CAPSTONE DESIGN 1

TEAM IKOH

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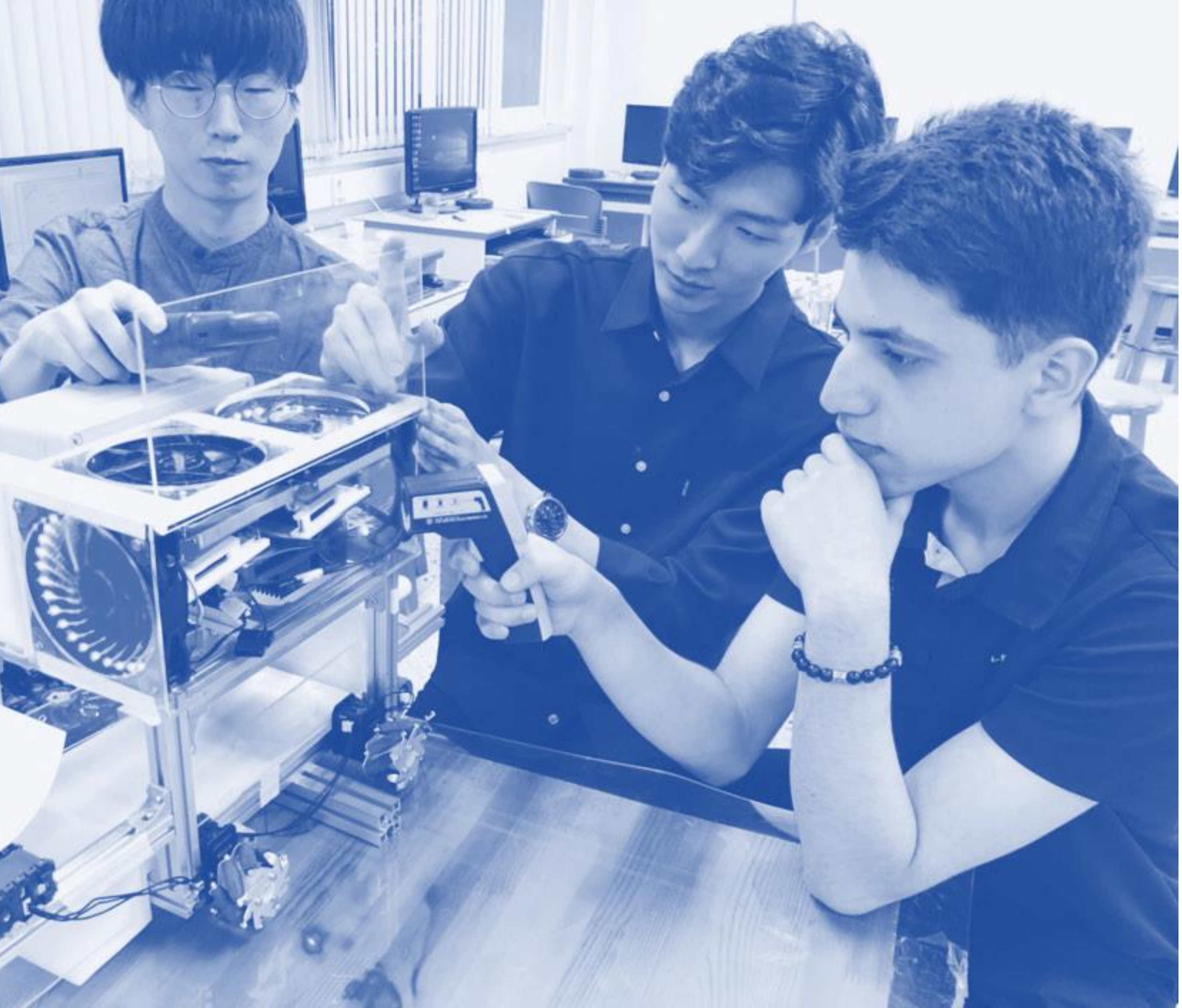


1. HEAT TRANSFER

PROBLEM DEFINITION

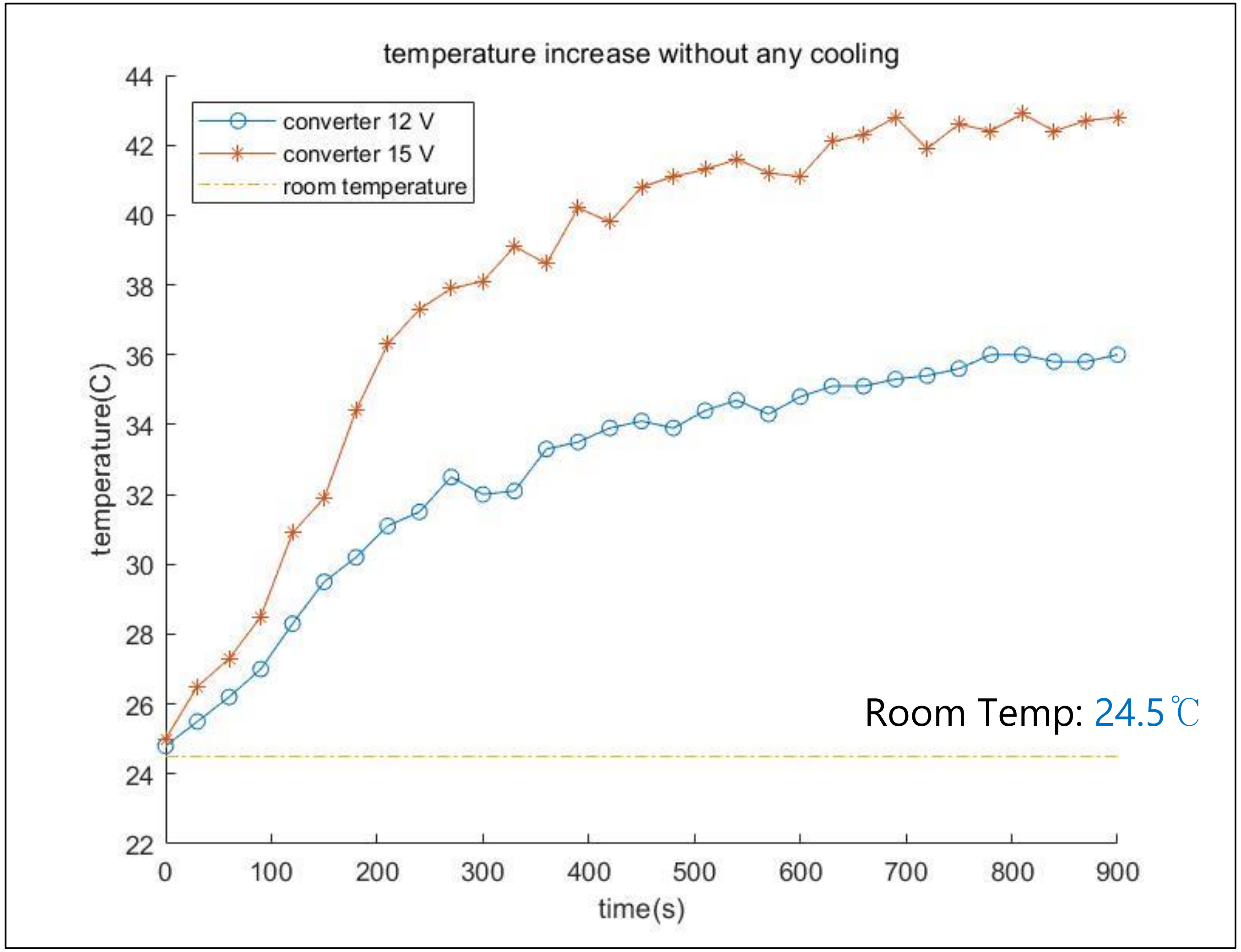
What is our objective?

Energy Mission (30 Points)

(Without Cooling)

Converter 12V T_{max}: **36.1 °C** (+11.6 °C)

Converter 15V T_{max}: **43.1 °C** (+18.6 °C)

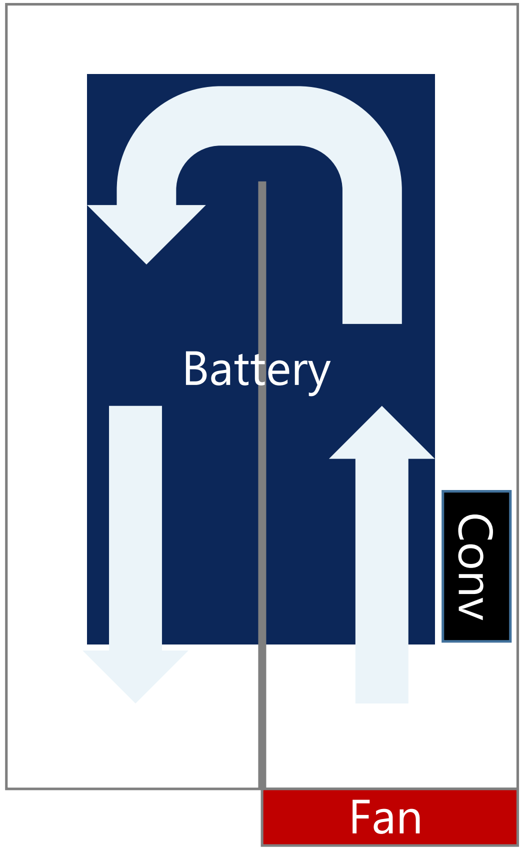


Our Aim:

To maintain the PMS system at room temperature (**ΔT ≈ 1°C**)

Heat Transfer

What is our previous design?



Can cool many surfaces (Battery (6 sides), Converter, myRio, etc) with only one fan

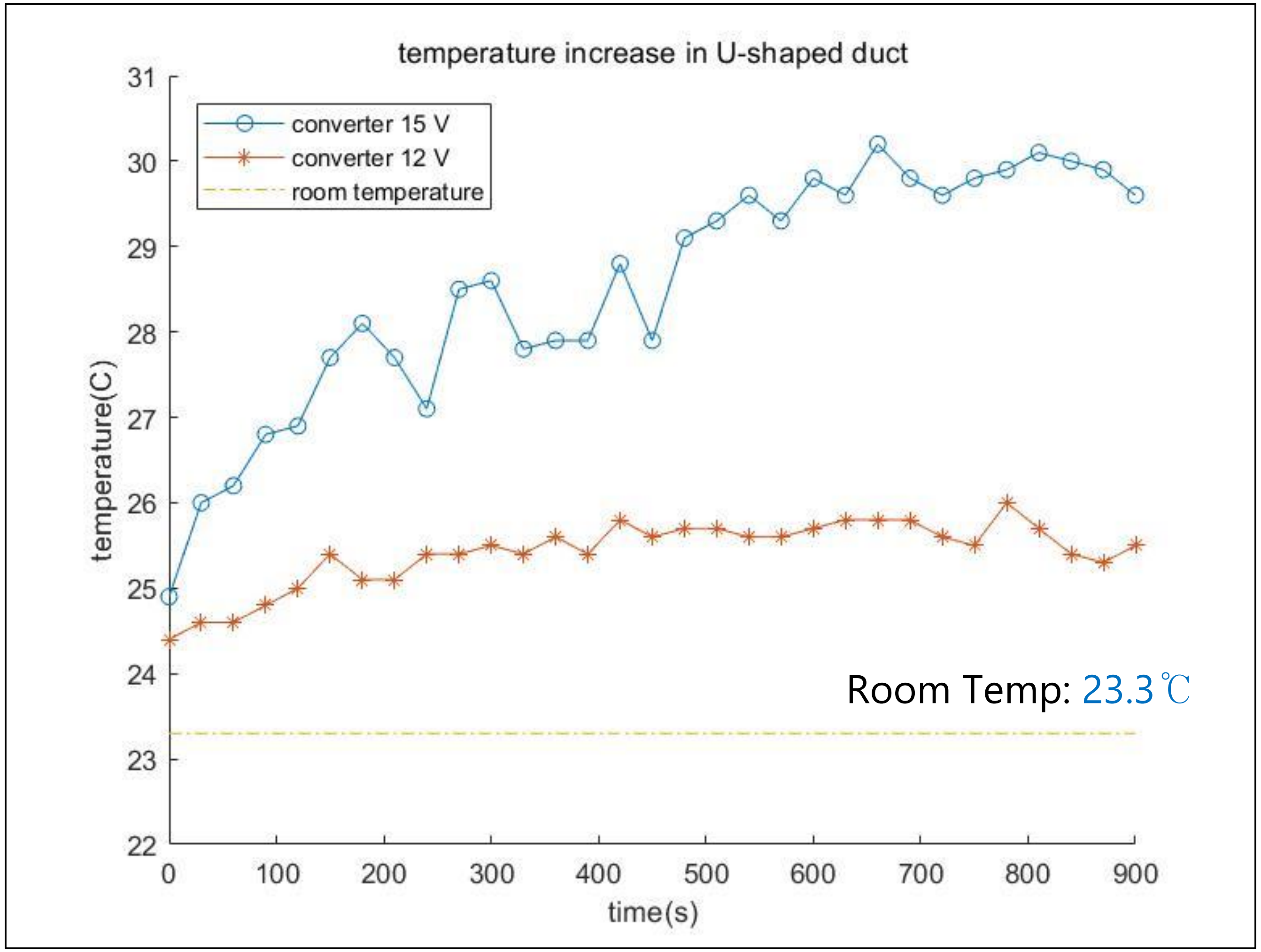
Heat Transfer

How efficient was our U-shaped design?

(With U-Shaped Duct)

Converter 12V T_{max}: **26.0 °C** (+2.7 °C)

Converter 15V T_{max}: **30.1 °C** (+6.8 °C)

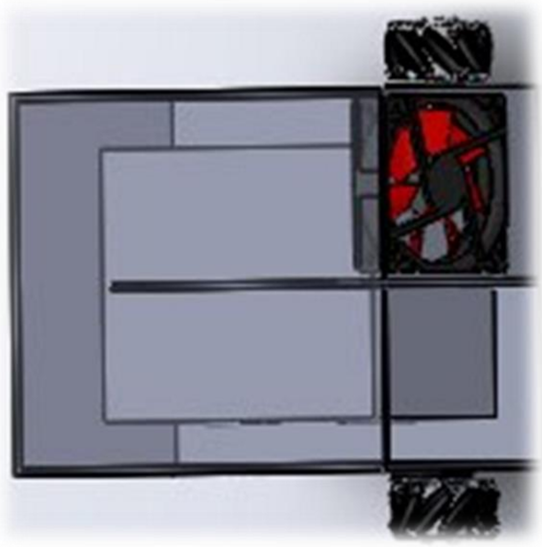


One fan was not enough to meet our aim!

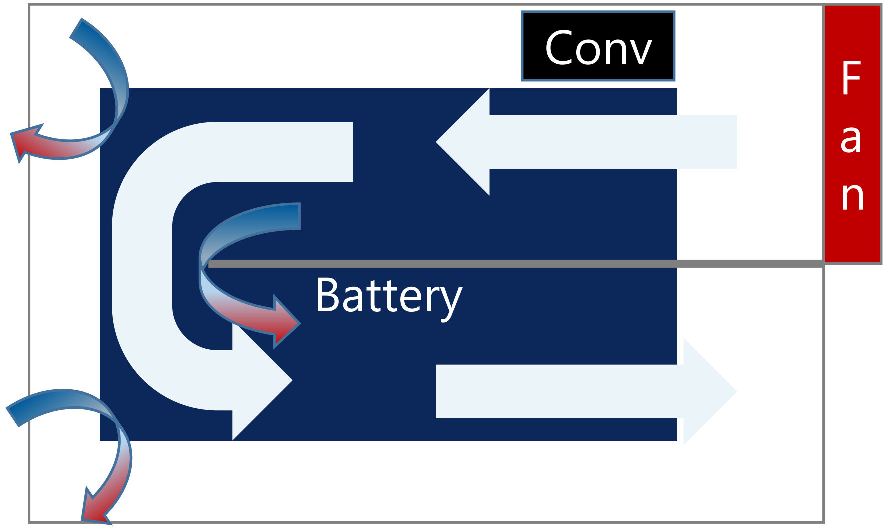
Heat Transfer

What were the problems of the U-shaped duct design?

Problem 1



Problem 2



Battery temperature was **lower than expected**:

NO need to cool many sides

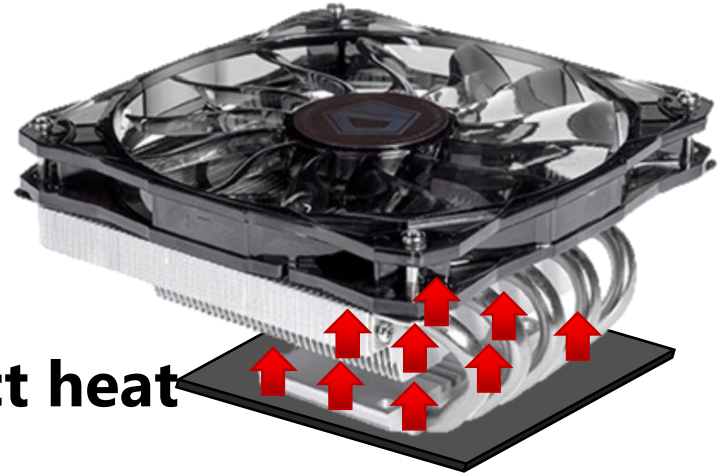
Sources of minor loss exist along the duct

Heat Transfer

How can we improve our duct design?

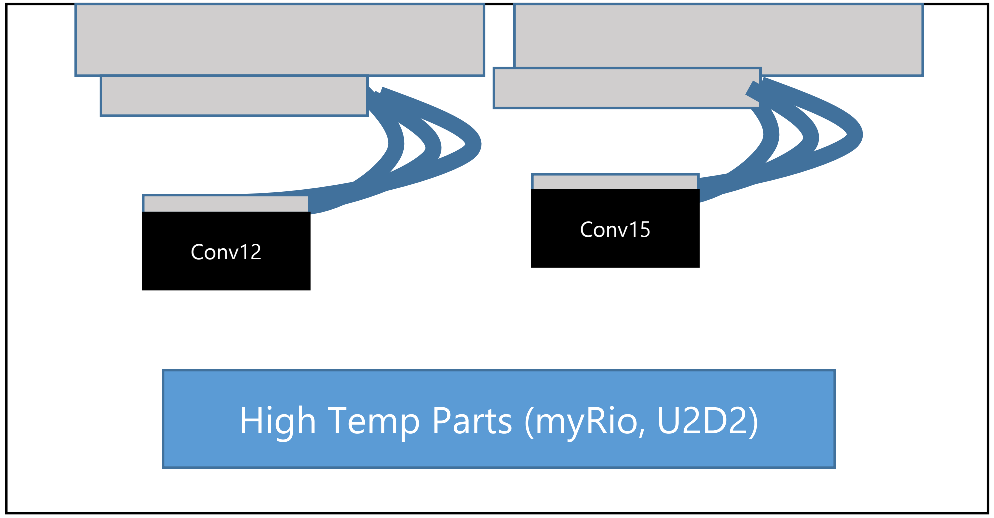
One fan was not enough to meet our aim!

Use CPU fan to efficiently extract heat



F
A
N

New Linear Duct



Side View

Use one fan for each converter!

Is this enough?

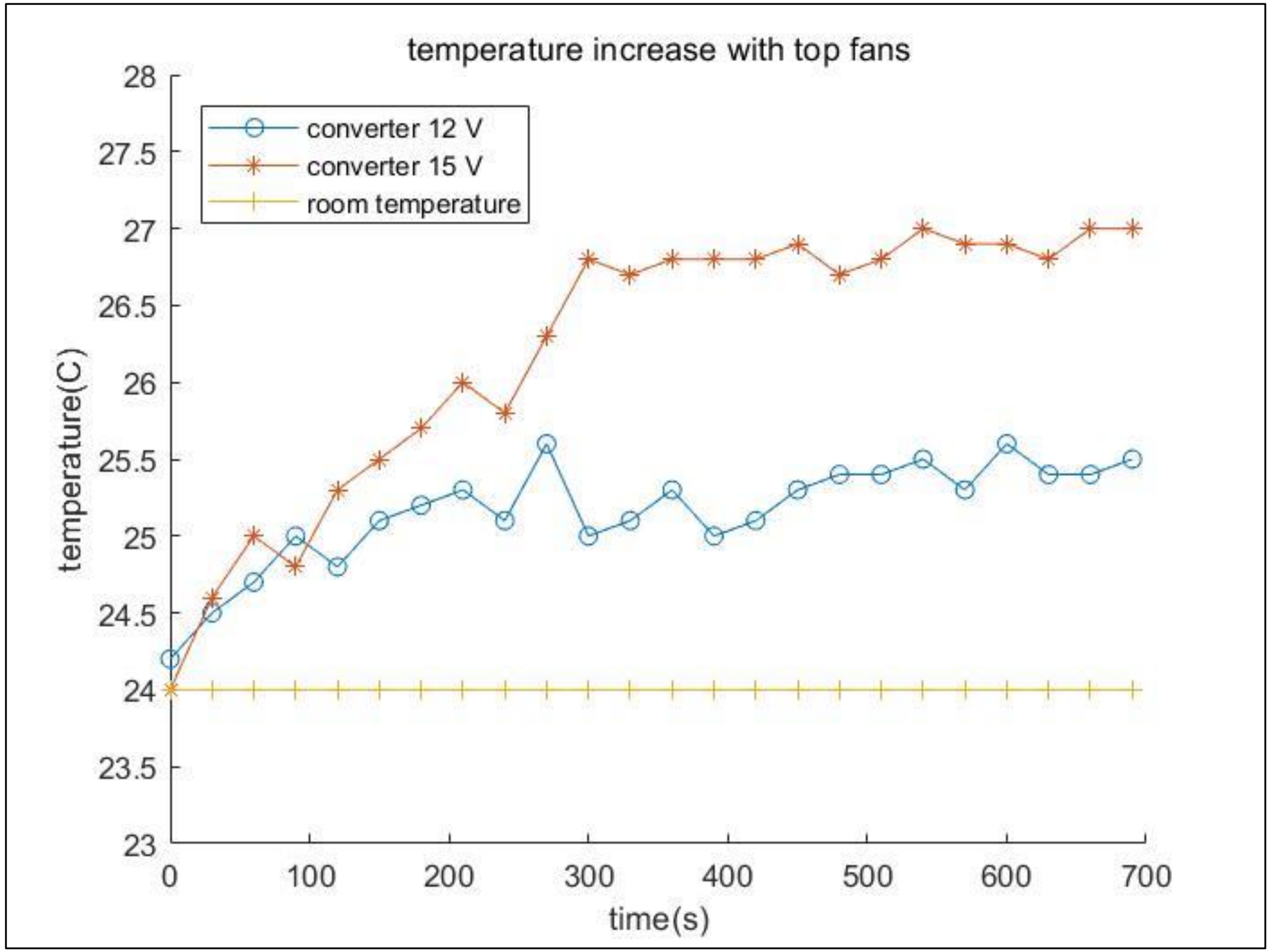
Heat Transfer

How efficient is the 2-fan design?

(With Top Fans)

Converter 12V T_{max}: **25.6 °C** (+1.6 °C)

Converter 15V T_{max}: **27.0 °C** (+3.0 °C)



How can we improve this **even more**?

Heat Transfer

Heat Transfer & Fluid Mechanics Analysis*

$$Q = h_{conv}A(T_s - T_{air})$$

How can we increase h?

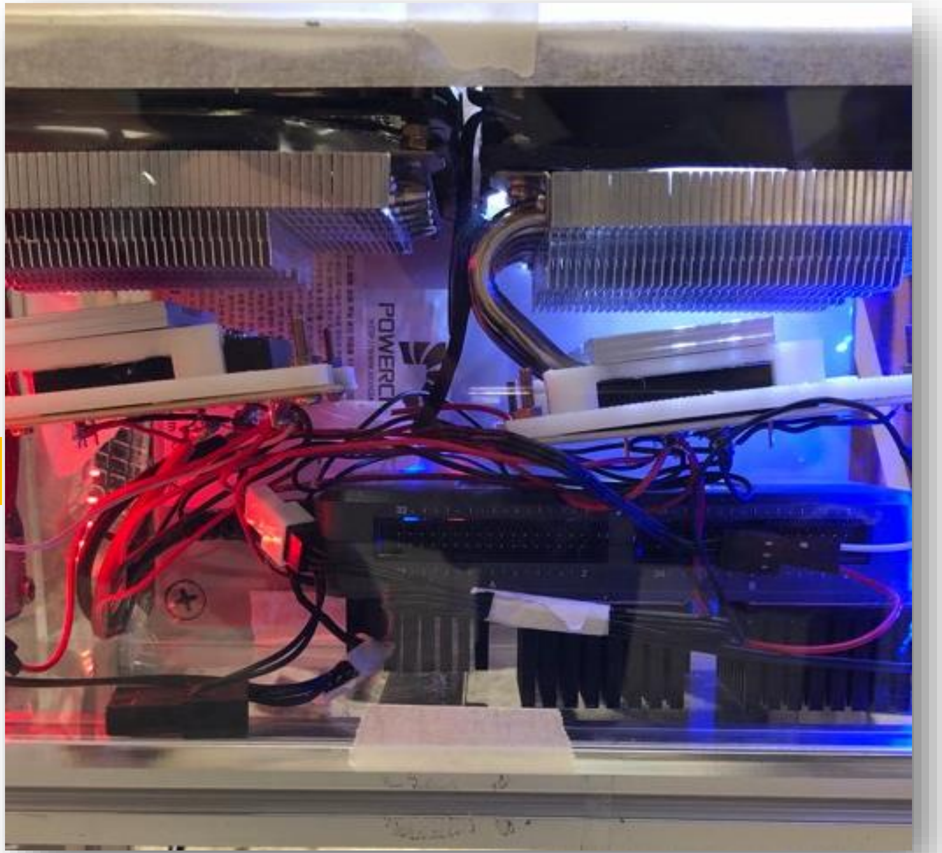
$h_{conv} \uparrow \leftarrow velocity \uparrow$

Fans are **pumps** that **increases fluid head** to induce fluid flow

$$H_{pump} = \cancel{\frac{P_2 - P_1}{\rho g}} + \frac{(\alpha_2 V_2^2 - \alpha_1 V_1^2)}{2g} + (z_2 - z_1) + \cancel{h_{turbine}} + h_{friction}$$

$$where \quad h_{friction} = \frac{V^2}{2g}\left(\sum \frac{fD}{L} + \sum K\right)$$

Our f $\uparrow$ so our V $\downarrow$



$H_{pump} \uparrow \rightarrow v_{fluid} \uparrow \rightarrow h_{conv} \uparrow \rightarrow R \downarrow \rightarrow$ Steady state temp $\downarrow$

*(White 8th Fluid Mechanics)

Heat Transfer

How does the improved cooling system work?

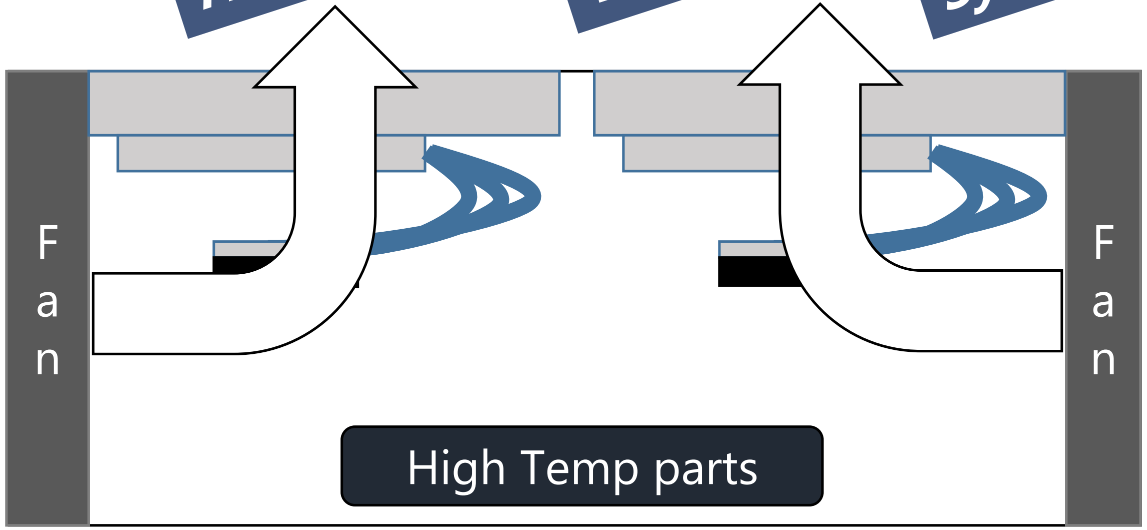
Add more pumps (fans) in series!

Fins, Thermal Pads, Thermal Grease

Warm Air Rises (Efficient)

Symmetrical (Even Cooling)

Focused Cooling of Parts



Symmetry

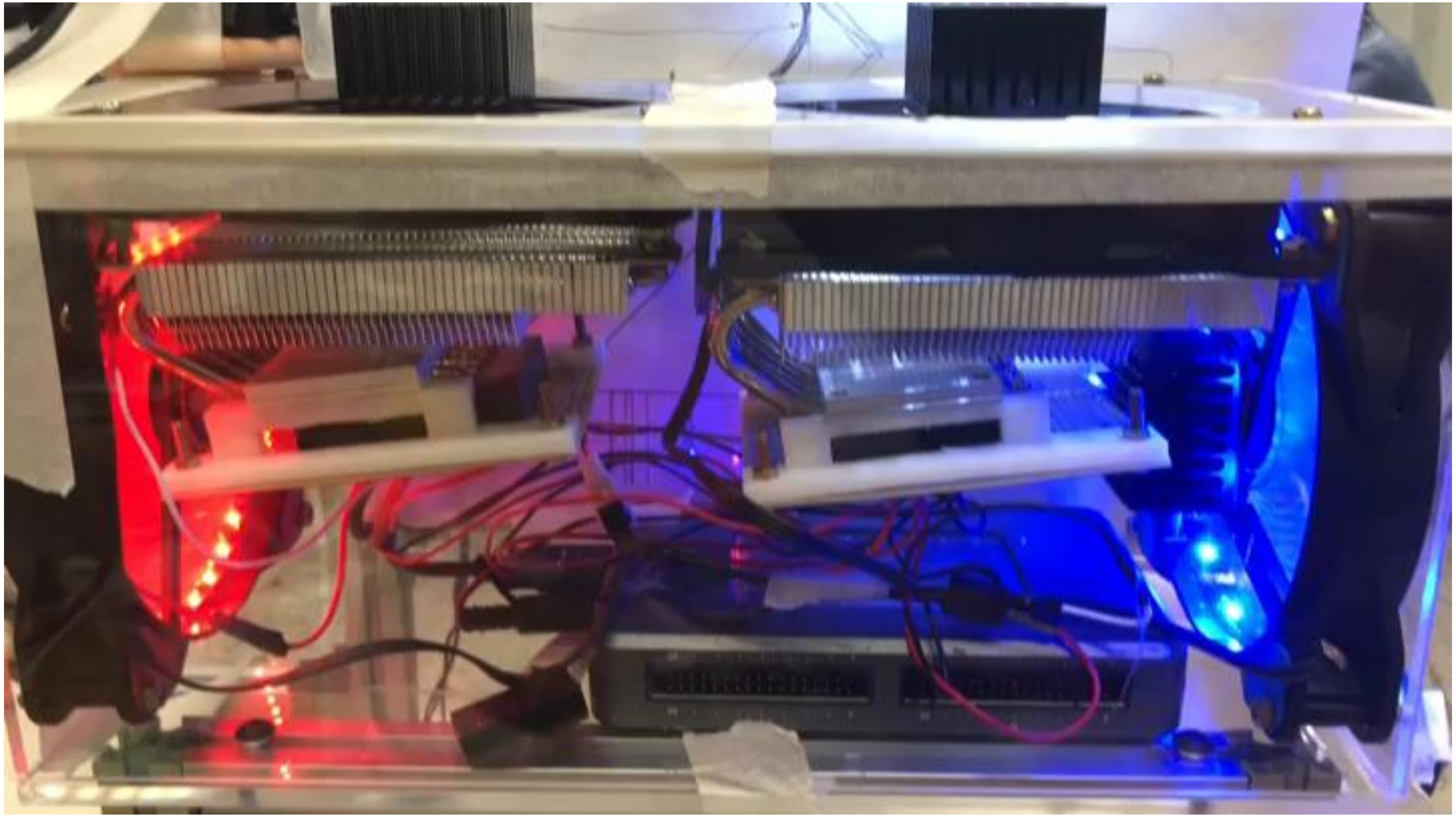
Color

Proportion

Aesthetics is important in engineering

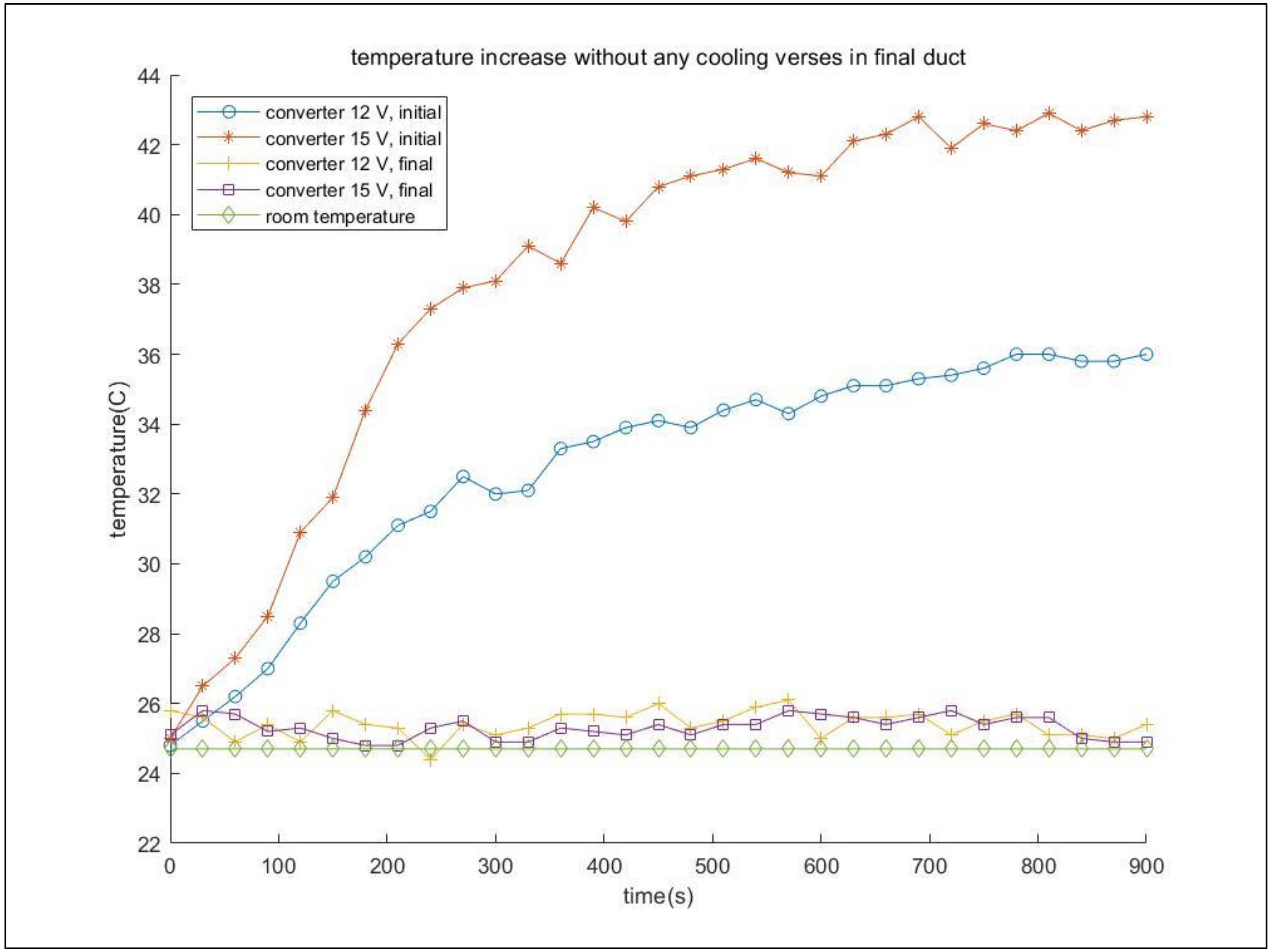
Heat Transfer

How does the improved cooling system work?



Heat Transfer

How effective is our new design?



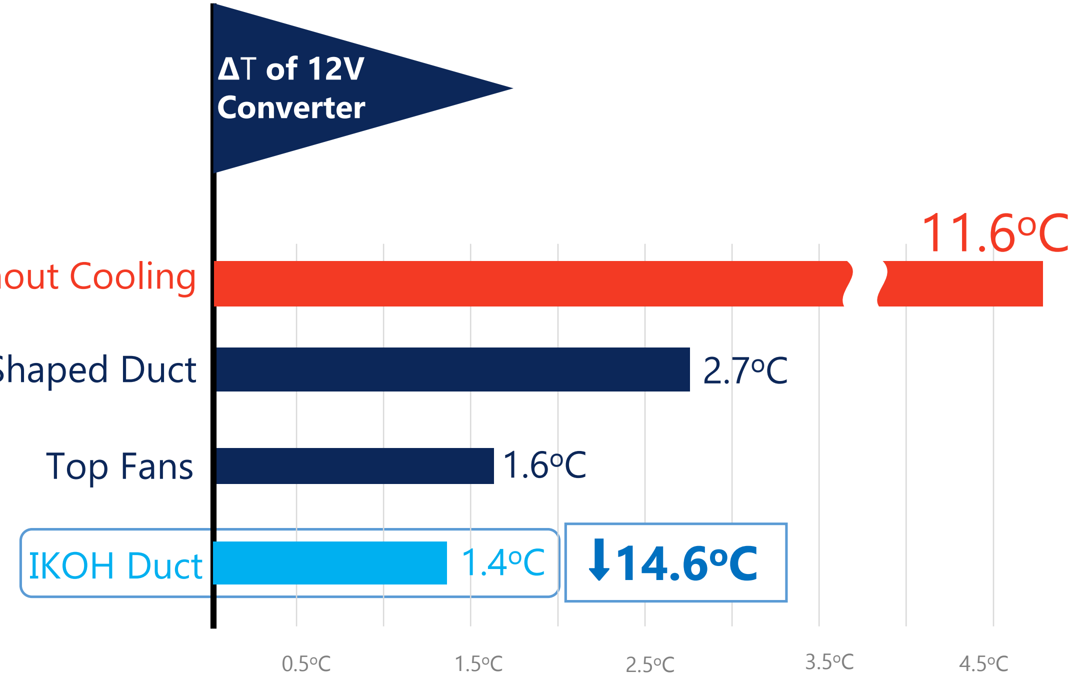
(With Final Duct)

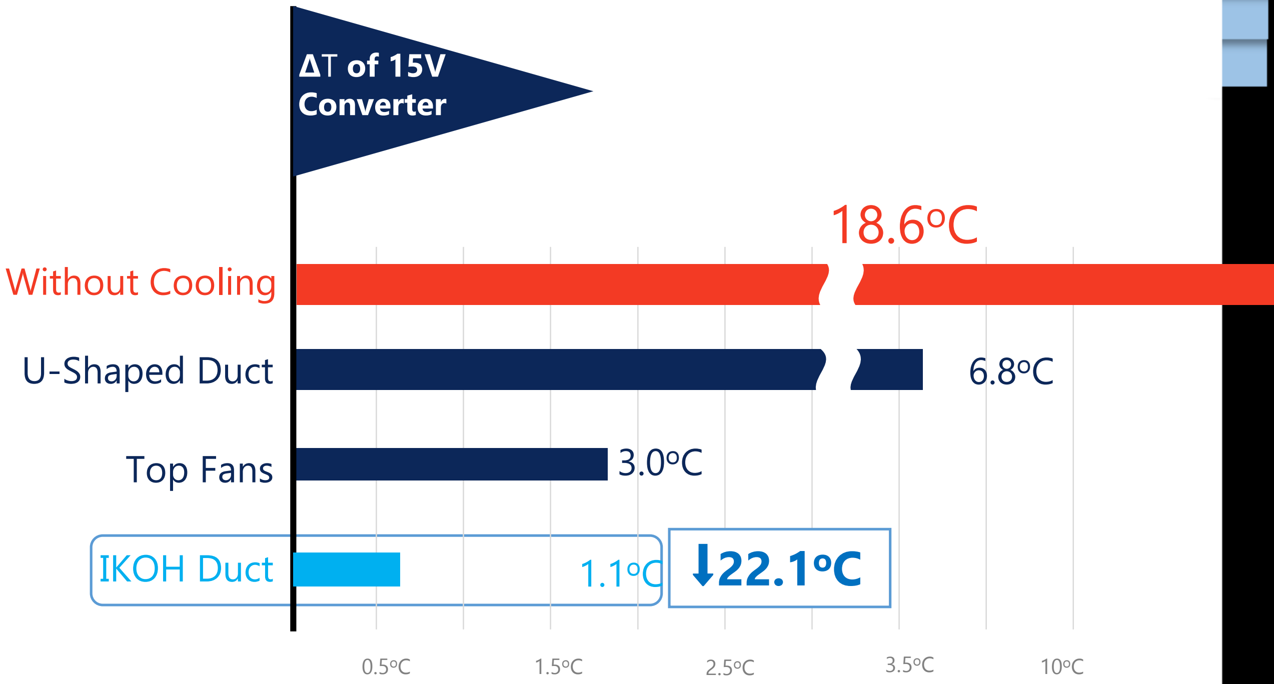
Converter 12V T_{max} : **26.1 °C** (+1.4 °C)

Converter 15V T_{max} : **25.8 °C** (+1.1 °C)

Heat Transfer

What is **Δ**T of each design?





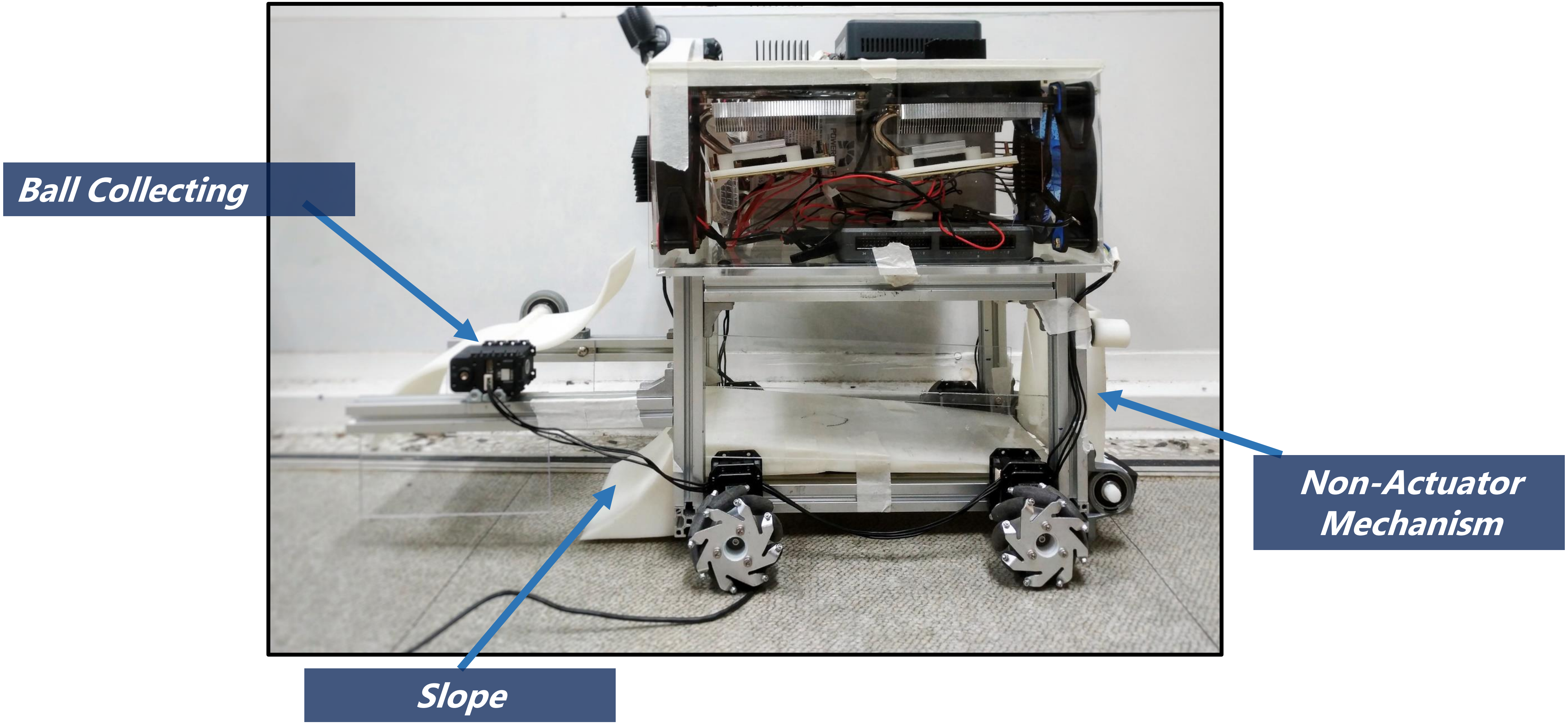
Aim: ΔT ≈ 1ºC ✓

Improved groundbrea**K**ing co**O**ling met**H**od

2. PICK-UP SYSTEM

Pick-Up System

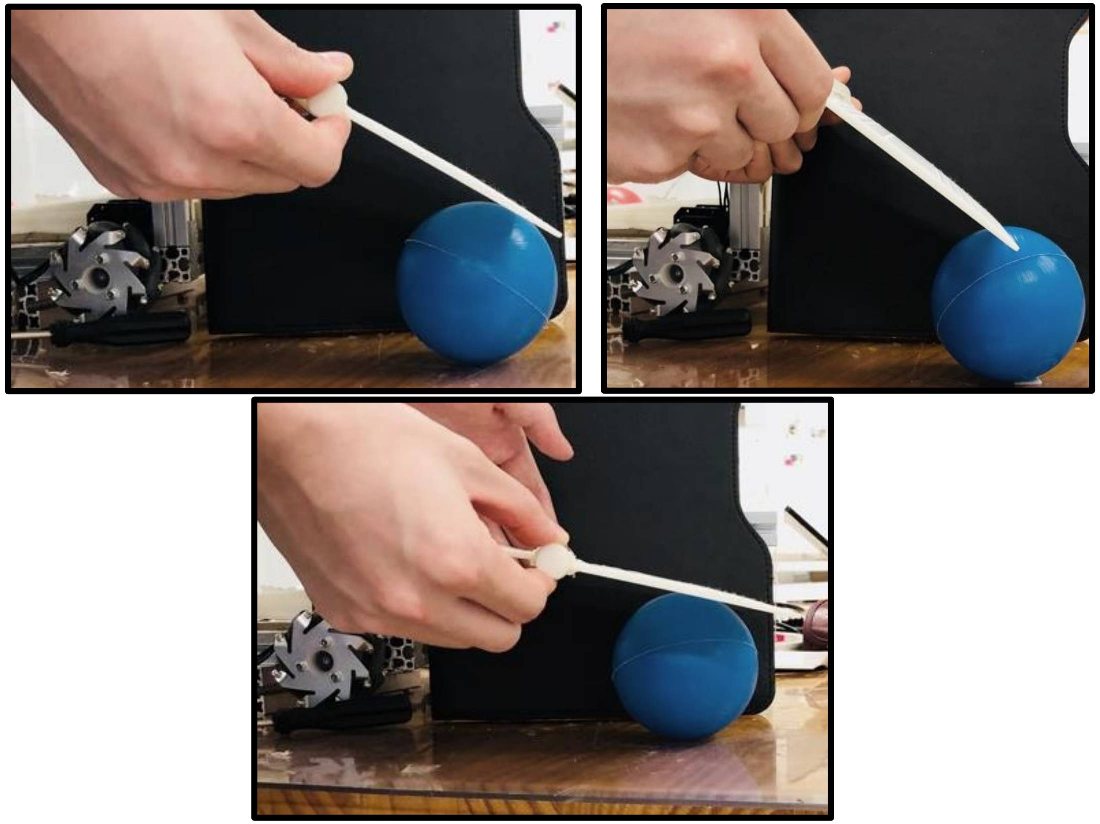
How do we pick up the ball?



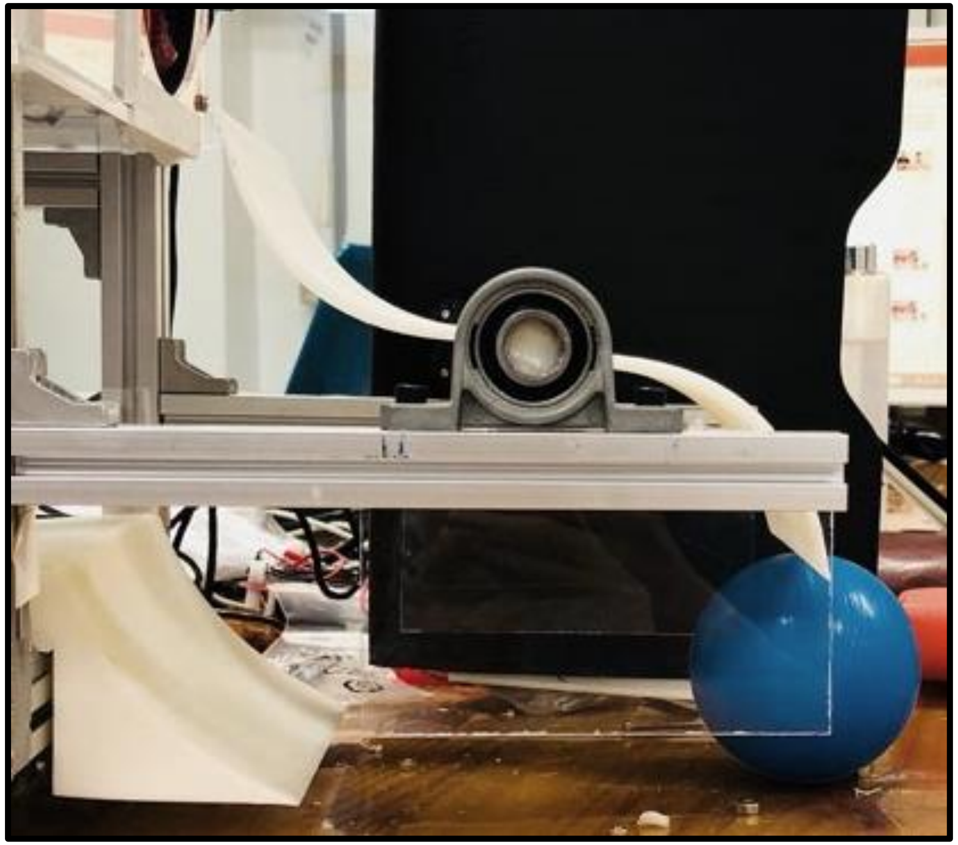
Pick-Up System

How did we modify the blade?

Previous blade (plate)



Modified blade (curved) shape



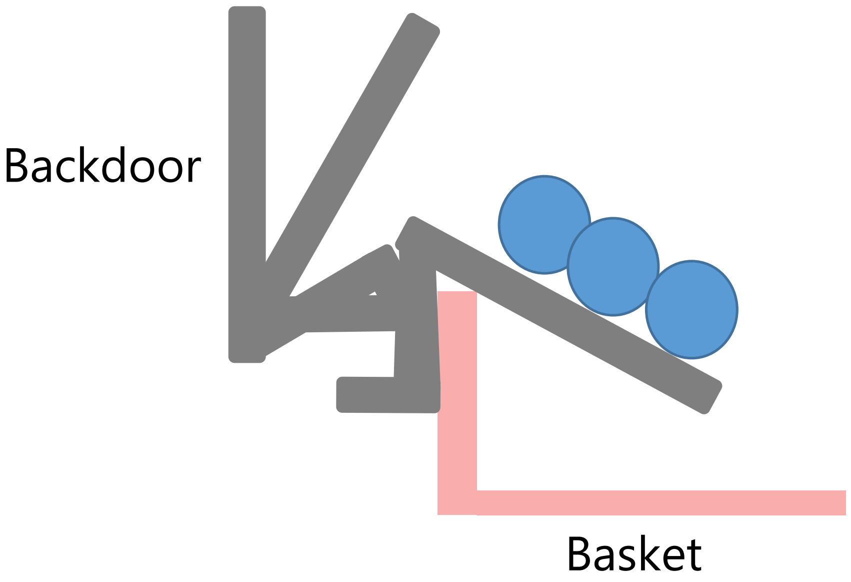
Problem : Balls get stuck **in many angles**

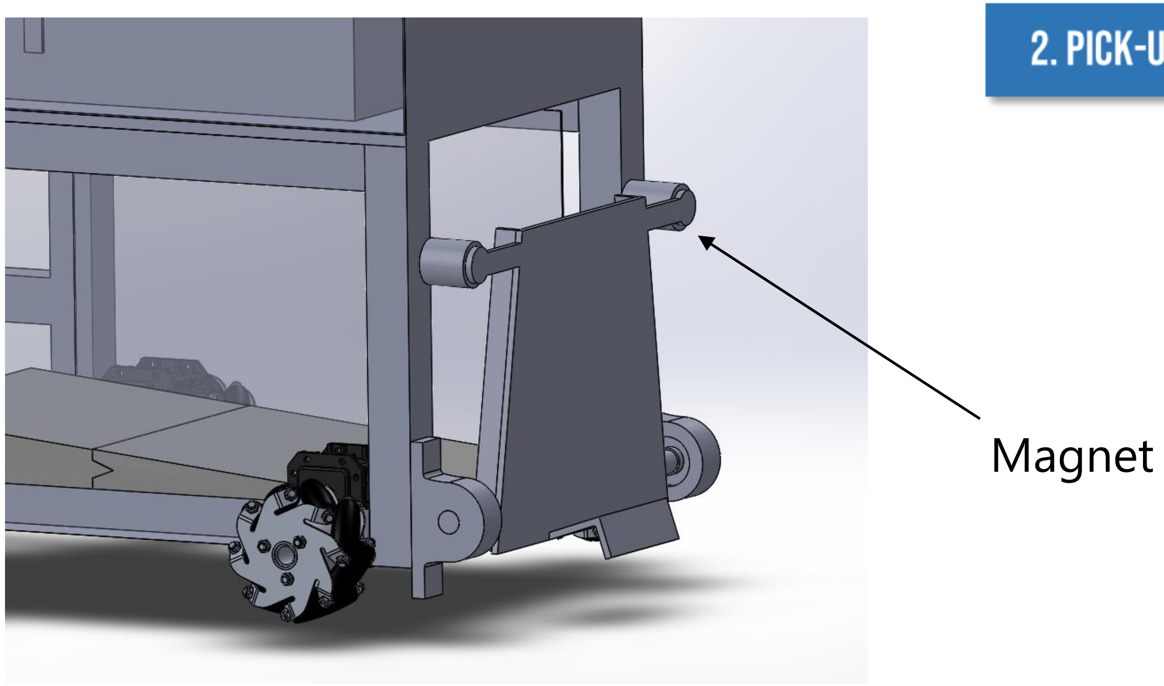
Solution : Balls **rarely** get stuck

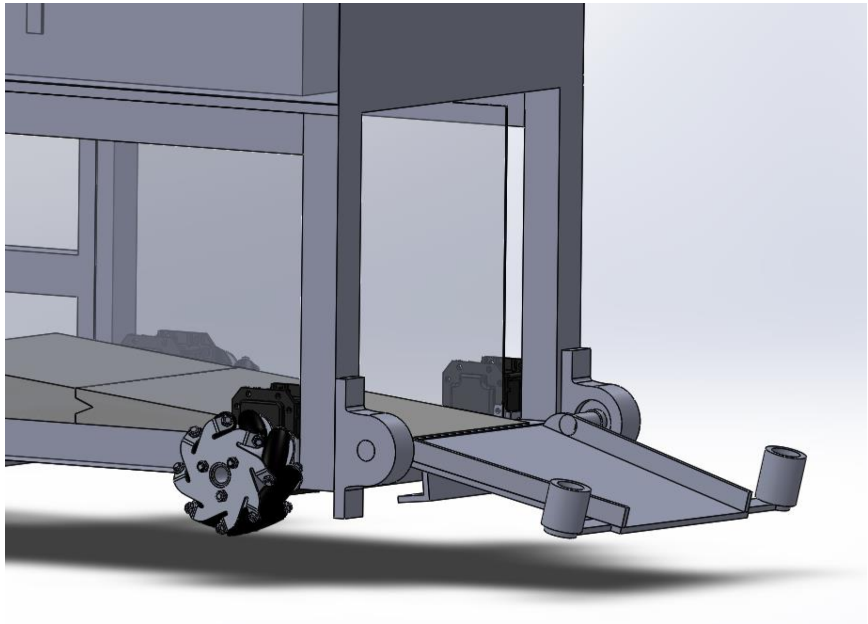
Pick-Up System

How do we release the ball?

Non Actuator



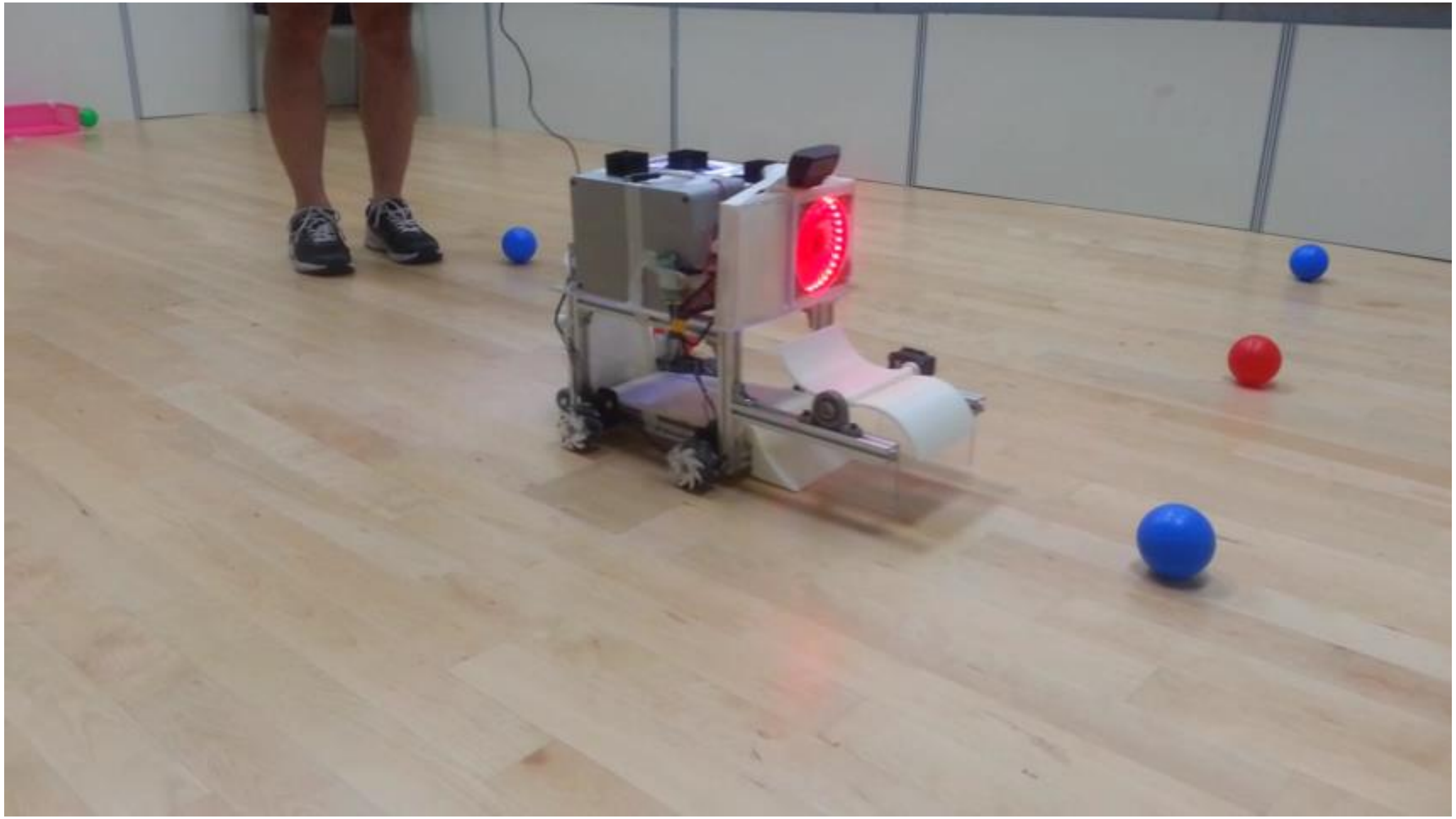




Cost is important in engineering
!

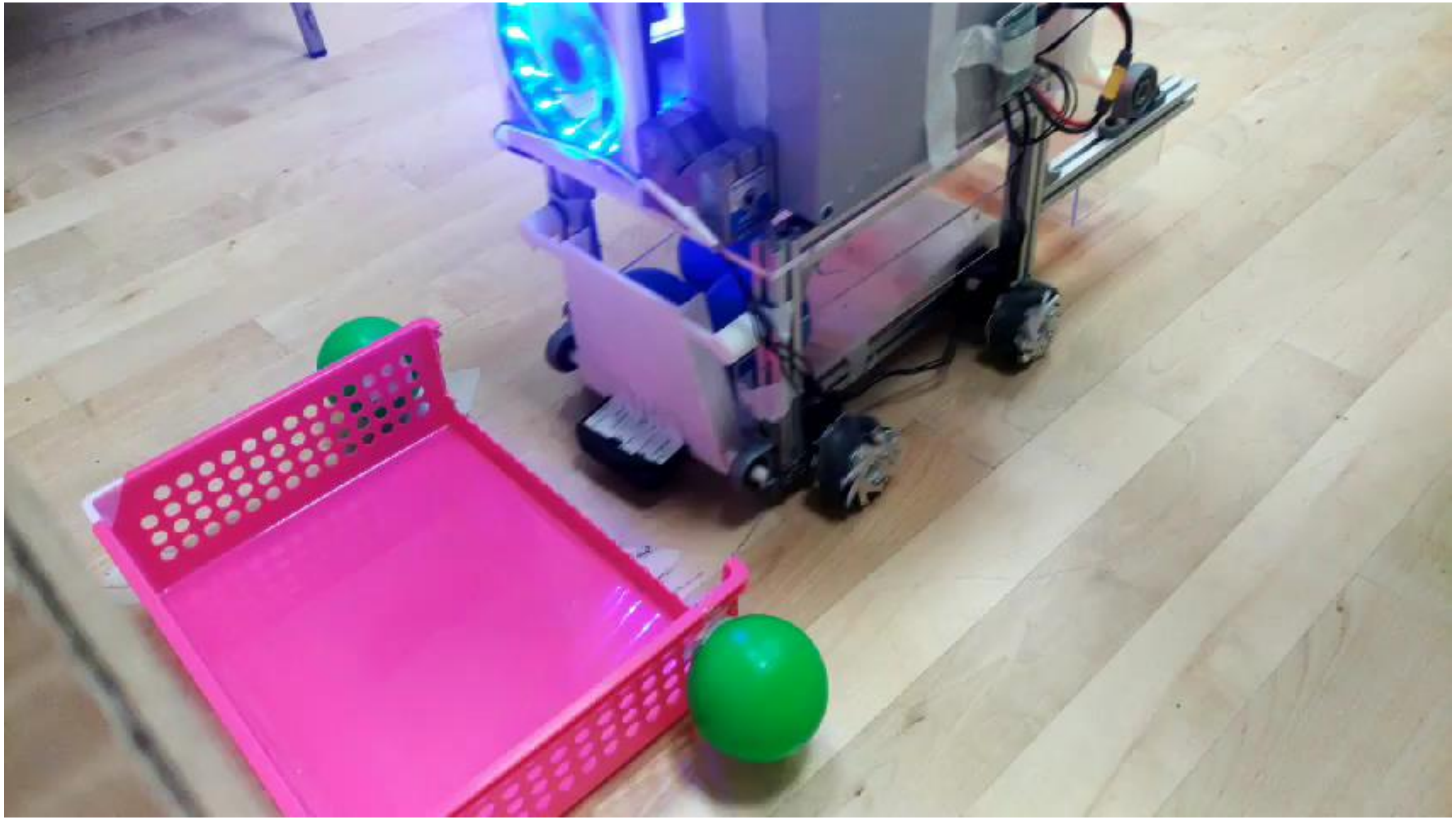
Pick-Up System

Ball pick-up



Pick-Up System

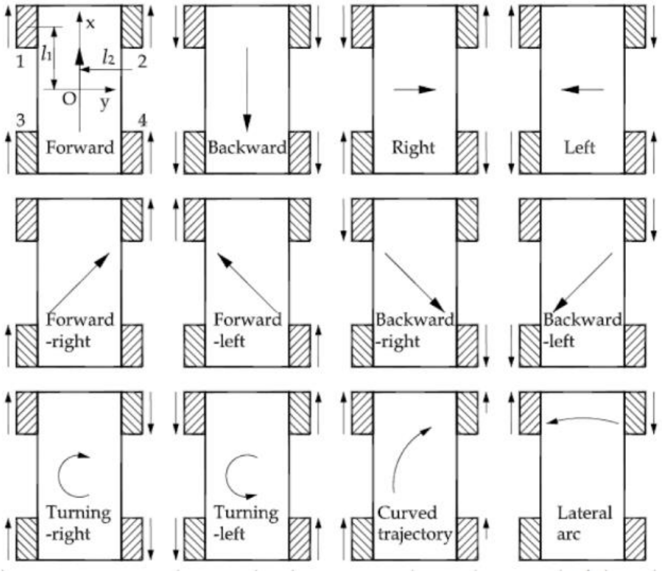
Ball release



3. MOTOR CONTROL

Motor Control

Wheel Kinematics



$$\begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix} = \frac{R}{4} \begin{bmatrix} 1 & 1 & 1 & 1 \\ 1 & -1 & -1 & 1 \\ -\frac{1}{l_1+l_2} & \frac{1}{l_1+l_2} & -\frac{1}{l_1+l_2} & \frac{1}{l_1+l_2} \end{bmatrix} \cdot \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} \Rightarrow \begin{bmatrix} \omega_1 \\ \omega_2 \\ \omega_3 \\ \omega_4 \end{bmatrix} = \frac{1}{R} \begin{bmatrix} 1 & 1 & -(l_1+l_2) \\ 1 & -1 & l_1+l_2 \\ 1 & -1 & -(l_1+l_2) \\ 1 & 1 & l_1+l_2 \end{bmatrix} \cdot \begin{bmatrix} v_x \\ v_y \\ \omega_z \end{bmatrix}$$

By using wheel kinematics…

- Accurate control is available.
- Green ball location can be estimated.

Motor Control

How to reduce vibration?

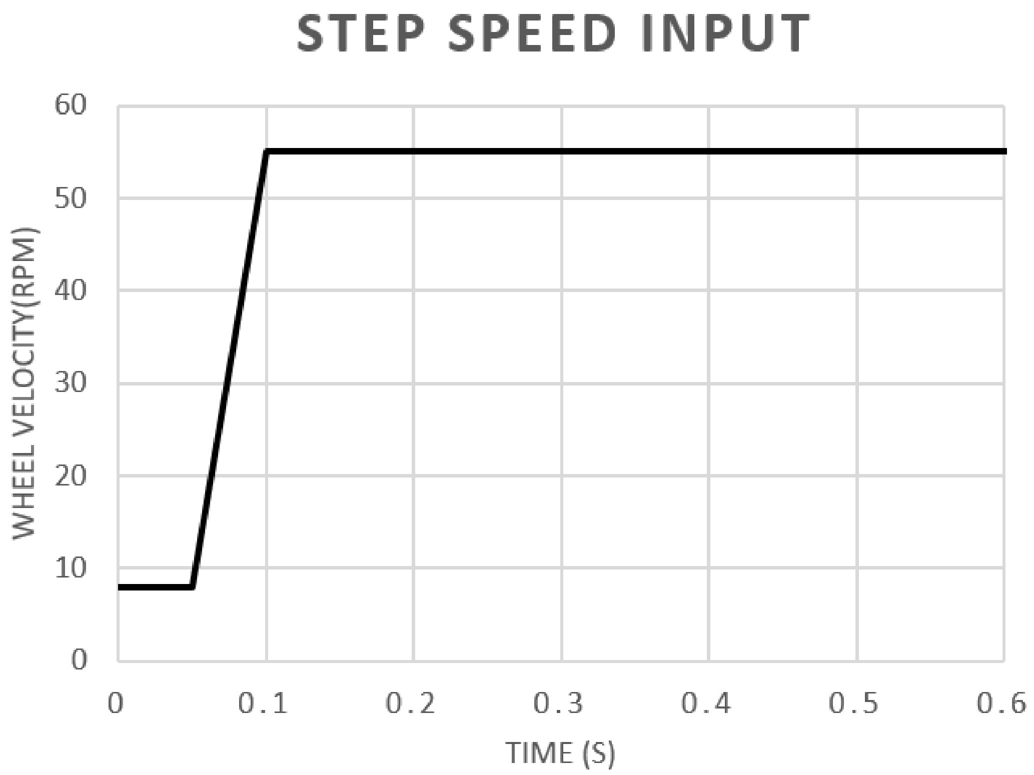
Reference filtering → Motor control (Software)

Vibration reduction

Vibration isolator → Vibration control (Hardware)

Motor Control

Vibration reduction using software



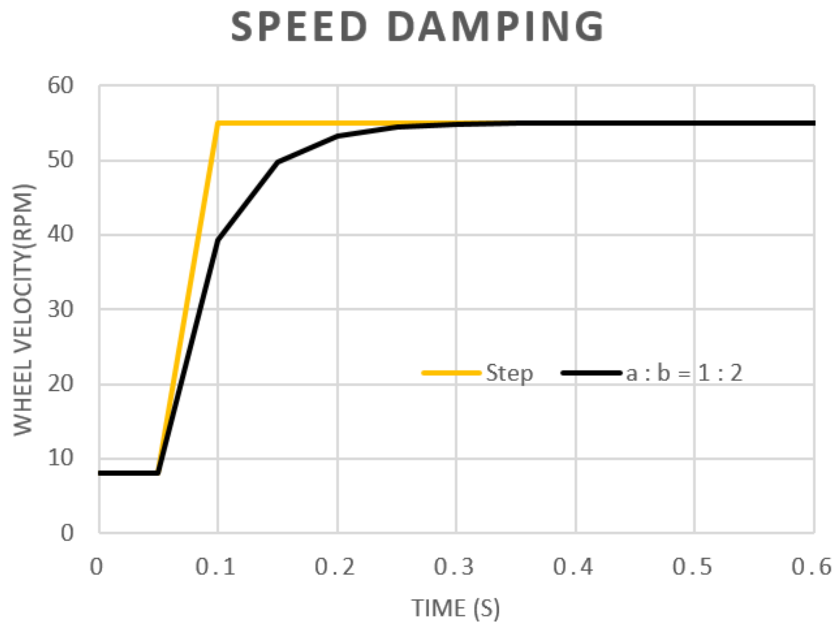
Problems of step function

- **Sudden acceleration and braking** induce vibration can damage motors.
- **Rotation** in place was **not operated well** because of webcam delay and low rpm.

→ Motor input should be modified.

Motor Control

Vibration reduction using software



Solution

- In each loops, the mean values of **previous and present storage variables** are used to calculate what is required in the next step
- We fixed the degree of damping for rotation as 1:2.

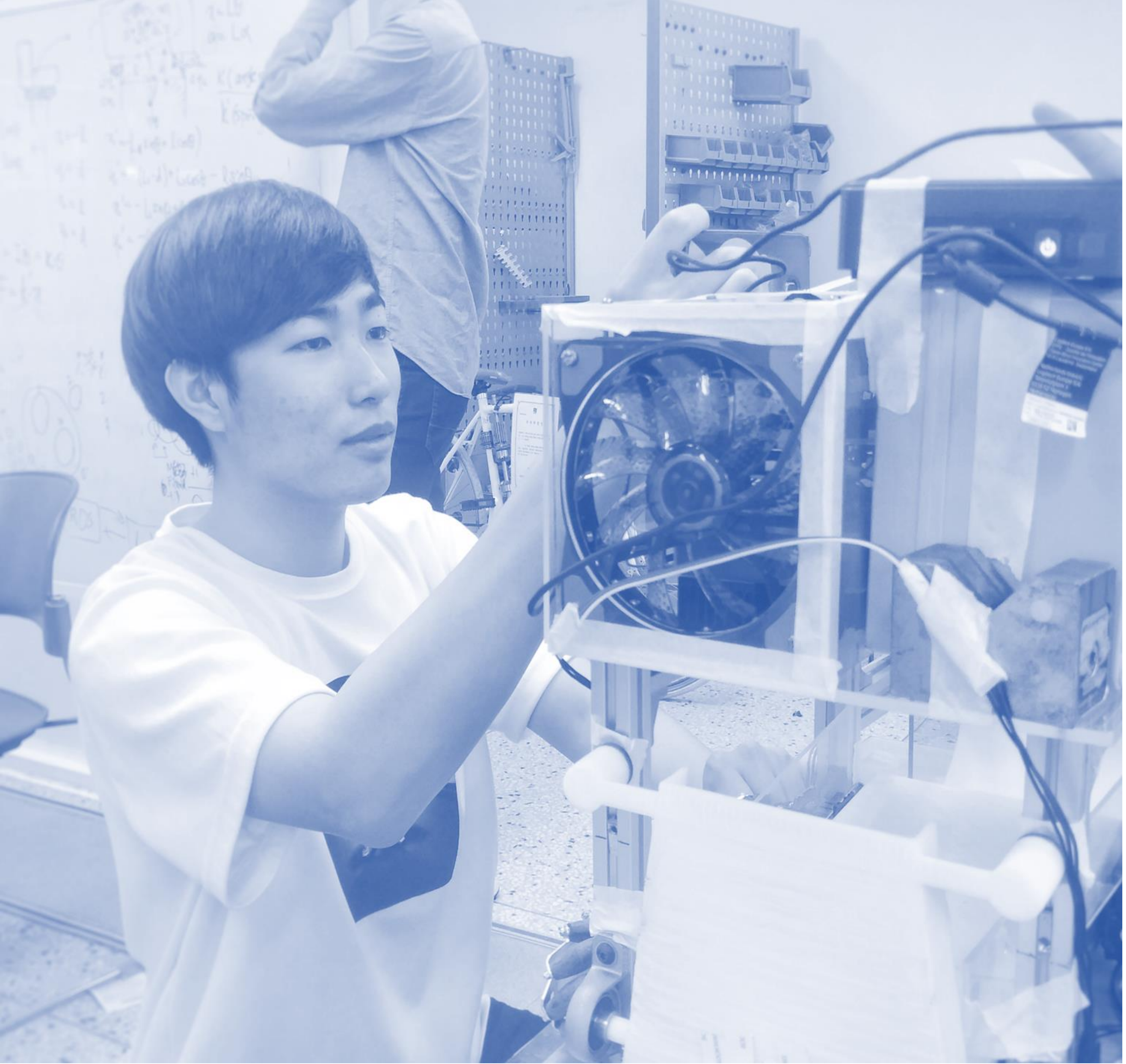
$$T = n\tau = 2(s), n = 40 \gg \tau = 0.05 \gg H = \frac{1}{\tau s + 1}$$

By Z transform, $\frac{Y}{U} = \frac{0.6321}{z - 0.3679}$, $(1 - 0.3679z^{-1})Y = 0.6321z^{-1}U$

$$y(n) - 0.3679y(n-1) = 0.6321u(n-1)$$

$$\therefore y(n) = 0.3679y(n-1) + 0.6321u(n) \simeq \frac{y(n-1) + 2u(n)}{3}$$

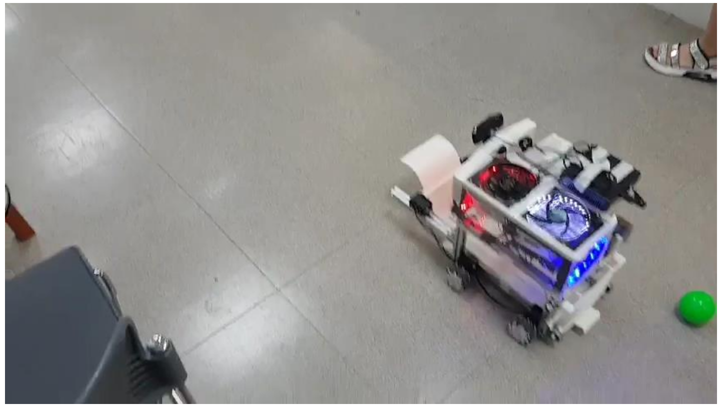
Act as low-pass filter : Reference filtering

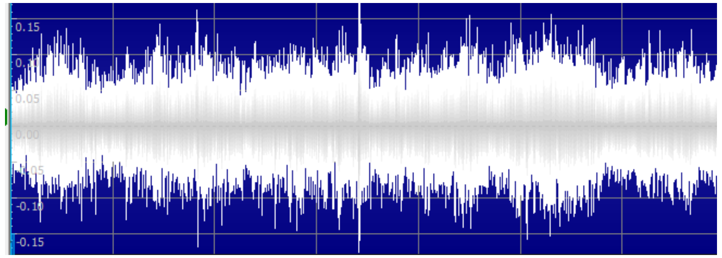


4. VIBRATION CONTROL

Vibration Control

Cause of vibration





$$f_{ex} = 7.159Hz$$

$$\omega_{f,ex} = 2\pi f_{ex} = 2\pi \times 7.159Hz = 44.981rad/s$$

$$\omega_{f,the} = 2\pi f = 2\pi n \omega_{wheel}$$

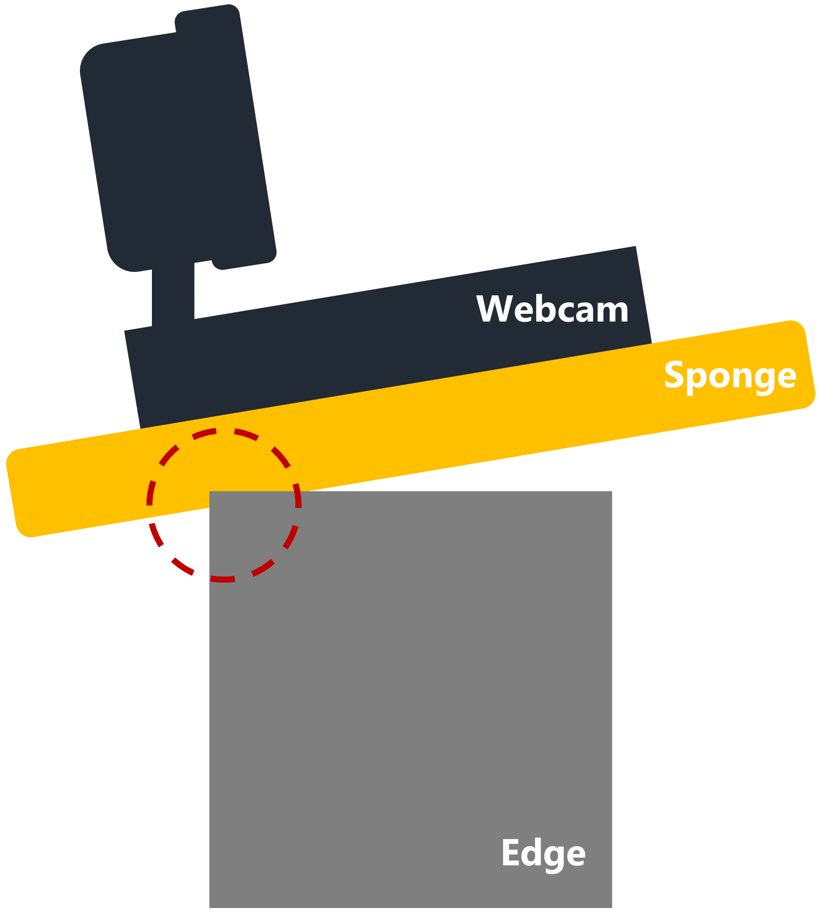
$$= 2\pi \times 8 \times (55rpm/60\sec) = 46.077rad/s$$

∴ Excitation by Mechanum Wheel

$$\omega_f = 46.077rad/s$$

Vibration Control

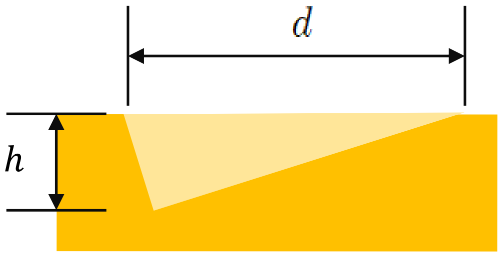
Vibration system design



Sudden acceleration

Sponge's Material property

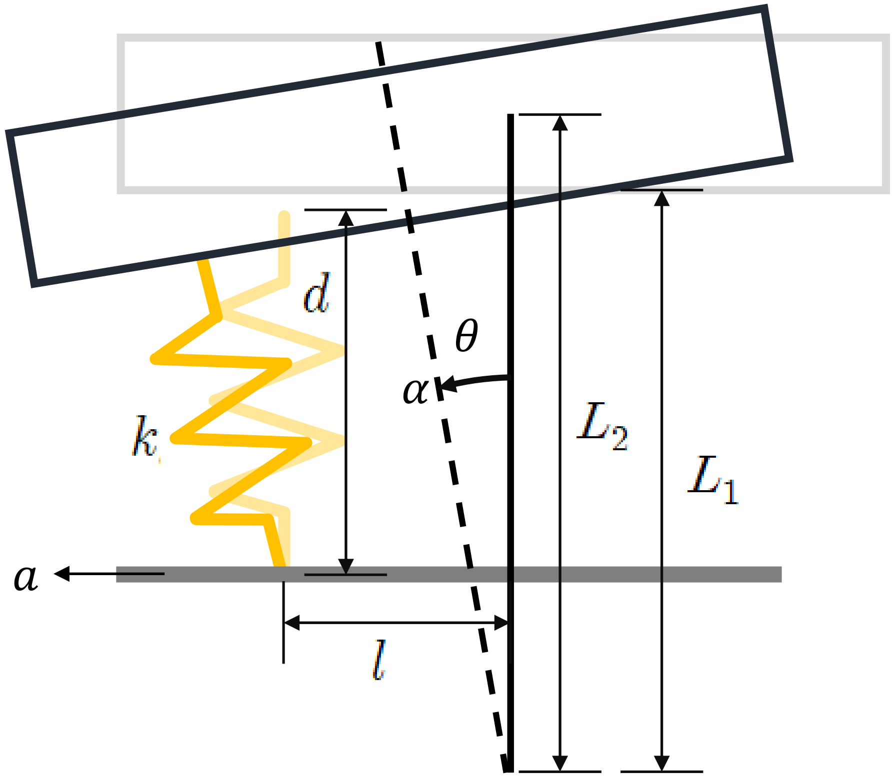
$$k_{sponge} = \frac{F}{\Delta x} = \frac{0.82kg \times 9.8m/s^2}{0.5mm} = 1.607 \times 10^4 N/m$$



$$k = k_{sponge} \times \frac{dh/2}{\pi D^2 h/4} = 247.421 N/m$$

Vibration Control

Vibration system modeling



$$\alpha = L_2 a$$

$$x = -l$$

$$x' = -L_1 \sin\theta - l\cos\theta$$

$$y = d$$

$$y' = -L_1(1-\cos\theta) + d - l\sin\theta$$

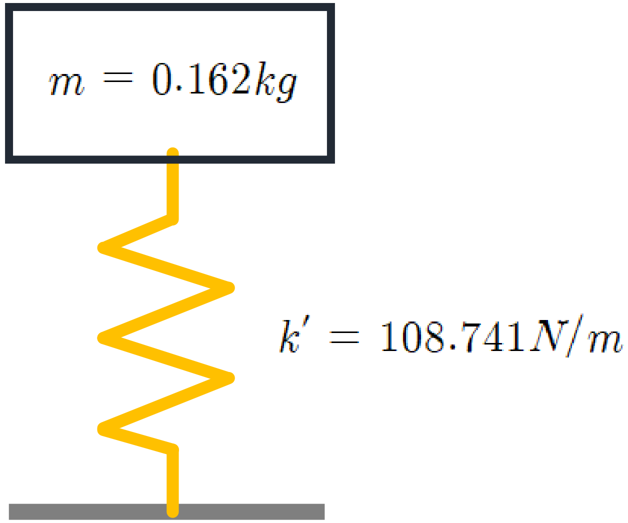
$$\triangle x = x - x'$$

$$\triangle y = y - y'$$

$$m L_2^2 \ddot{\theta} = -k\left(\sqrt{\triangle x^2 + \triangle y^2}\right) l\cos\theta$$

$$\therefore\ m\ddot{\theta} = -k'\theta$$

$$k' = 108.741 N/m$$



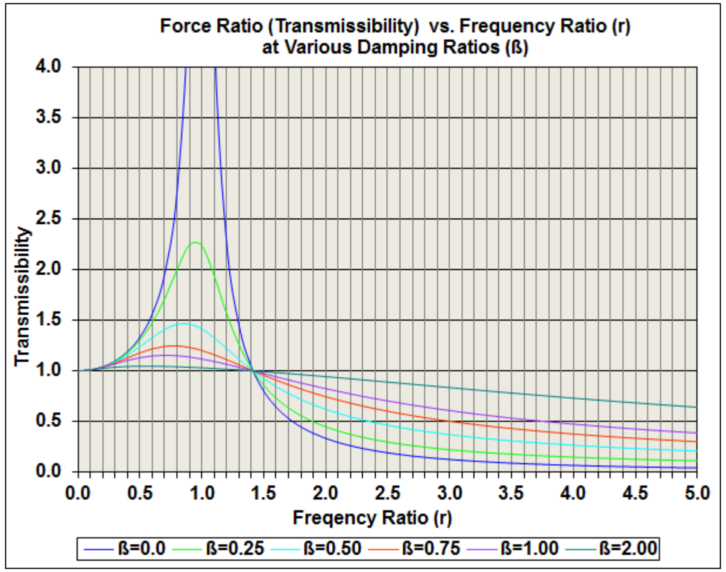
$$\omega_n = \sqrt{\frac{k'}{m}} = 25.908 rad/s$$

Vibration Control

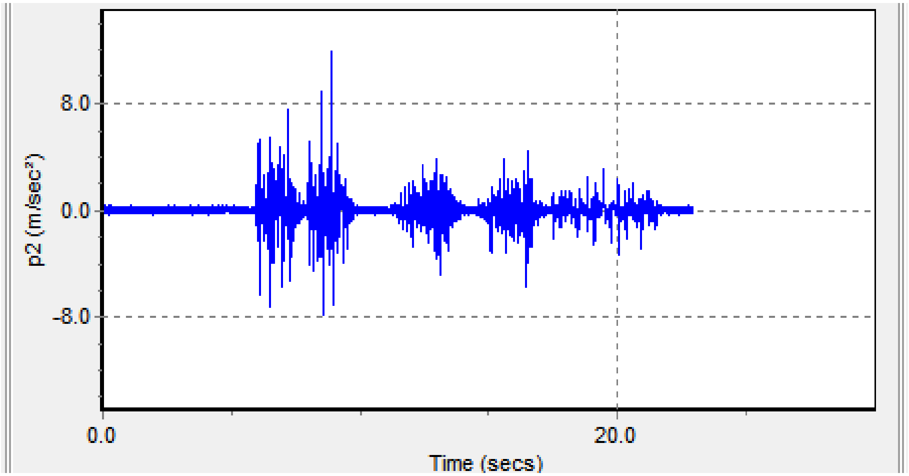
Reducing hardware vibration

$$\omega_n = \sqrt{\frac{k'}{m}} = 25.908 rad/s$$

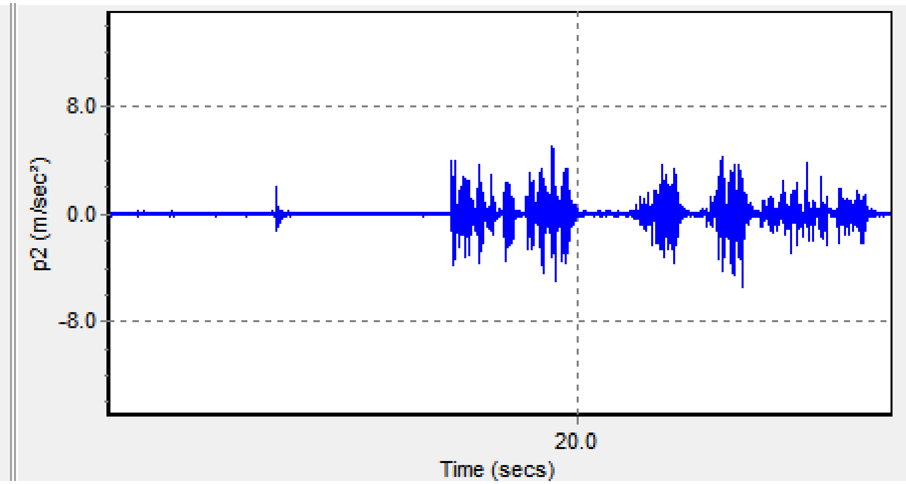
$$r = \frac{\omega_f}{\omega_n} = \frac{46.077 rad/s}{25.908 rad/s} = 1.778$$



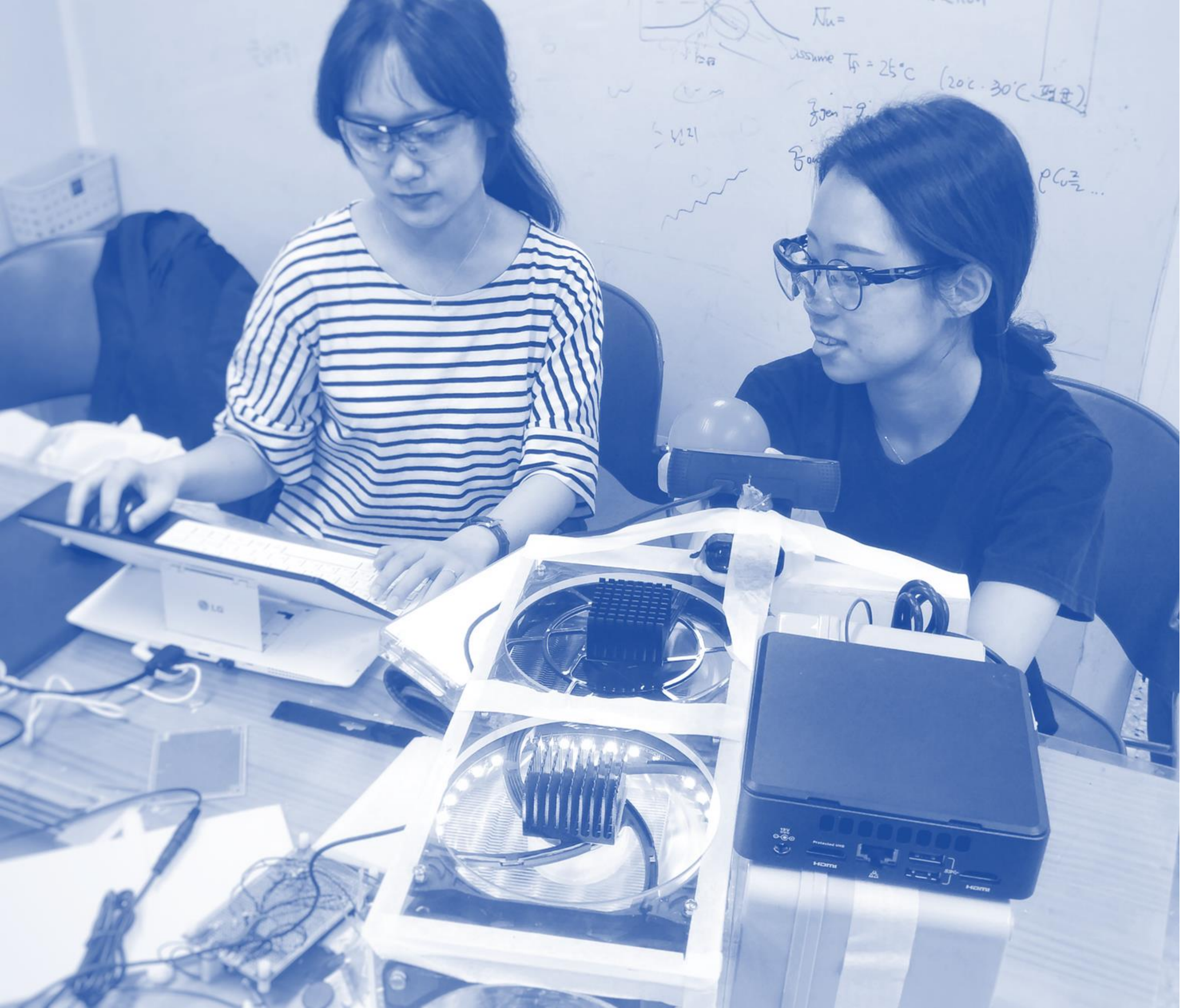
$$\therefore \text{Transmissibility} \simeq 0.5$$



Cam&Car directly attached



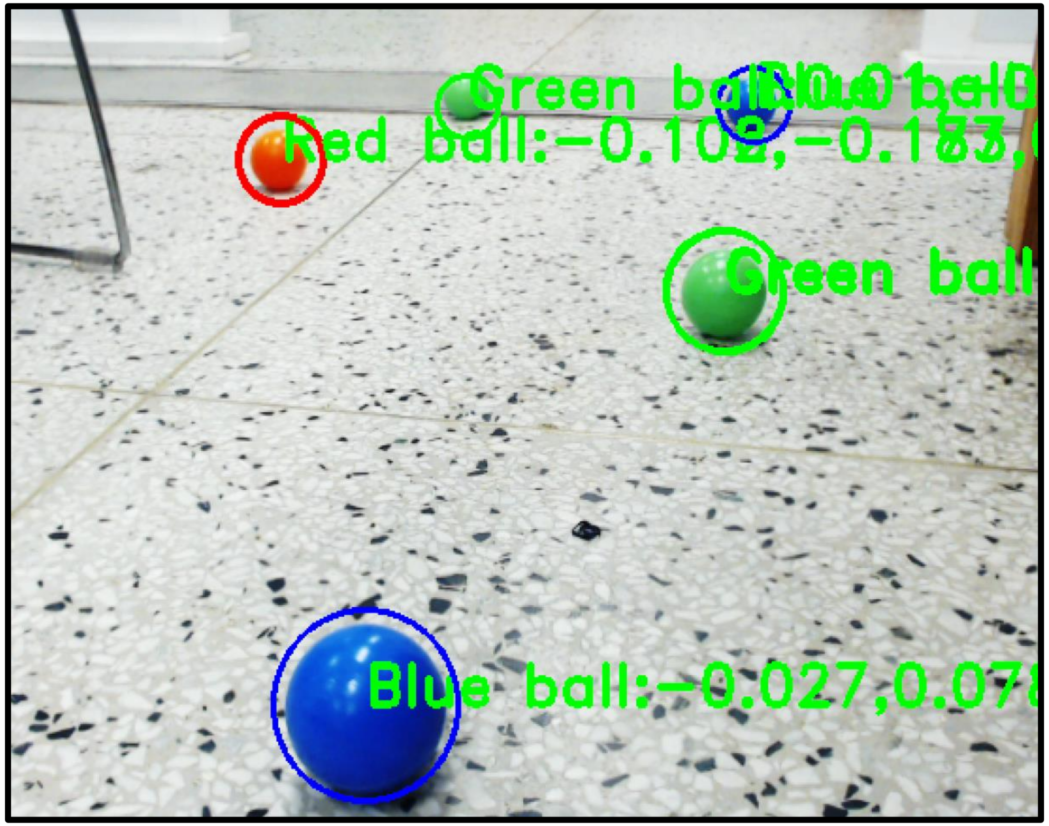
Cam-Sponge-Car attached



5. VISION & ROS ALGORITHM

VISION & ROS

Vision processing modification



Actual recognition(in Capstone room)

Actual recognition(in Lecture room)

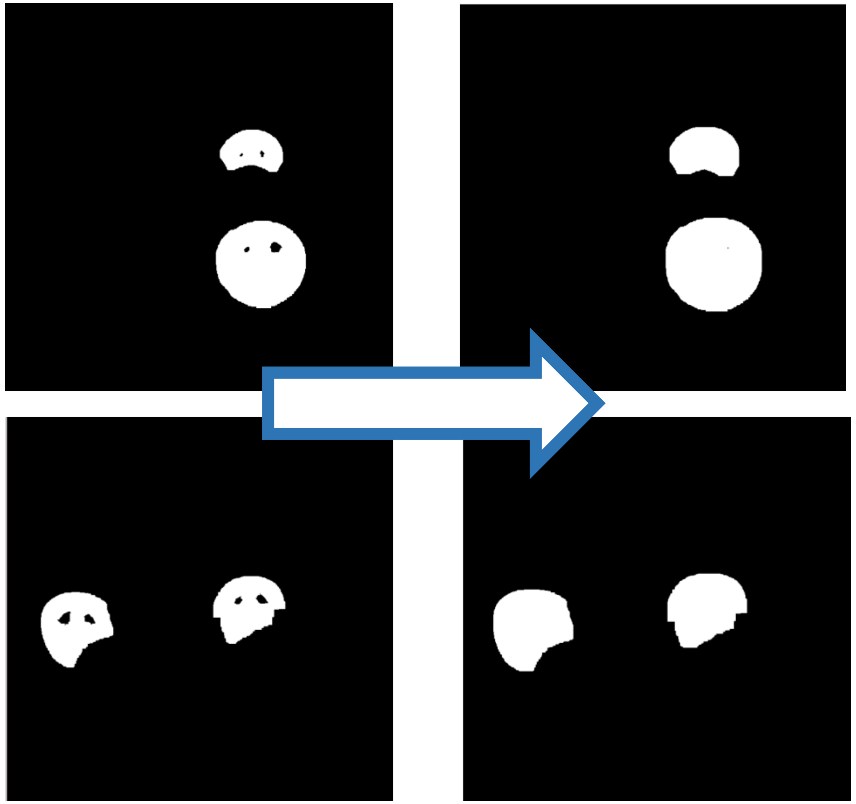
VISION & ROS

Vision processing modification

Problem #1 : Imperfect ball detection

Solution : Dilate image through morphological process (**widen white area**) & Adjust the tolerance

Vision processing modification



Blue ball

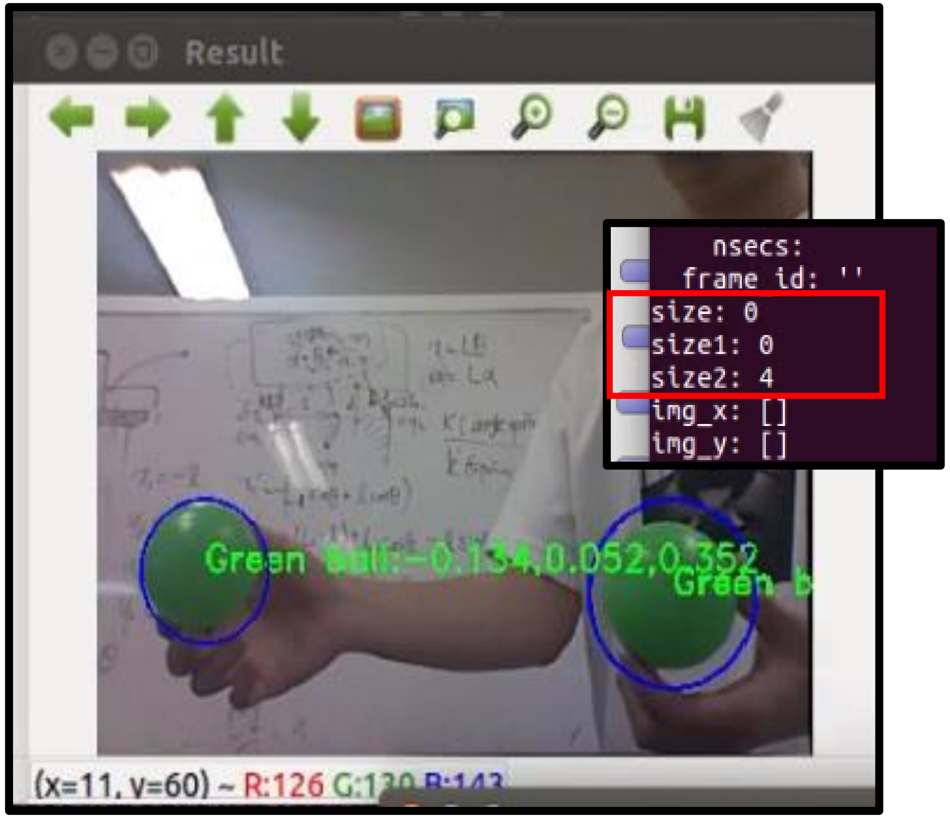
Red ball

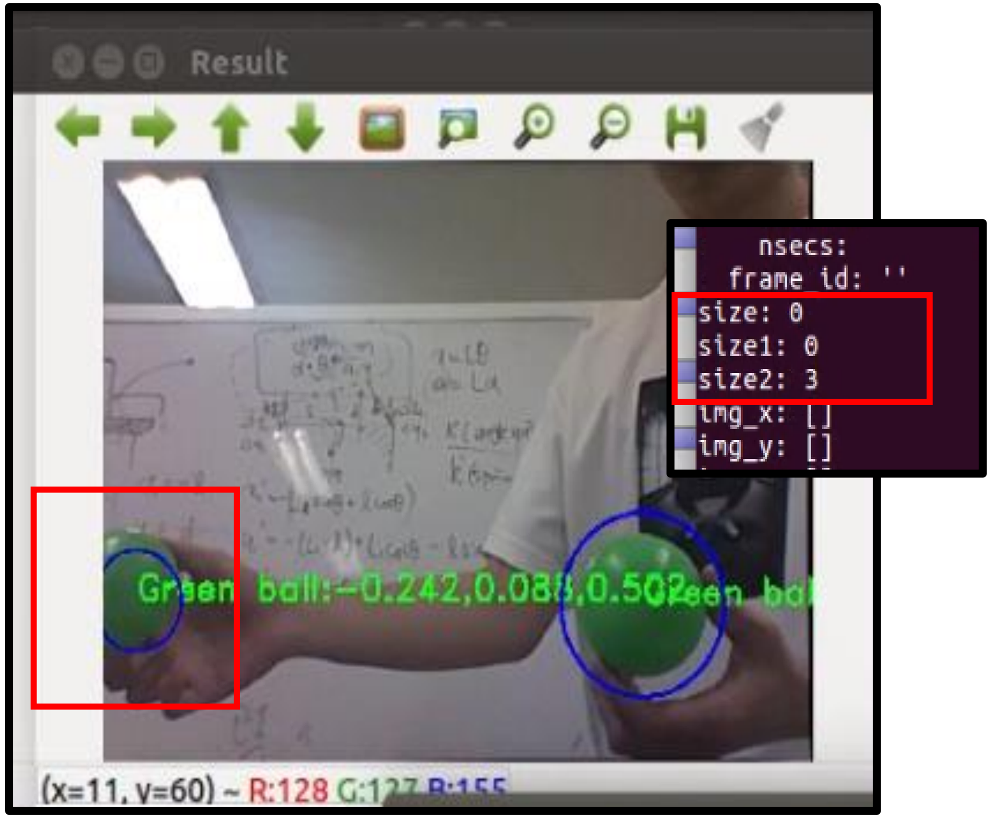
VISION & ROS

Vision processing modification

Problem #2 : **Overlapped counting** by contour (Recognize a ball as **two** different balls)

Solution : **Utilize** this problem to **distinguish a cropped ball** from distant ball





VISION & ROS

ROS

- ROS integration (2nd design review)

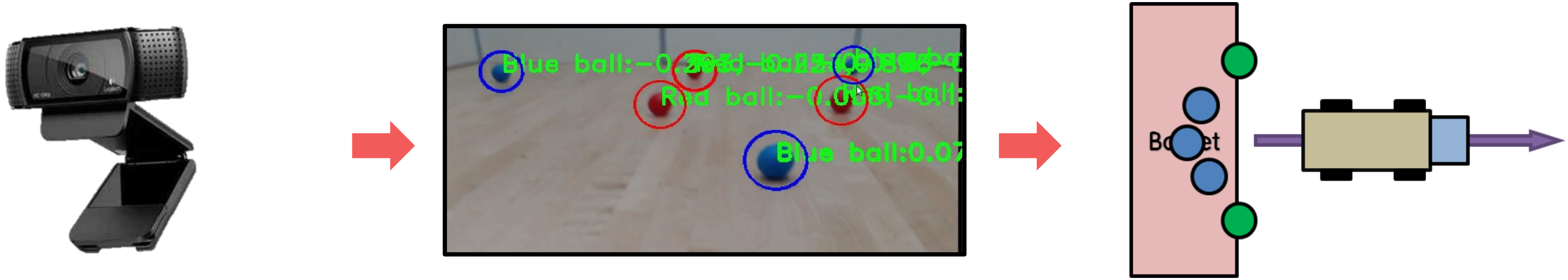


Image publisher → Image data → Ball detect → position → Path plan & Picking balls

- Path planning (Final design review)

VISION & ROS

ROS

2nd design review comments

1. Low maturity of pick-up algorithm
2. Inefficiency in the red ball avoidance

Improvements

1. Smooth movement by using damping
2. Double-checking of remain blue ball
3. Accurate combat(reverse) parking

Rightmost first(our algorithm)

Closest first

SUMMARY

Strengths of IKOH

6. SUMMARY

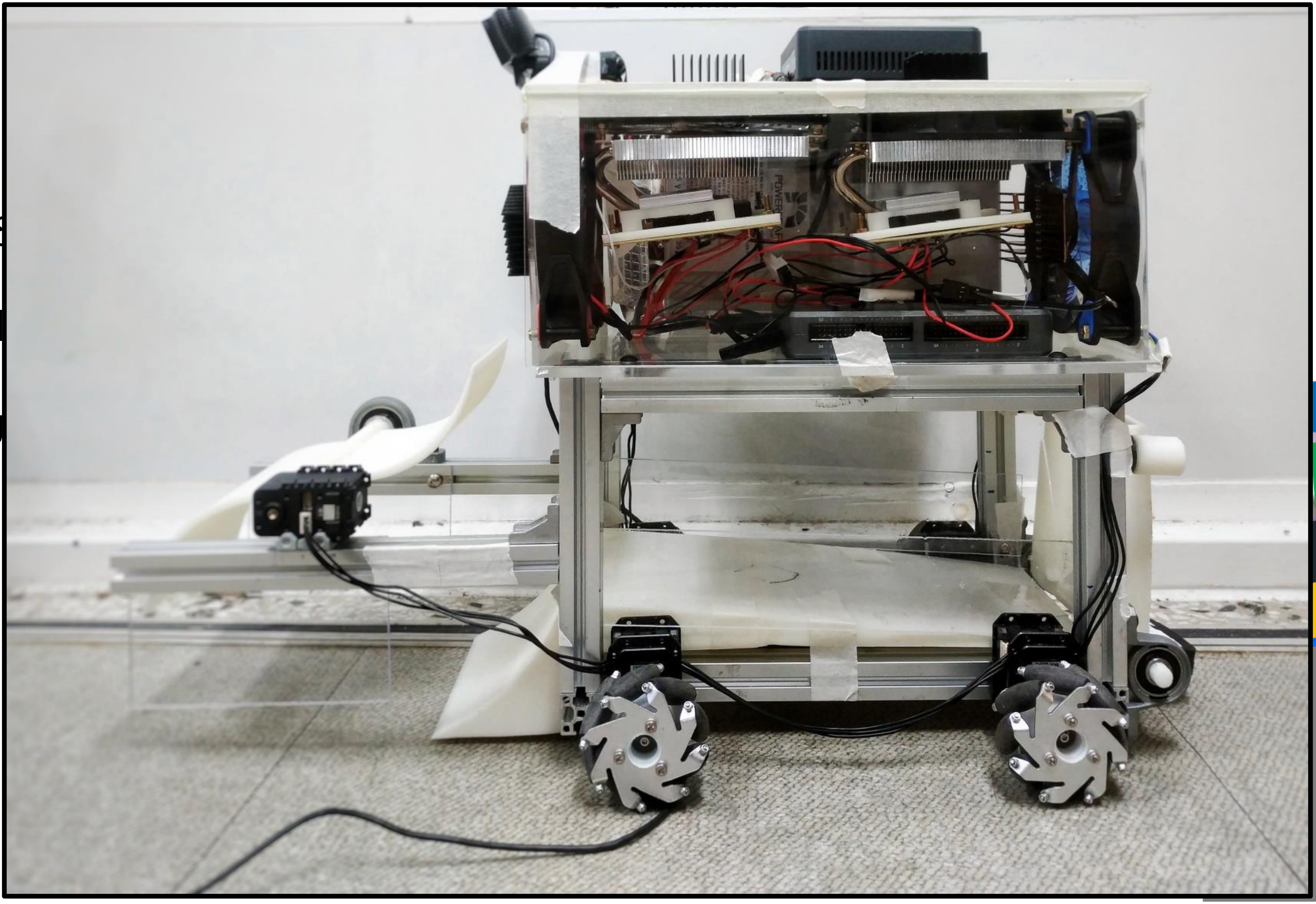
Heat Transfer :

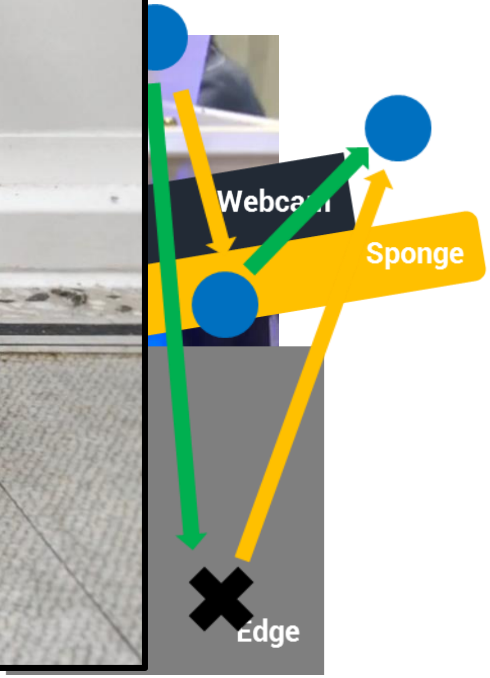
Pick-Up System

Motor Control

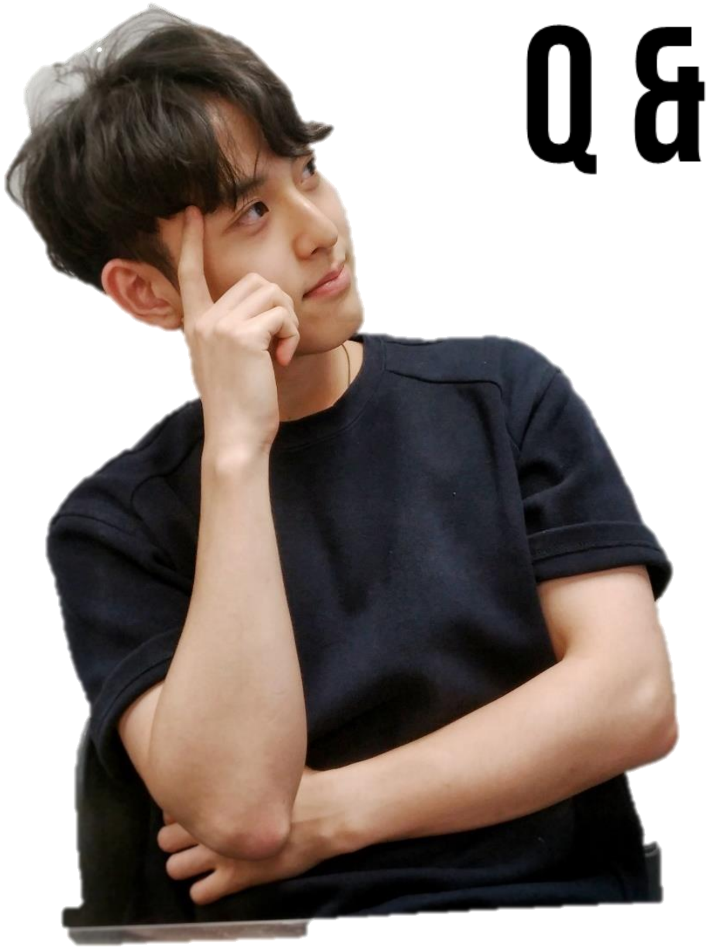
Vision + ROS A

Attractive Desig





THANK YOU



Q & A