Professor : SEIBUM CHOI

Group Member : Geonhee Jin Wook Taehong Taeyeon Vivek Woo Seok Yesung

CAPSTONE DESIGN 2

TEAM SBC

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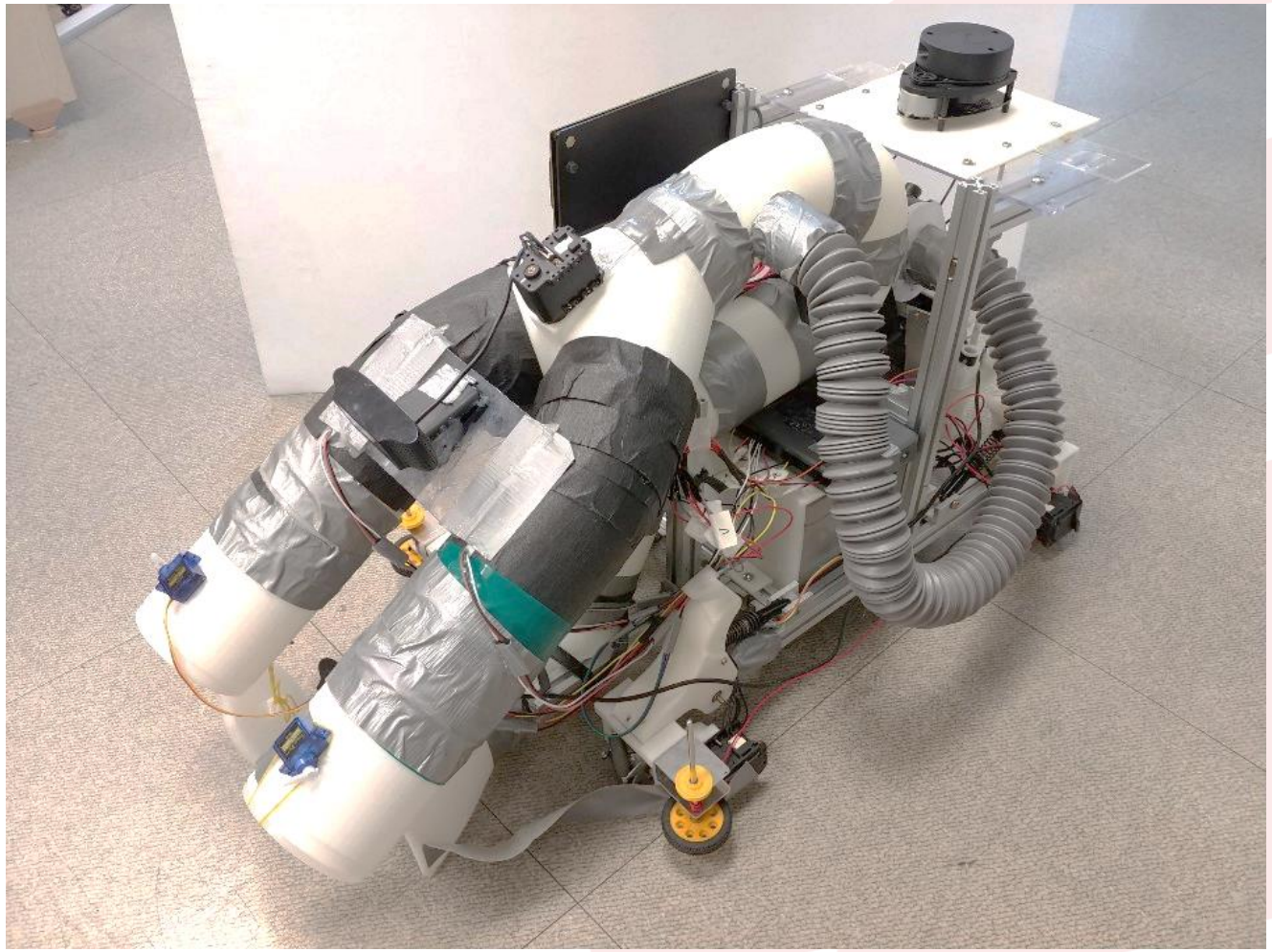
Super Ball Collector Specifications

Specifications	
Height	430mm
Width	225mm
Length	712mm
Weight	9.4kg
Maximum Suction Mass (by experiment)	~ 40g
Gear Ratio	3 : 1
Wheel Radius	30mm

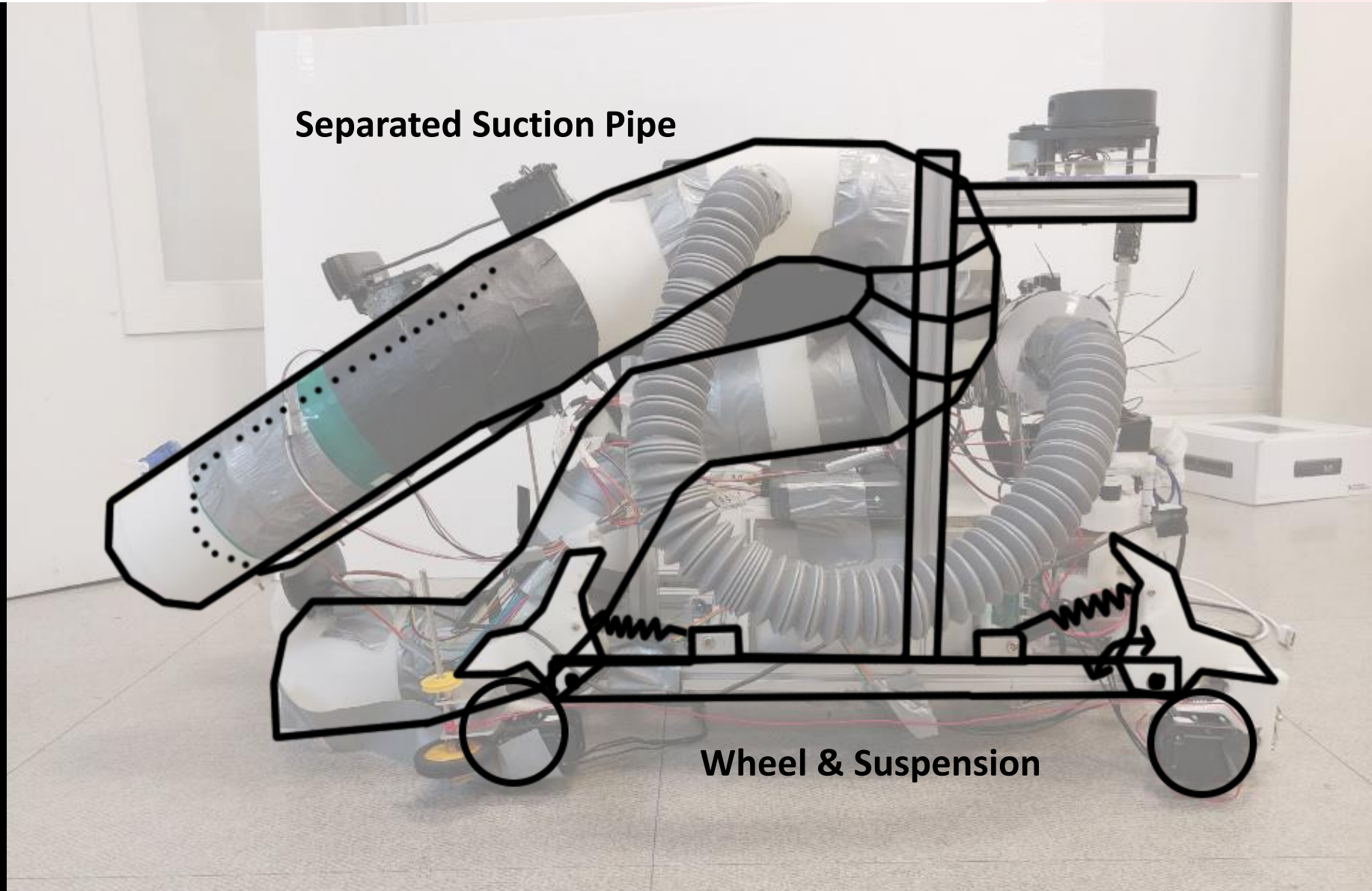
<SBC Specification Table>



<Super Ball Collector>

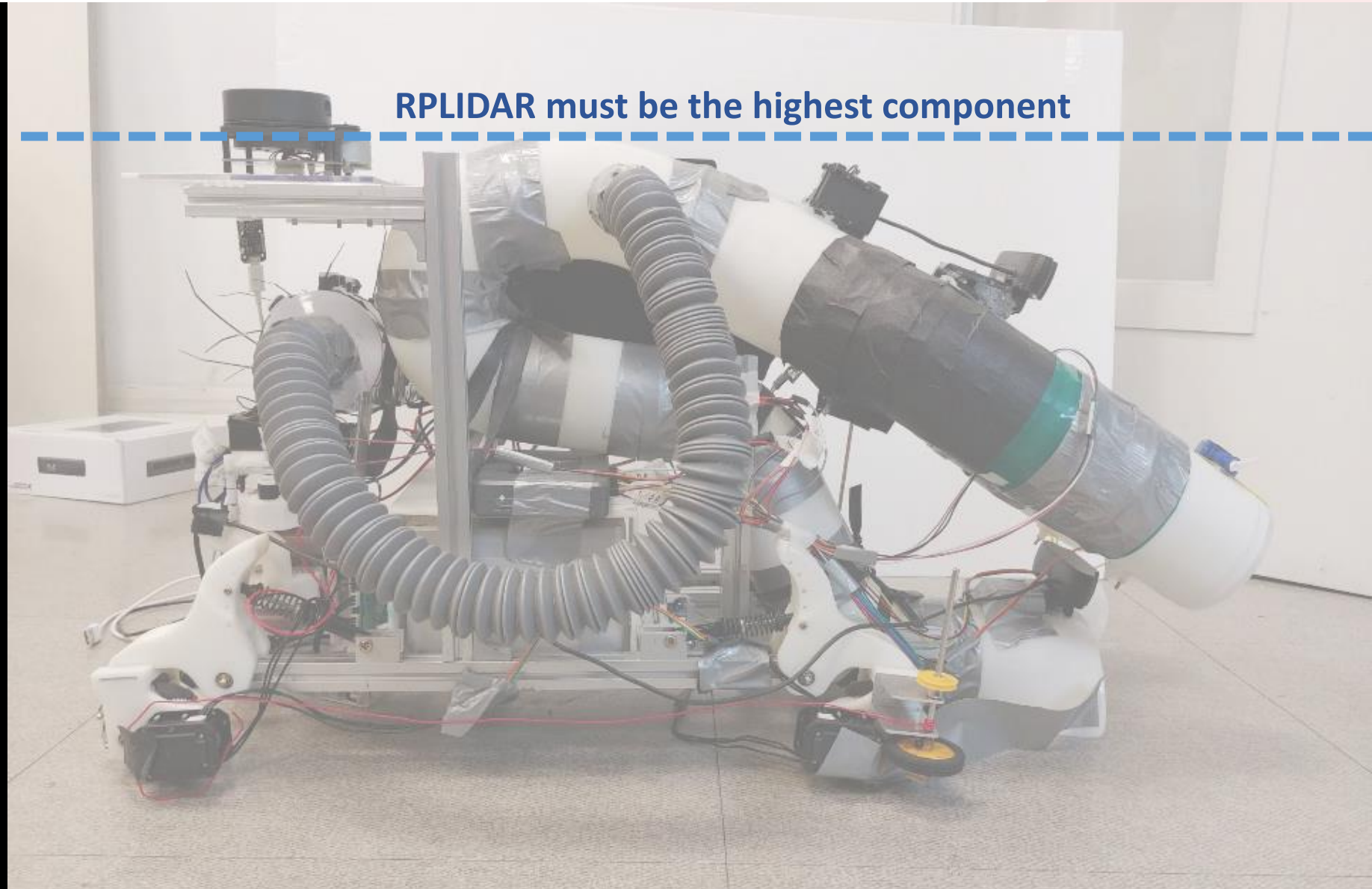
Hardware Overview

1. Structure



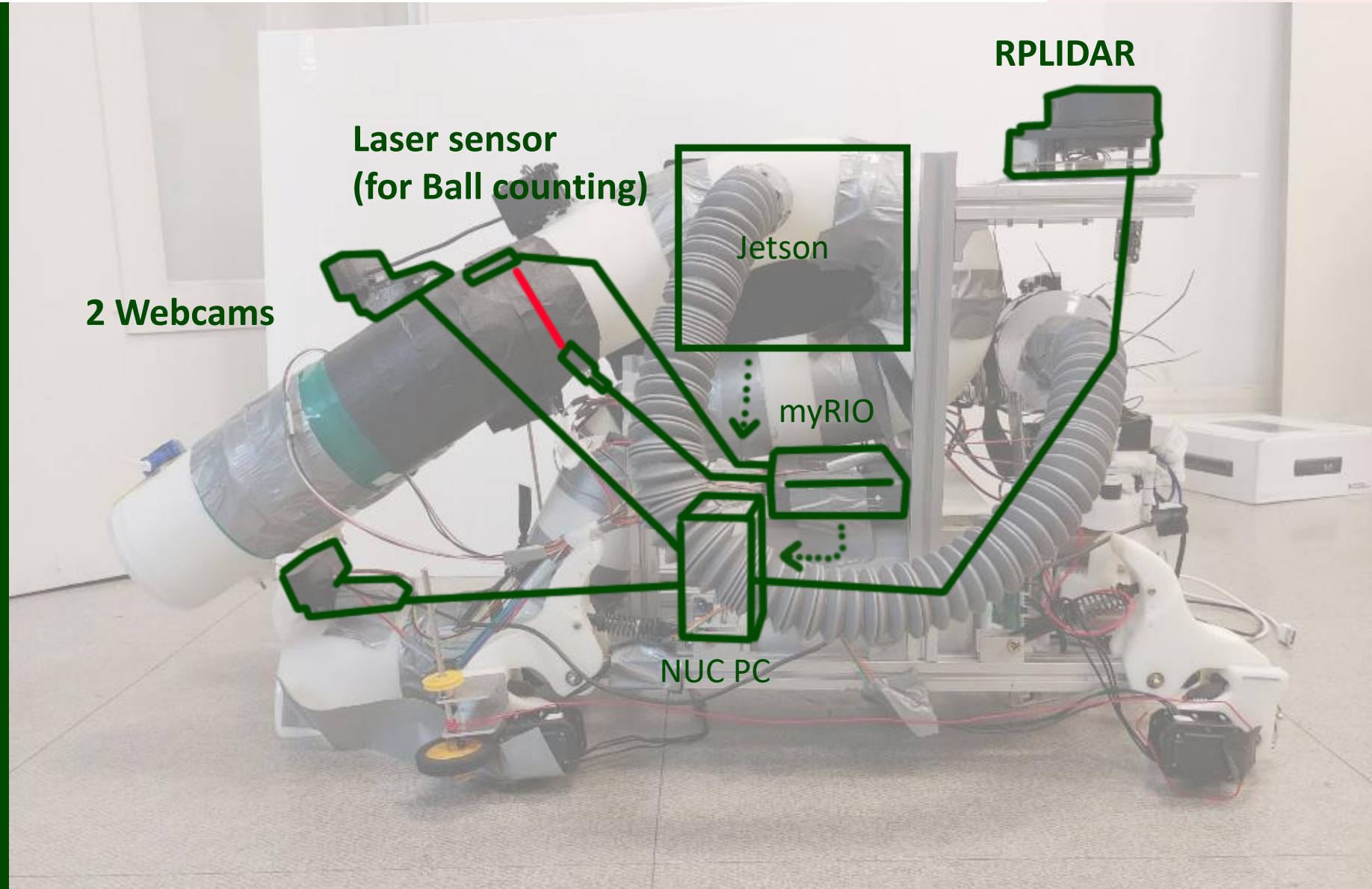
Hardware Overview

SLAM



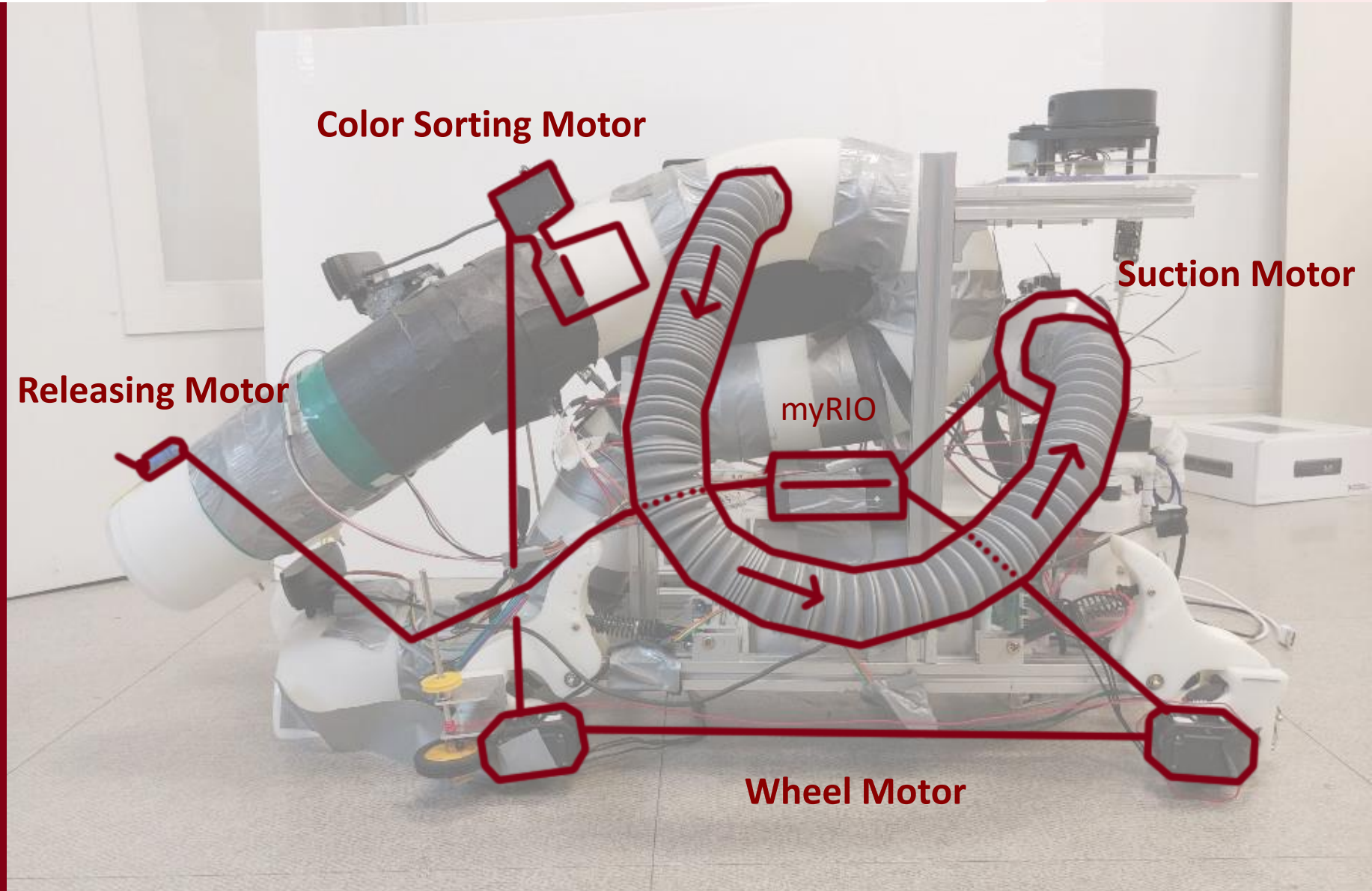
Hardware Overview

2. Sensor



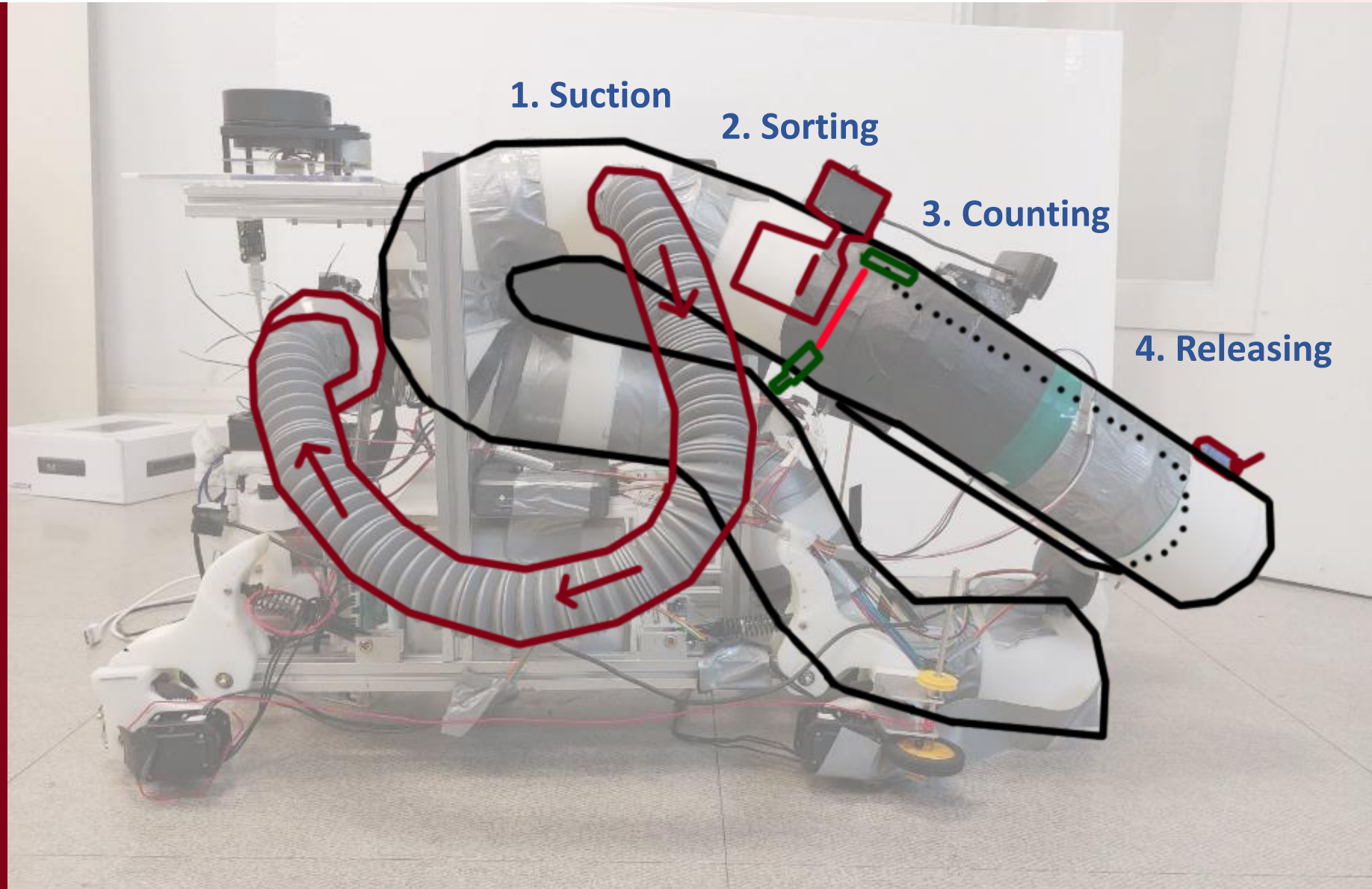
Hardware Overview

3. Actuator



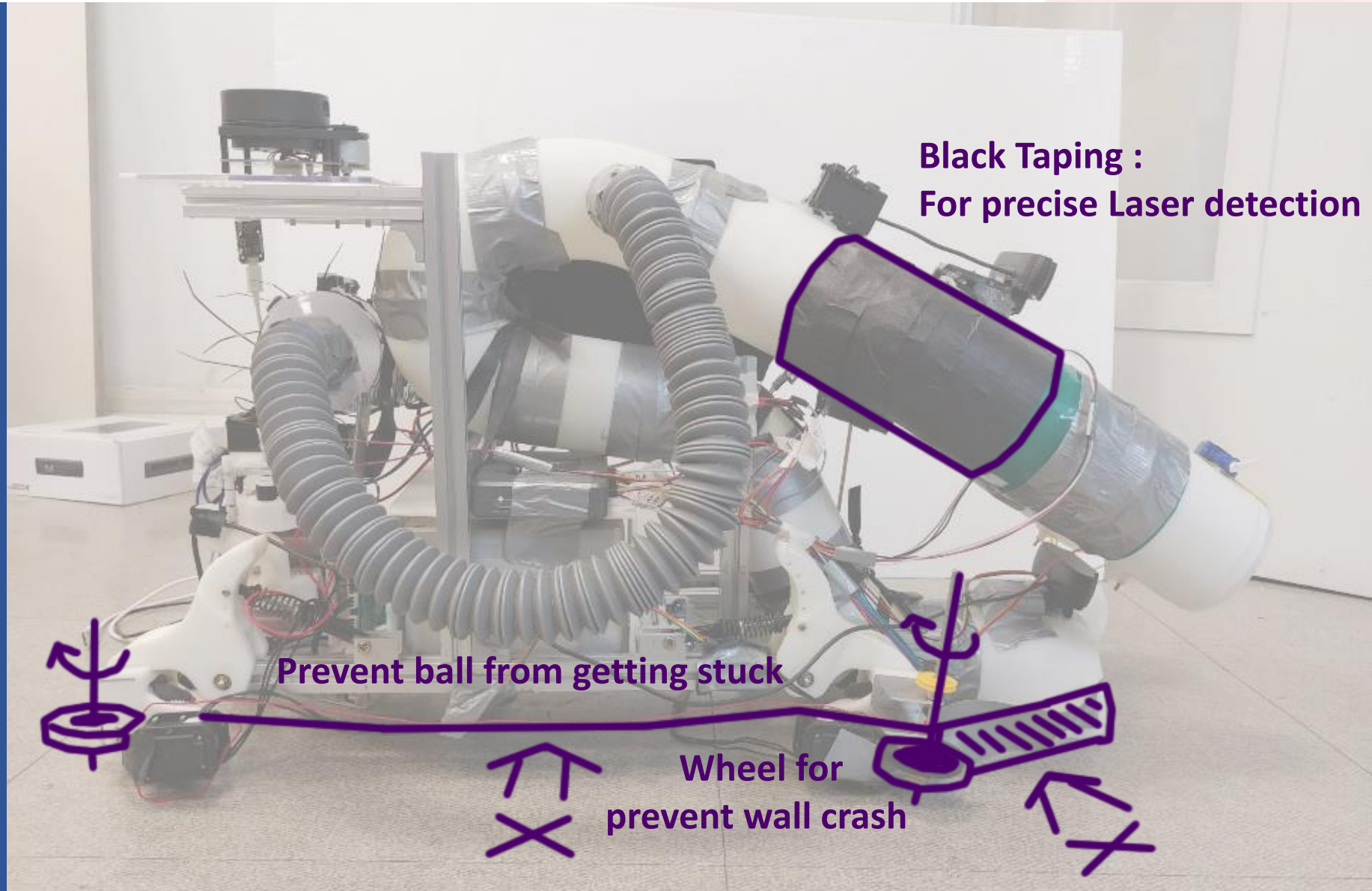
Hardware Overview

Ball suction



Hardware Overview

4. Mnor Details



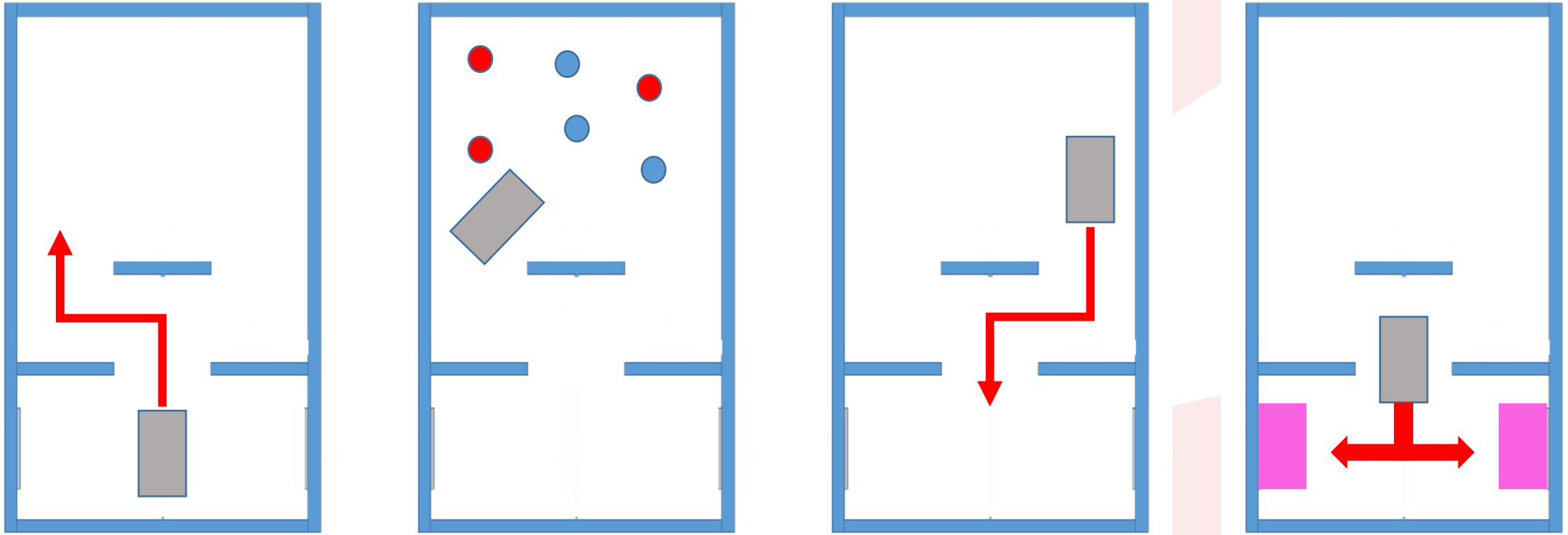
Software Overview

SLAM
(Go to the balls)

DQN
(Ball collecting)

SLAM
(Go to the basket)

CNN
(Cat / Dog)



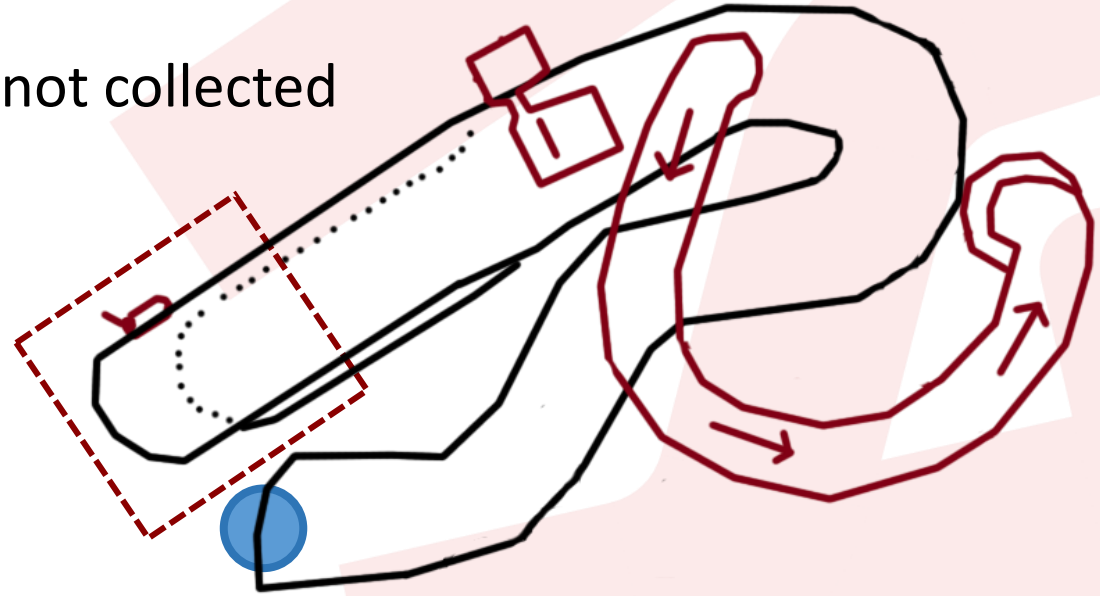
Mission Challenges

1. Need for verification of the collected balls

```
< ROS code >
While (DQN)
    If (do Suction)
        Collecting Ball
        Ball collected + 1
    If (Ball collected = 6)
        DQN Finish!
```

Ball Collected = 0

BUT Ball is not collected



Unexpected suction failure

Mission Challenges

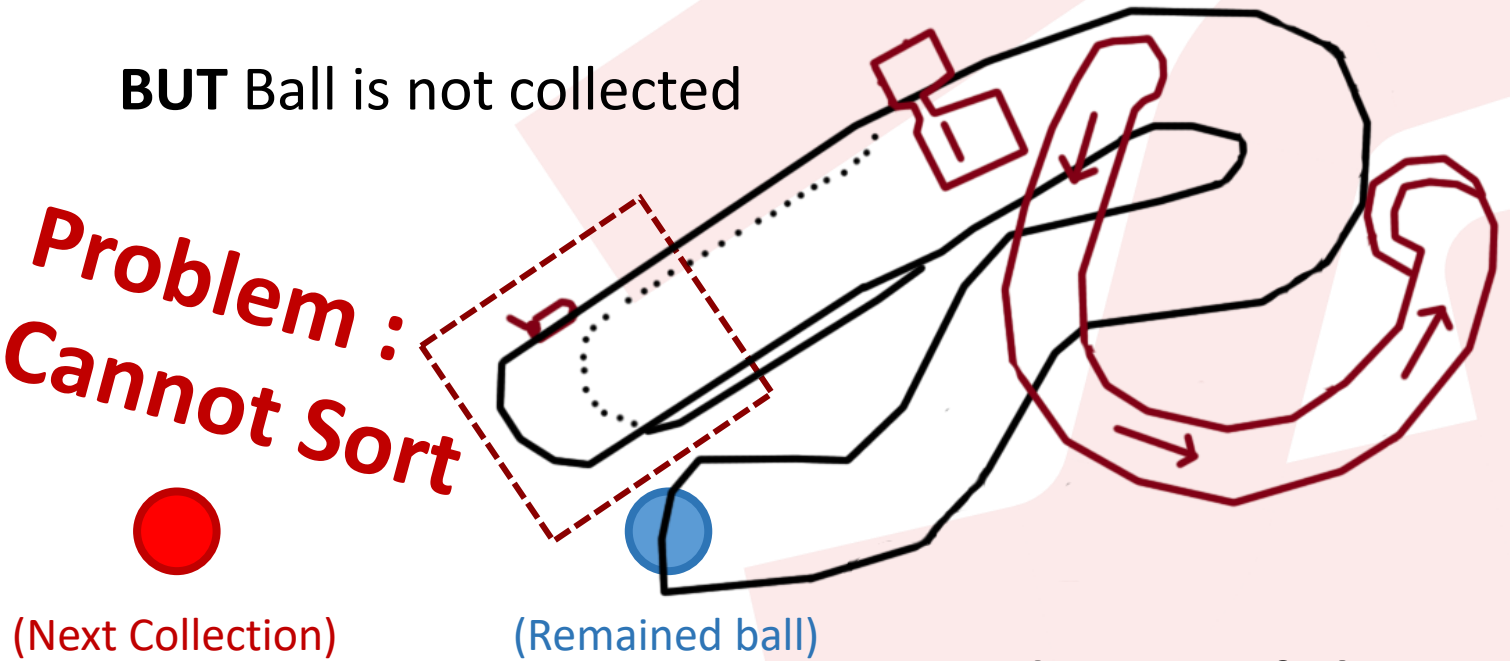
1. Need for verification of the collected balls

```
< ROS code >
While (DQN)
    If (do Suction)
        Collecting Ball
        Ball collected + 1
    If (Ball collected = 6)
        DQN Finish!
```

Ball Collected = **1**

BUT Ball is not collected

Problem : Cannot Sort



(Next Collection)

(Remained ball)

Unexpected suction failure

Mission Challenges

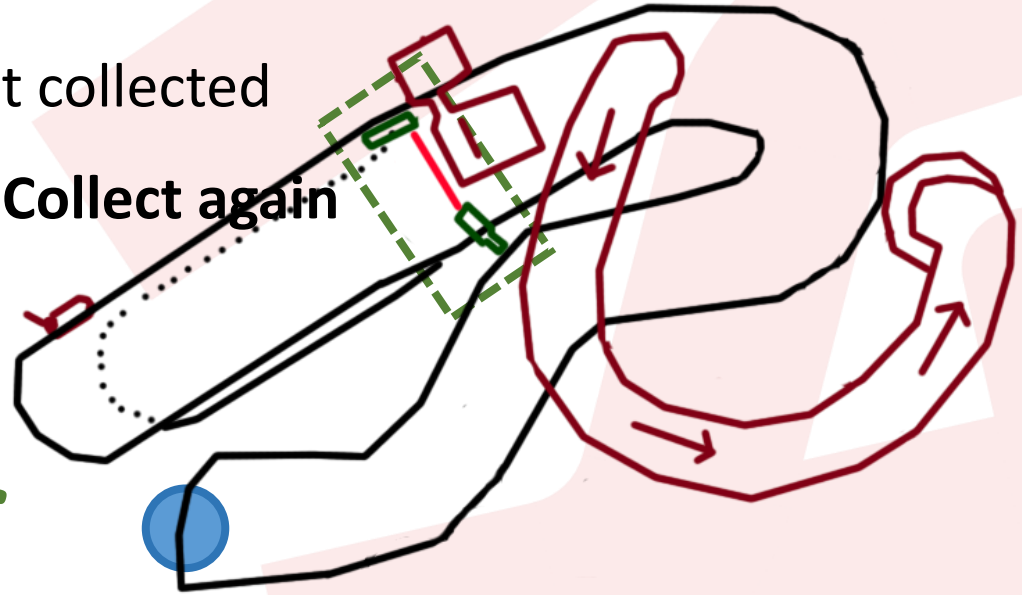
1. Need for verification of the collected balls

```
< Feedback ROS code >
Subscribe Sensor collected
While (DQN)
If (do Suction)
        Collecting Ball
        If (Sensor collected not changed)
            Go backward
    If (Sensor collected = 6)
        DQN Finish!
```

Ball Collected = 0

AND Ball is not collected

=> Go Back & Collect again



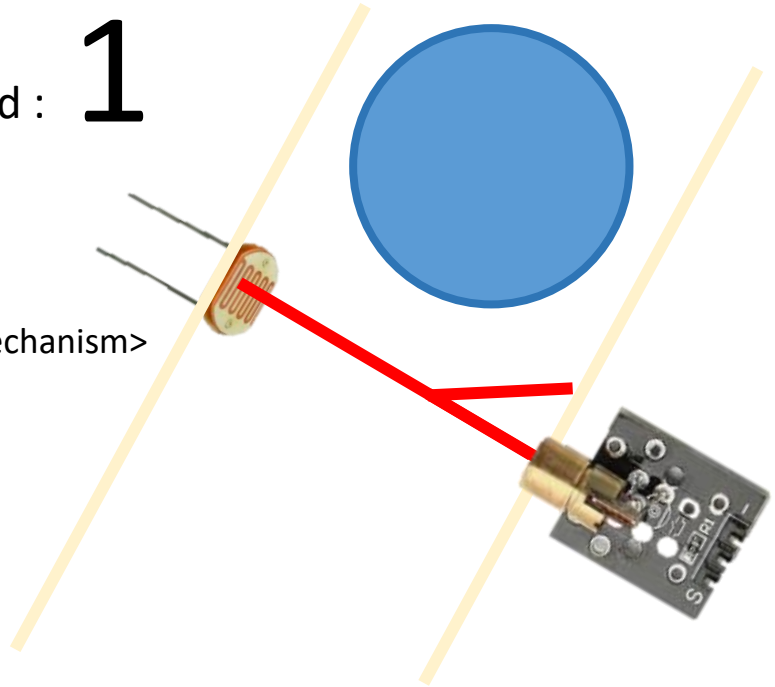
Unexpected suction failure

Solution : Laser Sensor

Expected working of Laser Sensor

1. Need for verification of the collected balls

Ball Collected : 1



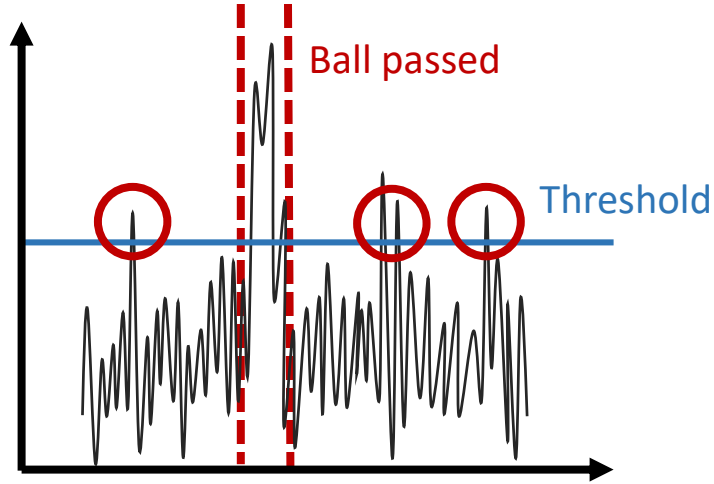
<Animated Collecting Mechanism>

<Ideal graph of Laser sensor>

Problem

Ball's moving speed is faster than we expected

Noise is MUCH bigger than we expected

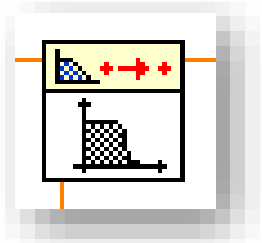


<Real graph of Laser sensor>

Implementation of Filter

1. Need for verification of the collected balls

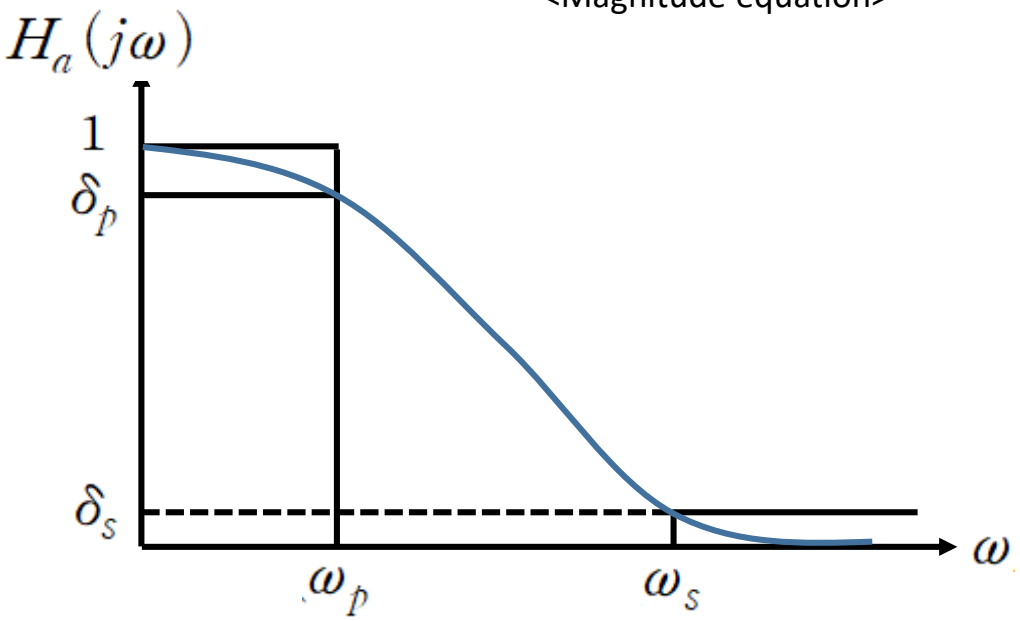
Noise Filtering : Point by point **Butterworth** Filter



<LabVIEW icon>

$$|H_a(j\omega)|^2 = \frac{1}{1+\left(\frac{\omega}{\omega_c}\right)^{2N}}$$

<Magnitude equation>



<Butterworth Filter's Magnitude graph>

Filter's order & cut-off frequency

$$N \geq \frac{\log_{10}\sqrt{\frac{\delta_p^2-1}{\delta_s^2-1}}}{\log_{10}\left(\frac{\omega_p}{\omega_s}\right)} \qquad \omega_c = \frac{\omega_p}{\left(\frac{1}{\delta_p^2}-1\right)^{1/2N}}$$

Required Filter's $(\omega_p, \delta_p)(\omega_s, \delta_s)$

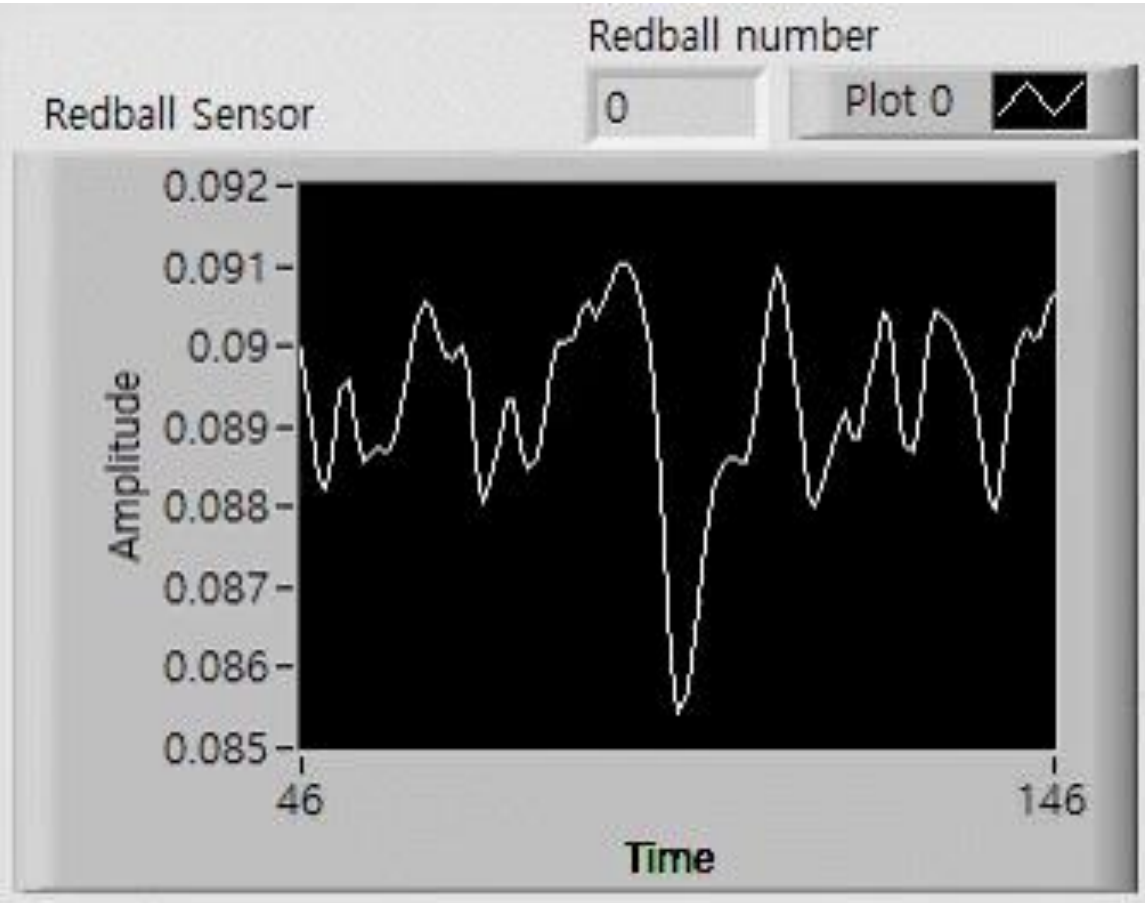
$= (13\pi, 0.95), (20\pi, 0.05)$

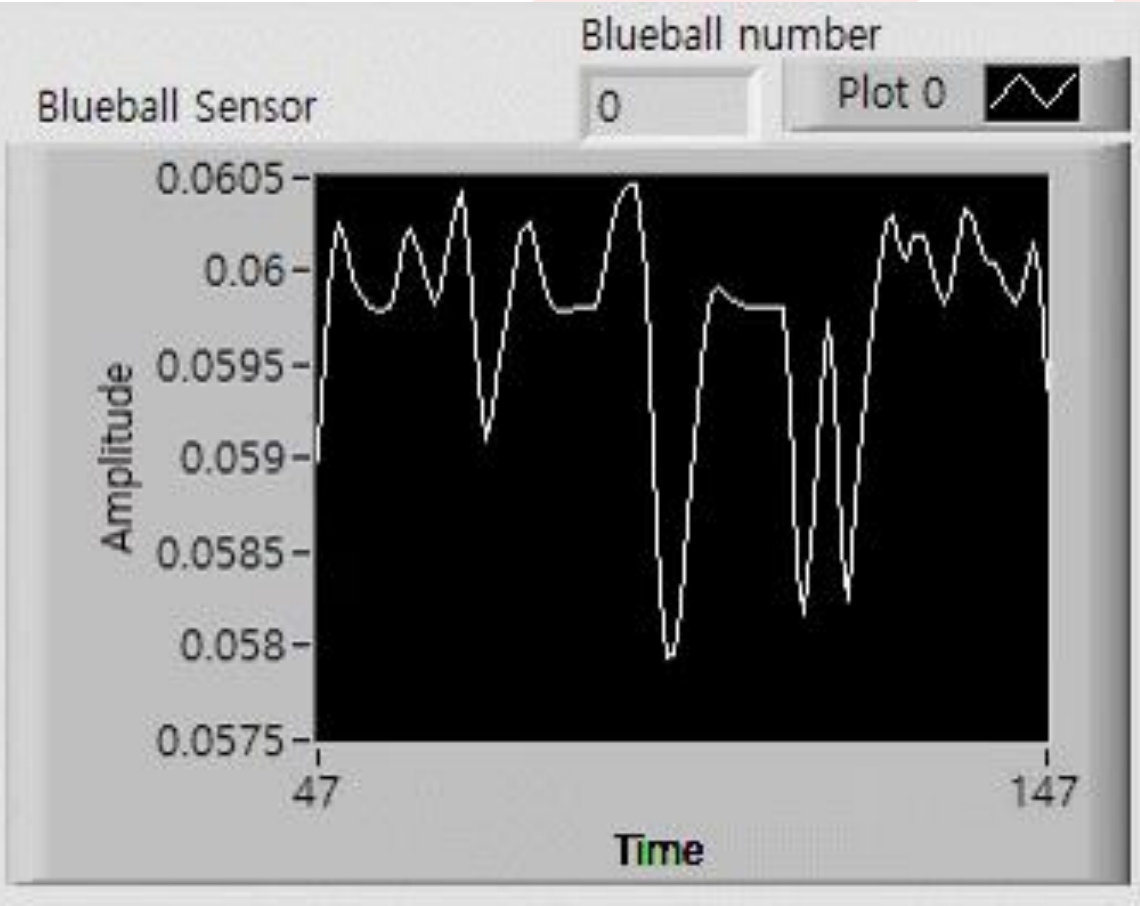
$\therefore N \geq 2.699 \quad (N = 3)$

$\omega_c = 59.179\,\mathrm{rad/s}$

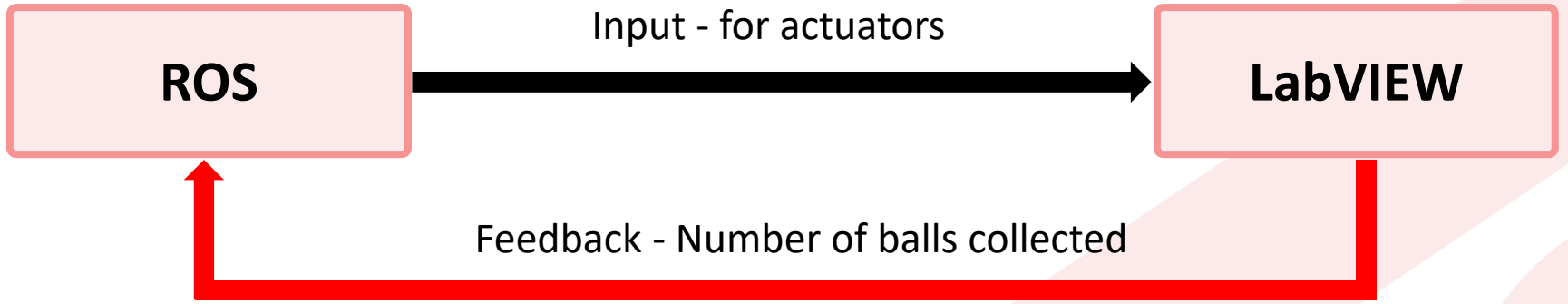
Expected working of Laser Sensor

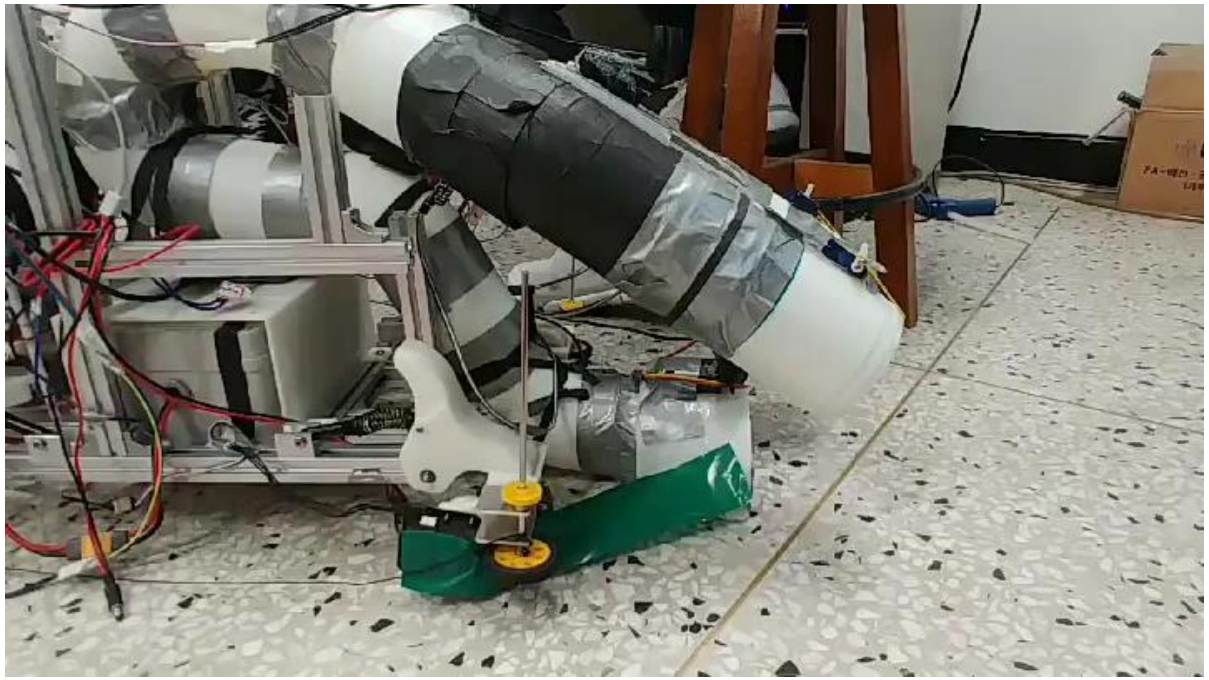
1. Need for verification of the collected balls

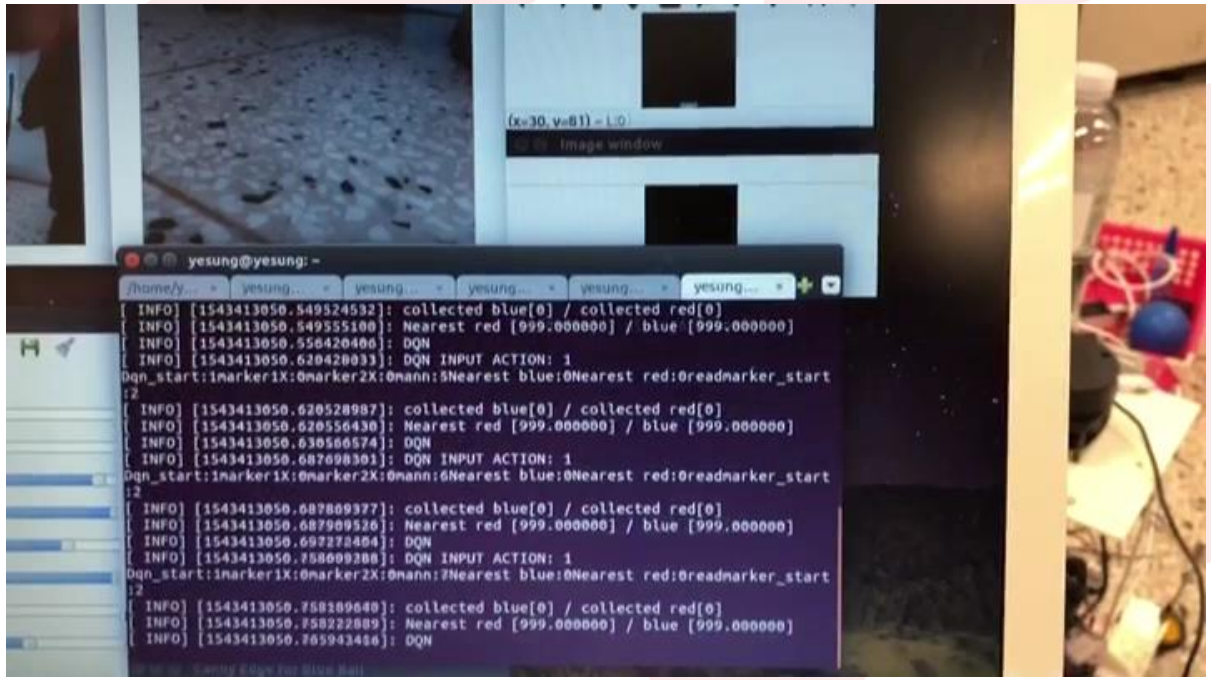




Strengths of SBC – Laser sensor

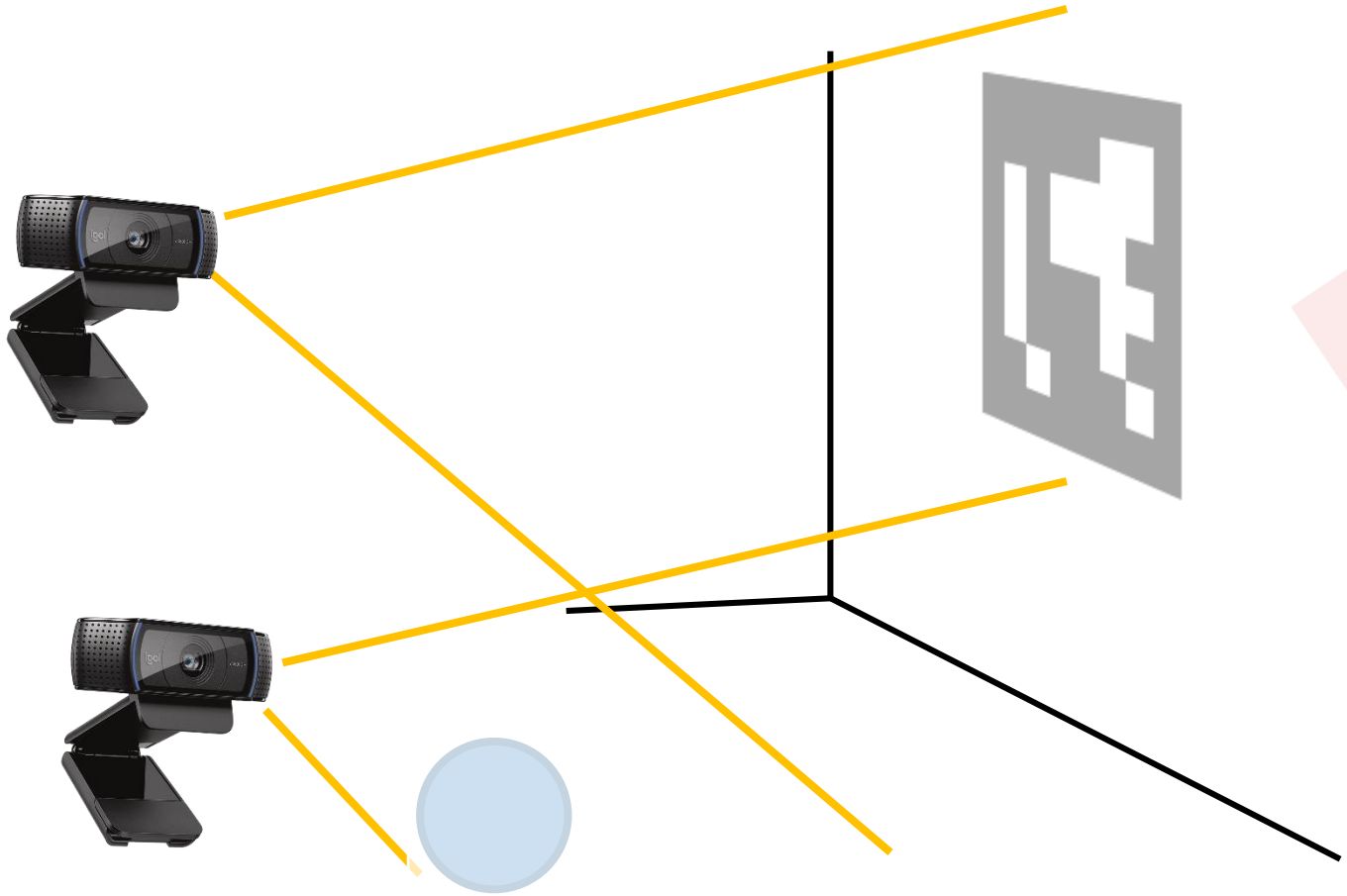






Mission Challenges

2. Limited Camera's Field of View



Dilemma

1. If we want to see **Aruco markers** :

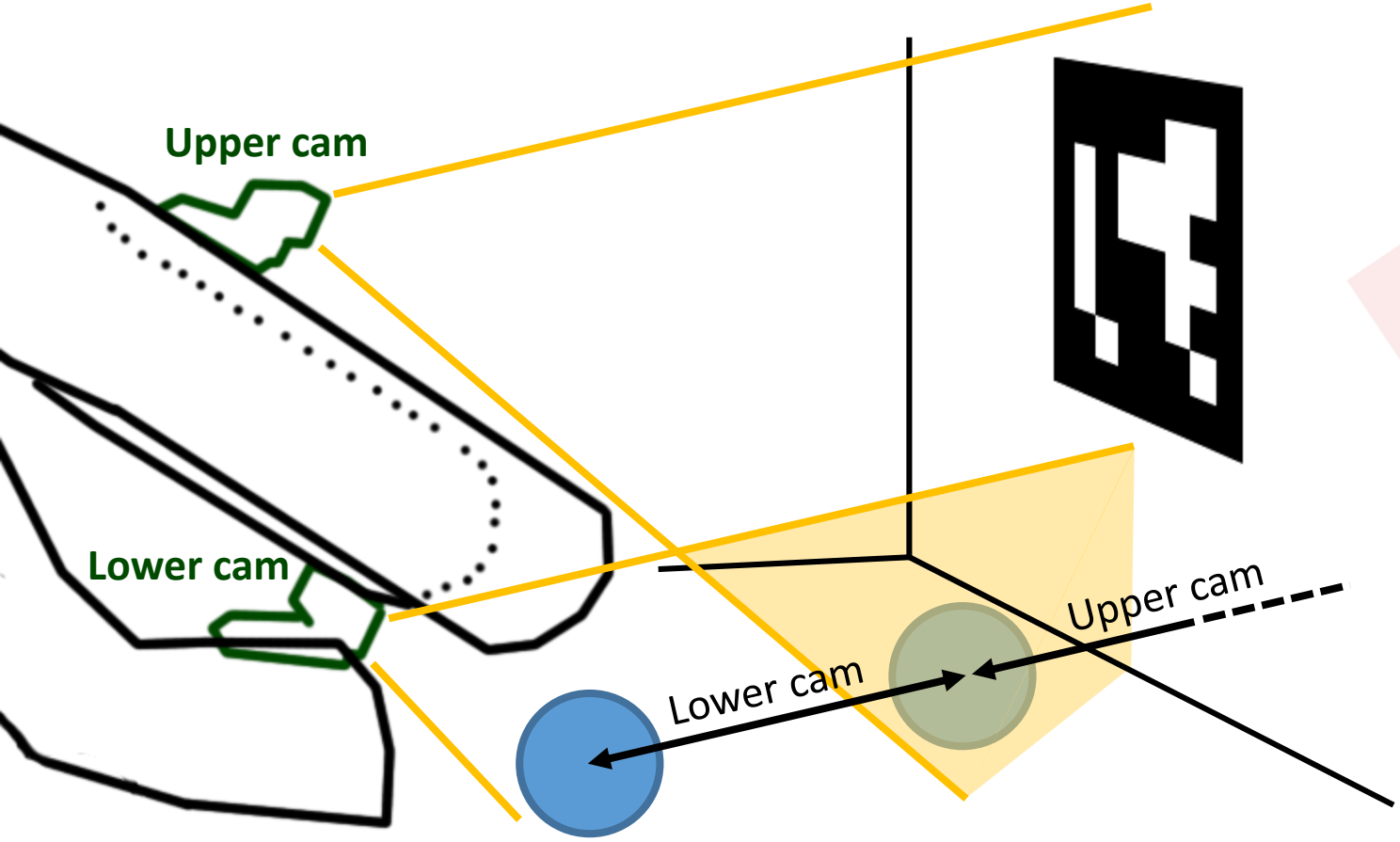
   We cannot see **the ball** in front of suction entrance

2. If we try to see **the ball**:

   We cannot see **Aruco markers**

Mission Challenges

2. Limited Camera's Field of View



Devised solution – Dual Camera

Problem 1

How to handle this area?

Solution 1

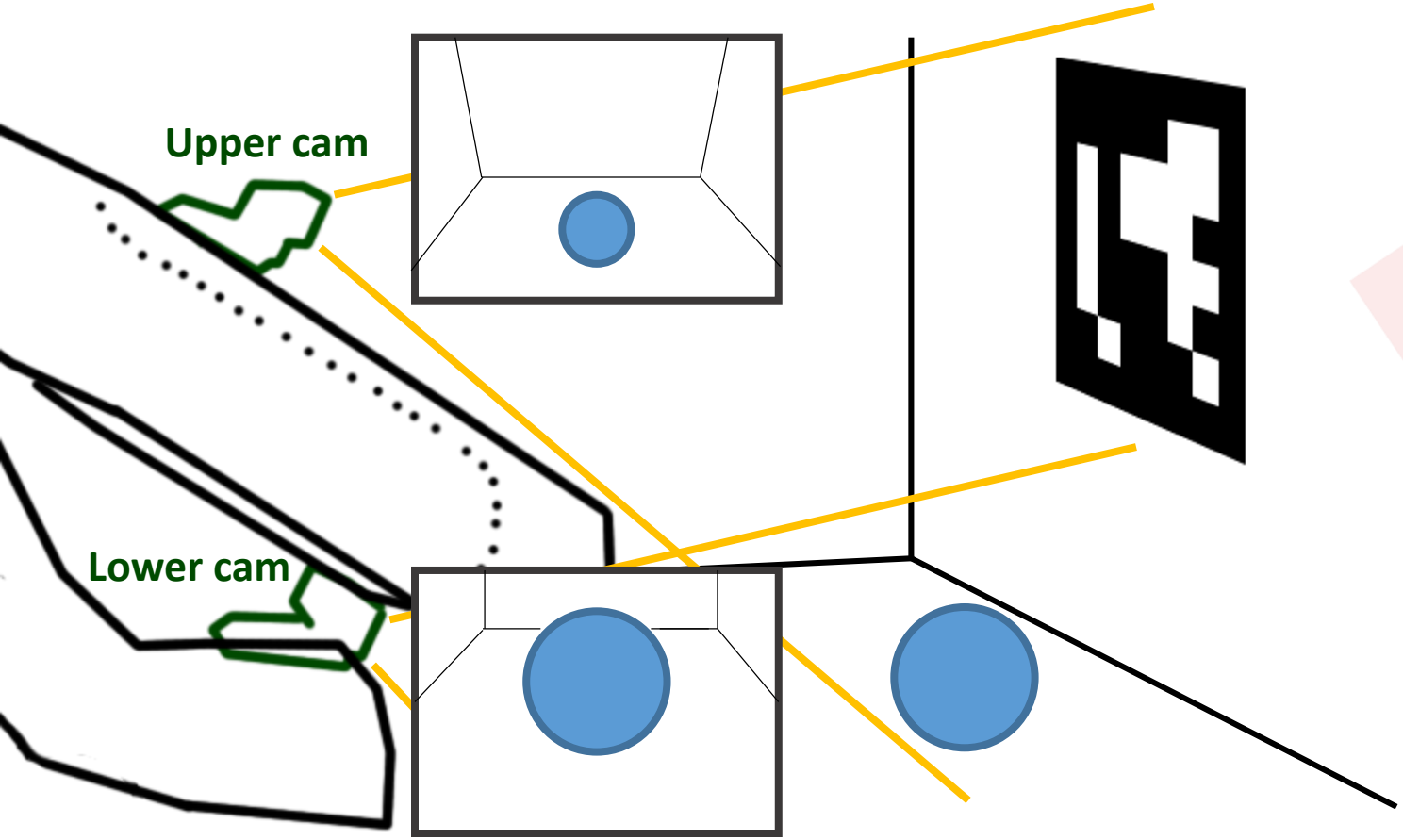
Aruco markers : Upper Cam

Balls : Divide the detection area

(by ROS code)

Mission Challenges

2. Limited Camera's Field of View



Devised solution – Dual Camera

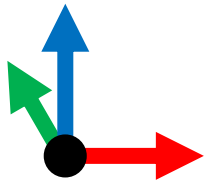
Problem 2

Two cameras have different view

How to get real ball's position?

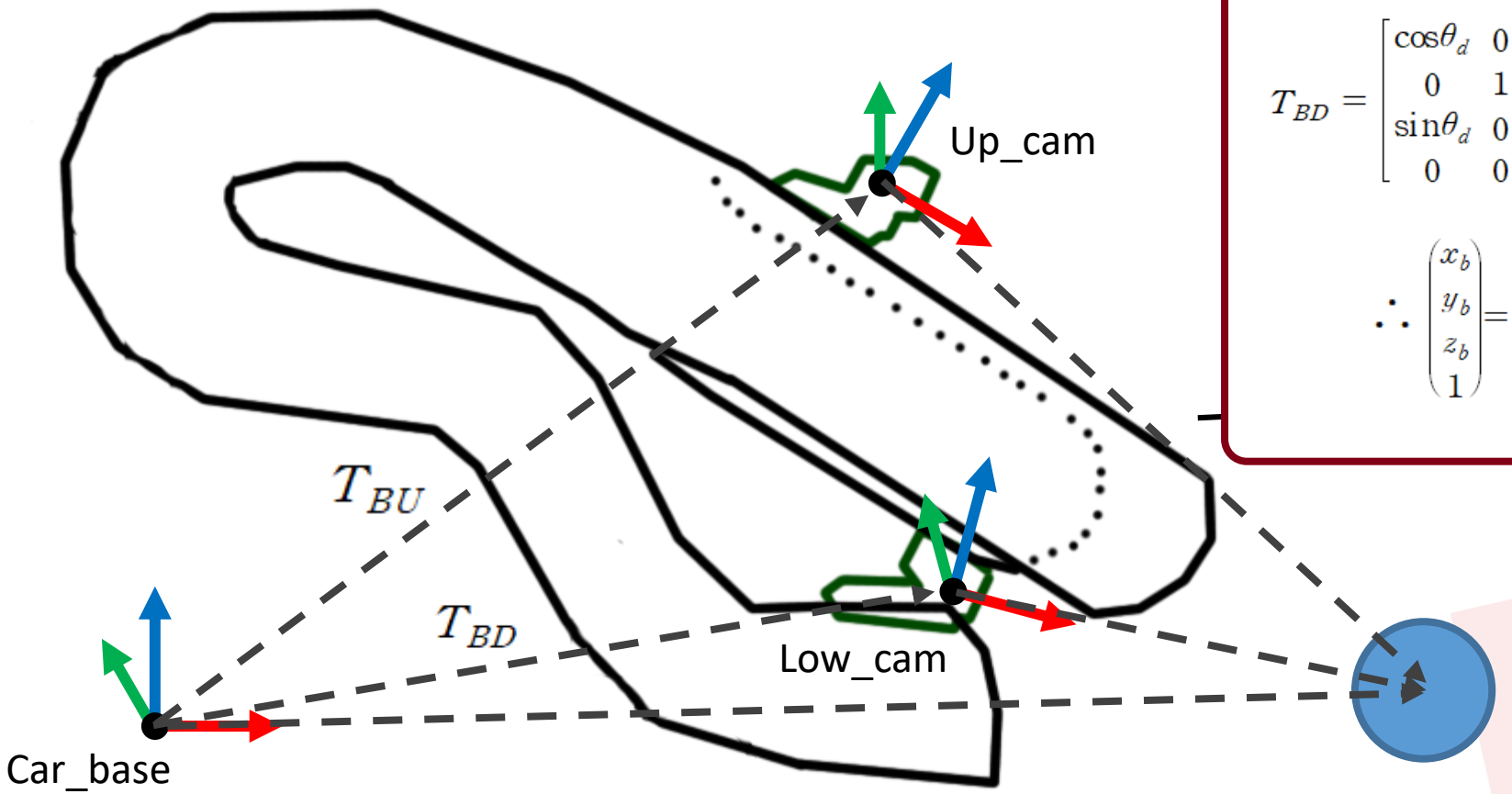
Solution 2

Give TF function!



TF Implementation

2. Limited Camera's Field of View

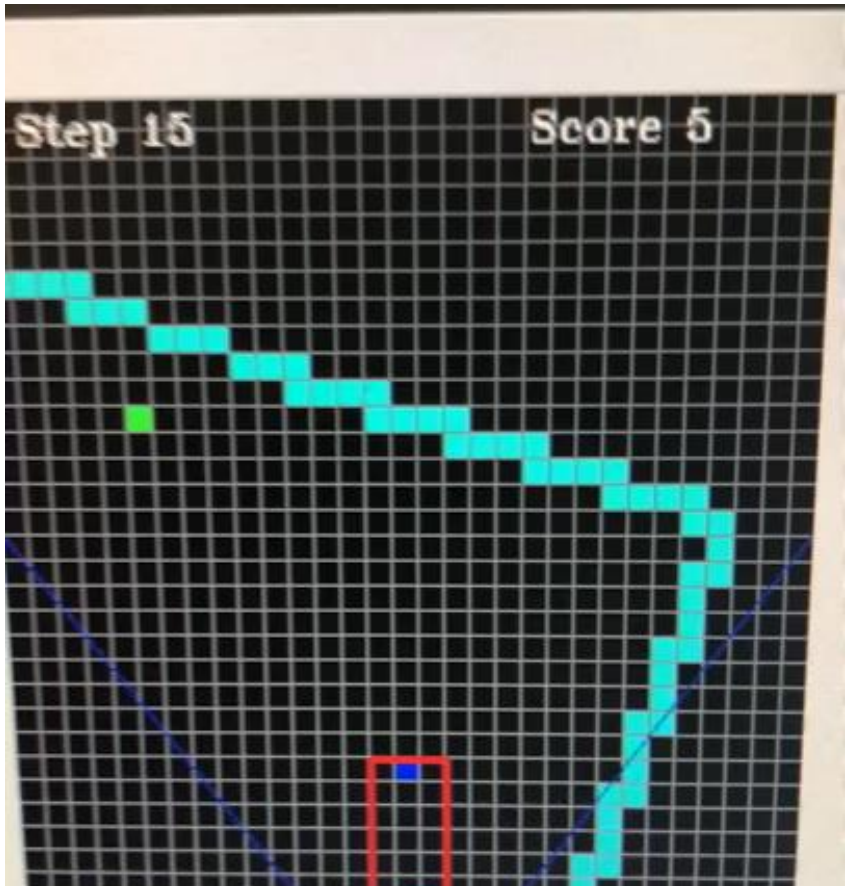


$$T_{BU} = \begin{bmatrix} \cos\theta_u & 0 & -\sin\theta_u & x_u \\ 0 & 1 & 0 & y_u \\ \sin\theta_u & 0 & \cos\theta_u & z_u \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.9063 & 0 & -0.4226 & 300 \\ 0 & 1 & 0 & 0 \\ 0.4226 & 0 & 0.9063 & 330 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

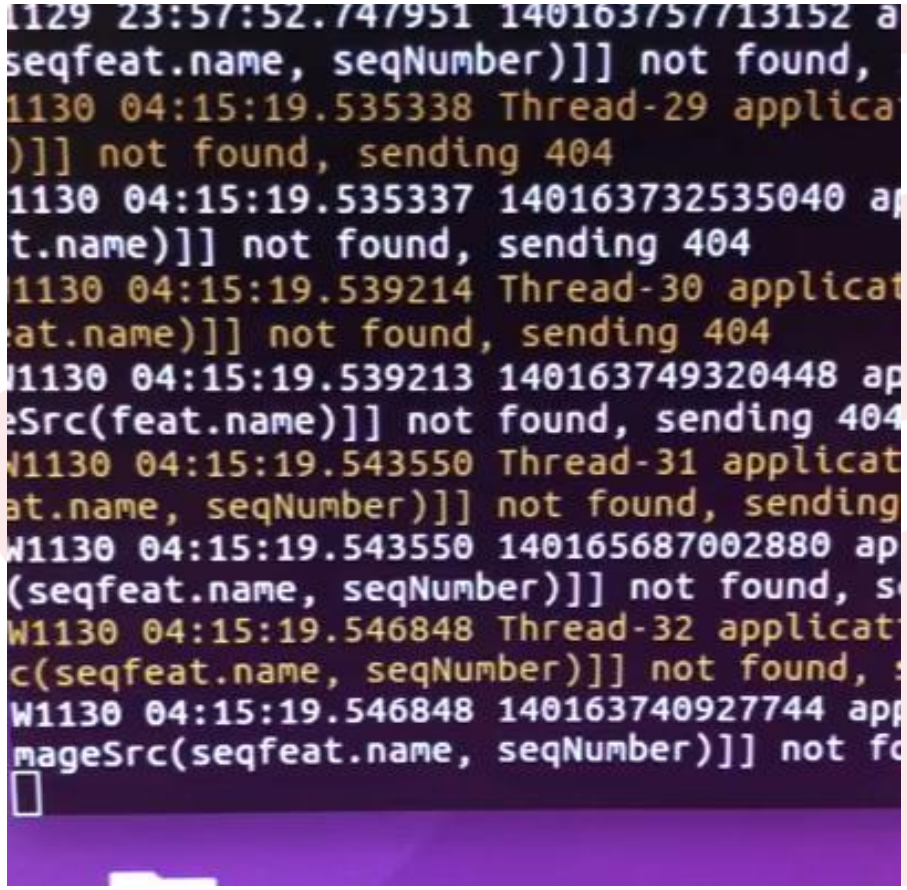
$$T_{BD} = \begin{bmatrix} \cos\theta_d & 0 & -\sin\theta_d & x_d \\ 0 & 1 & 0 & y_d \\ \sin\theta_d & 0 & \cos\theta_d & z_d \\ 0 & 0 & 0 & 1 \end{bmatrix} = \begin{bmatrix} 0.9397 & 0 & -0.3420 & 342 \\ 0 & 1 & 0 & 0 \\ 0.3420 & 0 & 0.9397 & 104 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\therefore \begin{pmatrix} x_b \\ y_b \\ z_b \\ 1 \end{pmatrix} = T_{BU}^{-1} \begin{pmatrix} x_u \\ y_u \\ z_u \\ 1 \end{pmatrix} \qquad \therefore \begin{pmatrix} x_b \\ y_b \\ z_b \\ 1 \end{pmatrix} = T_{BD}^{-1} \begin{pmatrix} x_d \\ y_d \\ z_d \\ 1 \end{pmatrix}$$

DQN Learning Process

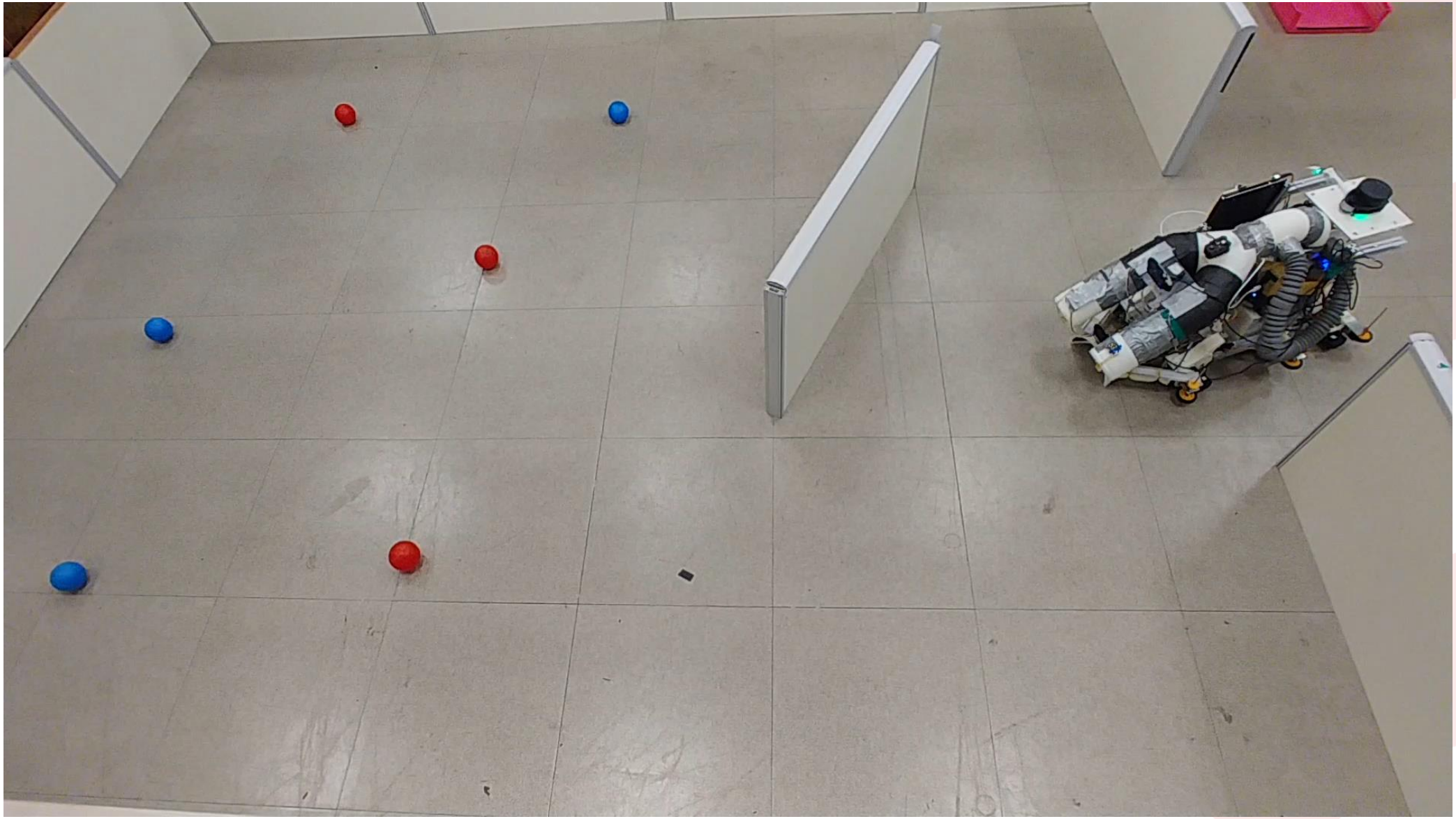


<Before DQN Learning>



<After DQN Learning>

DQN Video



Strengths of SBC

Robust System

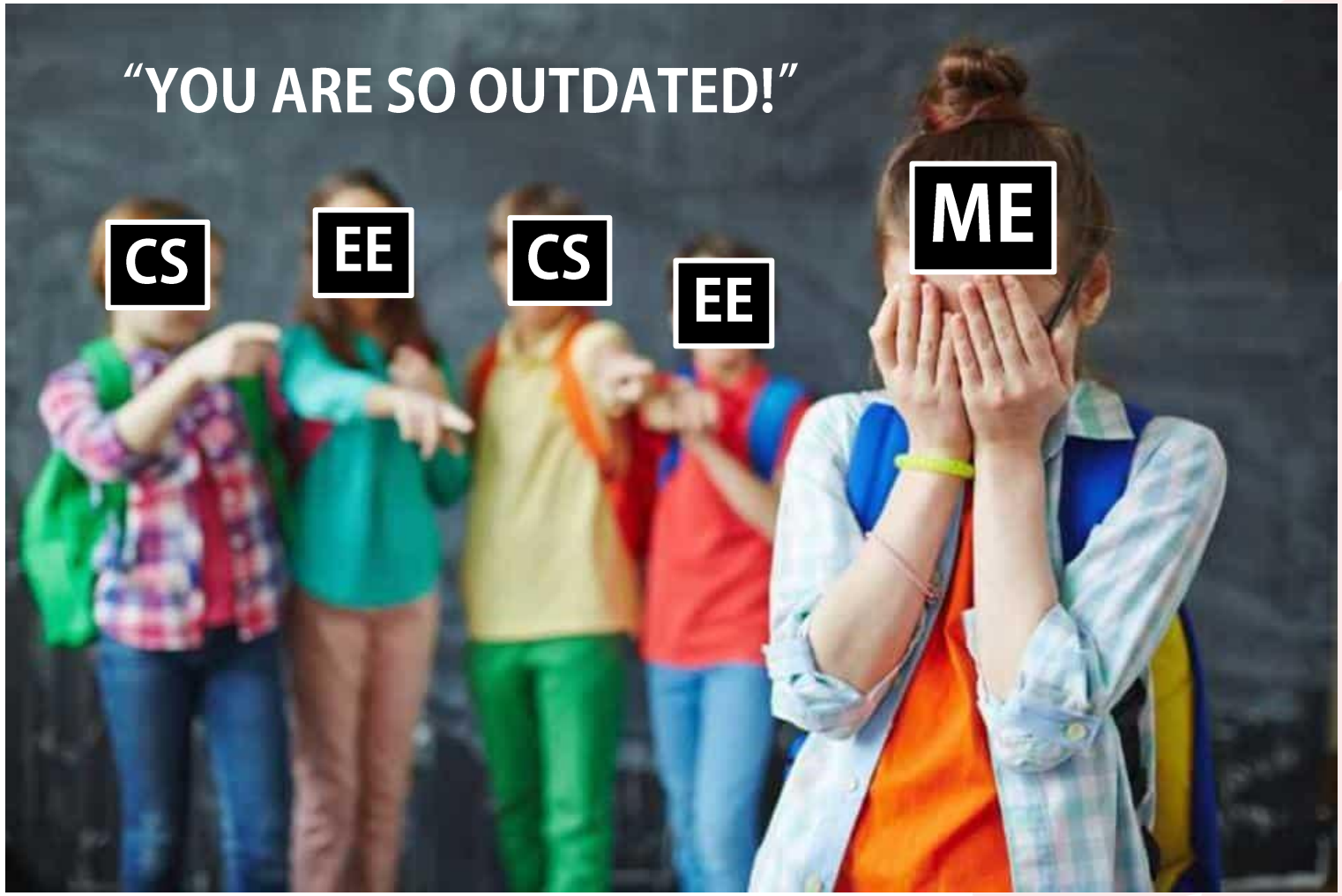
Dual Camera

Feedback Control

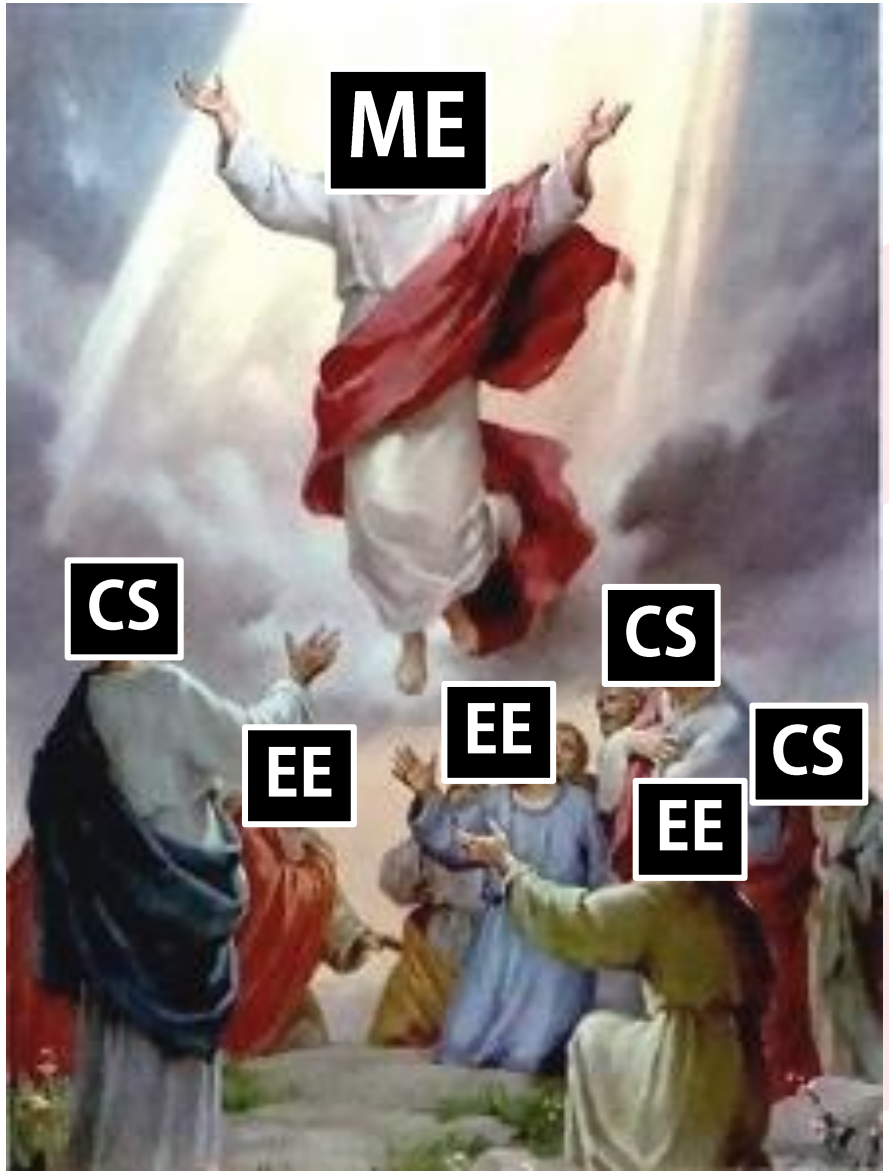
Capstone 1 vs Capstone 2

	Capstone 1 (Control Method)	Capstone 2 (Deep Learning)
Pros	• Efficient use of data • **Less room for error**	• Can be used for more general missions • **We got to learn and apply new technology** • Became “Deep Learning Master”
Cons	• **Have to consider every situation**	• **Not efficient for simple missions** • Requires a large amount of data • Time consuming • Hard to comprehend

Before Capstone Design



After Capstone Design



Thank you for listening!