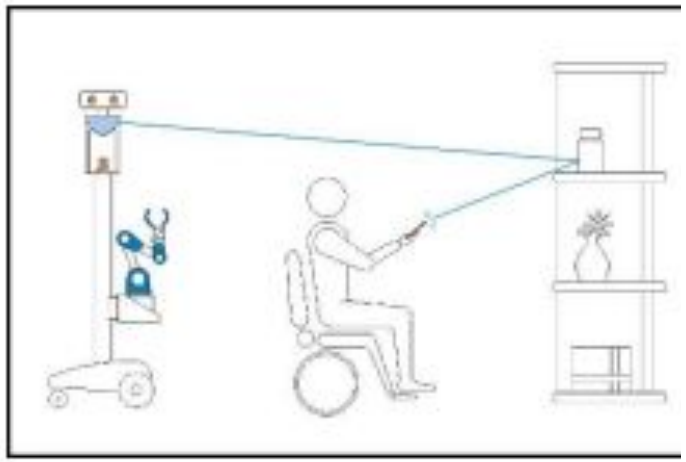

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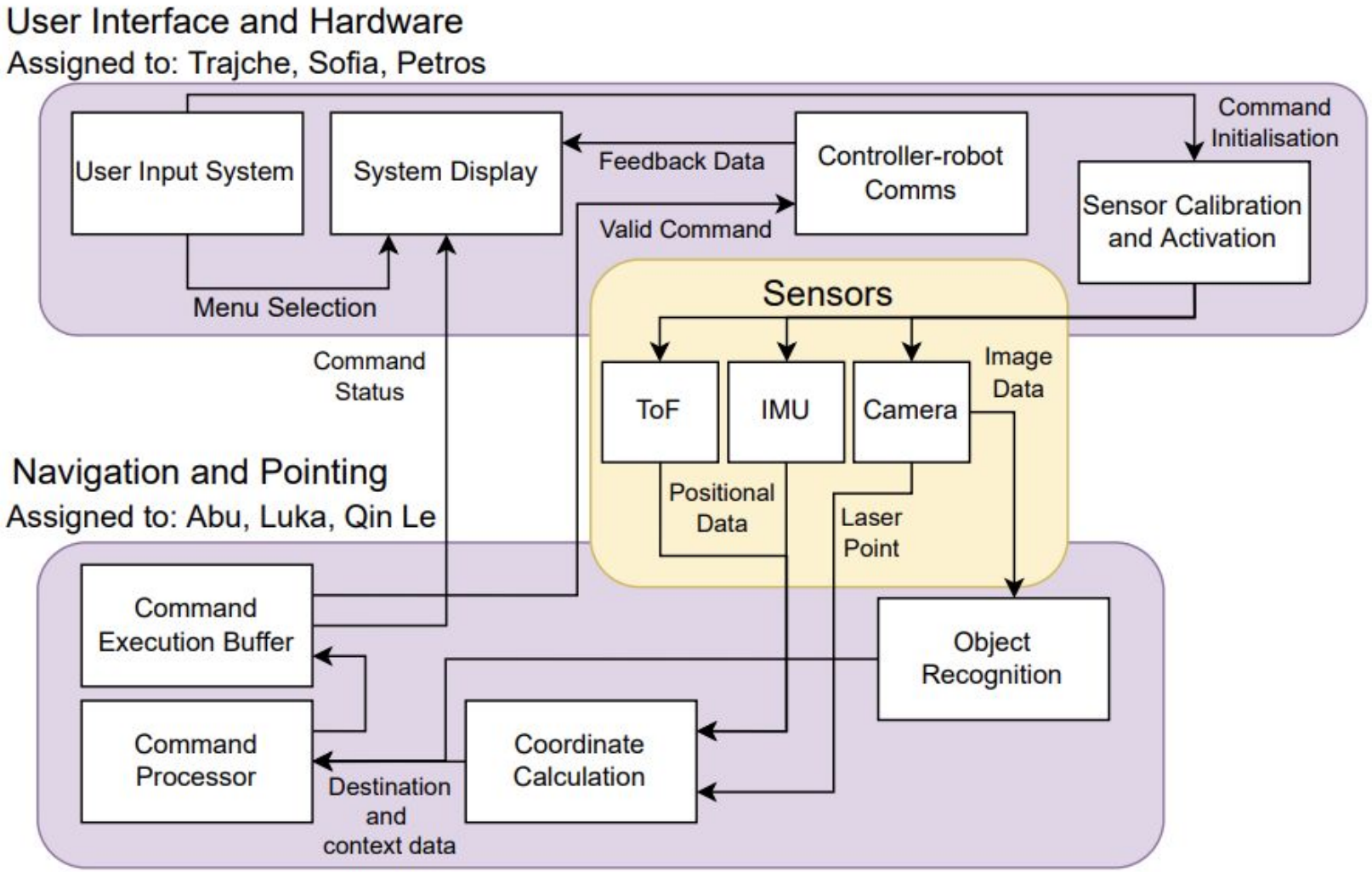
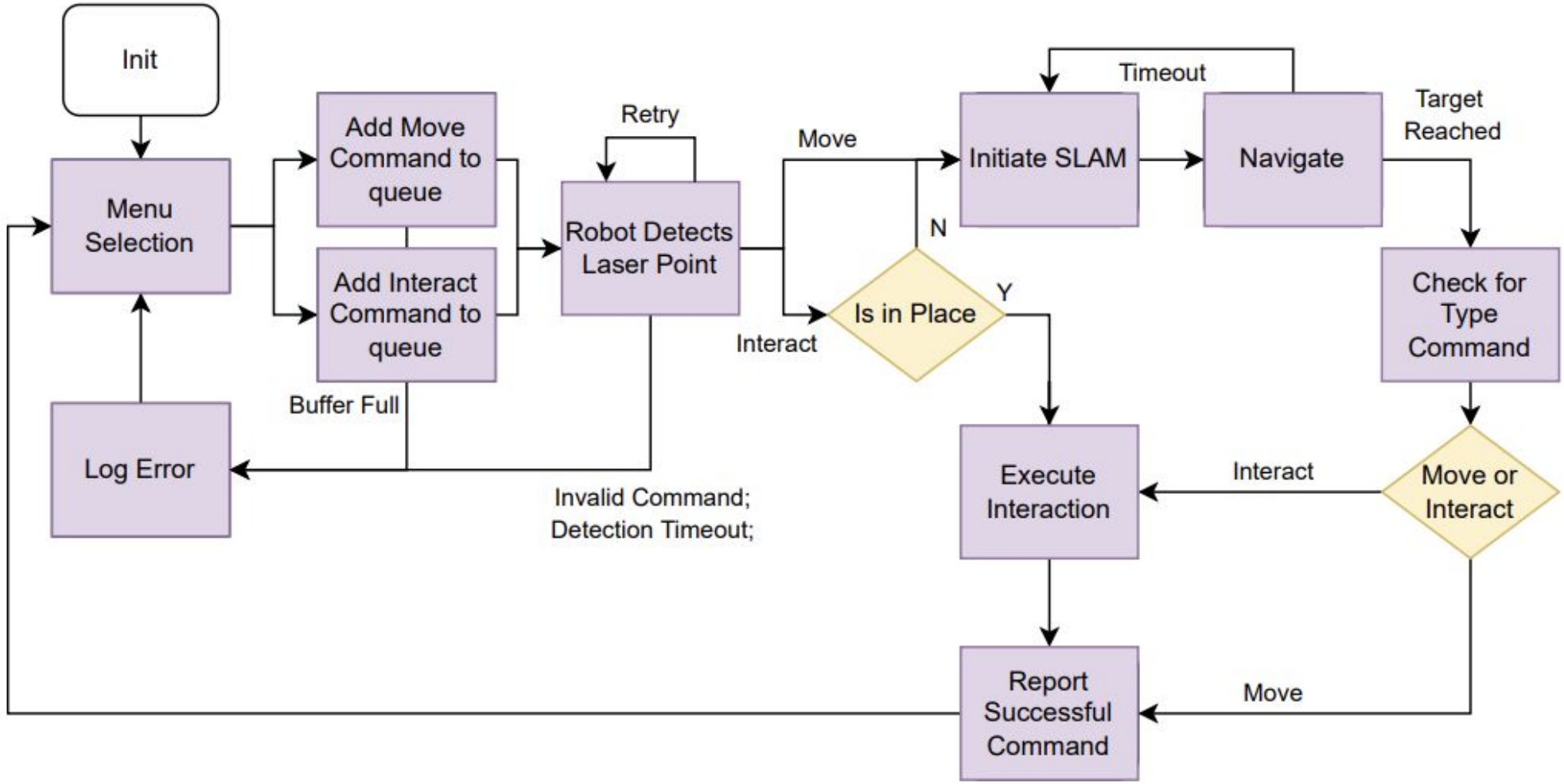
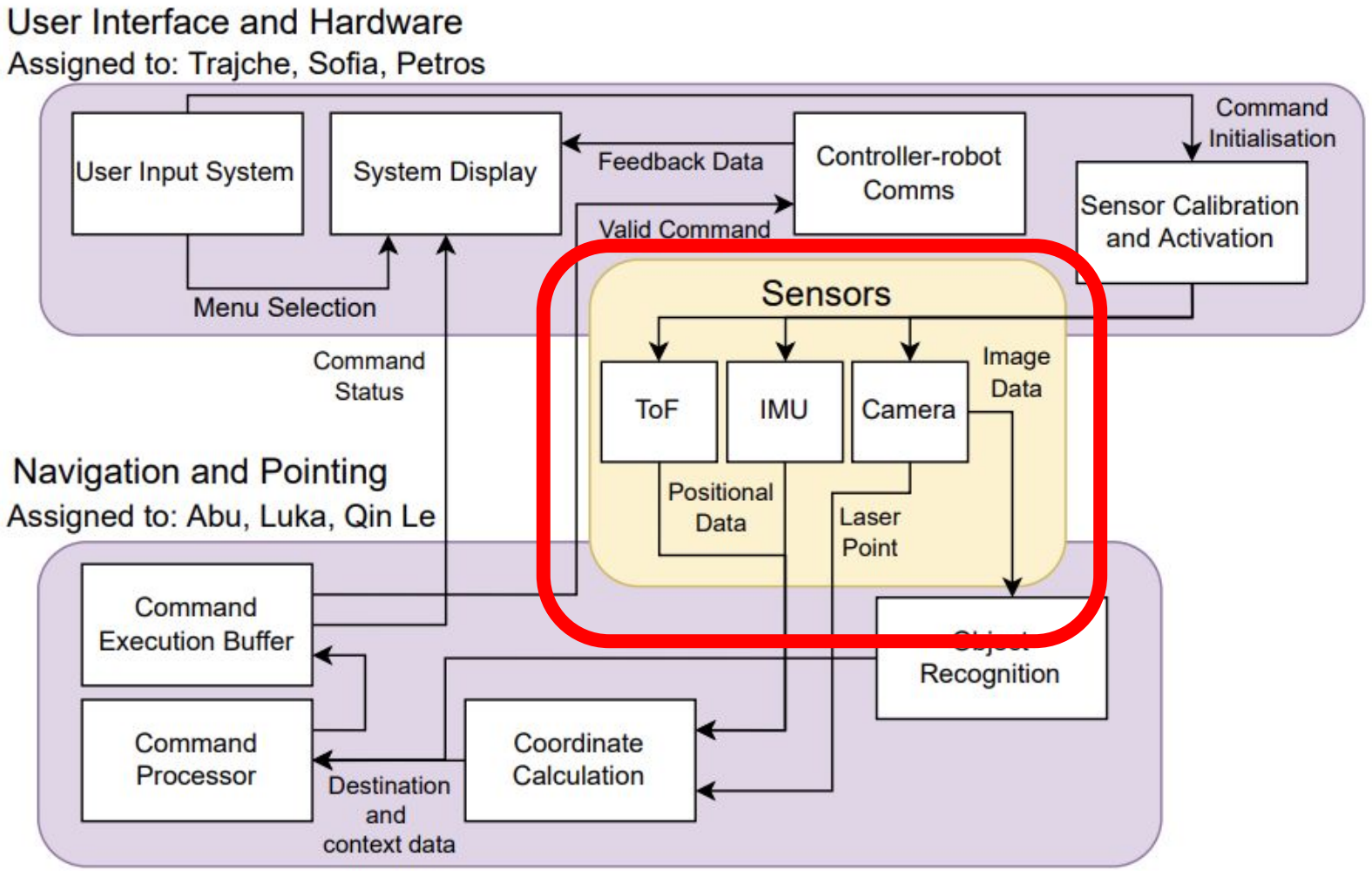
System Architecture



Software Flow Chart



Sensors


User Interface and Hardware
Assigned to: Trajche, Sofia, Petros
User Input System
System Display
Feedback Data
Controller-robot Comms
Command Initialisation
Sensor Calibration and Activation
Valid Command
Menu Selection
Sensors
ToF
IMU
Camera
Image Data
Positional Data
Laser Point
Command Status
Navigation and Pointing
Assigned to: Abu, Luka, Qin Le
Command Execution Buffer
Command Processor
Destination and context data
Coordinate Calculation
Recognition

Sensors

- RGBD (RGB + Depth) Camera
  - Intel Realsense D435i
  - Ideal for Cameras in Motion
  - Mounted on robot as auxiliary
  - 0.3m to 3 m range, 69° × 42° FOV
- Time of Flight (ToF) Sensor
  - VL53L3CX
  - Detects distances of 2-3 Metres (±5%)
  - Used to get distance from user to point
- Inertial Measurement Unit (IMU)
  - BMI270
  - Built in error compensation (< 1%)
  - Used in tandem with ToF sensor to get 3D area

Intel Realsense D435i [11]

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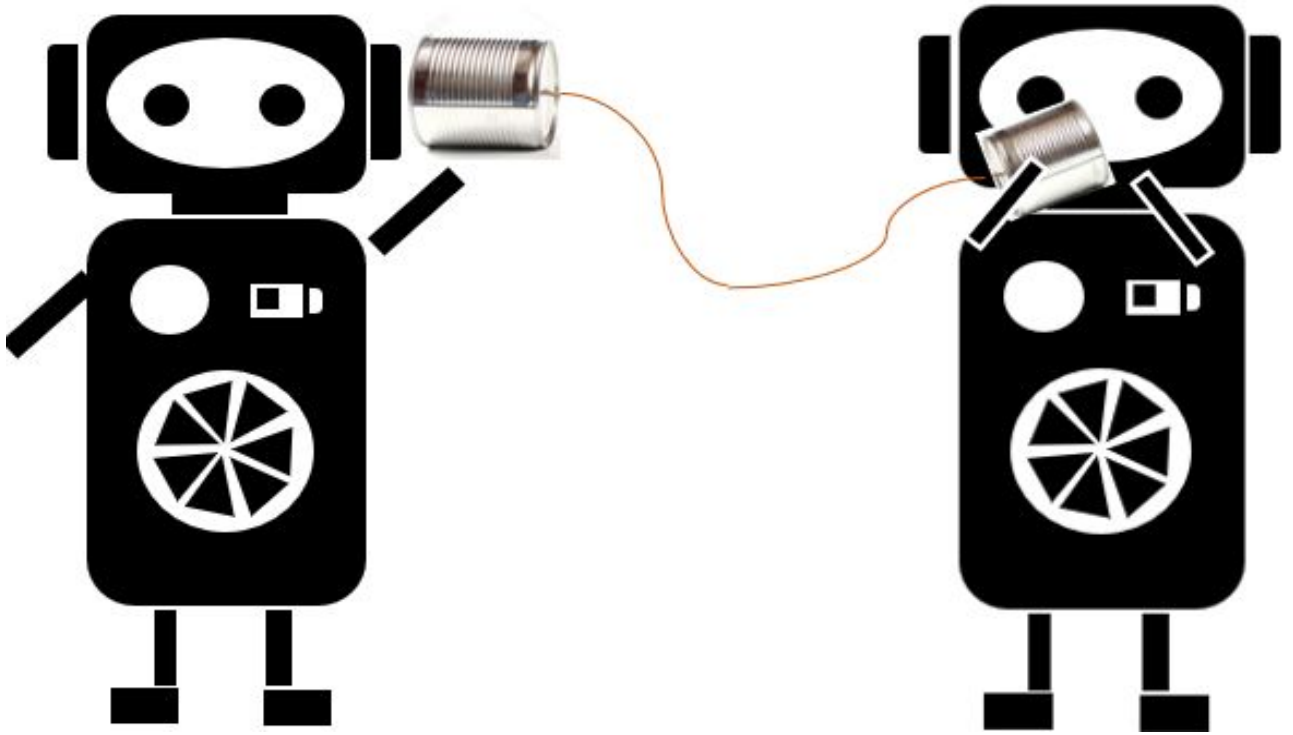
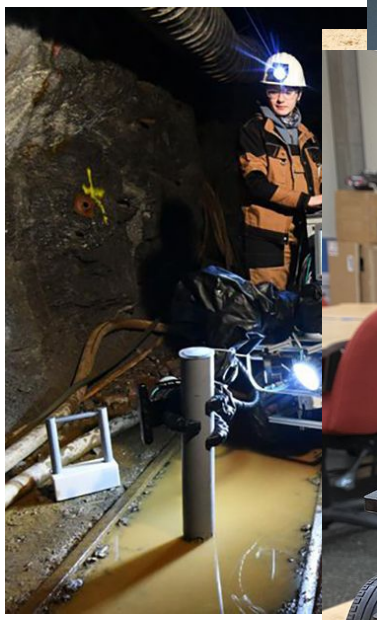
COMMUNICATIONS



Requirements for Communications

1. Reliability
2. Efficiency
3. Security
4. Scalability
5. Robustness



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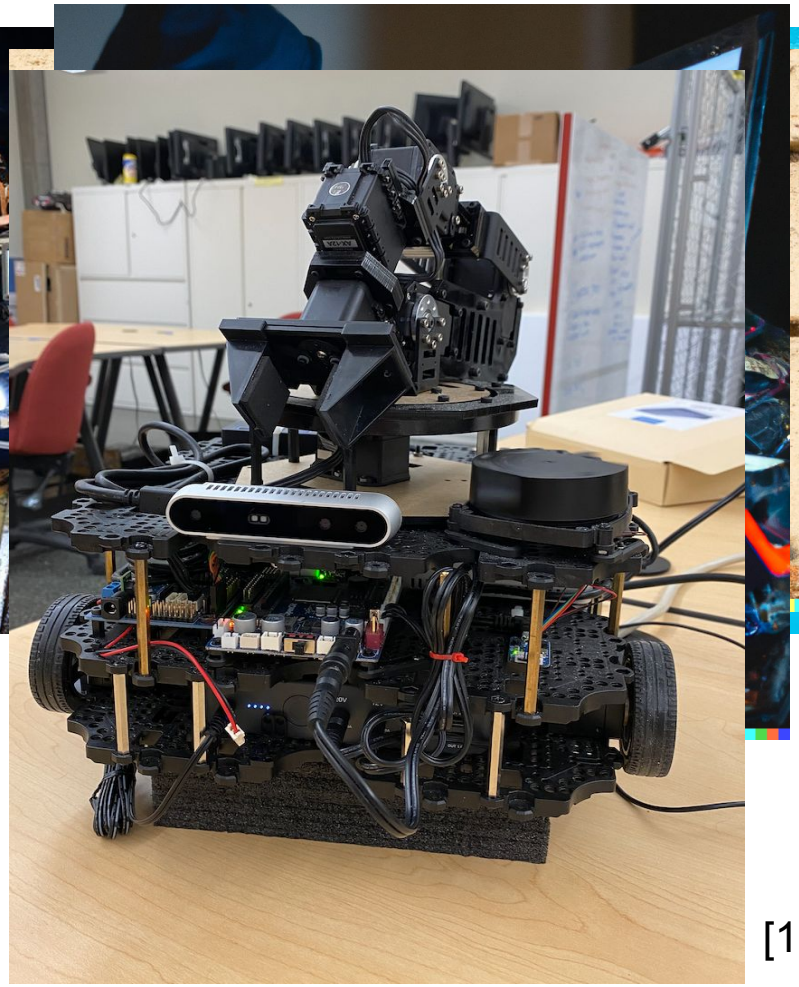

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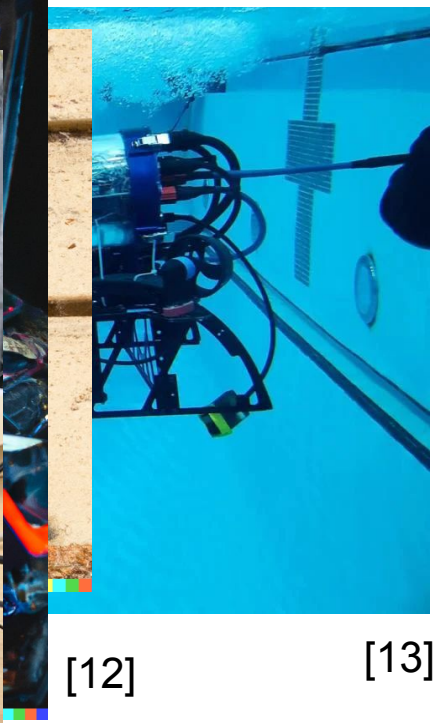

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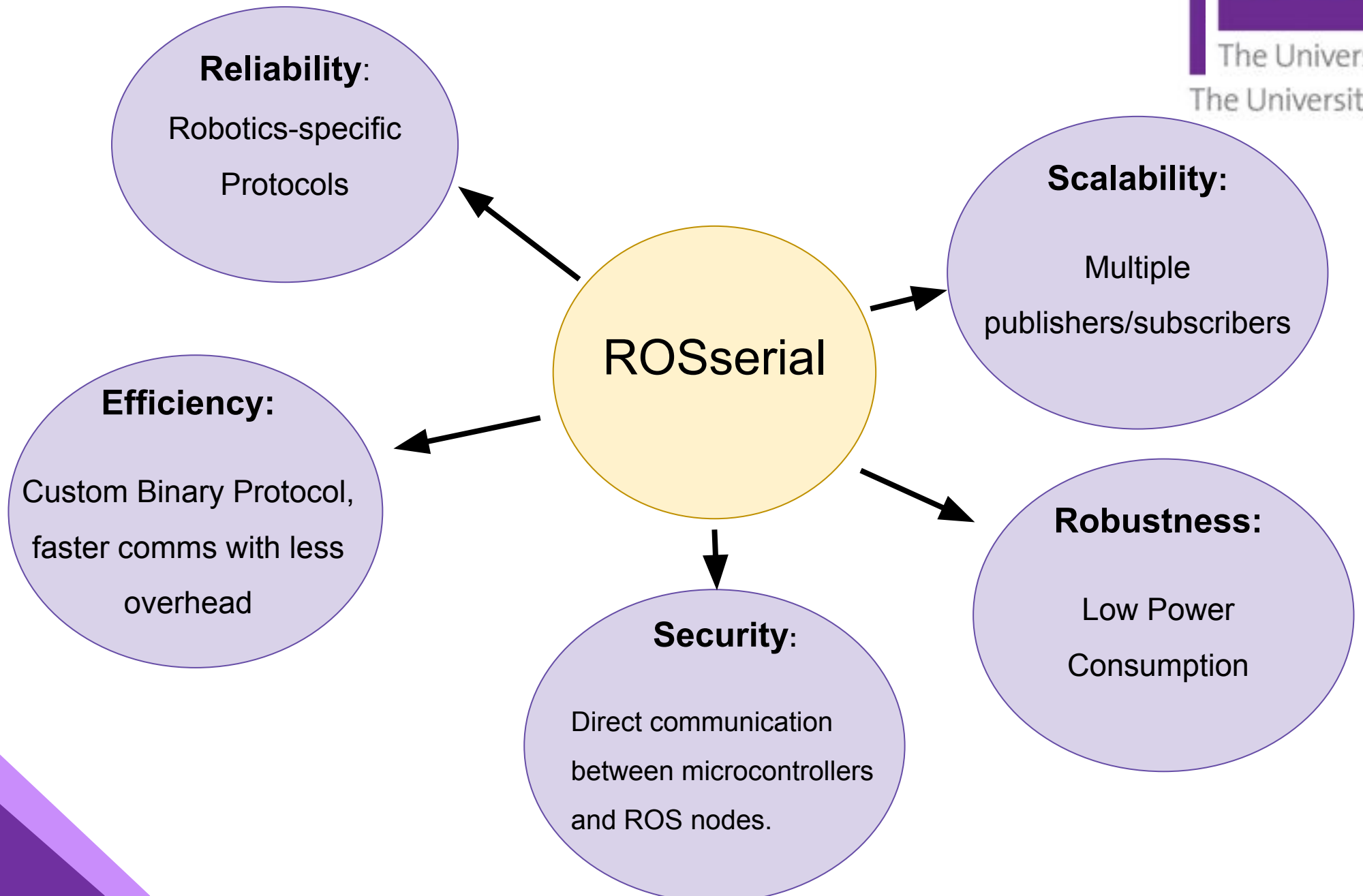

Current Implementation of ROSserial

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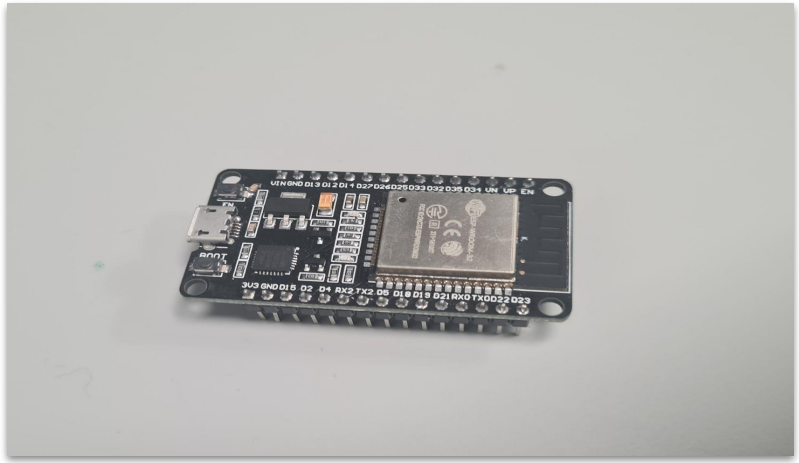
Handheld Device (ESP32 Wroom)

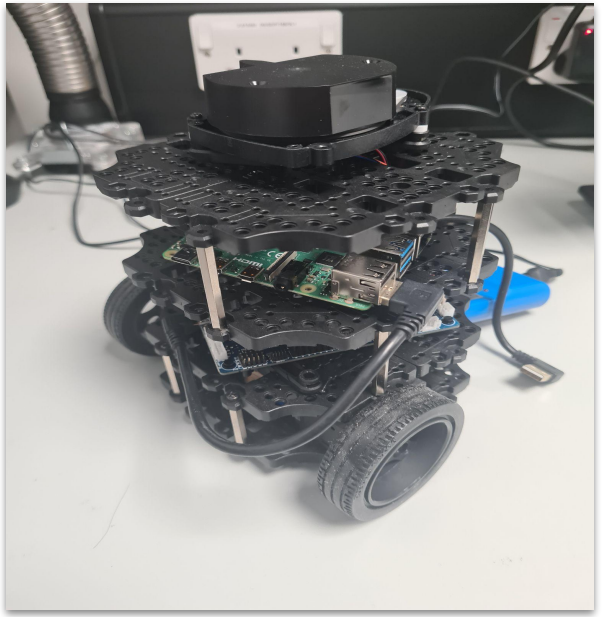
- Publisher: Node sending command notice to bot
- Subscriber: Node receiving acknowledgment of command finish



Bilateral ROSserial through TCP

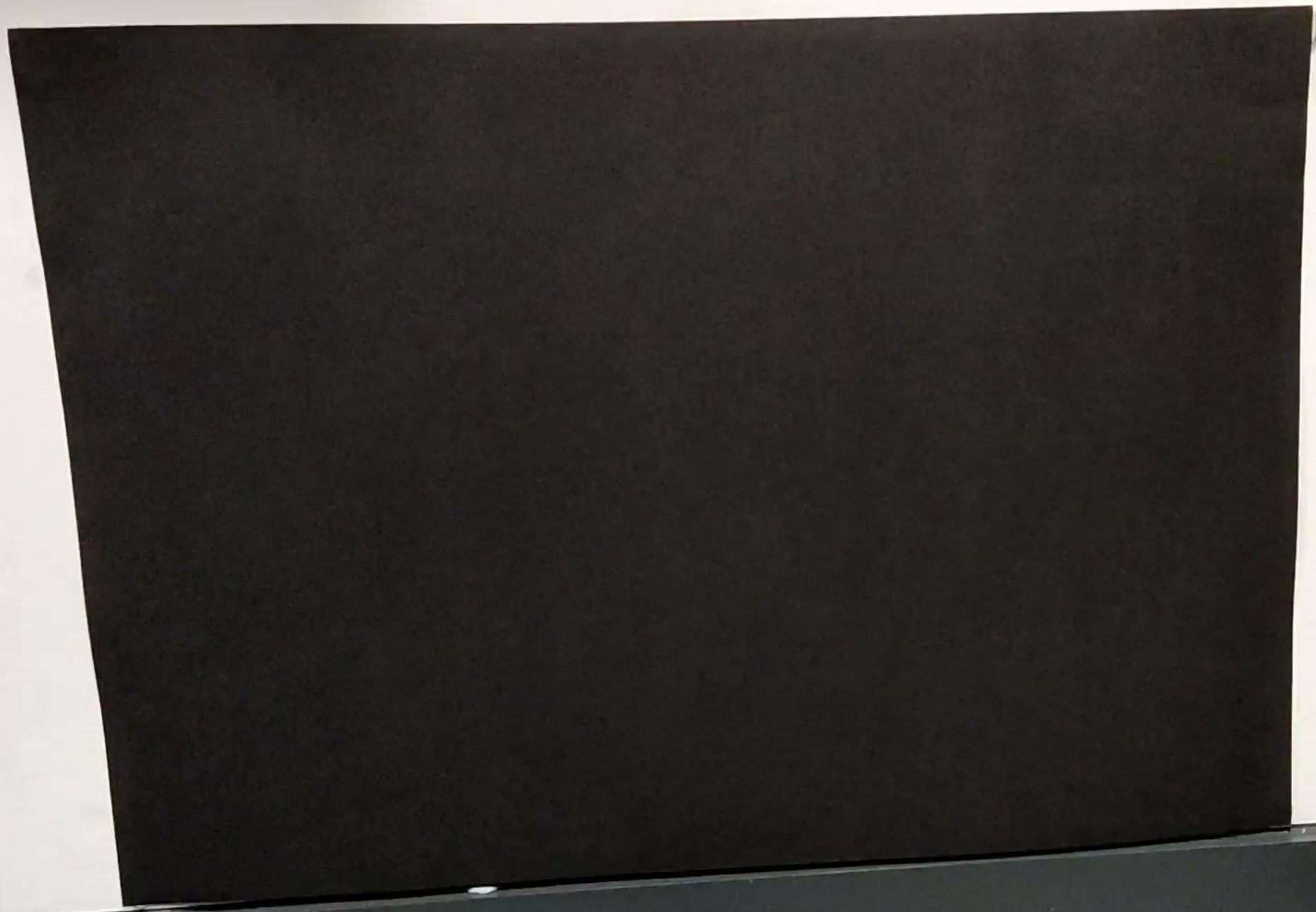
Turtlebot 3 (Raspberry Pi 4)

- Subscriber: Node receiving commands to initiate movement
- Publisher: Node sending movement completion



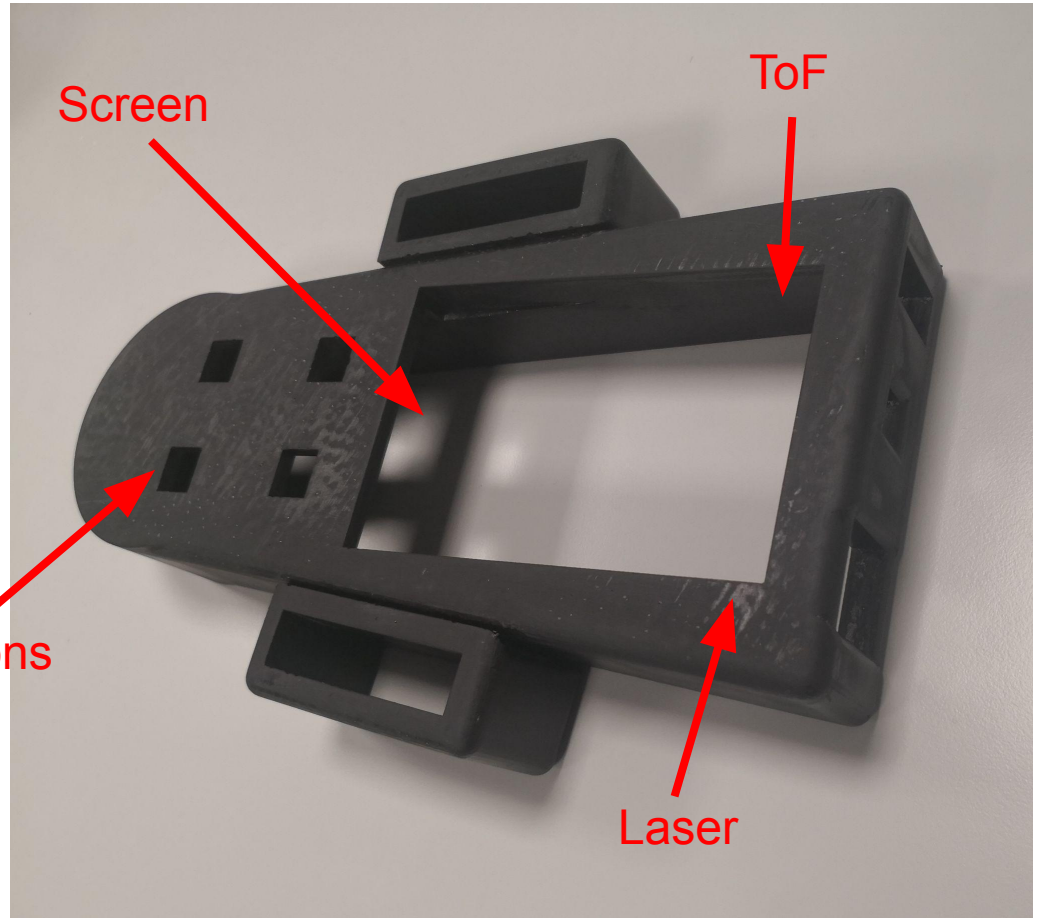
Laser Detection

- Laser to be detected by adding a band-pass filter tuned to the laser's wavelength and then performing real-time image processing
- First demo



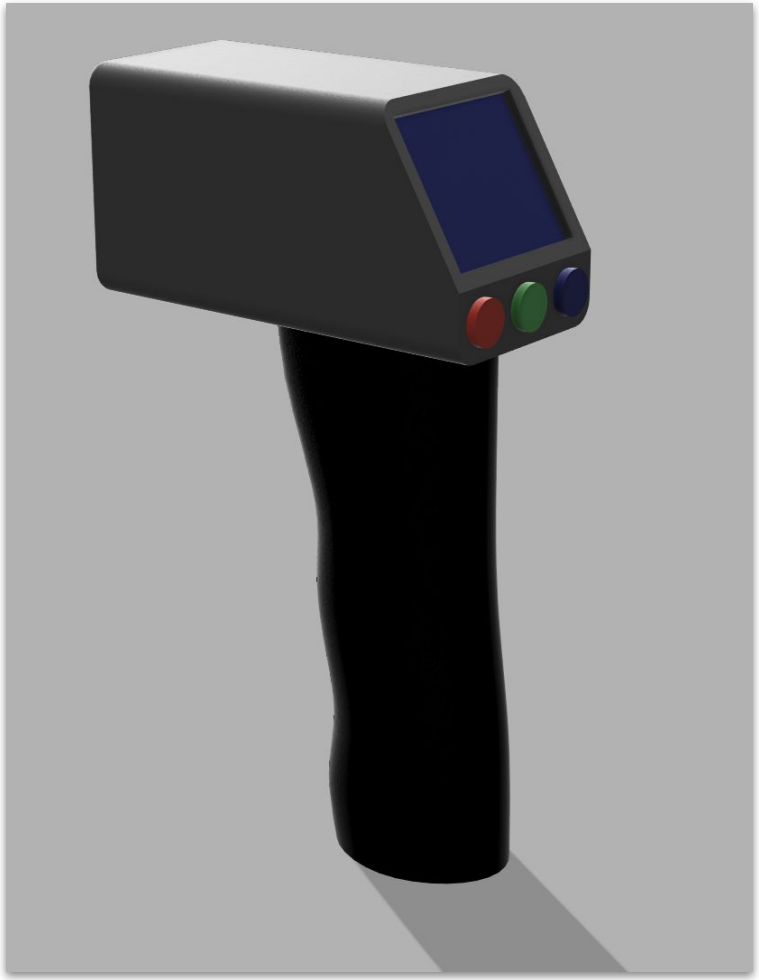
Wrist-Mounted (original design)

- Difficult to point accurately and send commands simultaneously
- Requires two hands to use
- Bulky and cumbersome
- Needs to be made ergonomic
- May pose risk in piercing PPE such as hazmat suits



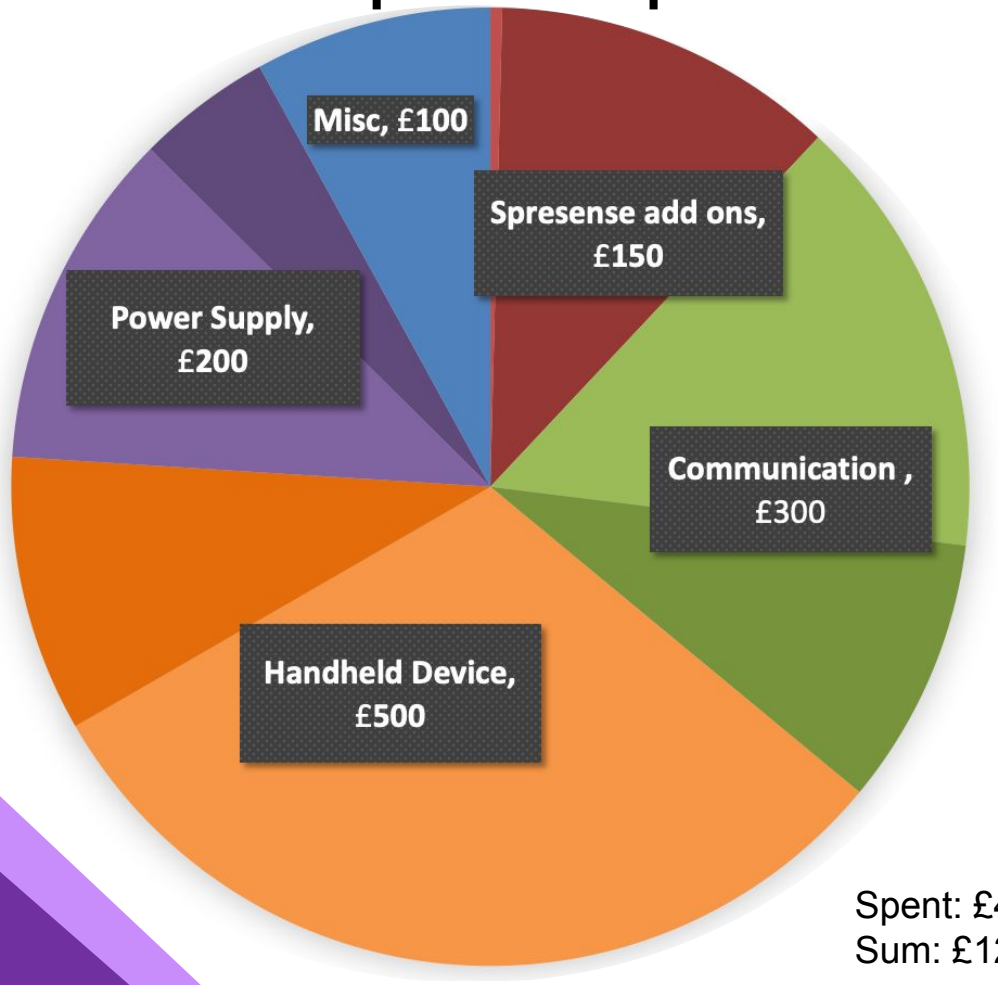
Hand-held device (new design)

- Ergonomic design
- Allows full motion of arm
- Precise aiming (macro movements with arm, adjustments with wrist)
- Easy to hold one handed
- Can be holstered when not in use
- Lightweight (<300g)



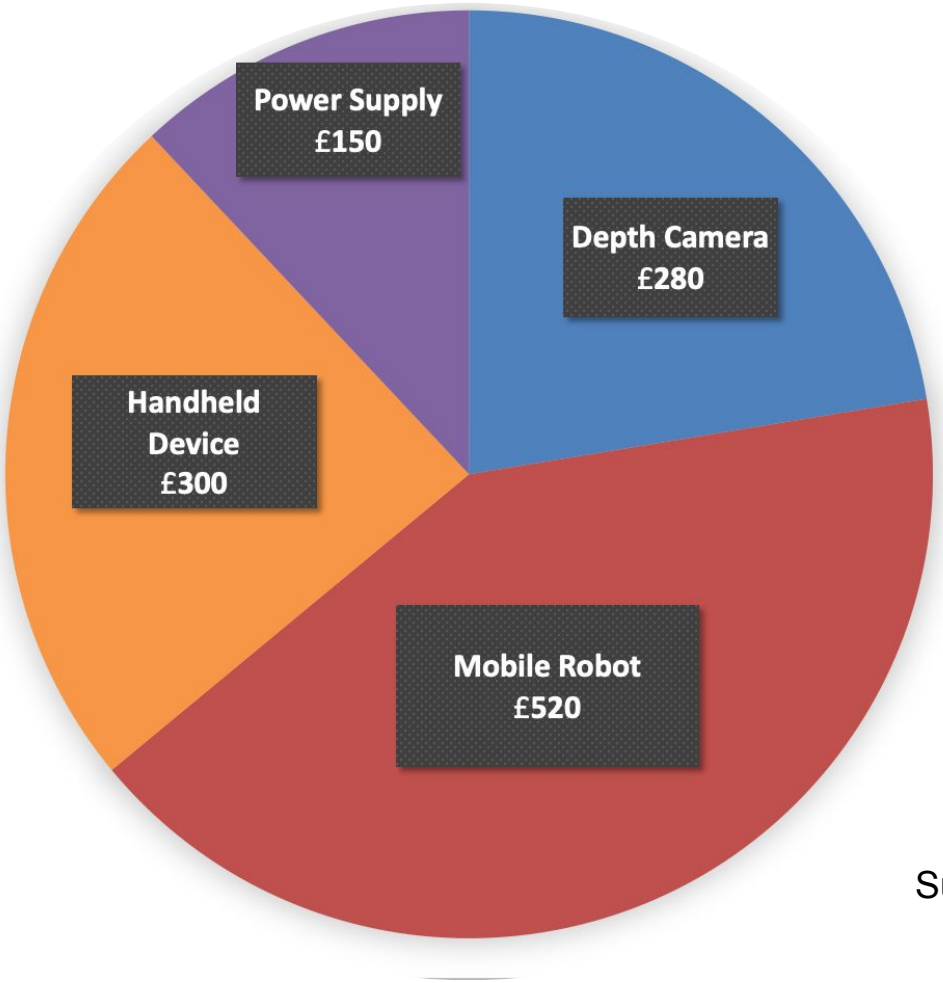
Budget

Current Expected Expenses



Spent: £450
Sum: £1250

Contingencies



Sum: £1250

Project Milestones & Planning

- Communication and User Interface
  - **Implement Bilateral communication through ROSSerial (Completed)**
  - Create menu and interface system on handheld screen
- Detection
  - **Implement Laser Detection on a 2D Plane (Completed)**
  - Implement Laser Detection in a 3D space with depth transform
- Advanced Commands
  - Implement route creation
  - Implement Robot basic precepts
- Training and accessibility
  - Create Example Training Resource
  - Create Demonstration Program

Project Milestones:	**Milestone:**
Block 3 (6/02/2023 - 17/03/2023):	Functioning Prototype
Block 4 (20/03/2023 - 28/04/2023):	Integrating subsystems & Testing
Block 5 (24/04/2023 - 12/05/2023):	Final Product (Tech Demo)

Risks and Contingencies

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Risk	Contingency
Camera cannot detect laser	Increased laser power, longer sampling time
Inaccurate TOF and Gyroscope sensors	Reassess laser and sensor specification
Long shipping times / delays	Contact ordering company and re-order if necessary
Damage or loss of components	Utilise budget contingency for replacements
Loss of productivity due to illness / other circumstances	Maintain logbooks on work done so anyone can take over from a task

Challenges Overcome

Challenge	Solution
Realsense not compatible with raspberry Pi 3B+	Switched to raspberry pi 4B+
MQTT not working with ROS	Switched to ROSserial
Spresense incompatible with dedicated wifi chips	Switched to ESP32 with built-in wifi during prototyping

Thank you for your attention!

References

[1] (Slide 3) Image courtesy of Industrial Aerobotics
Available at: https://www.industrialaerobotics.com/services

[2] (Slide 3) Image courtesy of wired.
Available at: http://www.wired.com/2012/06/u-s-needs-another-600-humans-to-fly-its-robot-planes/

[3] (Slide 4) Image courtesy of Krakow
Available at: https://www.krakow.pl/?dok_id=222169

[4] (Slide 4) Image courtesy of Silicon Republic.
Available at: https://www.siliconrepublic.com/machines/automated-factories-video

[5] (Slide 8) Image courtesy of alamy.
Available at:
https://alamy-ltd.ewrvdi.net/c/77643/748811/10905?u=https%3A%2F%2Fwww.alamy.com%2Fus-air-force-master-sgt-krystoffer-miller-325th-security-forces-squadron-operations-support-superintendent-operates-a-quad-legged-unmanned-ground-vehicle-at-tyndall-air-force-base-florida-march-24-2021-the-purpose-of-the-q-ugv-is-to-add-an-extra-level-of-protection-to-base-image442242308.html

References

[6] (Slide 9) Image courtesy of
C. C. Kemp, et al. “A point-and-click interface for the real world: Laser designation of objects for mobile manipulation,” *IEEE Xplore*, Mar. 01, 2008.
Available at: https://ieeexplore.ieee.org/abstract/document/6249441

[7] (Slide 9) Image courtesy of DJI
Available at: https://www.dji.com/uk/avata

[8] (Slide 12) Image courtesy of Clearpath Robotics
Available at: https://www.clearpathrobotics.com/autonomy-research-kit/

[9] (Slide 12) Image courtesy of (Warehouse robot infographic)
Available at: https://www.dreamstime.com/illustration/warehouse-automation.html

[10] (Slide 12) Image courtesy of
C. C. Kemp, et al. “A point-and-click interface for the real world: Laser designation of objects for mobile manipulation,” *IEEE Xplore*, Mar. 01, 2008.
Available at: https://ieeexplore.ieee.org/abstract/document/6249441

[11] (Slide 16) Image courtesy of Intel Realsense
Available at: https://www.intelrealsense.com/depth-camera-d435i/

[12] (Slide 18) Image generated by Dall-E
Available at: https://openai.com/dall-e-2/

[13] (Slide 18) Image courtesy of Amador High Underwater Robotics Club

Available at: https://avbotz.com/

[14] (Slide 18) Image courtesy of EOS

Available at:https://eos.org/features/underground-robots-how-robotics-is-changing-the-mining-industry

[15] (Slide 18) Image courtesy of Reddit

Available at: https://www.reddit.com/r/robotics/comments/jrzydz/used_turtlebot_3_with_real_sense_camera_for_sale/