Team Double Decker

Capstone Design 2

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Team member : Jeongsu Park, SangWon Yoon, DuckYoung Kim,
Won Choi, SeongWoong Hong, Cheol Sagong

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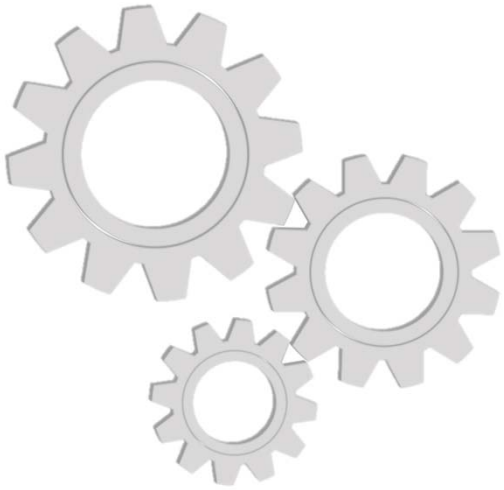
Contents

System Key Feature



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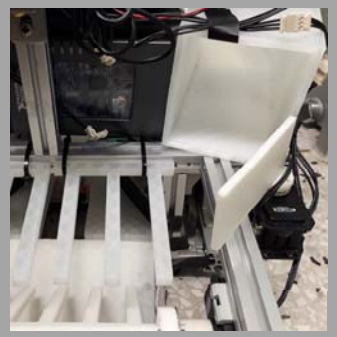
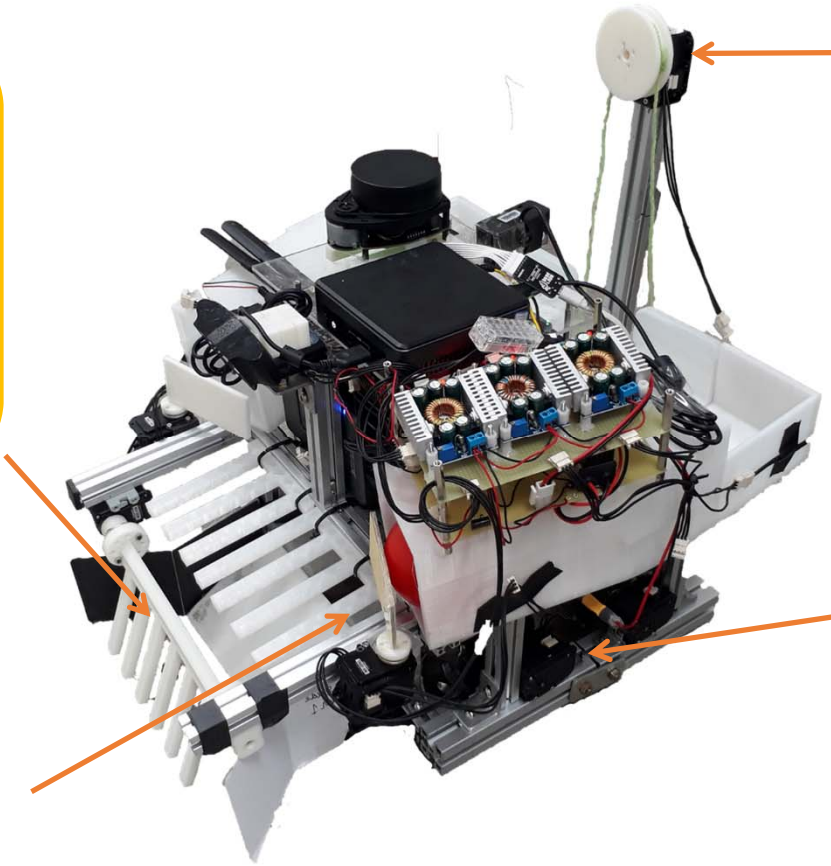
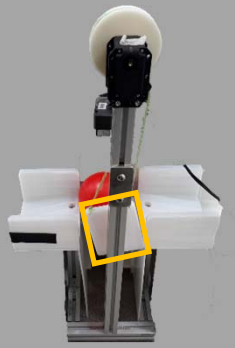
System Key Features

Roller & Frontal slide
Comb shape



Door + Guide





Elevator system

Gear System

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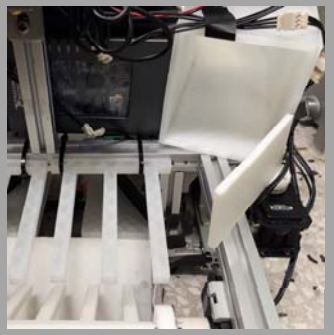
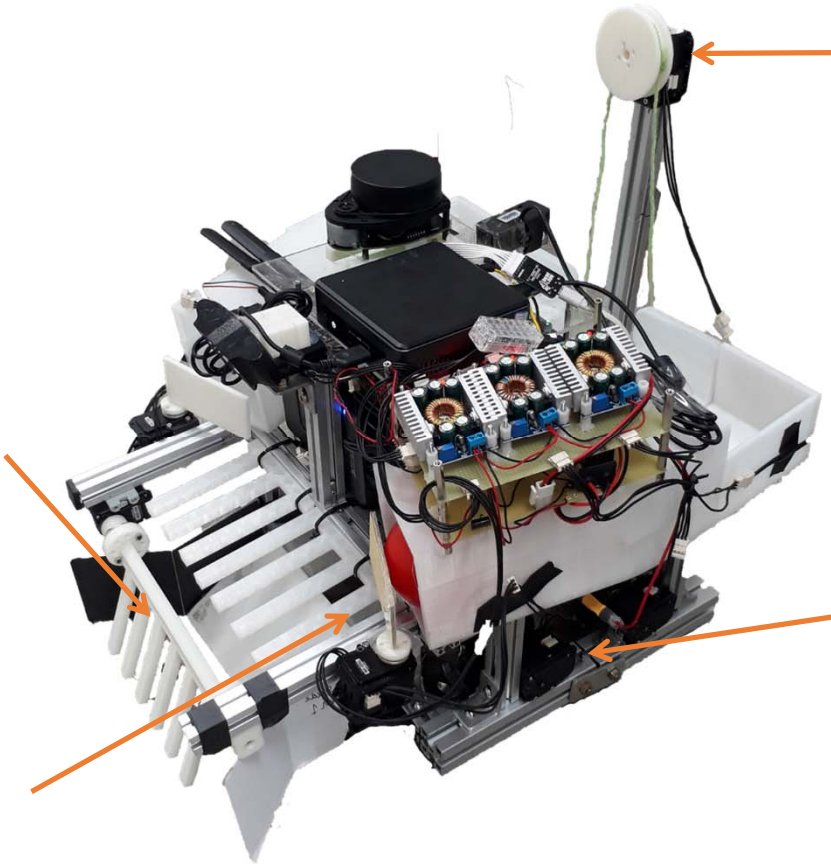
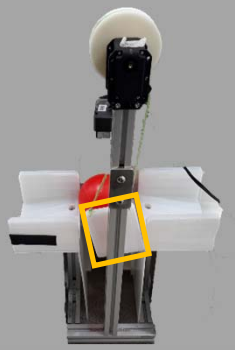
System Key Features

Roller & Frontal slide
Comb shape



Door + Guide





Elevator system

Gear System

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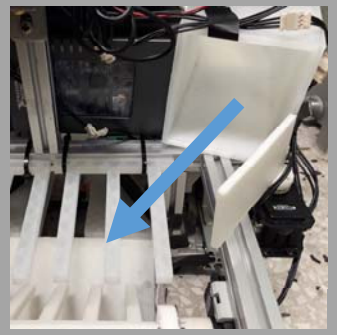
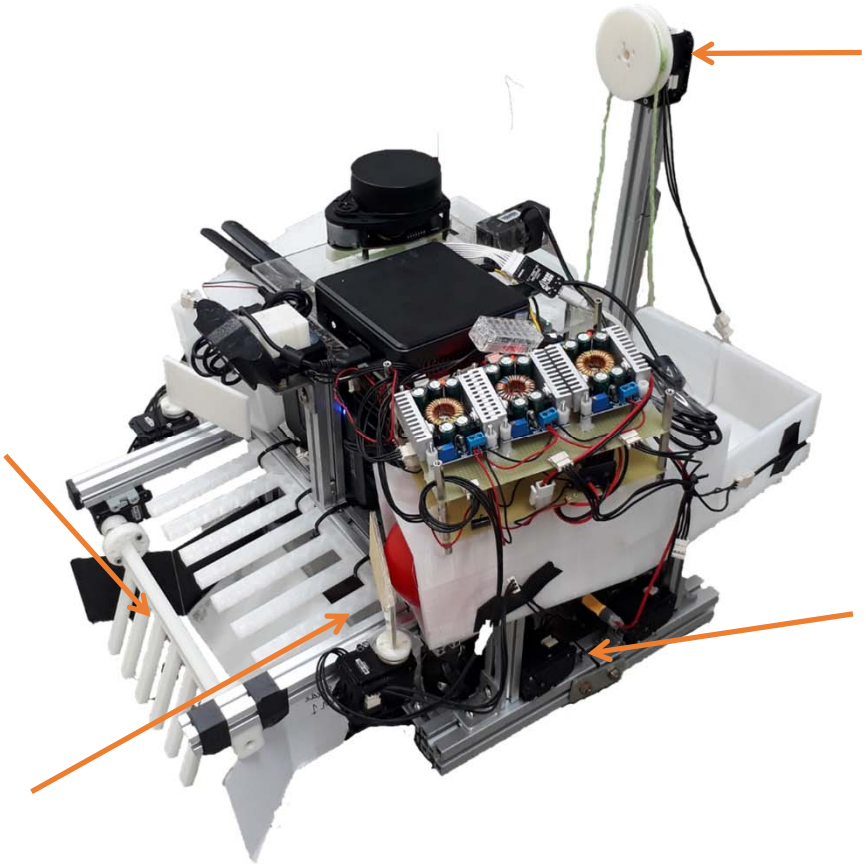
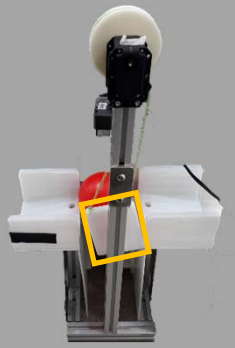
System Key Features

Roller & Frontal slide
Comb shape



Door + Guide





Elevator system

Gear System

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System Key Features

Roller & Frontal slide
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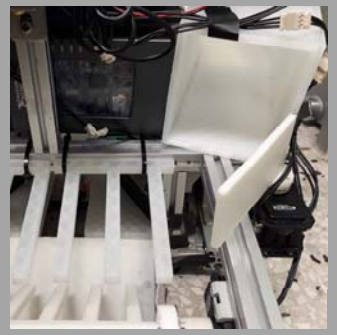
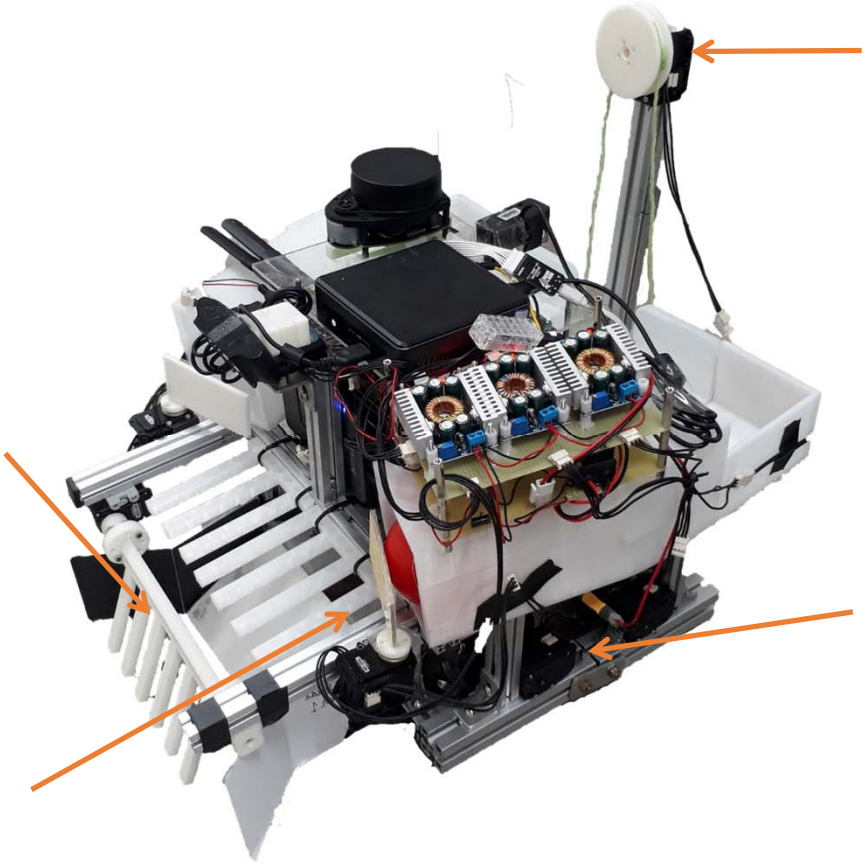
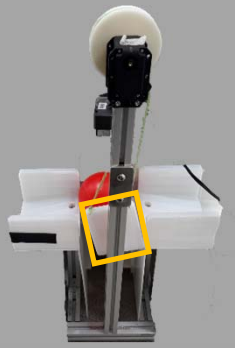


Door + Guide





Elevator system

Gear System

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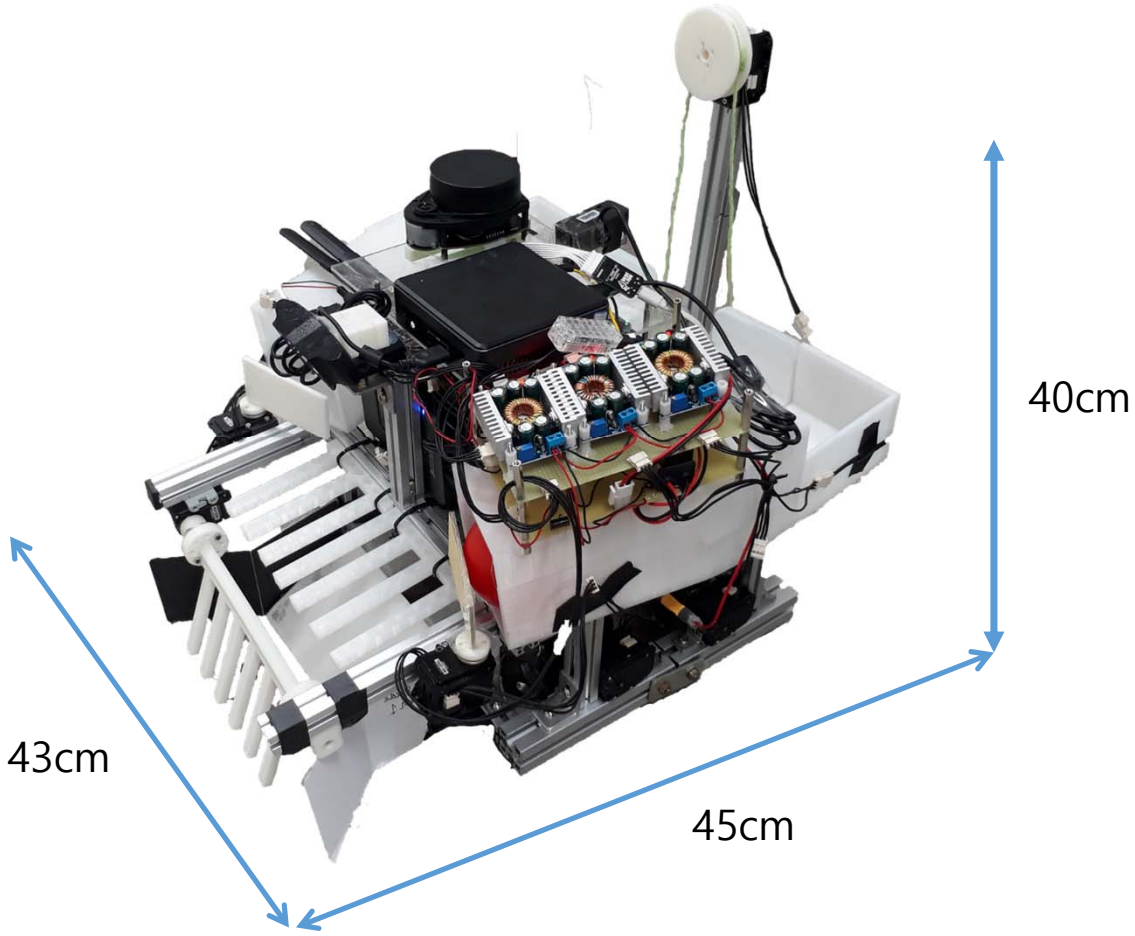
System Dimension

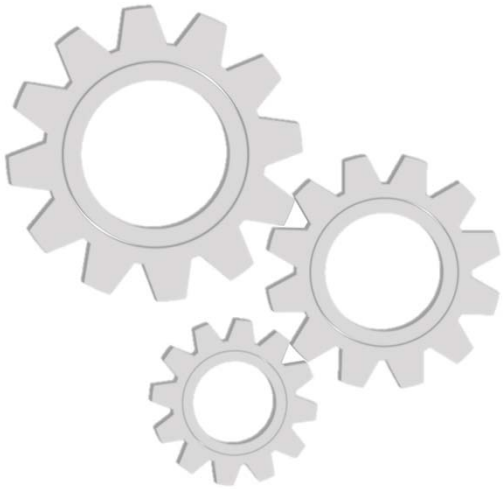
$m = 12.6kg$

$V_{max} = 45cm/s$

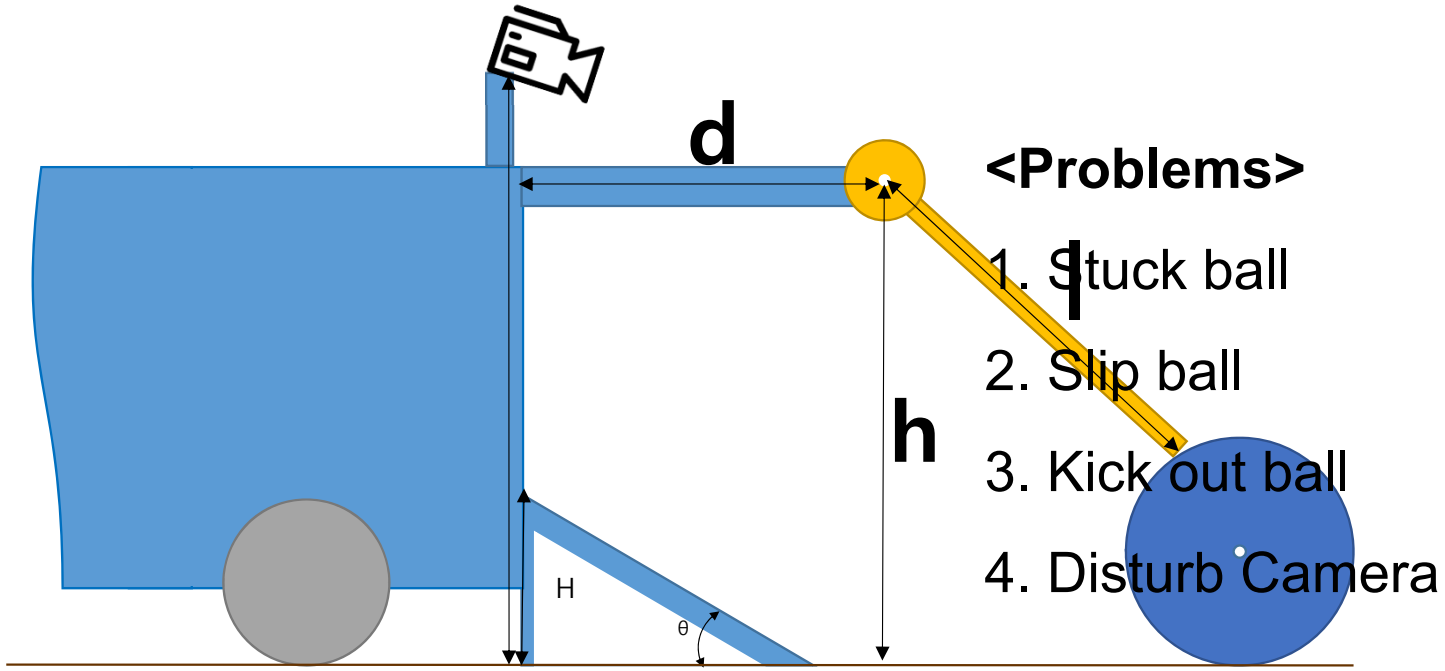


Hardware 1

Roller

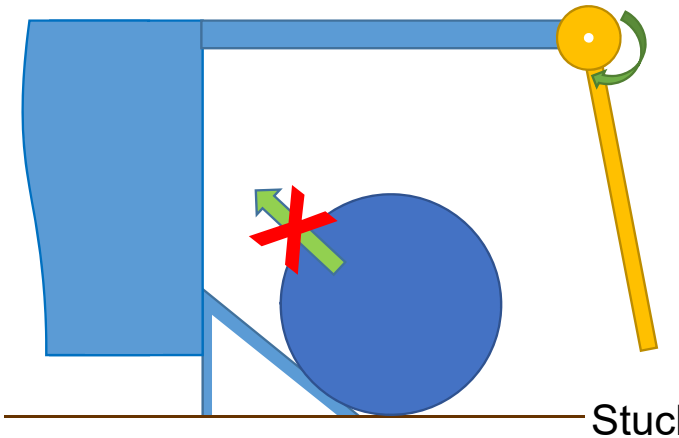


Roller Design



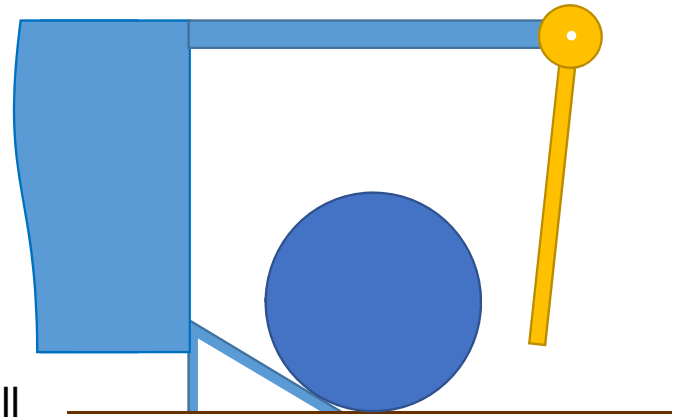
Optimize Roller Dimension!

Roller – Problems



Stuck ball

1

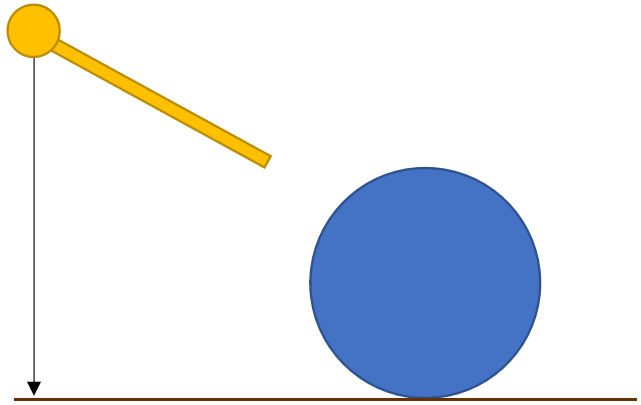


2

Slip ball

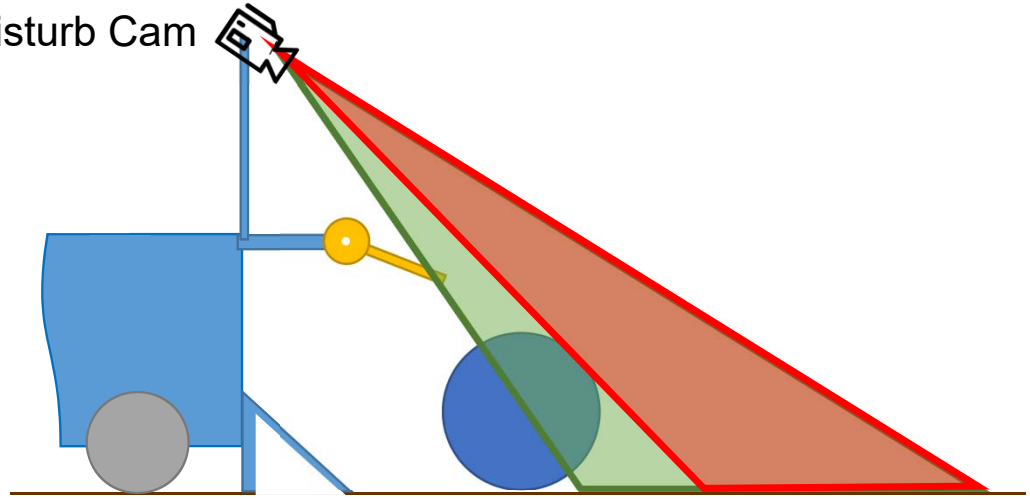
Kick out ball

3



4

Disturb Cam



Roller - Solutions

1. Sweep Up Condition

Objective : sweep force $F_x > 0$

$\sum F_x > 0$ when $l > h - r$

2. Ball Enter Condition

Objective : ball should get into the storage

$$l \geq \sqrt{(h - H - r)^2 + d^2} - r$$

3. Roller sweep

Minimize $D_1 - D_2$

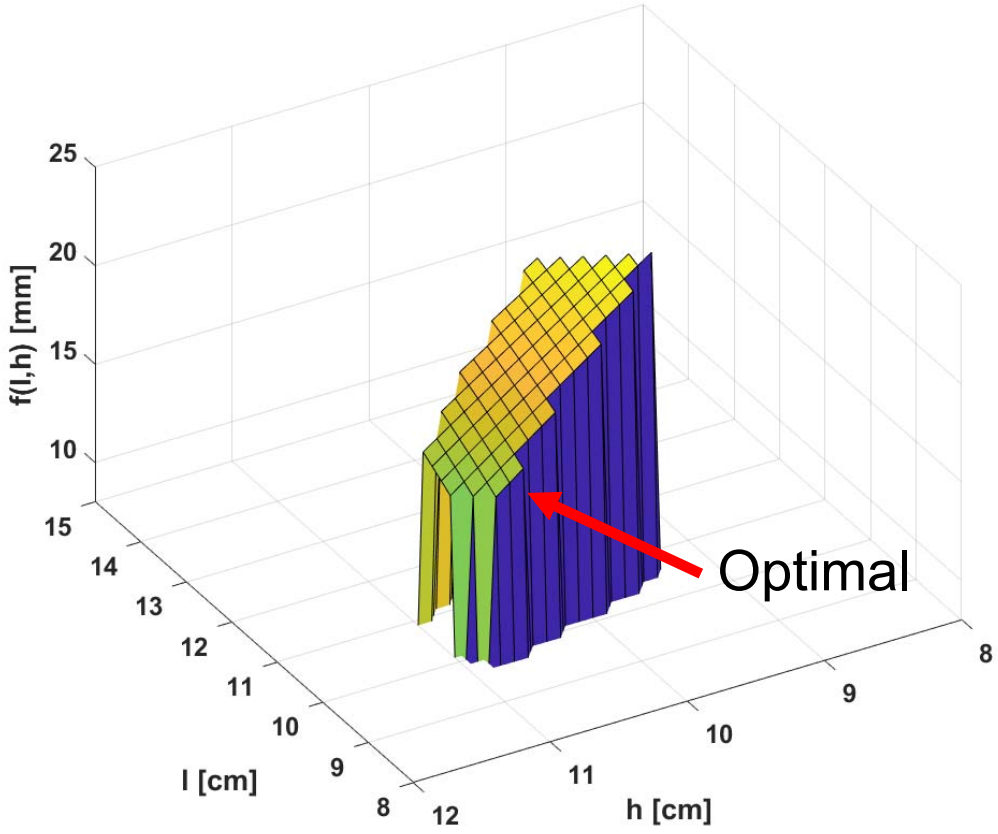
Numercial Analysis – MonteCarlo Simulation

4. Detecting Range Condition

Objective : $D_{max} \geq 3\sqrt{2}$ & minimize D_{min}

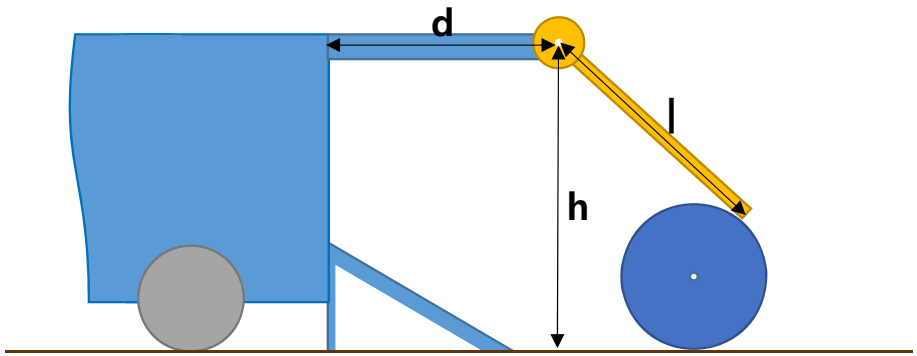
$$sin^{-1}\left(\frac{l}{\sqrt{(d - 6cm)^2 + (H_c - h)^2}}\right) + tan^{-1}\left(\frac{l}{H_c - h}\right) = 42°$$

Roller – Optimized Dimension



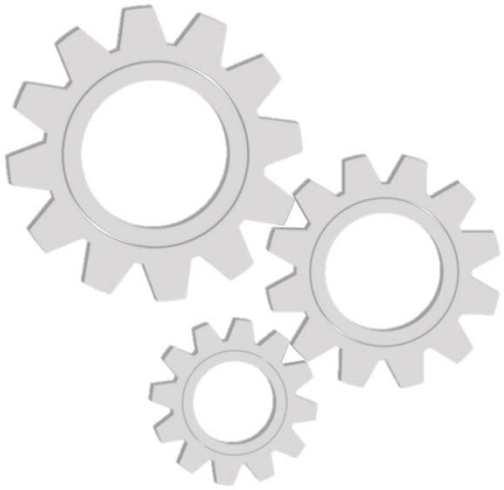
f(l,h) = Kick out range

➔ h=14cm, l=10.2cm d=12cm



Hardware 2

Elevator



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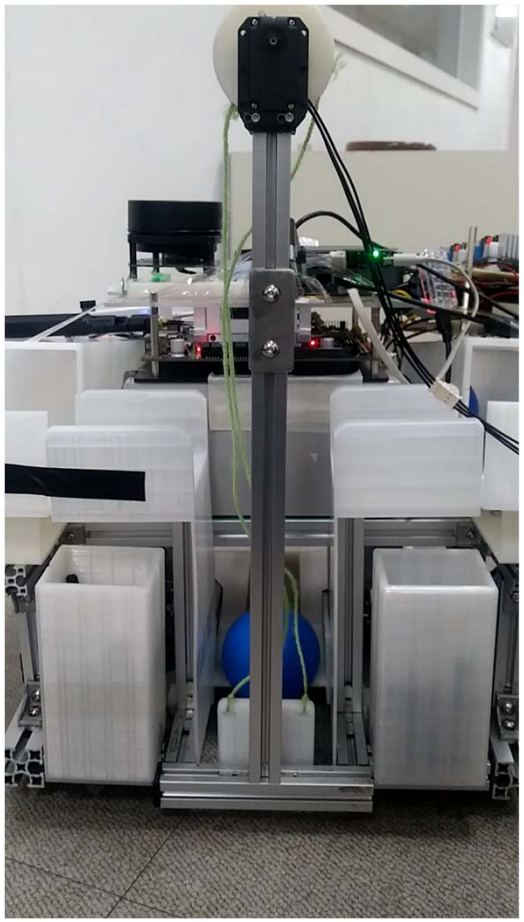
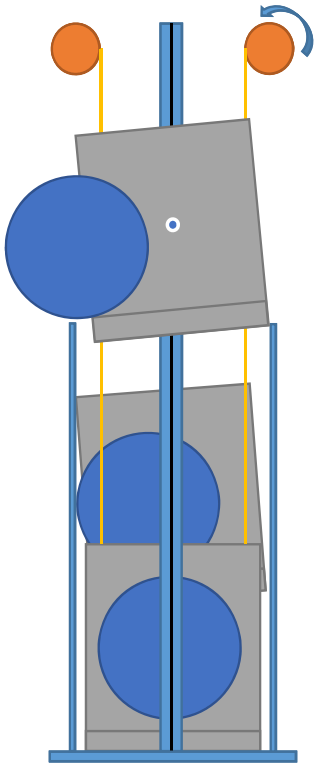
Elevator system



Elevator system



<Blue ball enters>

<Contradiction>

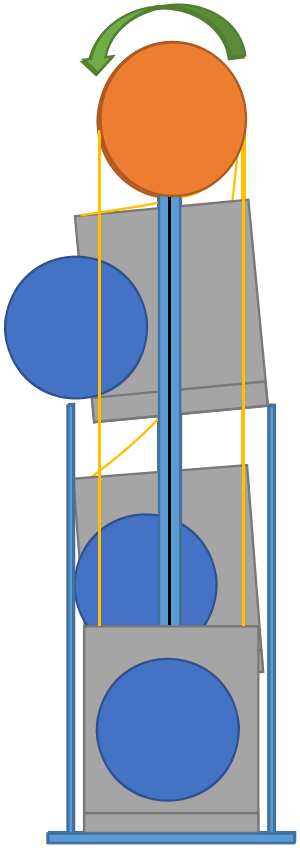
The number of motors
needs to be reduced(10)

↕

Control complexity increases(46)

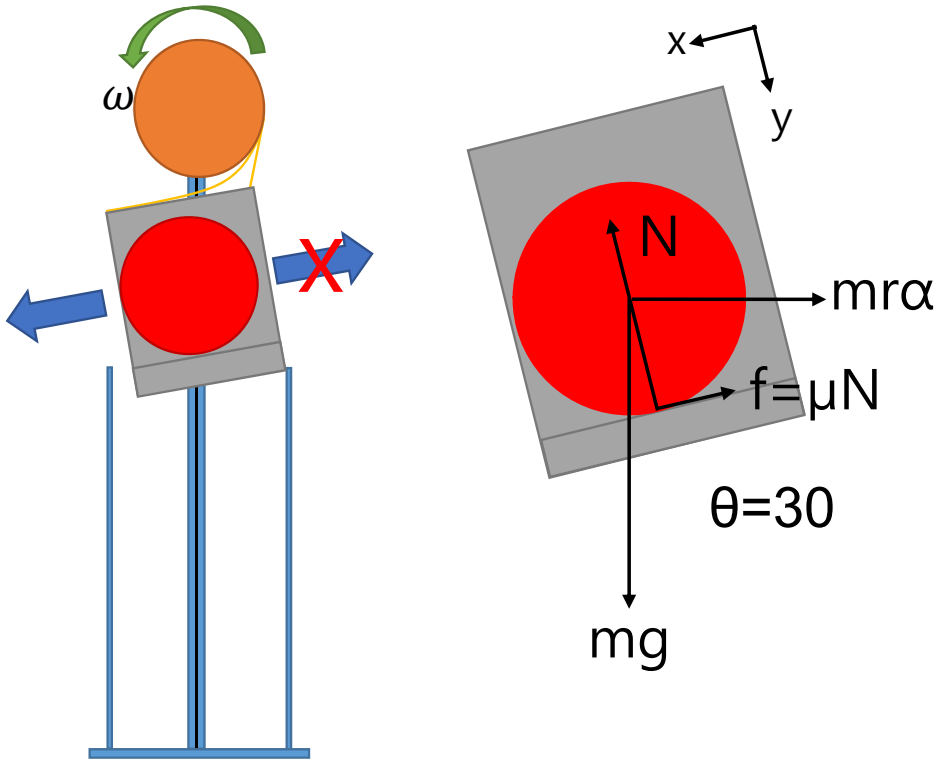
Mechanics substitution(28)

➔**1 motor, 2 functions**



<Blue ball enters>

Elevator Safety



100% secure to Separate

$$\sum F_y = mg \cdot cos\theta - mr\alpha \cdot sin\theta - N = 0$$

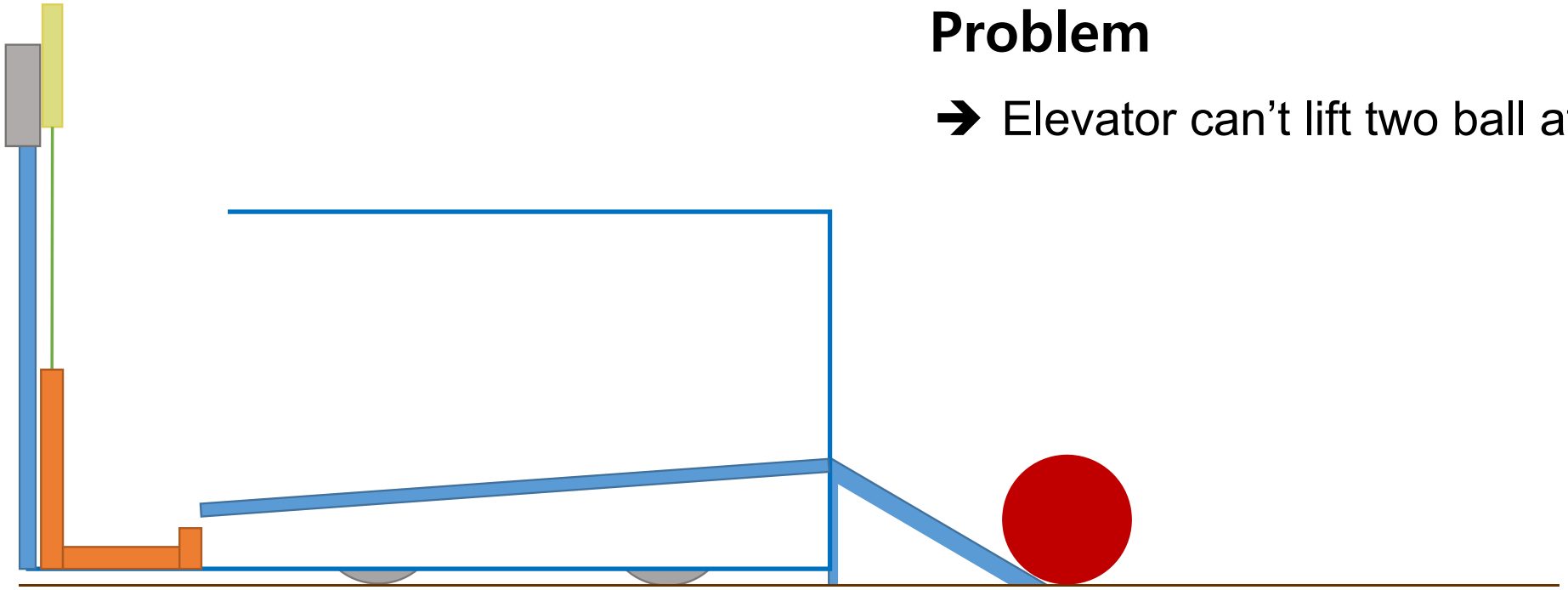
$$\sum F_x = mg \cdot sin\theta - mr\alpha \cdot cos\theta - \mu_s N > 0$$

$$\alpha < 38.8 rad/s^2$$

Vehicle's α_{max} : 2 rad/s^2

➔ Can separate well!

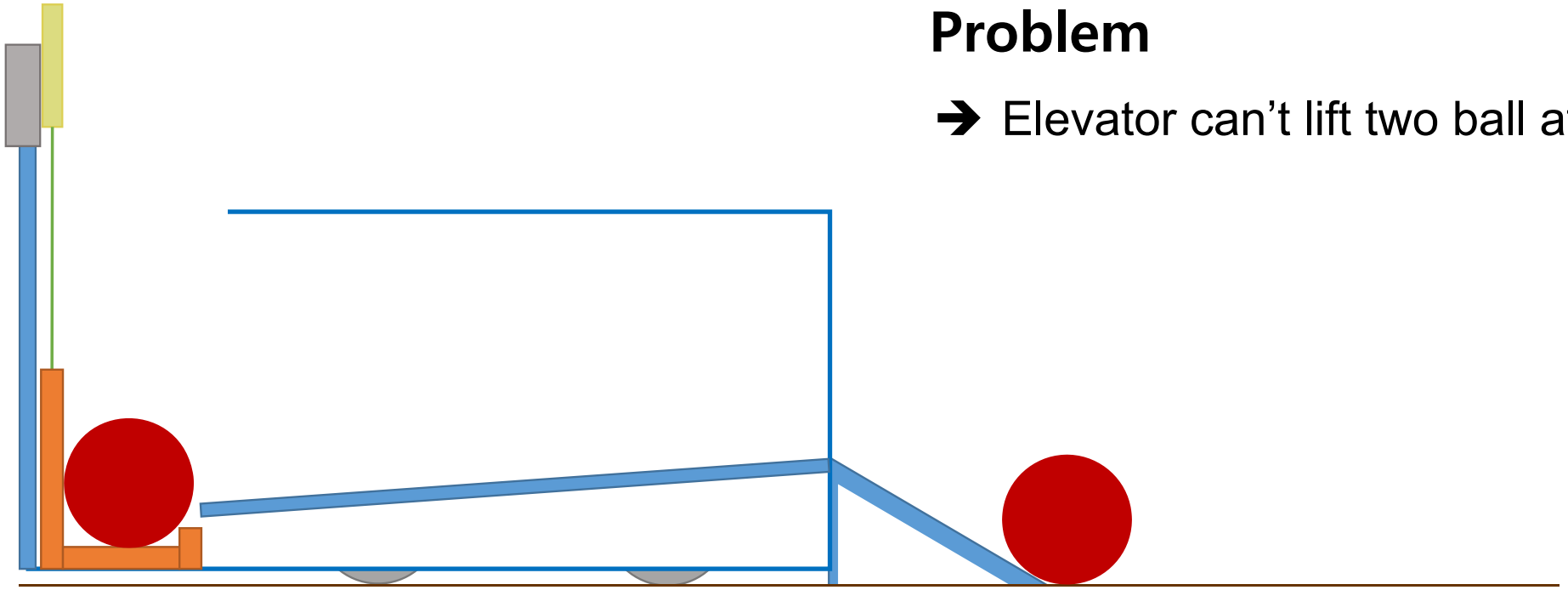
Elevator Safety : Ball Keeper



Problem

➔ Elevator can’t lift two ball at once

Elevator Safety : Ball Keeper



Problem

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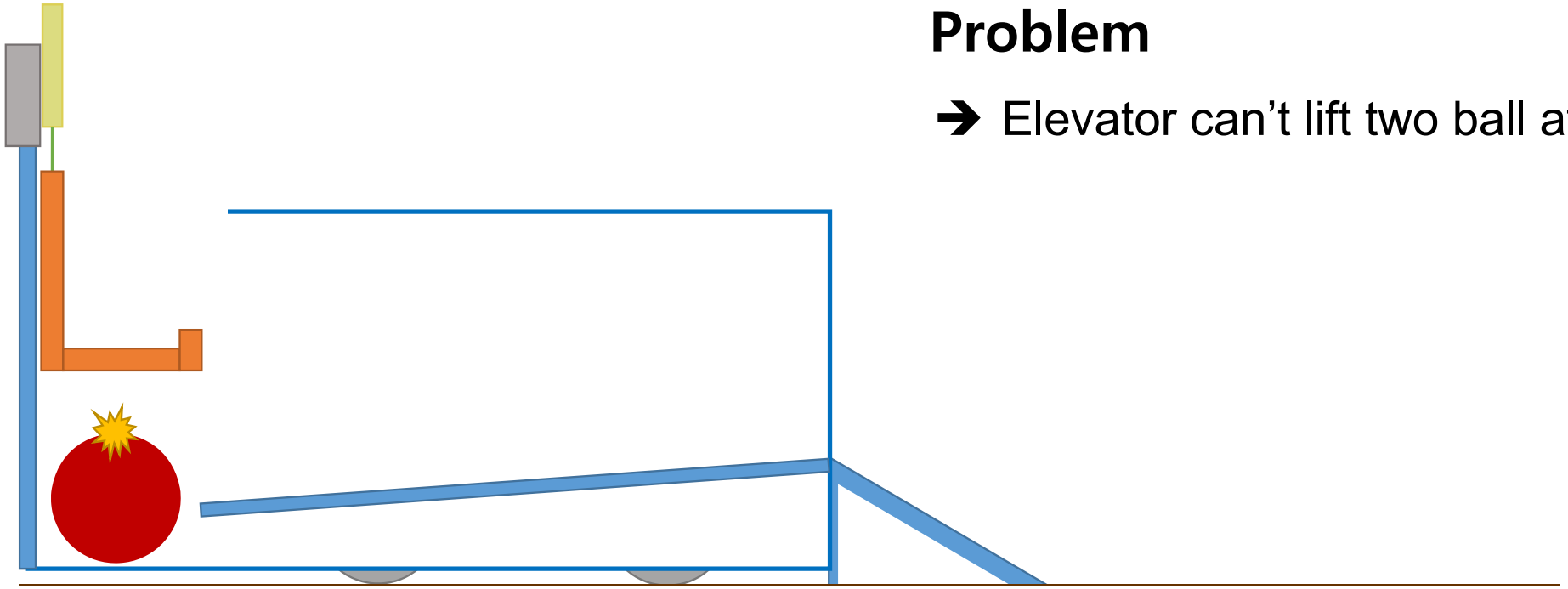
Elevator Safety : Ball Keeper



Problem

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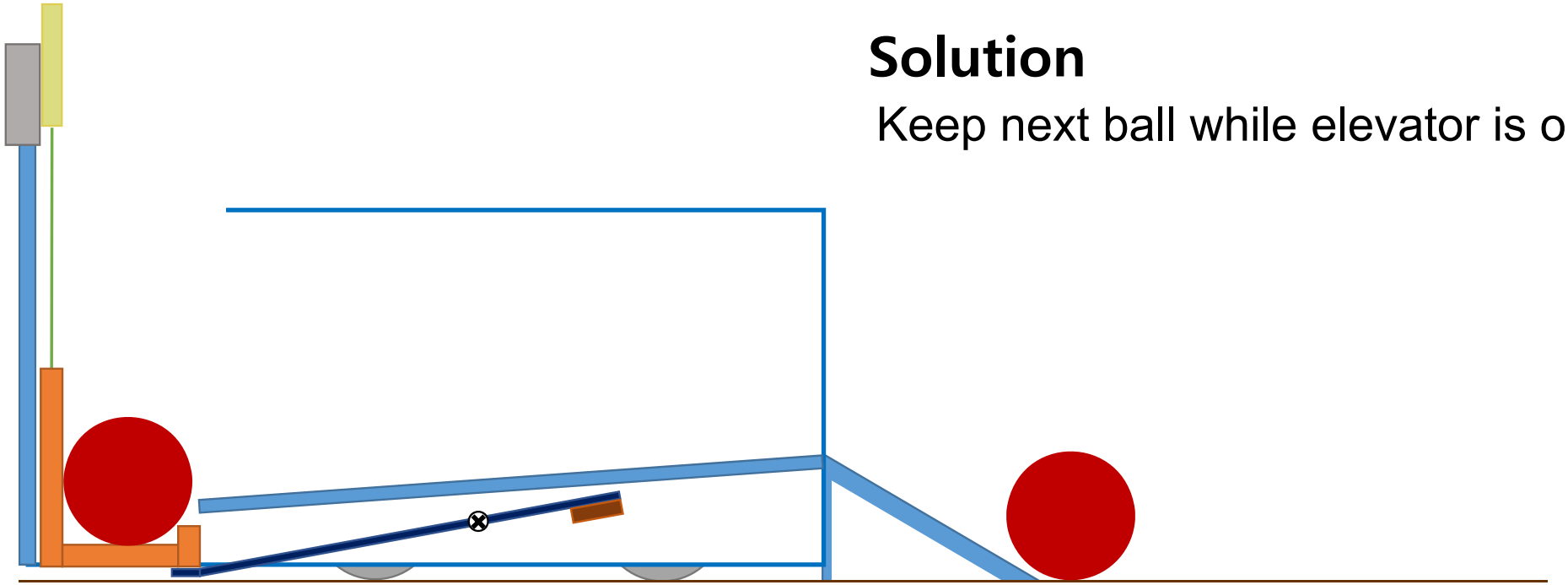
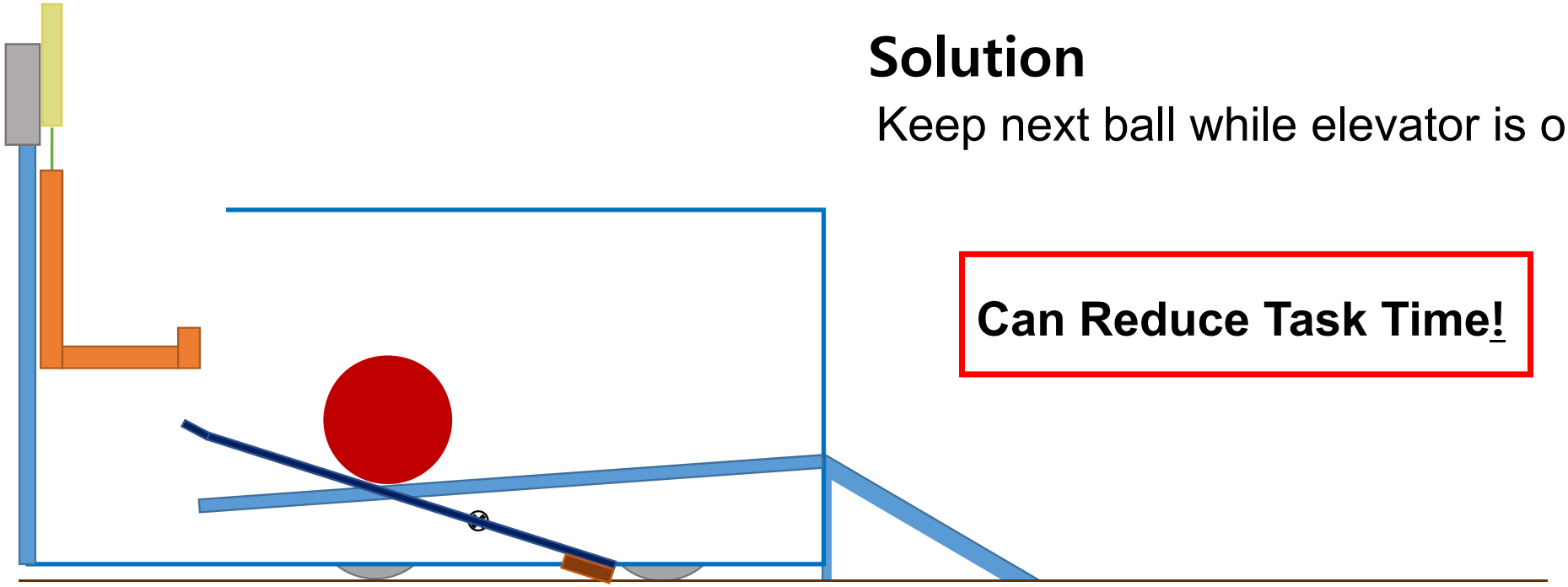
Elevator Safety : Ball Keeper



Solution

Keep next ball while elevator is operating

Elevator Safety : Ball Keeper



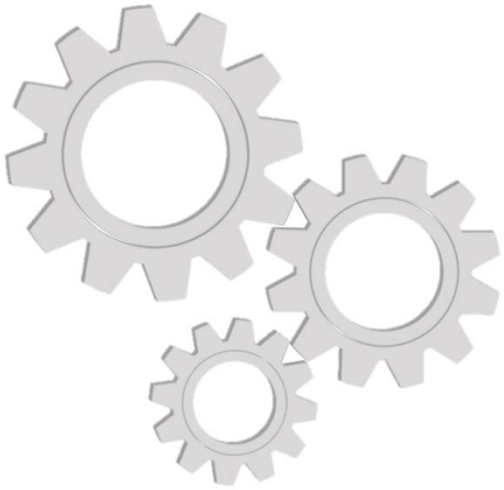
Solution

Keep next ball while elevator is operating

Can Reduce Task Time!

Hardware 3

Ball Releasing



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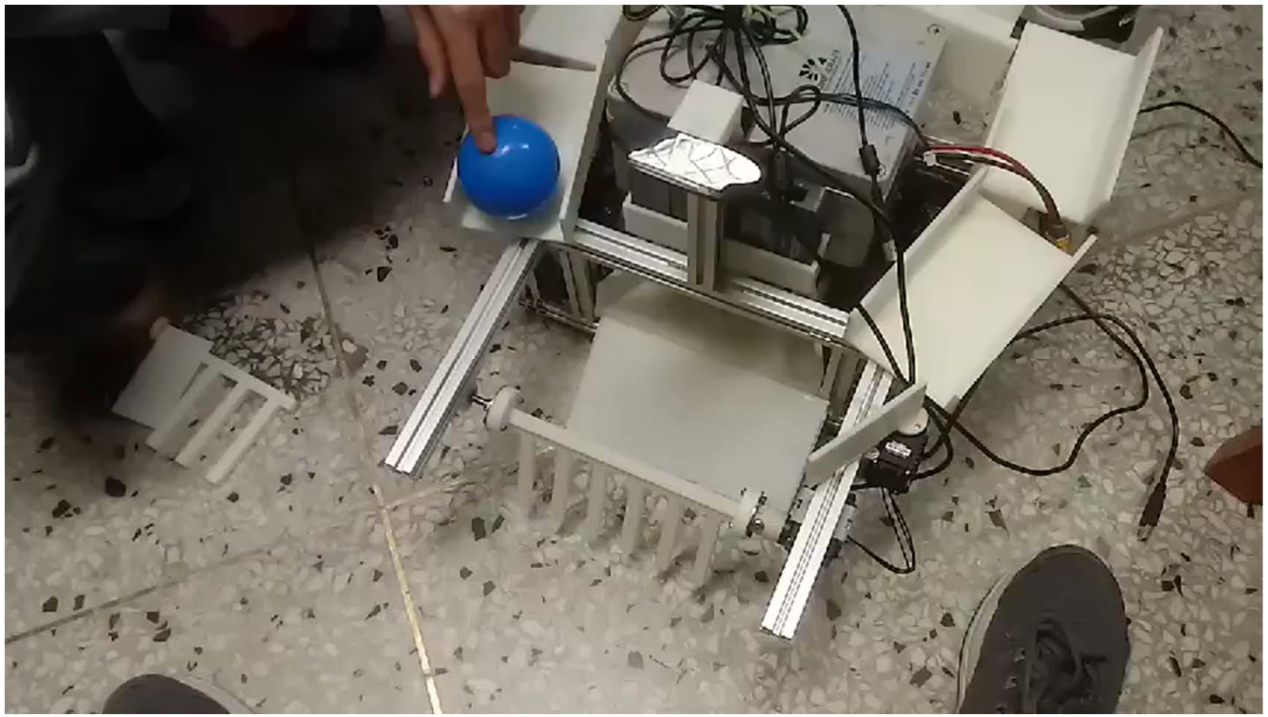
Ball releasing system



<Problem>

Need Door and Guide(8)

↕

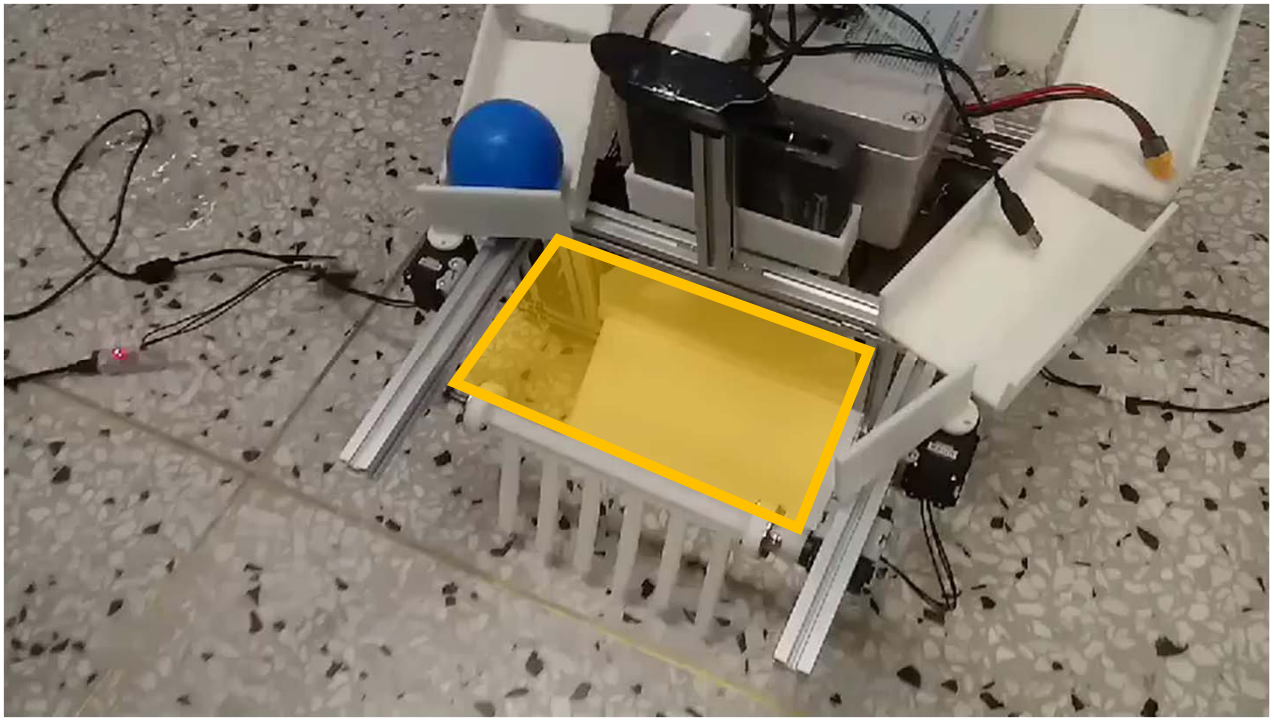
Complexity, Volume(12)

<Solution>

Merging(5)

➔**Door + Guide**

Ball releasing system



<Problem>

Need Slide for Ball(13)

↕

Disturb Roller Rotaion(12)

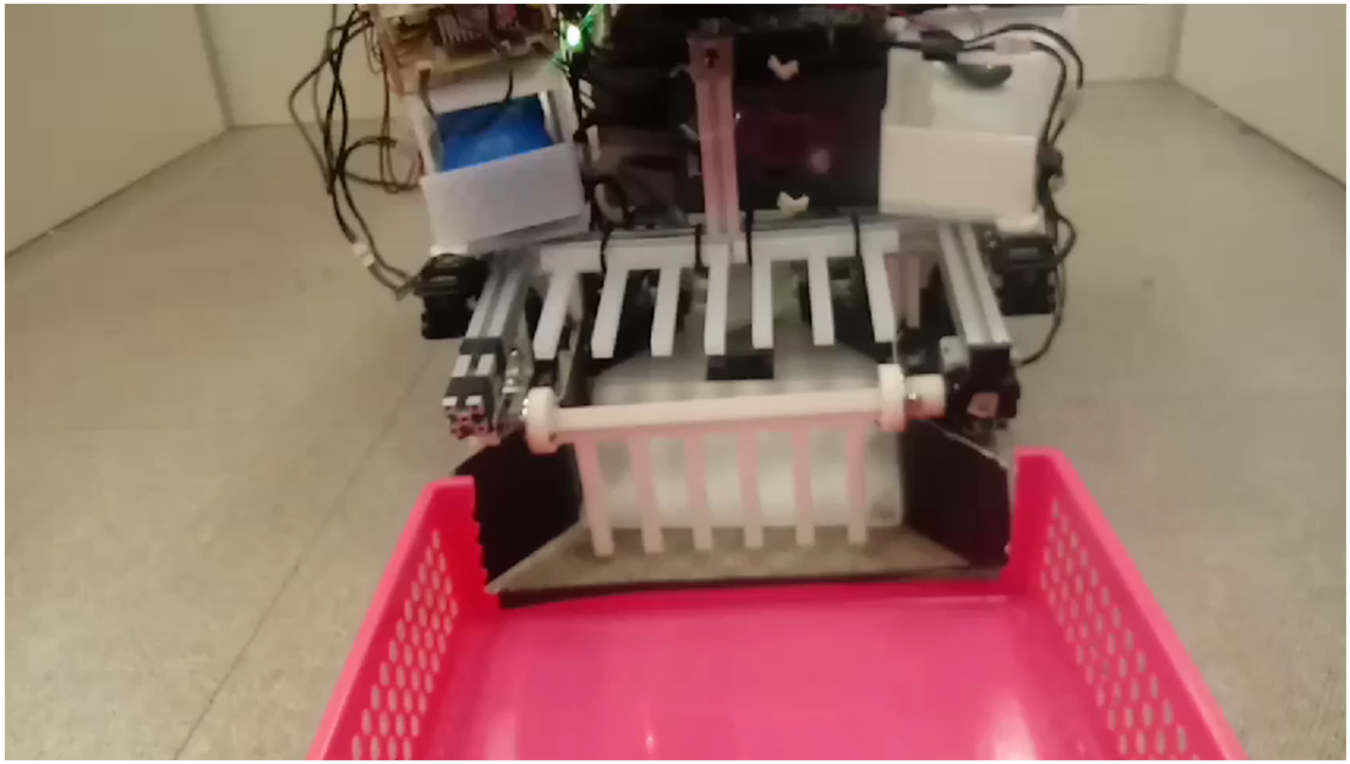
<Solution>

Separation of space(1)

➔**Comb shape slide**

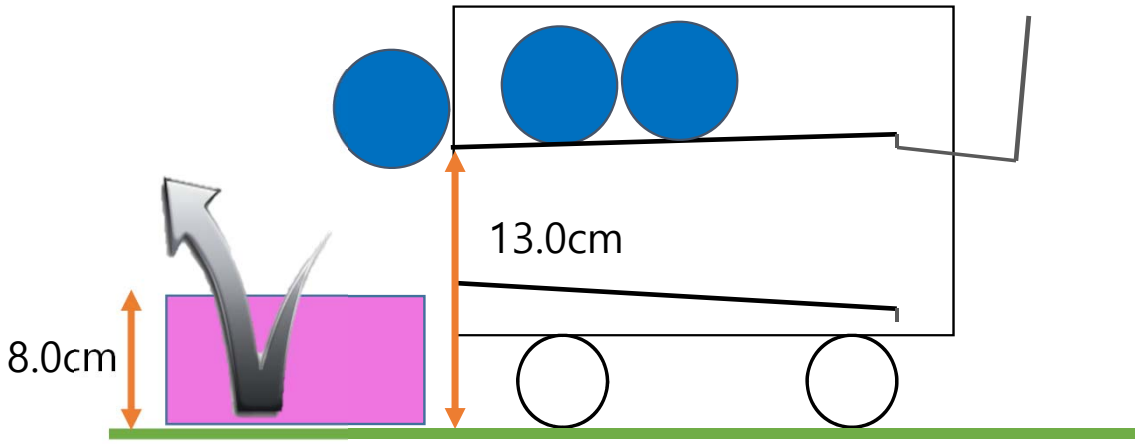
Ball releasing system

<Final Design>



Ball releasing system

Bounce out?



<side view>

<Experiment>

- Releasing height(h) = 93.0cm
- Bouncing height(h') = 34.6cm

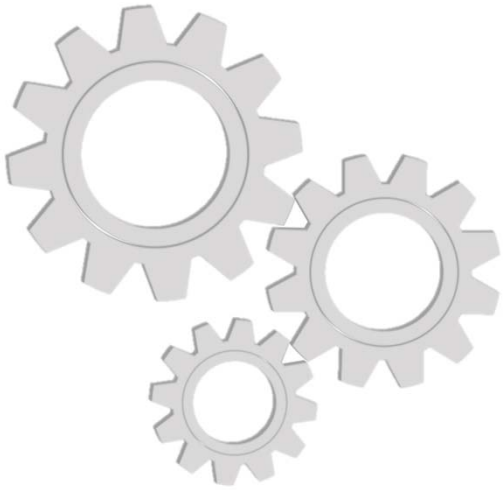
Restitution coefficient(e)

$e = \sqrt{\frac{h}{h'}} = \sqrt{\frac{34.6}{93.0}} = 0.610$

$h_p = e^2 H = 4.8\text{cm} < 8.0\text{cm}$ (e=0.610, H=13cm)

Never bounce out!

Hardware 4



Function improvement

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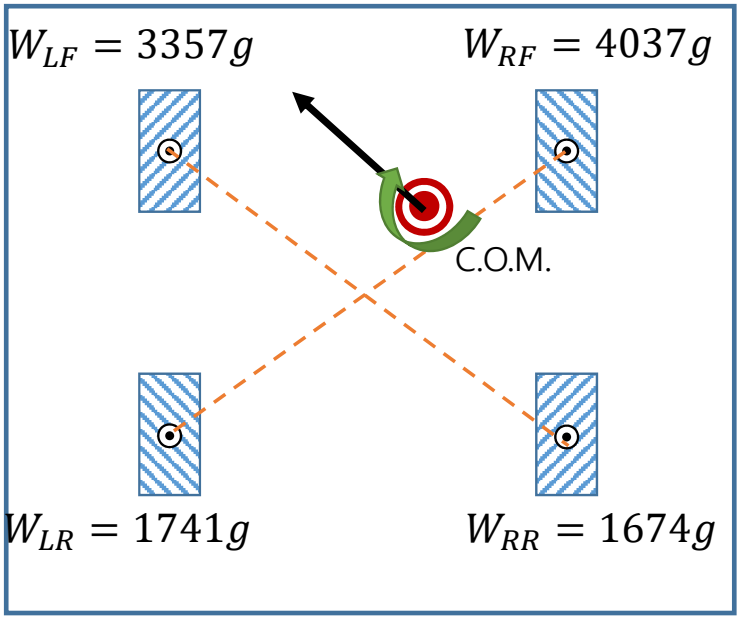
Oversteer

<Problem>

<Root Cause Analysis>

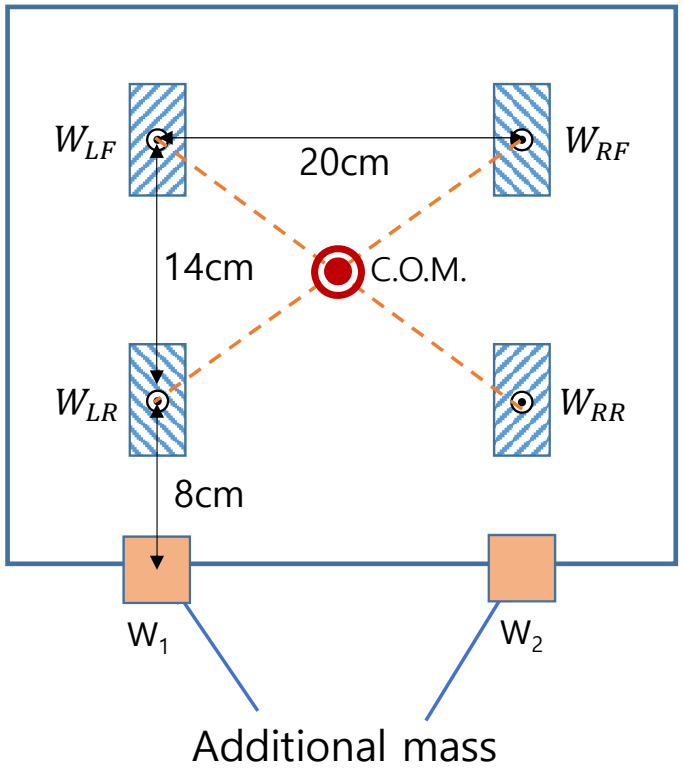


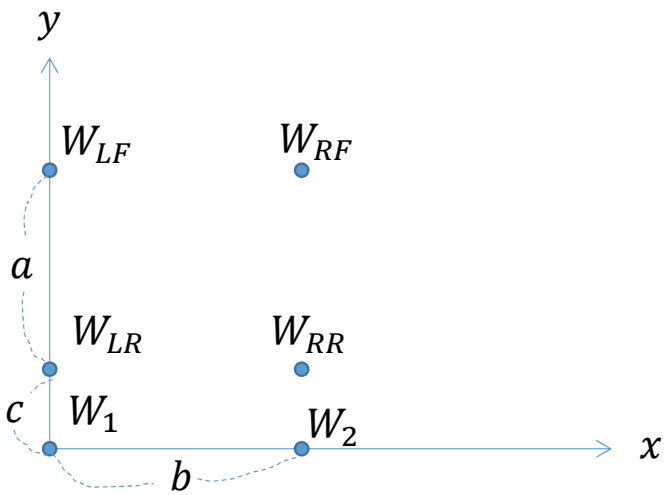
Angular momentum occurs!

Unbalanced weight to wheel

Oversteer- Additional weight

<Solution>



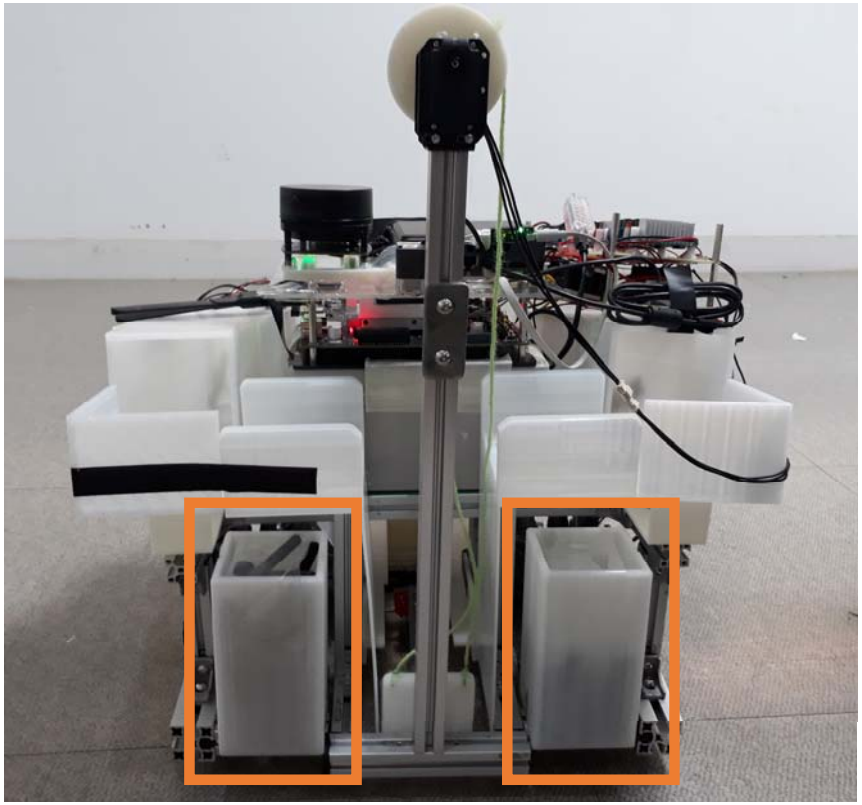


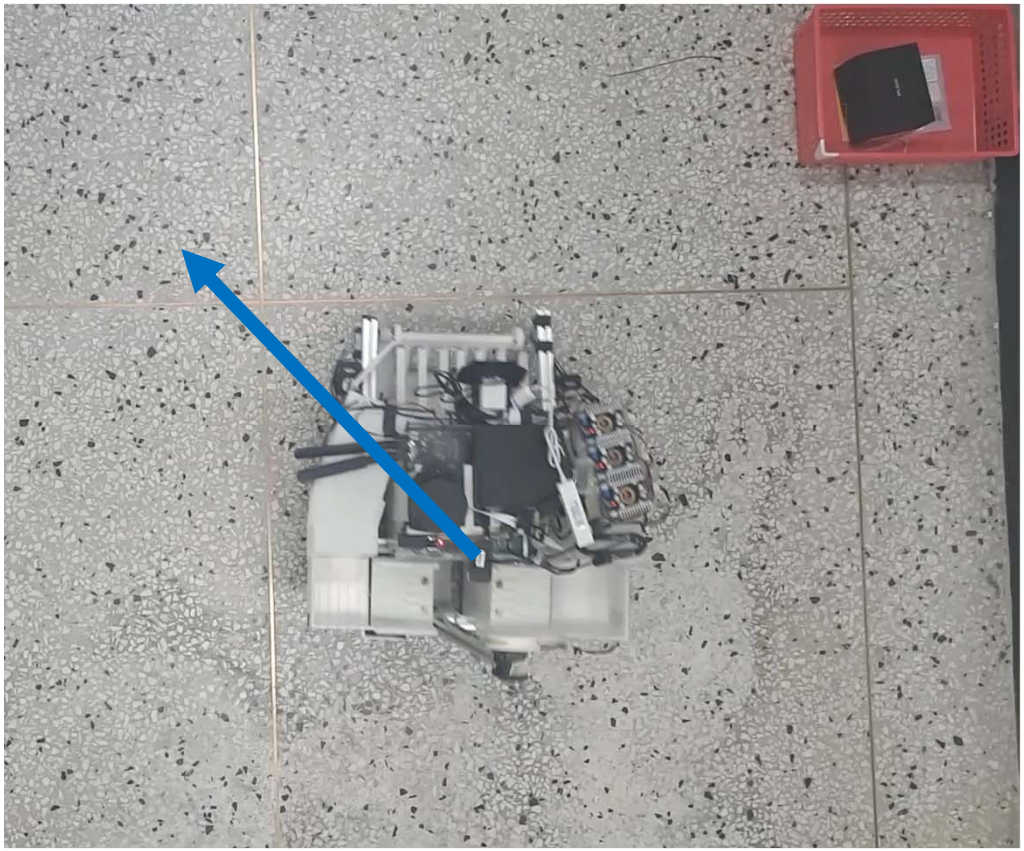
$$X_{com} = \frac{b}{2} = \frac{(W_{RF} + W_{RR} + W_2)b}{W_{RF} + W_{LF} + W_{LR} + W_{RR} + W_1 + W_2}$$

$$Y_{com} = \frac{a + 2c}{2} = \frac{(a + c)(W_{LF} + W_{RF}) - c(W_{LR} + W_{RR})}{W_{RF} + W_{LF} + W_{LR} + W_{RR} + W_1 + W_2}$$

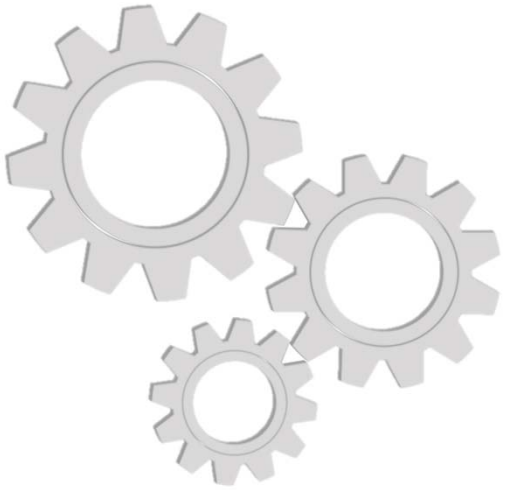
$$W_1 = 1245g \qquad W_2 = 621g$$

Oversteer- Additional weight



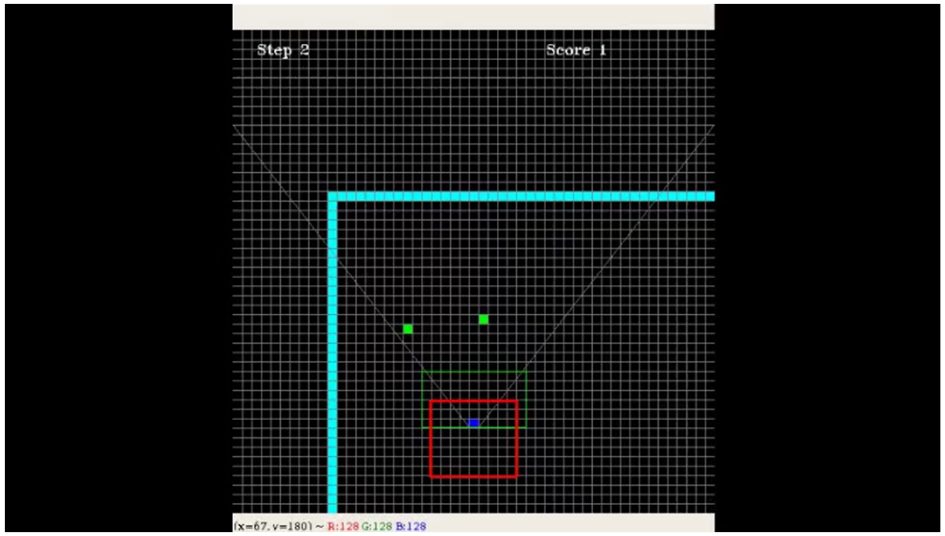


Software



DQN

DQN



Repeat certain actions

➔ **Longer task time**

DQN

<Original>

Use domain knowledge

Analytic answer

<DQN>

Repeated operation

Experimental answer

If we can find analytic answer

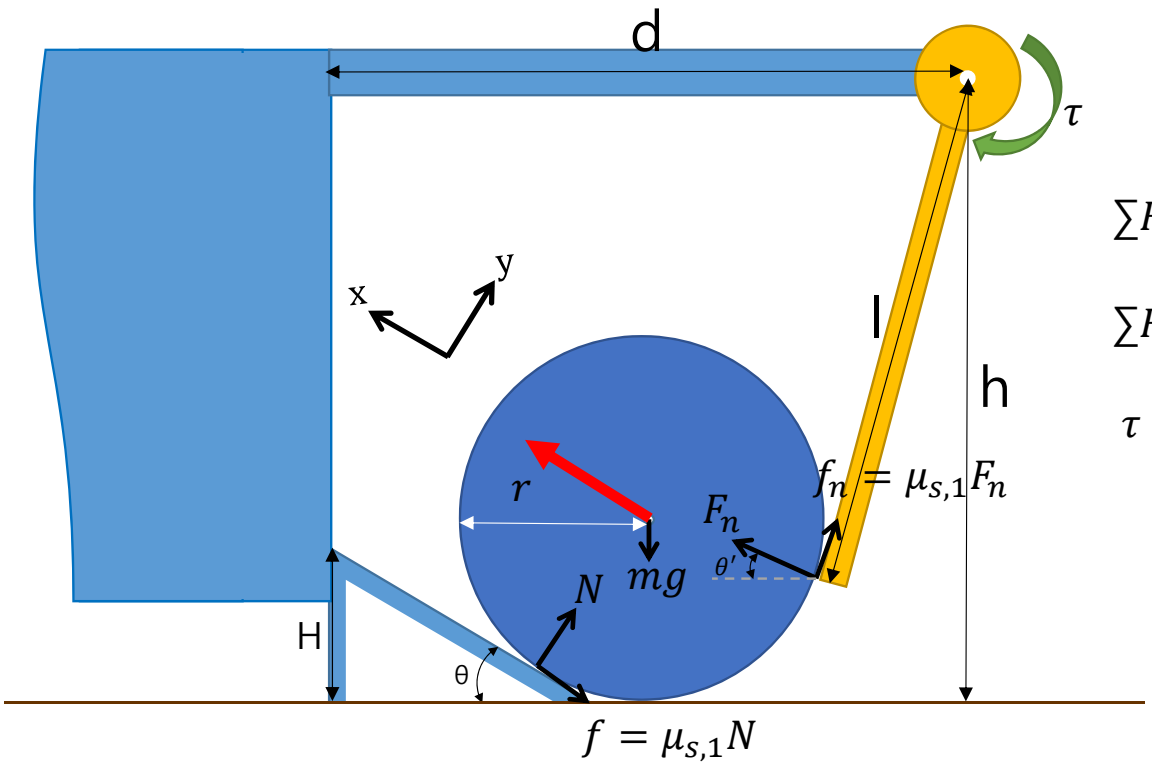
➔ Domain Knowledge >> DQN

Thanks

QnA

Appendix 1-1. Roller dynamics

2. Sweep Up Condition



Objective : sweep force $F_x > 0$

$$\sum F_x = -\mu_{s,1}N + F_n\cos(\theta-\theta') + \mu_{s,1}F_n\sin(\theta-\theta') - mgsin\theta$$

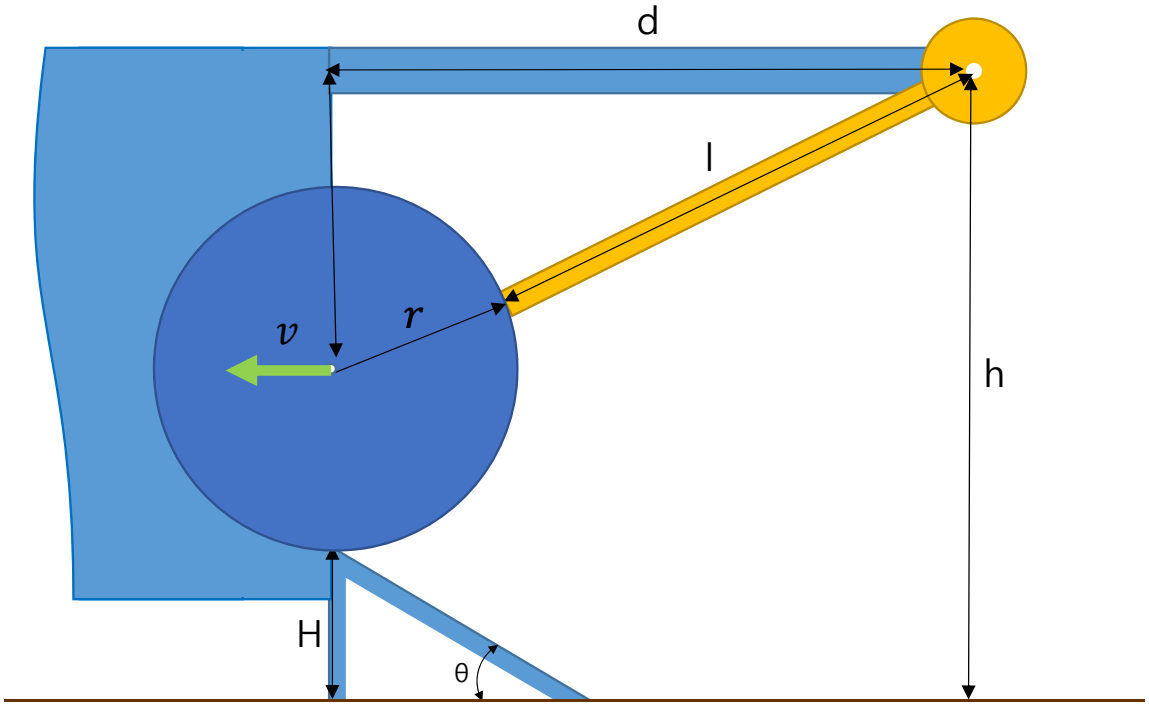
$$\sum F_y = \mathrm{N} - F_n\sin(\theta-\theta') + \mu_{s,1}F_n\cos(\theta-\theta') - mgcos\theta = 0$$

$$\tau = F_n l$$

$\sum F_x > 0$ when $l > h - r$

Appendix 1–2. Roller dynamics

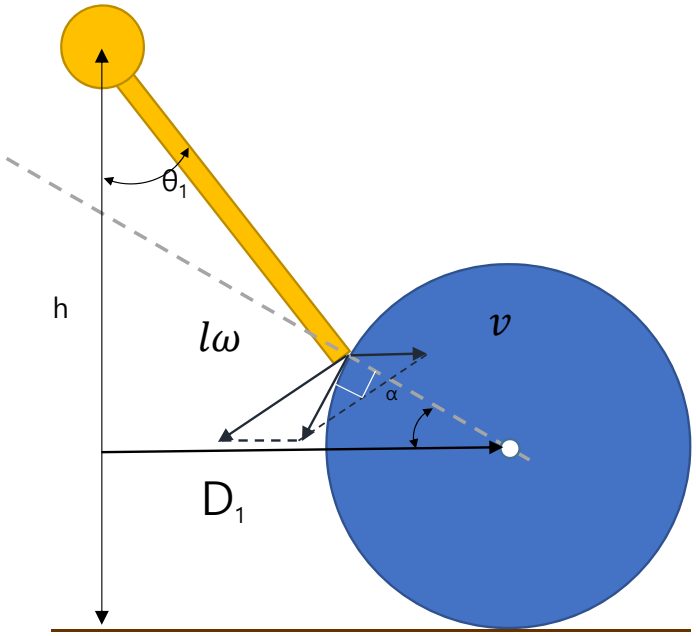
3. Roll In Condition



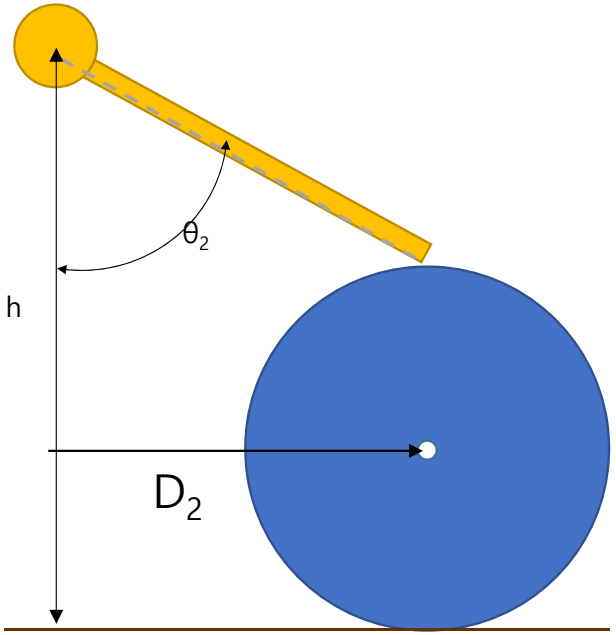
Ball "Roll In"
geometric condition

$$l \geq \sqrt{(h - H - r)^2 + d^2} - r$$

Appendix 1–3. Roller dynamics



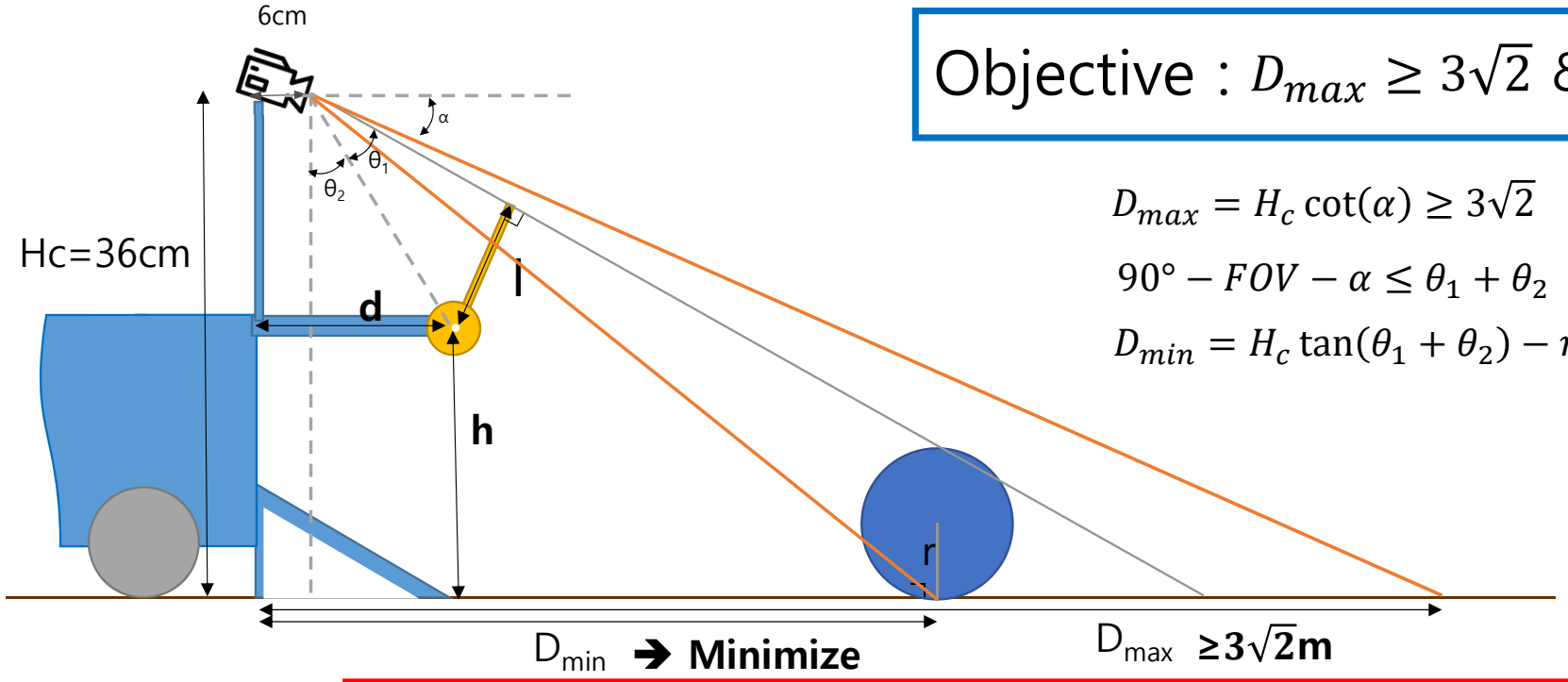
(Case1)
Roller pass by ball



(Case2)
First time ball enters

Appendix 1–4. Roller dynamics

1. Detecting Range Condition



Objective : $D_{max} \geq 3\sqrt{2}$ & minimize D_{min}

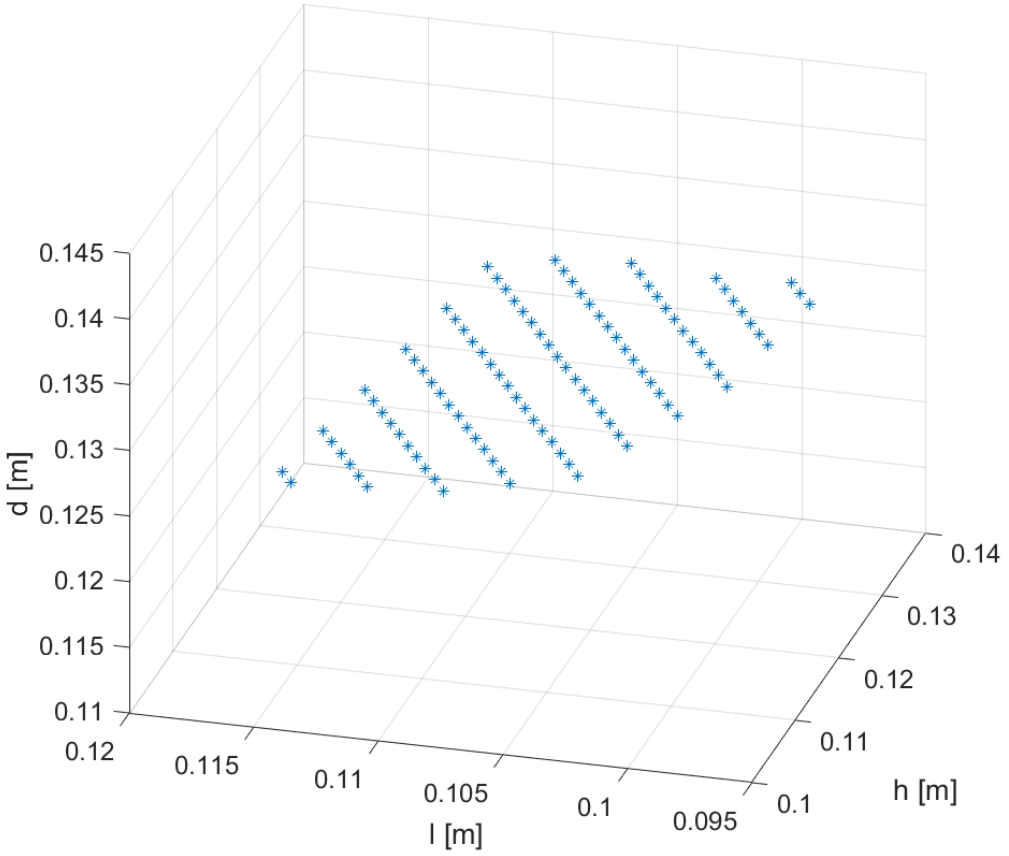
$$D_{max} = H_c \cot(\alpha) \geq 3\sqrt{2} \quad \rightarrow \quad \alpha \leq 4.8°$$

$$90° - FOV - \alpha \leq \theta_1 + \theta_2$$

$$D_{min} = H_c \tan(\theta_1 + \theta_2) - r \times tan(45° + \frac{\theta_1 + \theta_2}{2})$$

$$sin^{-1}\left(\frac{l}{\sqrt{(d - 6cm)^2 + (H_c - h)^2}}\right) + tan^{-1}\left(\frac{l}{H_c - h}\right) = 42°$$

Appendix 1–5. Possible sets of l d h



Appendix 1–5. Roller Dynamic Constraints

1. Sweep Up Condition

Objective : sweep force $F_x > 0$

$\sum F_x > 0$ when $l > h - r$

2. Ball Enter Condition

Objective : ball should get into the storage

$$l \geq \sqrt{(h - H - r)^2 + d^2} - r$$

3. Roller sweep

Minimize $\frac{\theta_1 - \theta_2}{360°}$

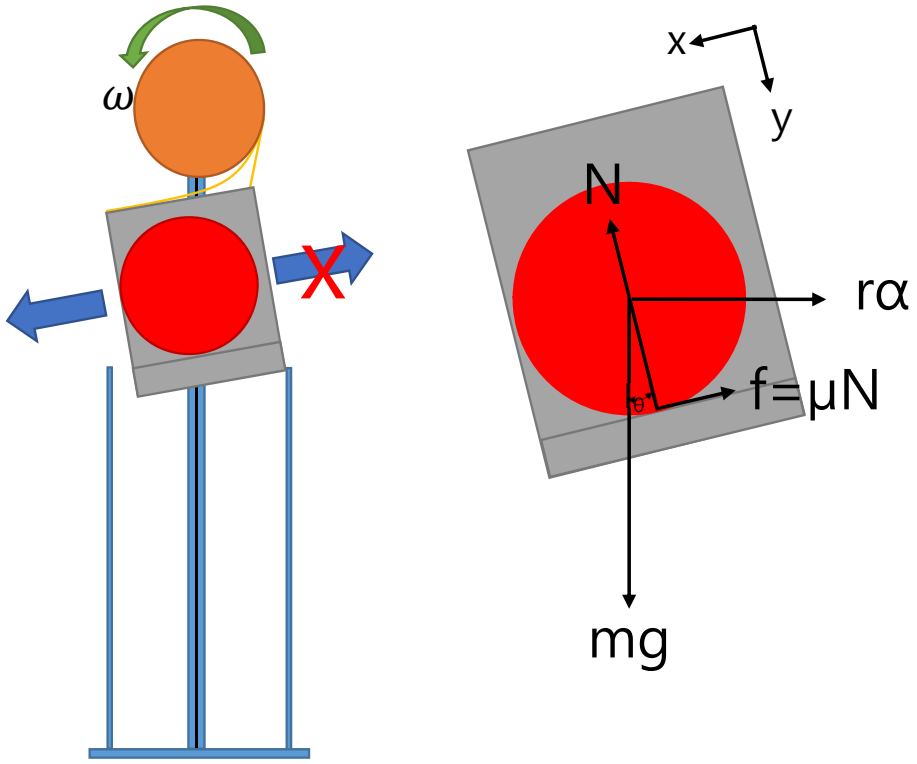
Numercial Analysis – MonteCarlo Simulation

4. Detecting Range Condition

Objective : $D_{max} \geq 3\sqrt{2}$ & minimize D_{min}

$$sin^{-1}\left(\frac{l}{\sqrt{(d - 6cm)^2 + (H_c - h)^2}}\right) + tan^{-1}\left(\frac{l}{H_c - h}\right) = 42°$$

Appendix 2. Elevator Safety



-100% secure to Separate

$$\sum F_y = mg \cdot cos\theta - r\alpha \cdot sin\theta - N = 0$$

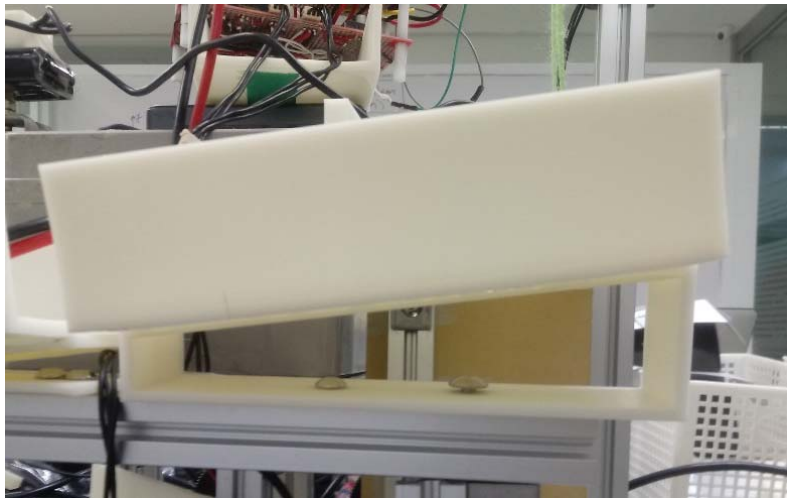
$$\sum F_x = mg \cdot sin\theta - r\alpha \cdot cos\theta - \mu_s N > 0$$

$$mg(sin\theta - \mu_s cos\theta) - r\alpha(cos\theta - \mu_s sin\theta) > 0$$

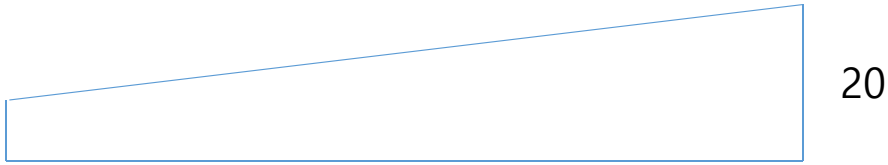
$$\theta = 30° \Rightarrow \ \alpha < 38.8\, rad/s^2$$

Appendix 3. Storage Slope

Can ball roll in storage?



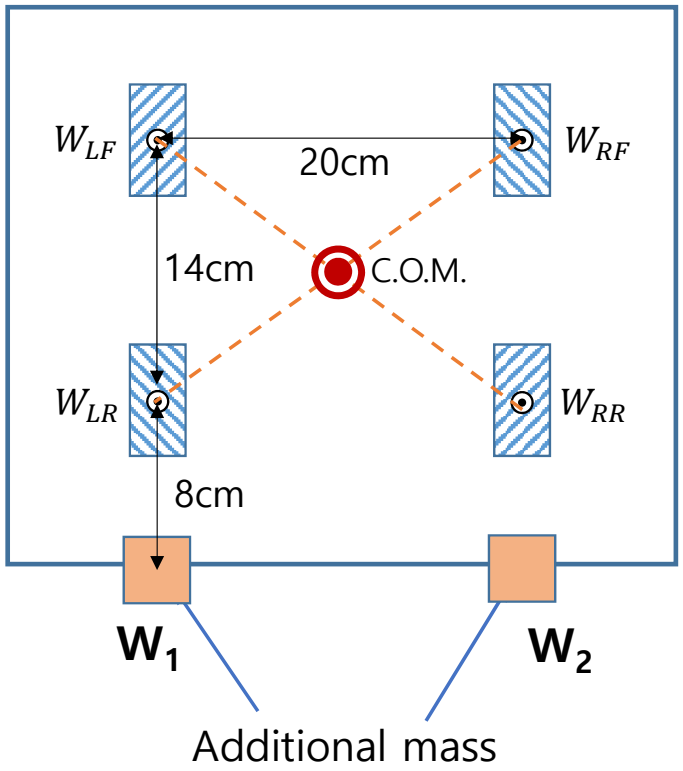
Static friction coefficient μ = 0.09

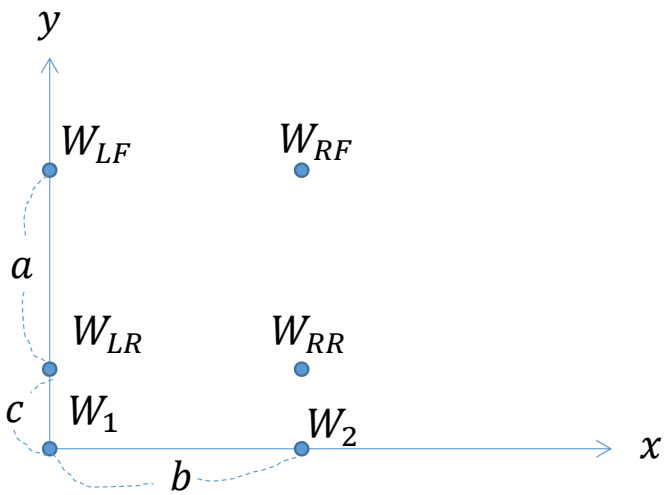


Needed angle of inclination = 5.3°

Our storage's angle of inclination = 7.6°

Appendix 4. Oversteer- Additional weight





$$X_{com} = \frac{b}{2} = \frac{(W_{RF} + W_{RR} + W_2)b}{W_{RF} + W_{LF} + W_{LR} + W_{RR} + W_1 + W_2}$$

$$Y_{com} = \frac{a + 2c}{2} = \frac{(a + c)(W_{LF} + W_{RF}) - c(W_{LR} + W_{RR})}{W_{RF} + W_{LF} + W_{LR} + W_{RR} + W_1 + W_2}$$

$$W_1 = 1245g \qquad W_2 = 621g$$