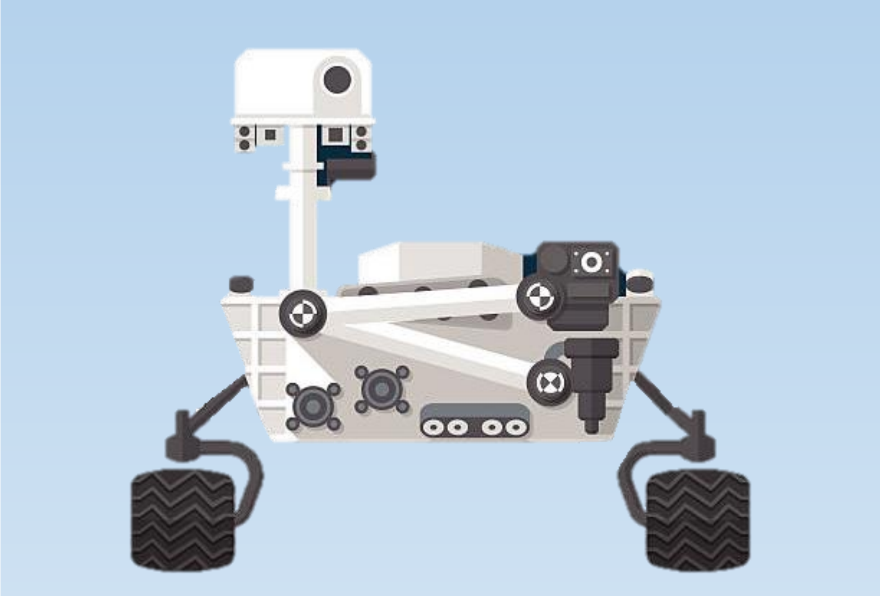


Hybrid System

Advisory Professor : 김형수 교수님

Advisory TA : 정문경 TA

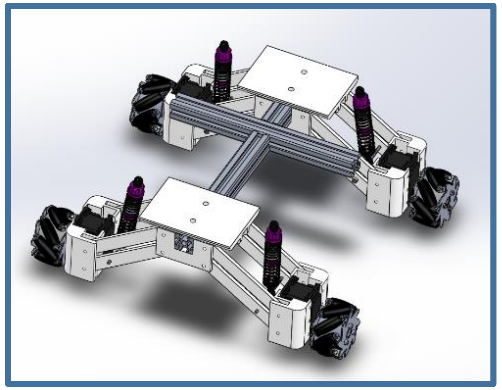
Team Members : Ashar Alam, Mahshid Khodadad, 류준일, 류현준, 박지환, 조인준, 최지훈, 최호열

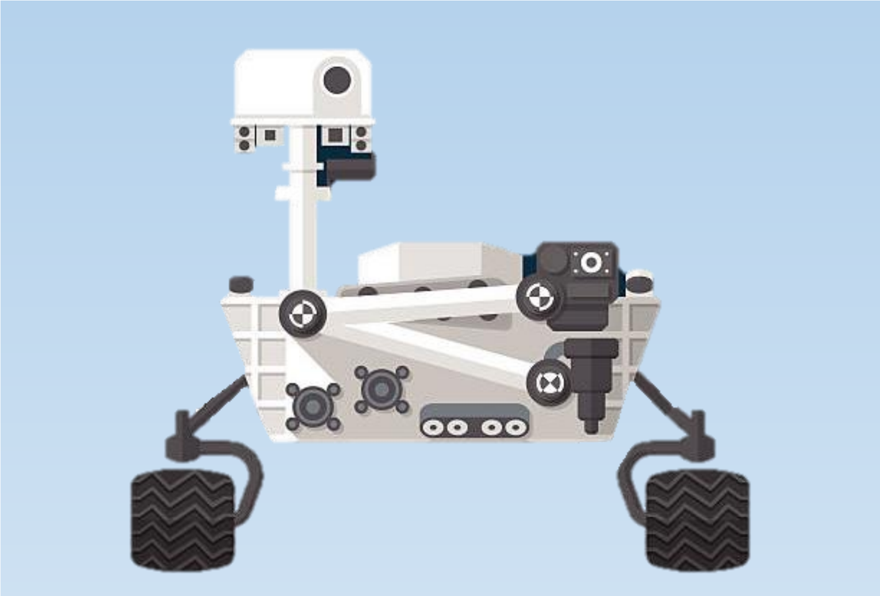
KAIST

Department of Mechanical Engineering

ENGINEERING FOR MANKIND

Contents

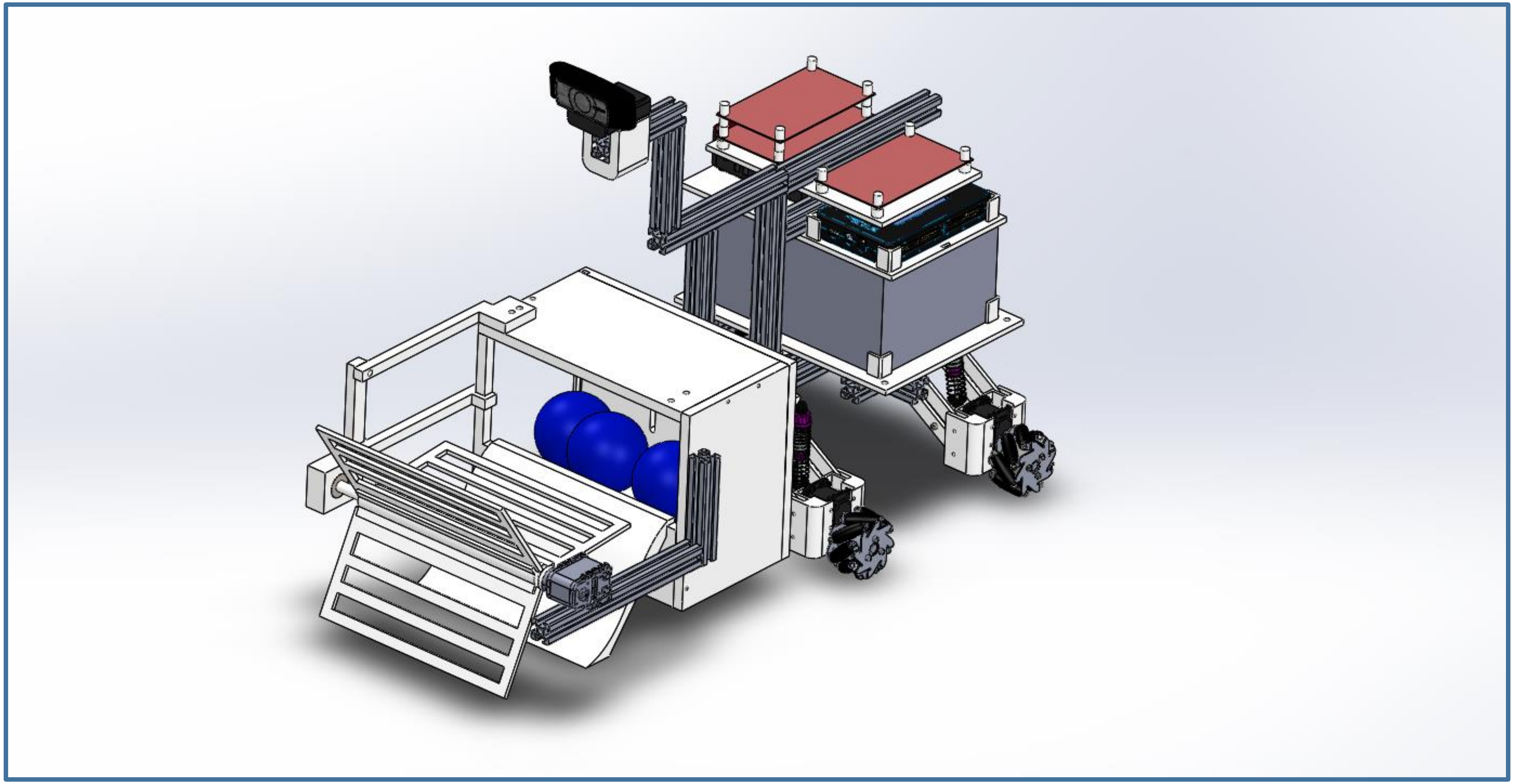




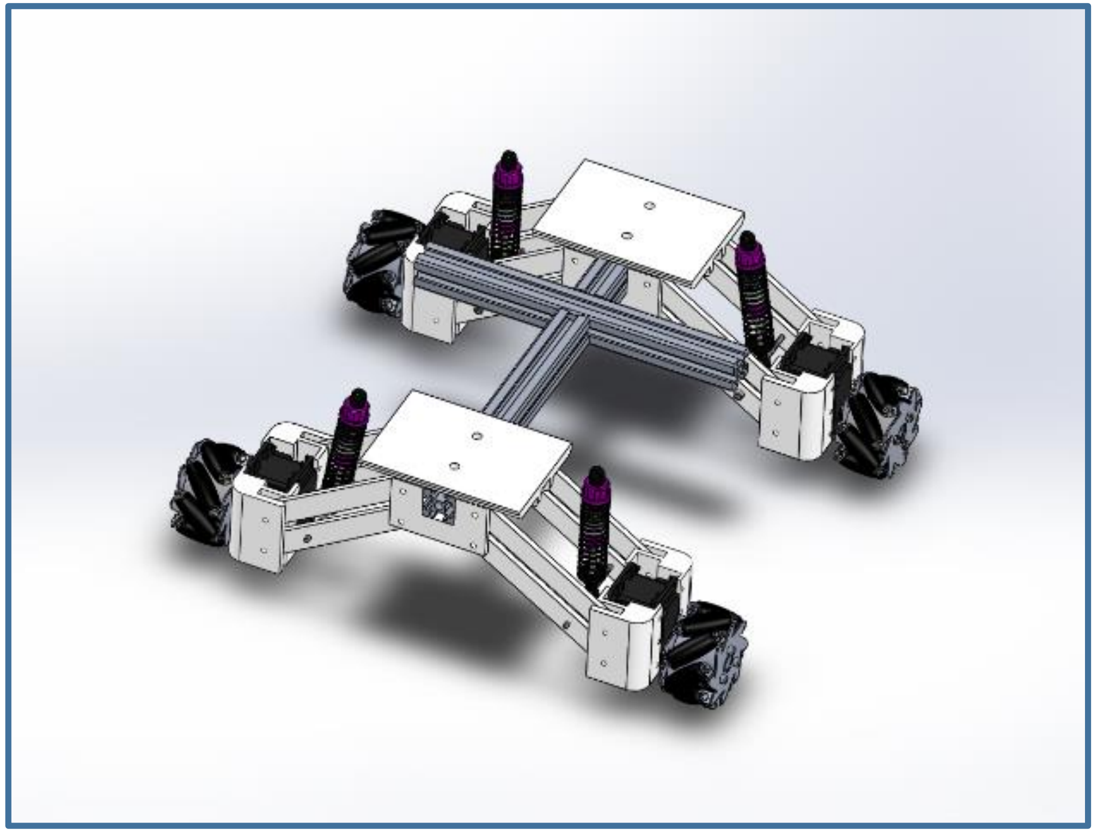
Section – A

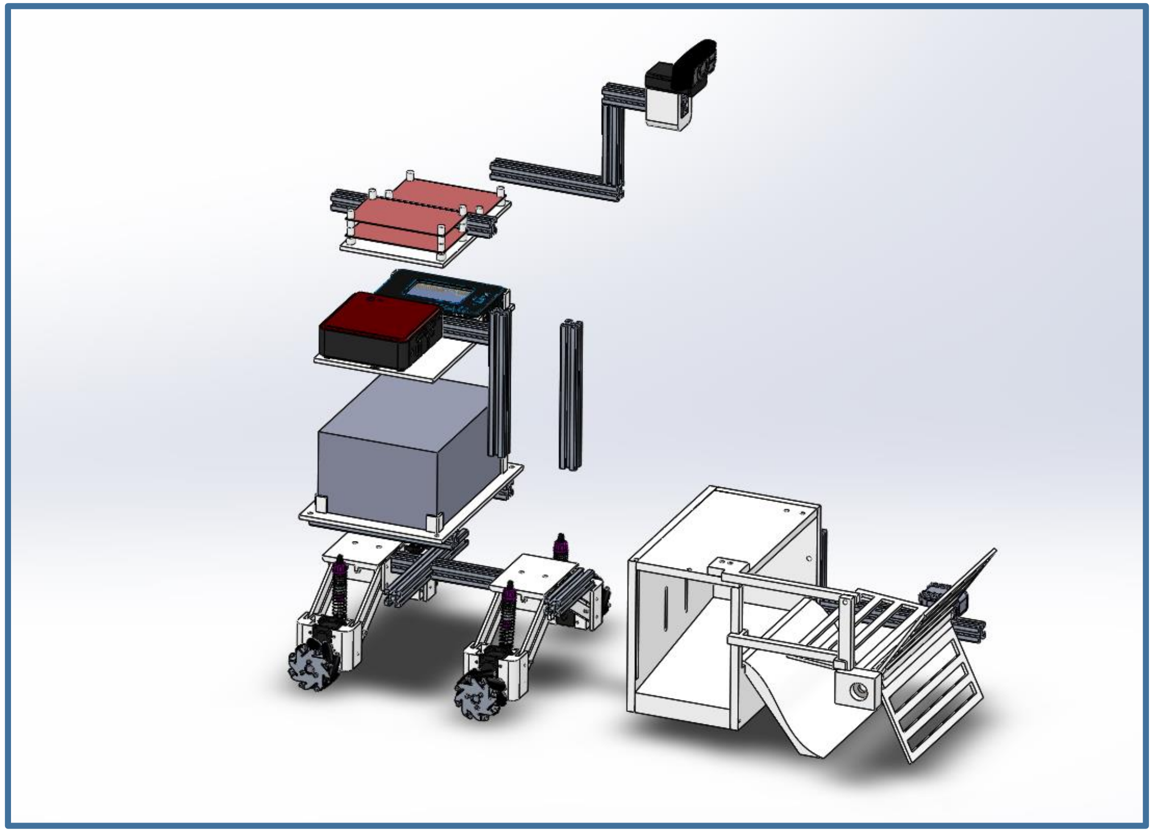
System Overview

Hybrid System



Key Features

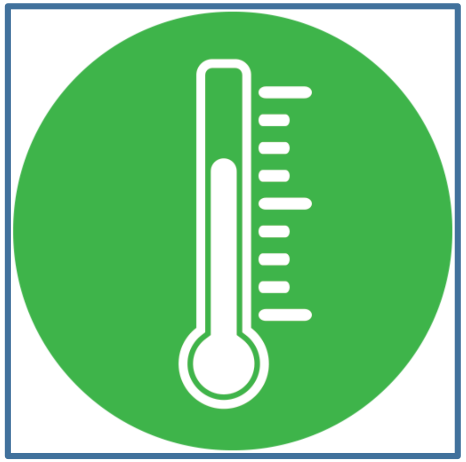




Independent Suspension

Modularity

Problem and Solution

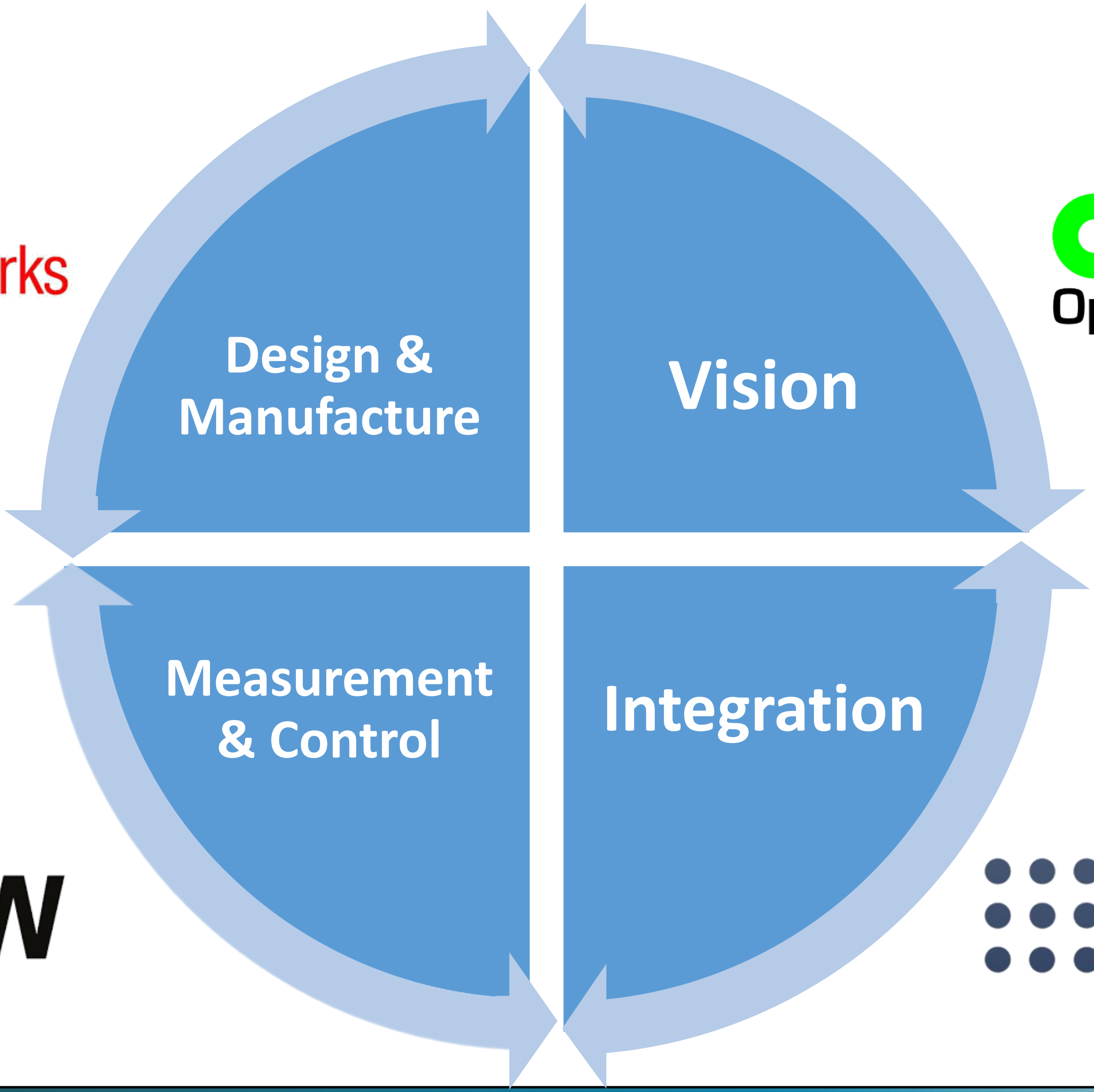


- ➢ Performance
  - ✓ Precise ball picking
  - ✓ < 5 mins

- ➢ Cooling
  - ✓ Passive cooling
  - ✓ < 70°C

- ➢ Creativity
  - ✓ Independent suspension
  - ✓ Modular design

Team Structure



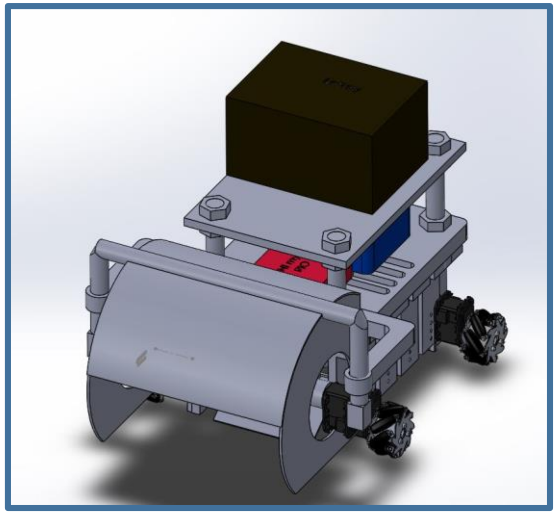
SolidWorks

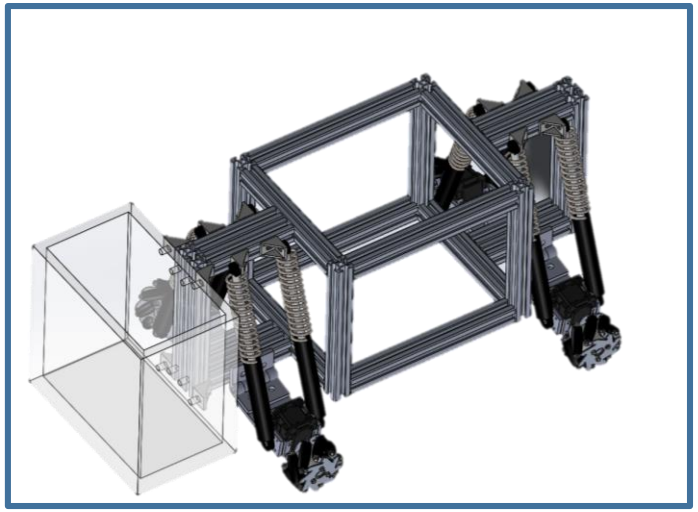
OpenCV

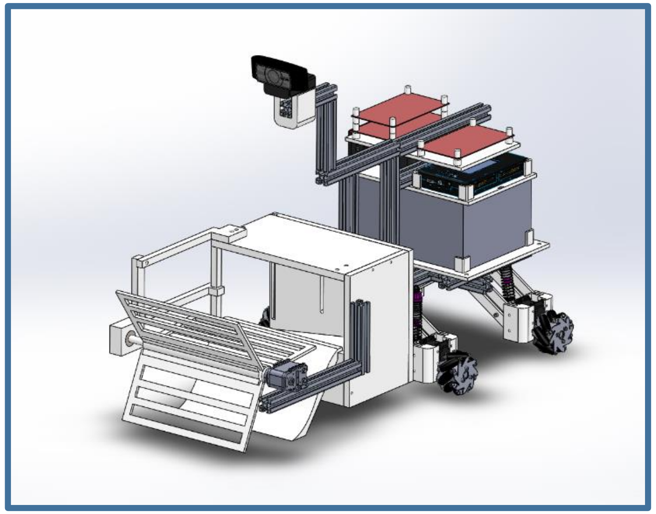
NATIONAL INSTRUMENTS LabVIEW

ROS

Capstone Design: Evolution of Design







System Overview

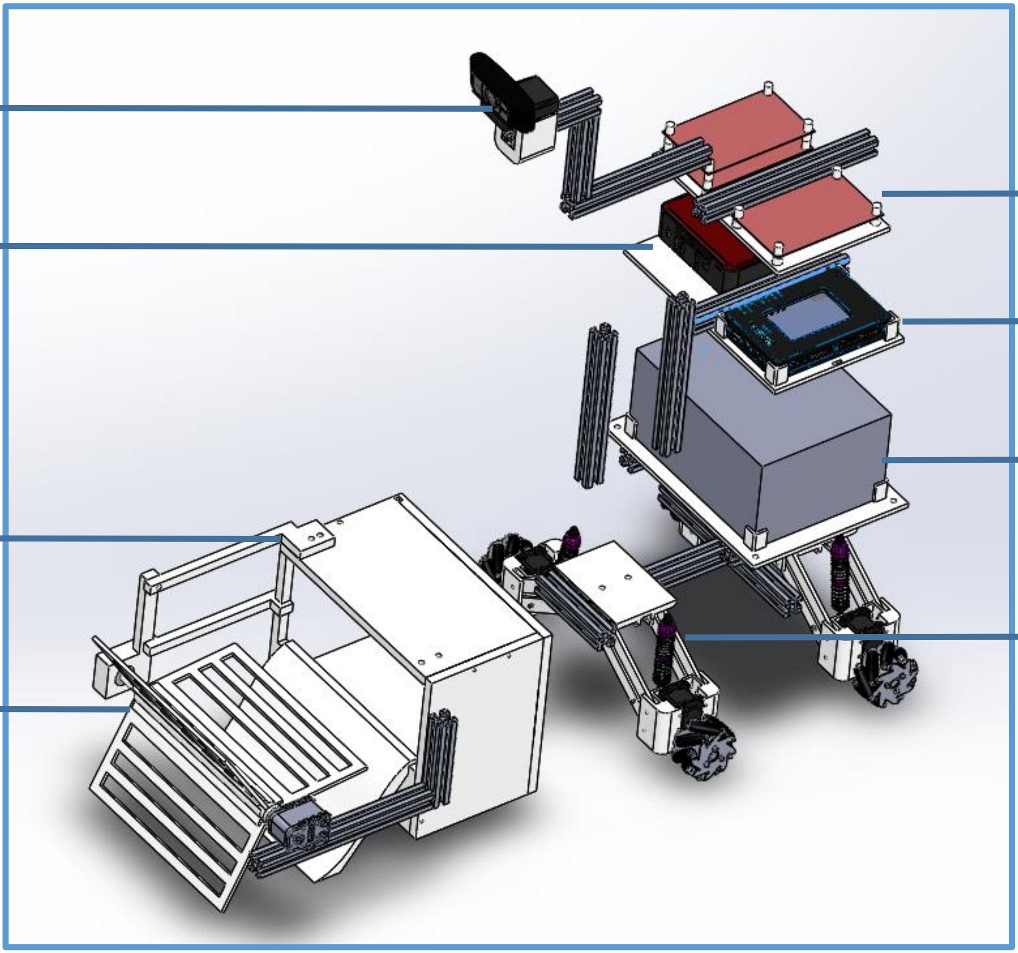
System → Whole Design → Detection → Picking → Deposition

Camera

NUC

Storage

Gripper



Converters

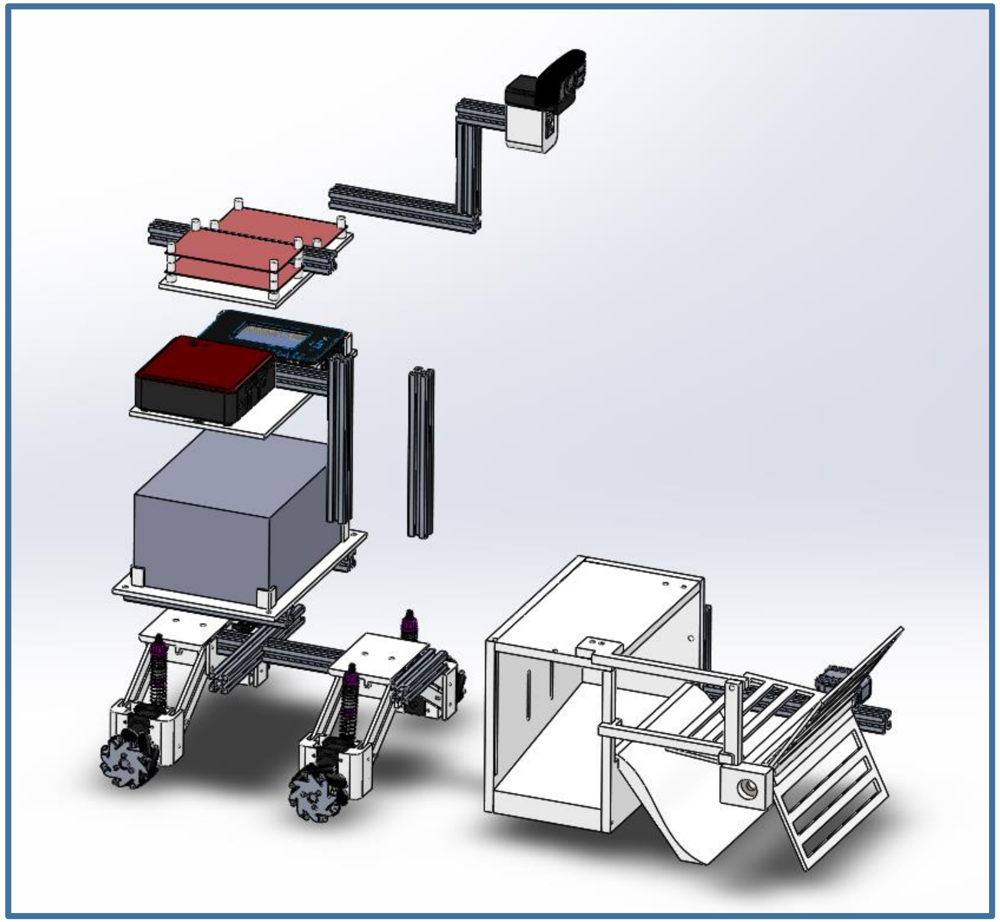
myRio

Battery

Suspension

System Overview

System | Whole Design | Detection | Picking | Deposition



➢ Merits of Modularity

✓ Easy to repair

✓ Modifications would be easily implemented for Capstone Design II

✓ Design changes have a smooth and swift transition

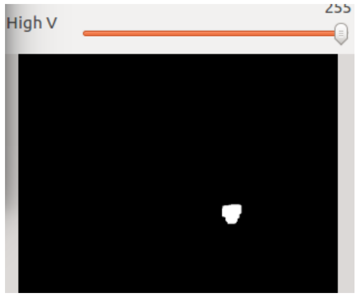
System Overview

System → Whole Design → Detection → Picking → Deposition

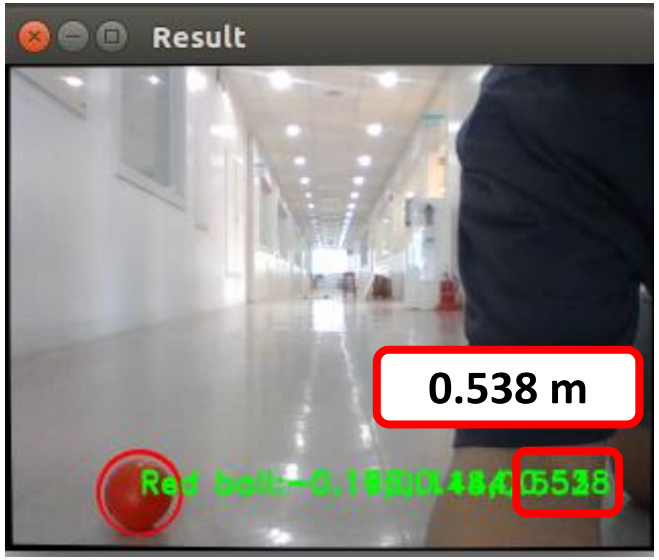
Over-sized Detection Error

Detected Image	Detected Blob
	

Incorrect Detection Error

Detected Image	Detected Blob
	

Distance Estimation Error

Condition	Before
	

System Overview

System | Whole Design | Detection | Picking | Deposition

By Using...

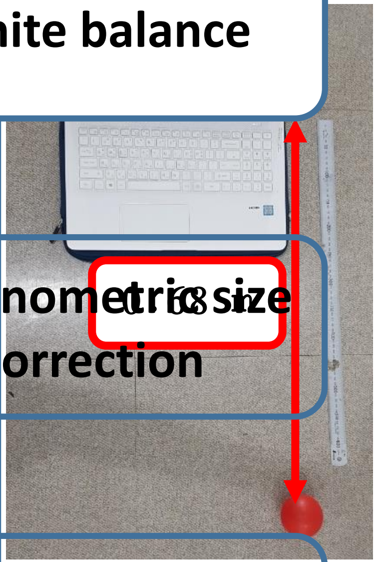
ista

Condition

White balance

Trigonometric size correction

Re-Calibration

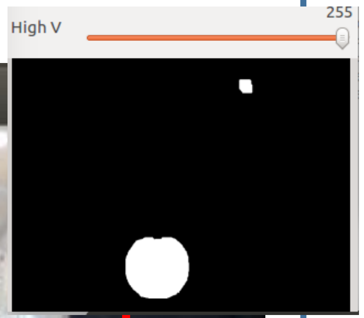


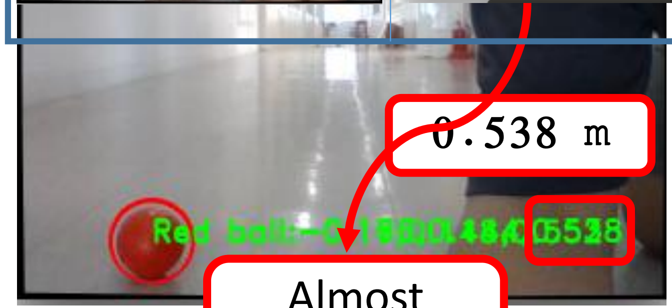
Correct Detection

Detected Image

Before

Detected Blob





Almost Circular

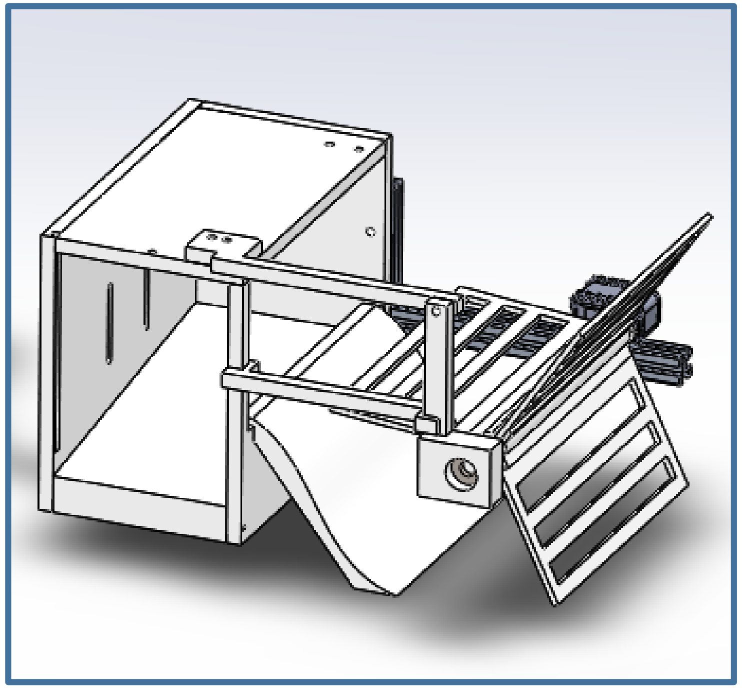
Correct Distance Estimation

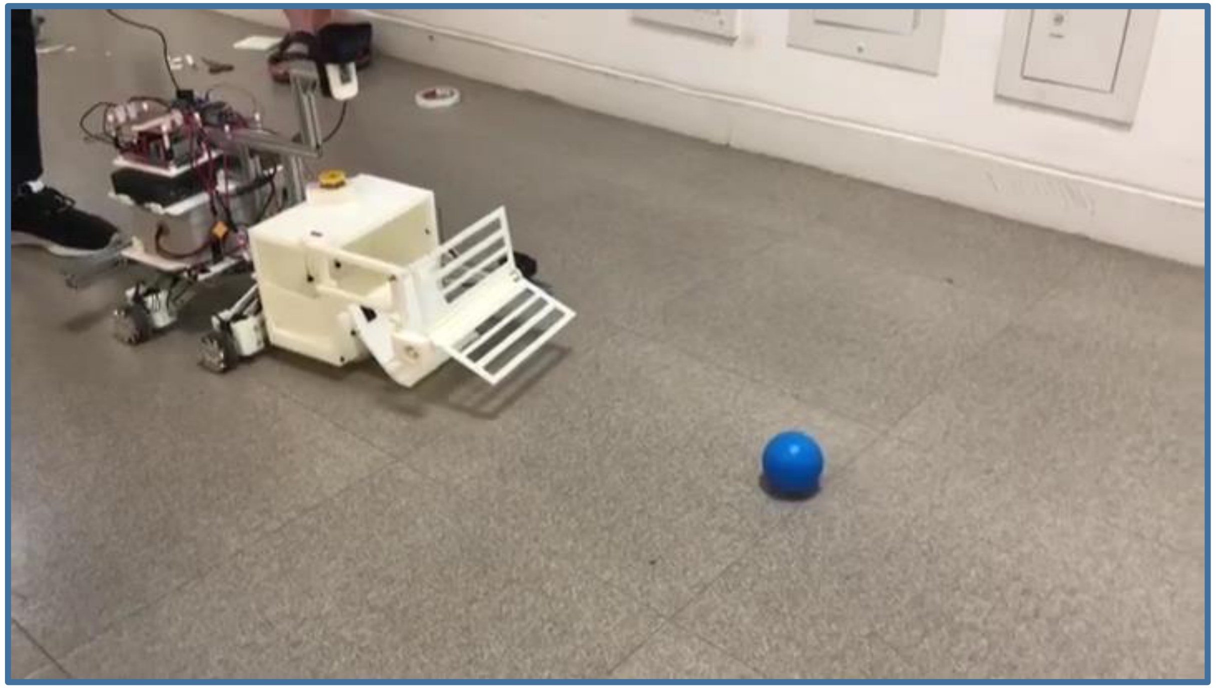
Condition

After

System Overview

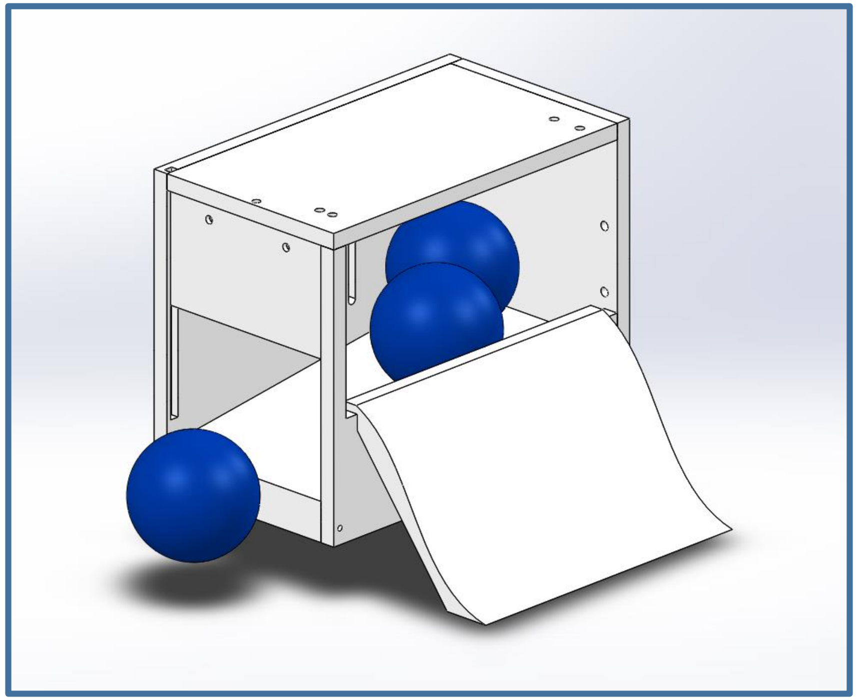
System | Whole Design | Detection | Picking | Deposition

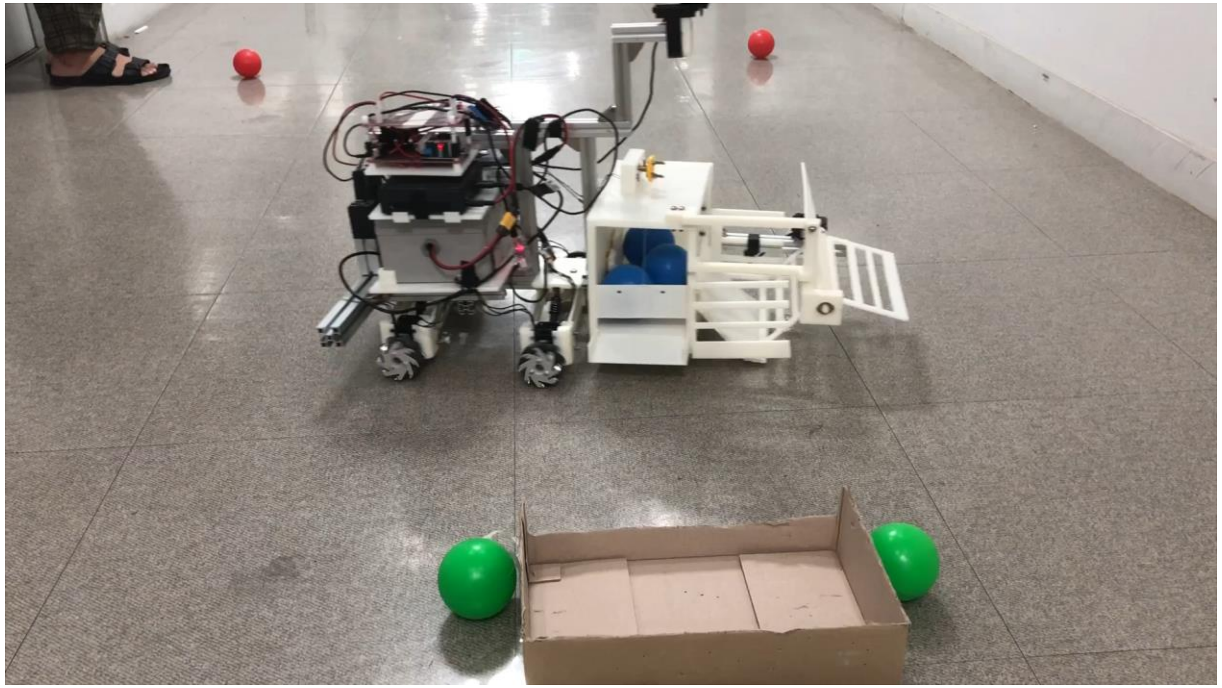


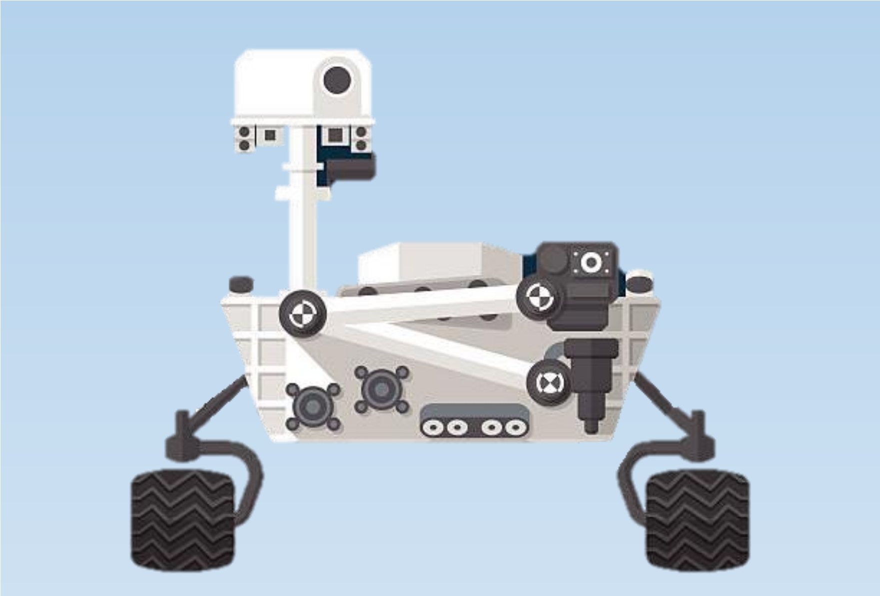


System Overview

System → Whole Design → Detection → Picking → Deposition







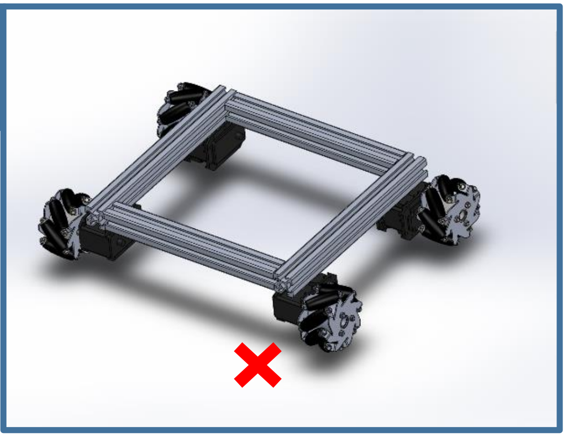
Section – B

System Analysis

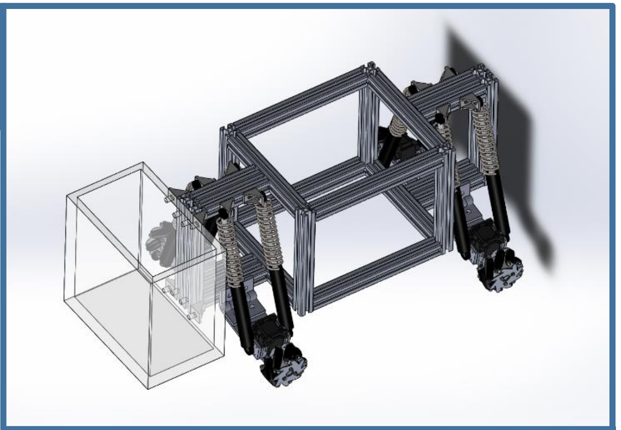
System Analysis

Suspension | Overview | Modelling | Video | Graphs

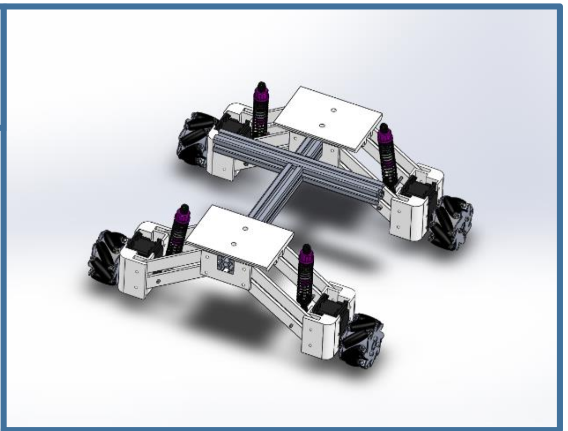
Ver #1

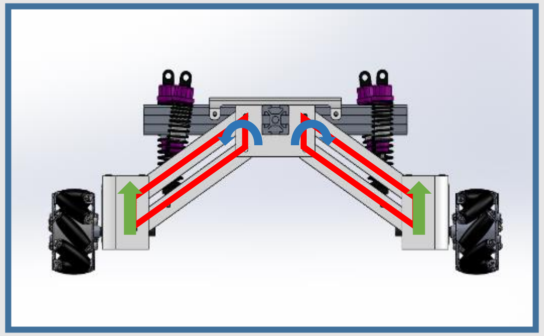


Ver #2



Ver #3

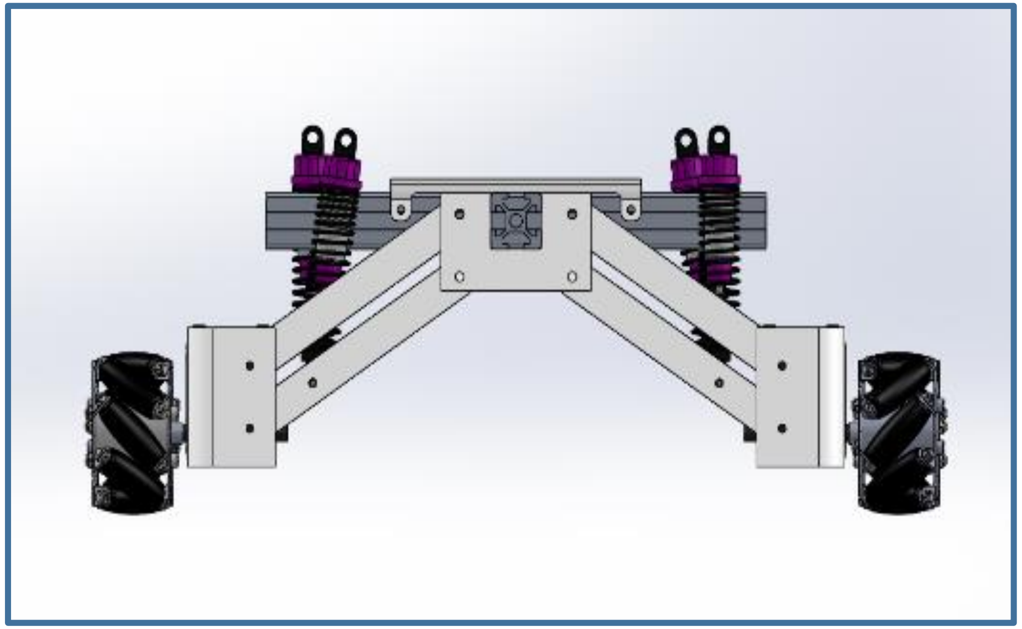




Ver #1: No suspension

Ver #2: MacPherson strut

Ver #3: SLA suspension

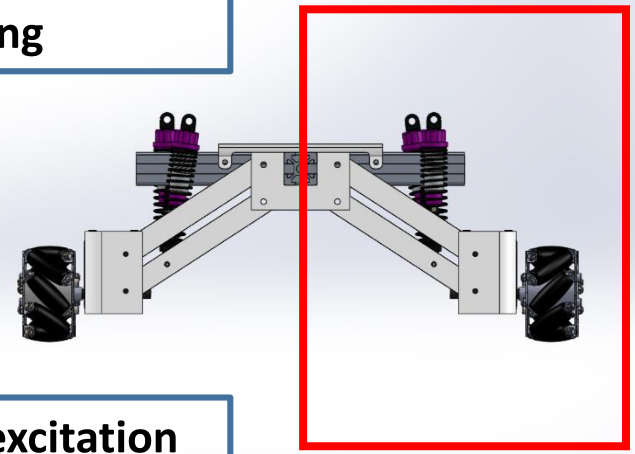


- ➢ Merits of suspension
- ✓ Better traction
- ✓ Precise detection

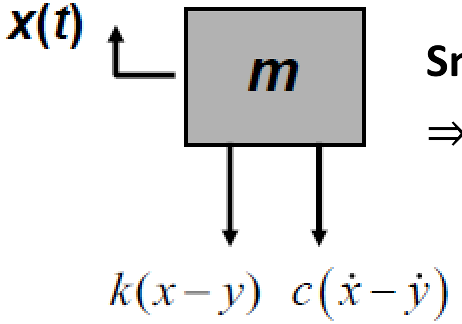
System Analysis

Suspension | Overview | **Modelling** | Video | Graphs

1/4th suspension modelling



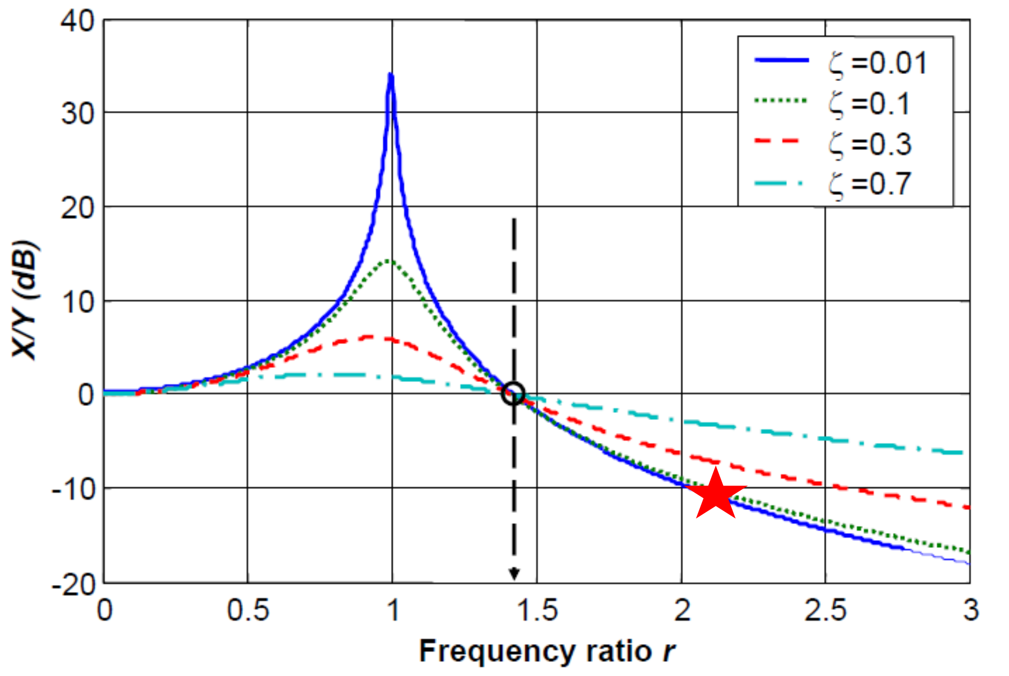
Base excitation



Smooth road

$\Rightarrow \omega_n = \frac{2\pi}{T}$

$\Rightarrow r = \frac{\omega}{\omega_n}$

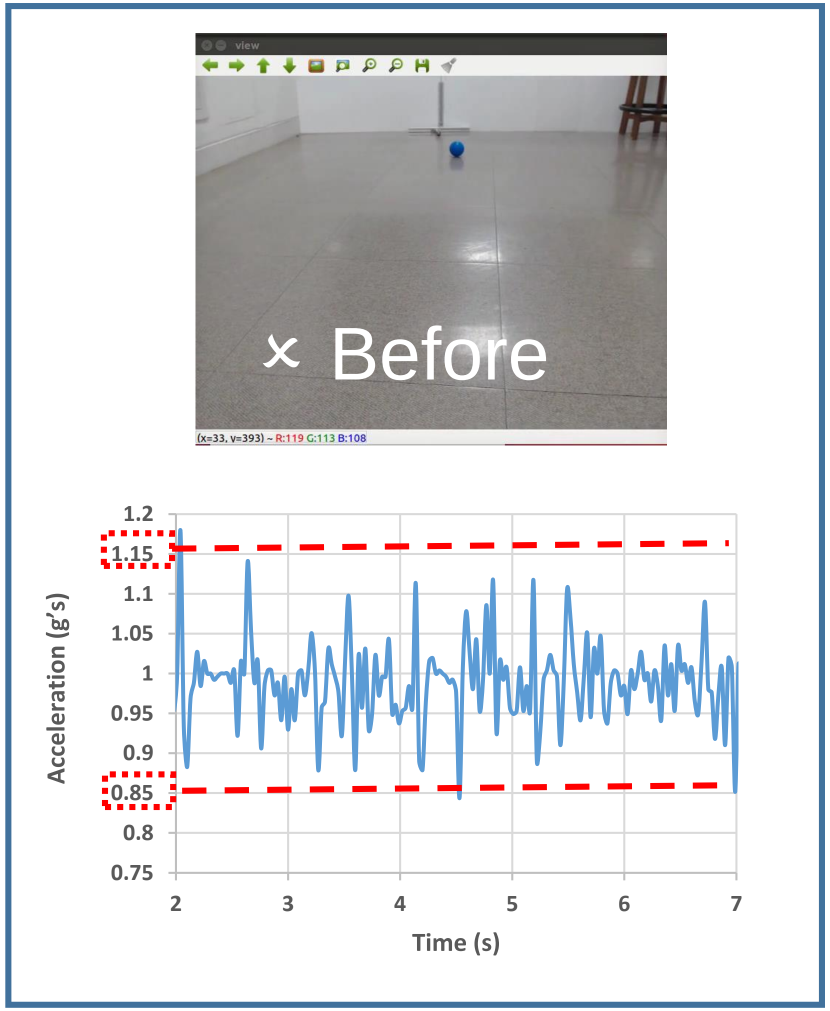


ω = 60 rpm -> K< 118.44 N/m necessary

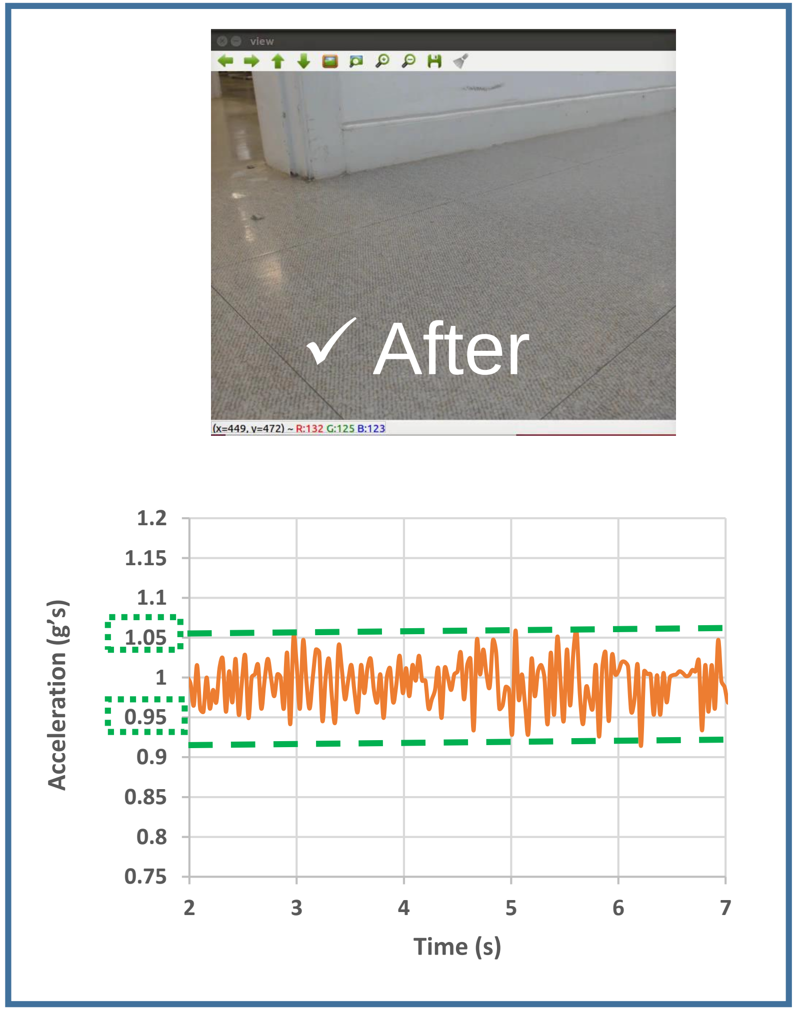
$\Rightarrow$ Our K value : 53.33 N/m

r = 2.114

System Analysis

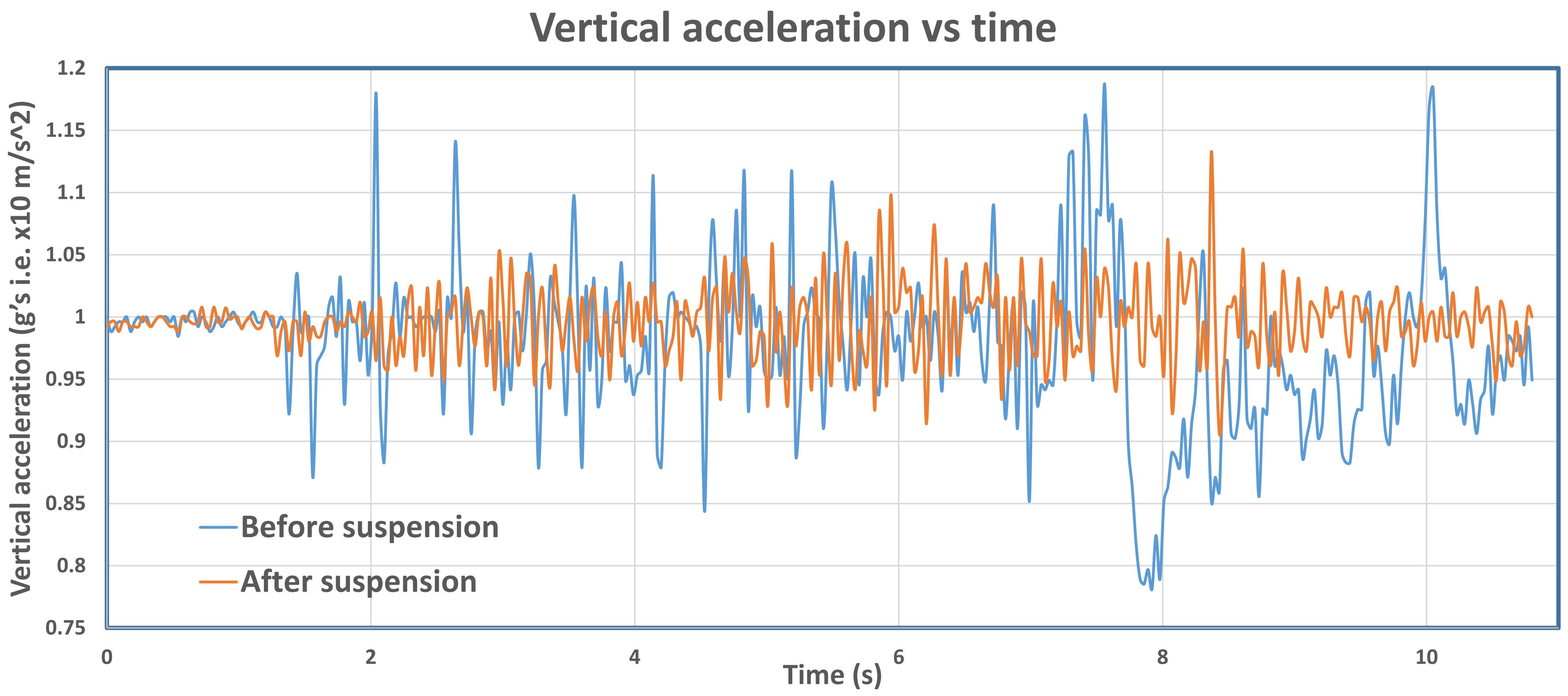


$$\frac{A_{after}}{A_{before}}: -10dB \approx 0.316$$



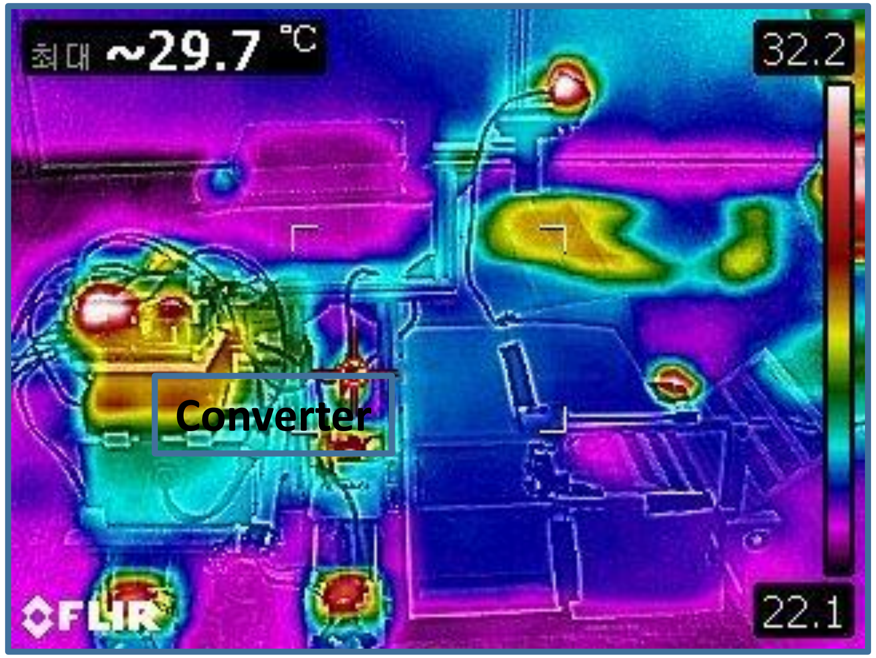
System Analysis

Suspension | Overview | Modelling | Video | Graphs

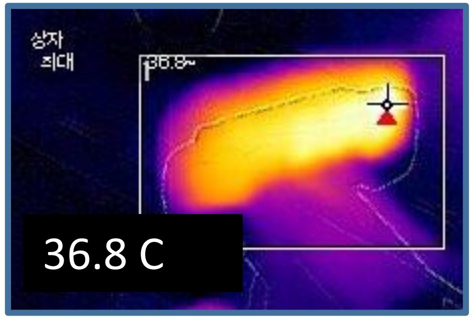


ENGINEERING FOR MANKIND KAIST

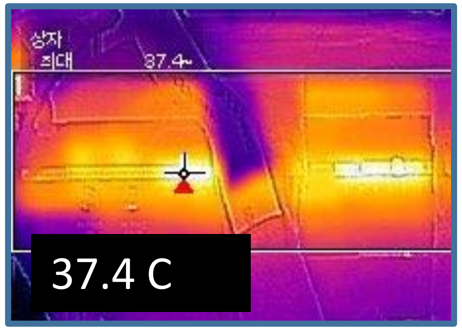
Heat Transfer → IR Camera → Calculation → Cost vs benefit



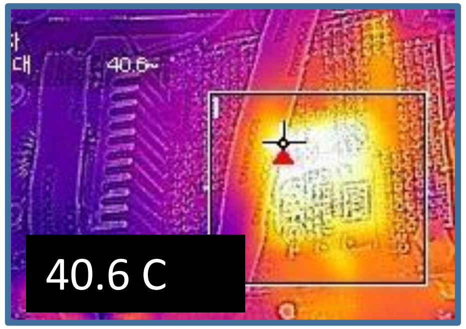
Hot Spots



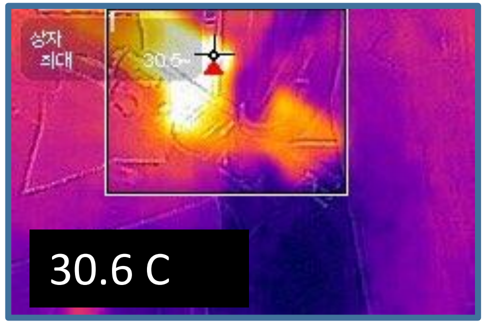
Camera



MyRio



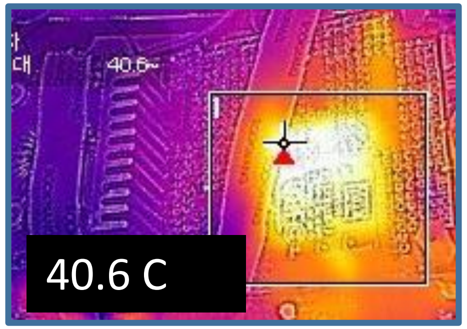
Converter



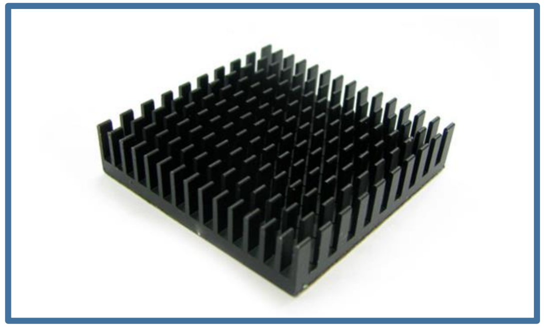
DYNAMIXEL Motor

System Analysis

Heat Transfer → IR Camera → Calculation → Cost vs benefit



Converter



Aluminum fin

Fan

Free Convection

- h = 8.97
- Q= 0.323 W
- T_s = 40.6 ℃

Adiabatic case

- Using thermal resistance
- q = M tan(mL)
- T_s = 36.71 ℃

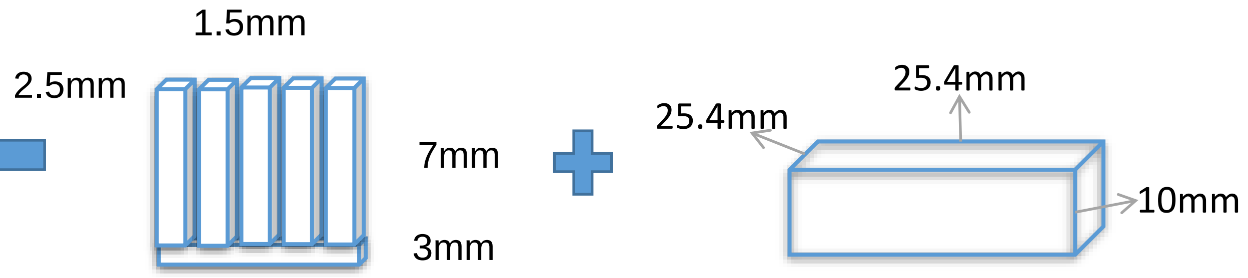
Forced convection

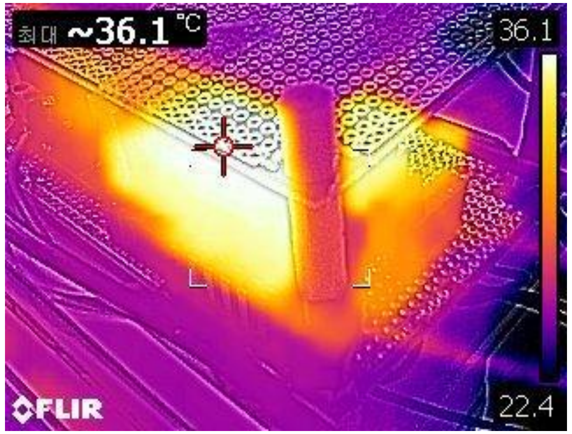
- Using thermal resistance
- h = 20.5 $^{W}/_{m^2.K}$
- T_s = 31.8 ℃

System Analysis

Heat Transfer → IR Camera → Calculation → Cost vs benefit

Theoretical calculation with fin gives
T_s = 36.7 ℃

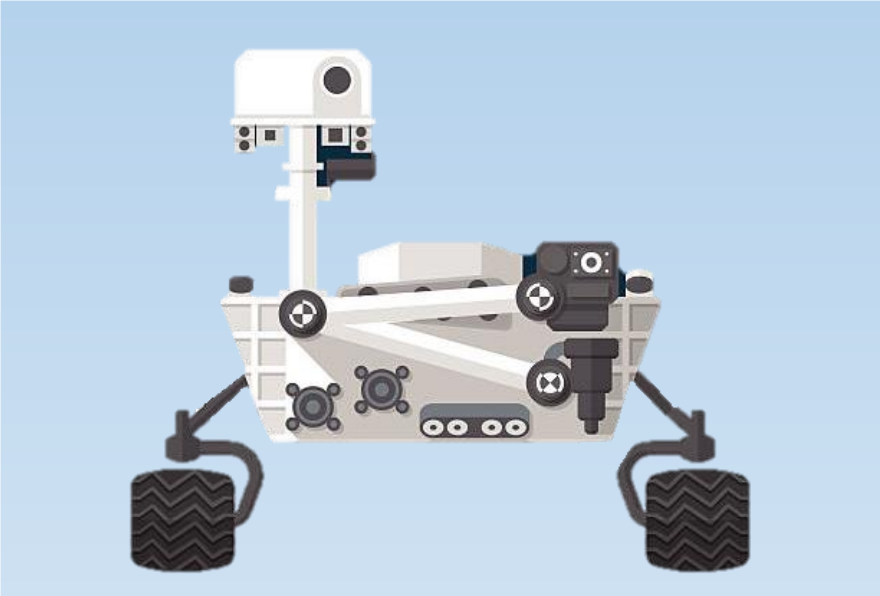




Experimental T_s = 36.1 ℃

	Fin	Comparison	Fan
Cost	2,000 KRW	X 7	15,000 KRW
Battery Usage	0	X 2	2.16 W
Cooling, ΔT_s	-3.9 ℃	X 2	-8.8 ℃
T_s	36.7 ℃	2 vs 7	31.8 ℃

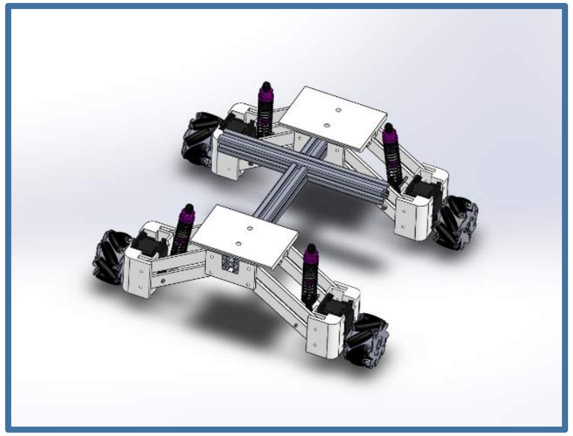
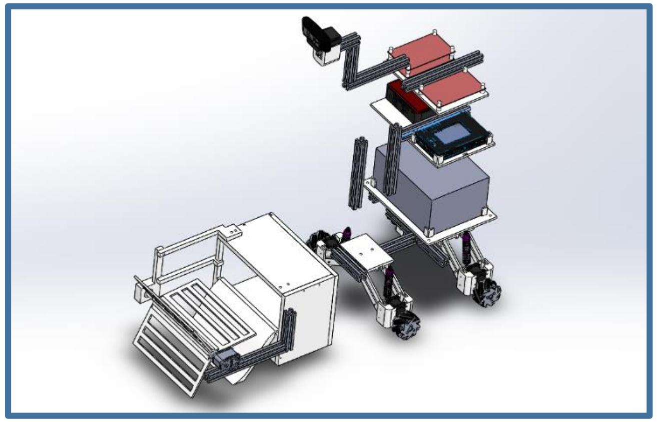
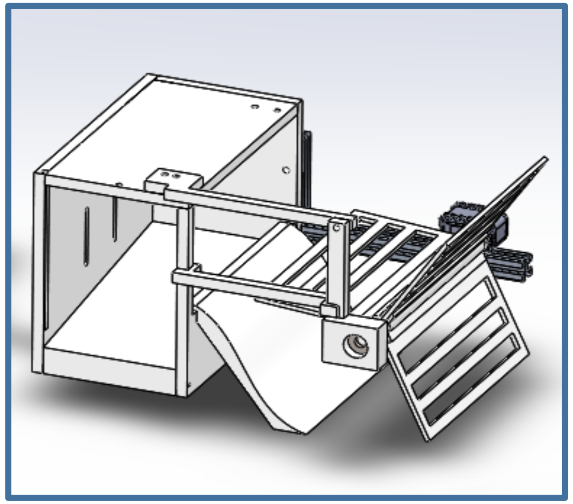
Hence, we decided to install **only Fin**

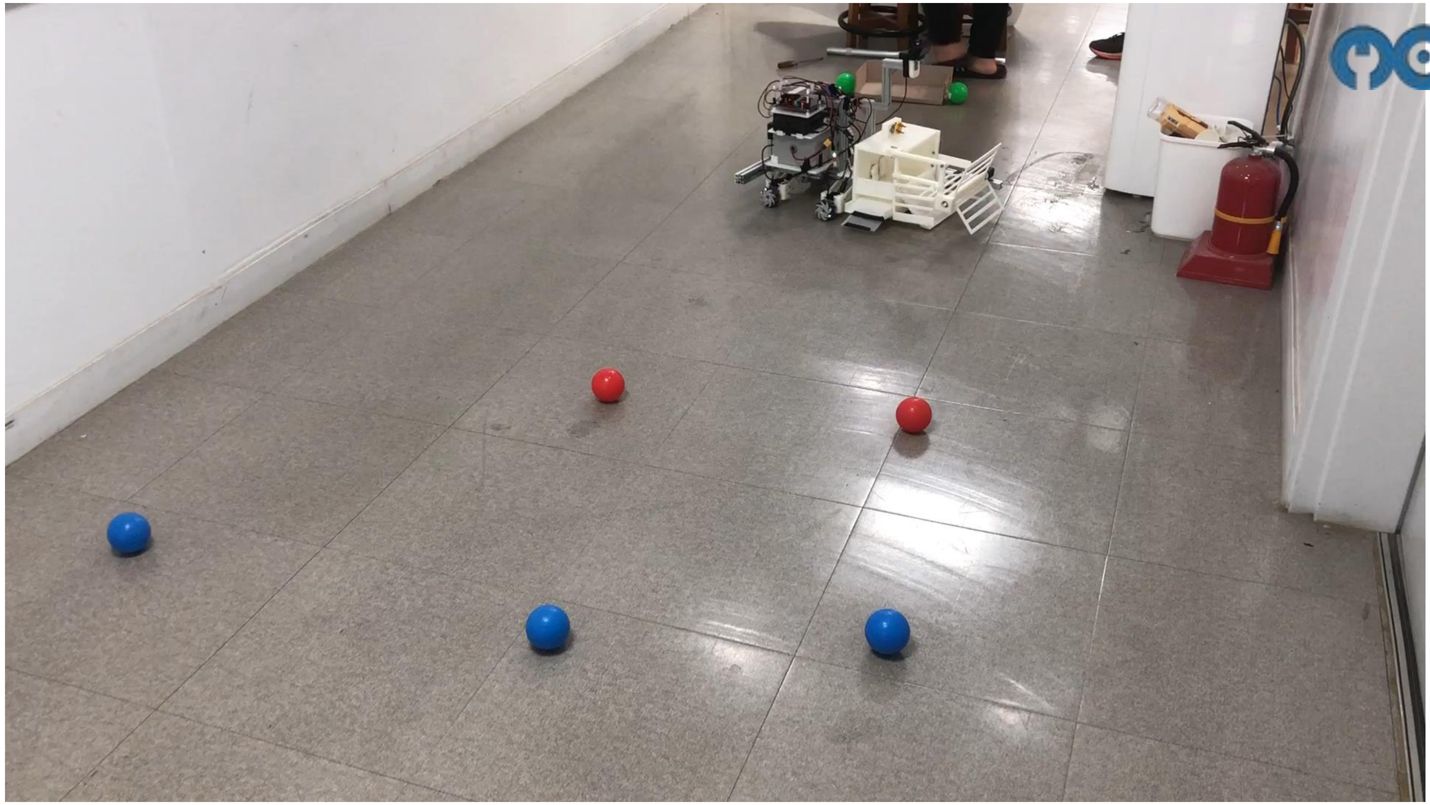


Section – C

Conclusion

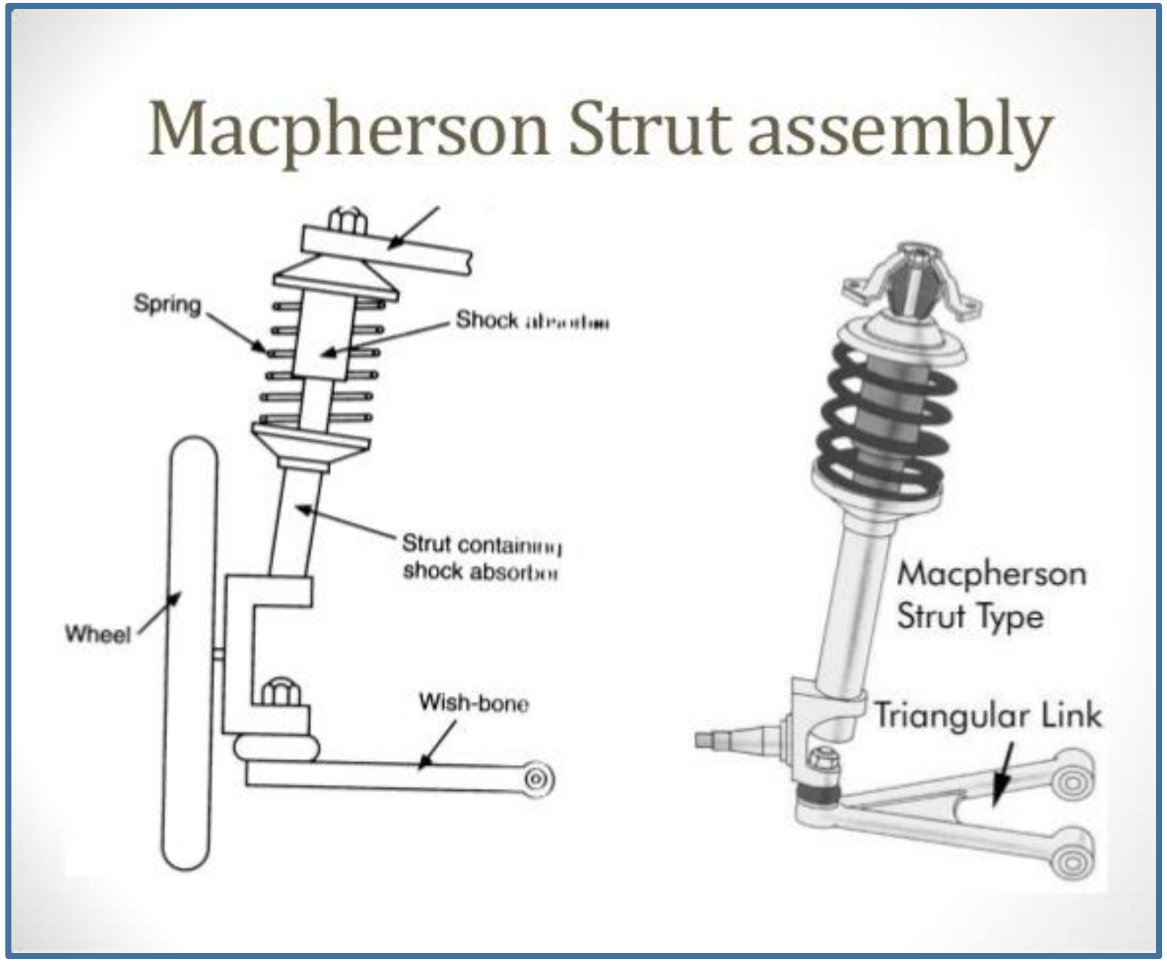
➢ Summary
- ✓ Independent Suspension
- ✓ Modular vehicle
- ✓ Minimizing cost by heat analysis
- ✓ Simple Blade Type Gripper

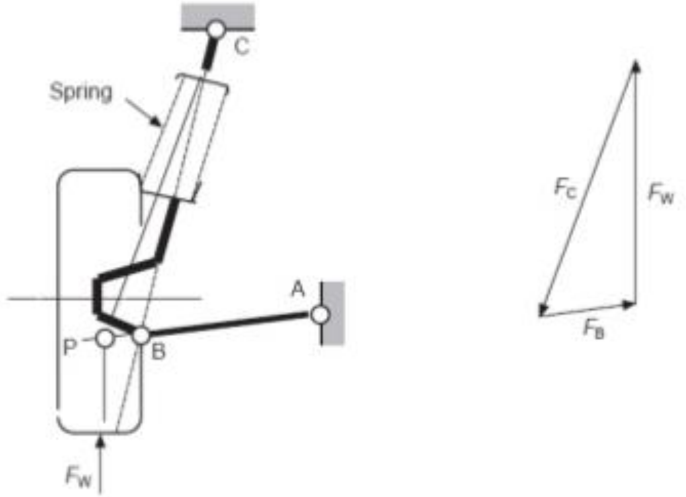



Thanks for listening

Questions or comments are welcome



Vertical loading- Macpherson



Force analysis of a MacPherson strut, (a) Wheel loading, (b) Forces acting on the strut

Figure from Smith,2002

Appendix

ENGINEERING FOR MANKIND KAIST

$$r = \frac{\omega}{\omega_n} > \sqrt{2}$$

$$\omega_n = \sqrt{\frac{k}{m}} < \sqrt{2}\omega$$

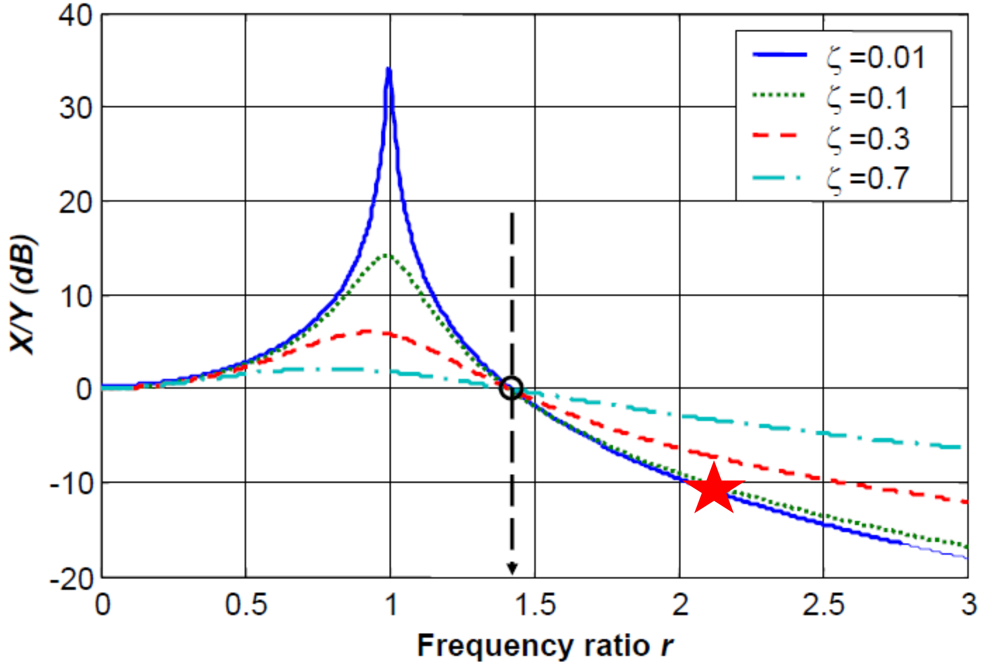
$$m = 6kg, \omega = 60rpm = 2\pi\ rad/s$$

$$\therefore k < 118.44\ N/m$$

	SPRING SPEC.				PJT. NAME : Suspension Spring
					DOC. NO. :
					DATE :
SPRING TYPE : Compression Coil Spring					
MATERIAL : SUS316					
Modulus of transverse elasticity (G)	7000		Number of active coils (Ne)	23	
Wire diameter (d)	0.8	mm	Free length(L)	38	mm
Center diameter (D_m)	14.2	mm	Displacement(l)	20	mm
Total number of active coils (Nt)	15		Tensile stress(σ)	53	kg/mm^2
External diameter			Spring Pitch		
$OD = d + D_m$	15.00	mm	$p = \frac{L}{N_e + 1}$	1.58	mm
Internal diameter			Maximum compression height		
$ID = D_m - d$	13.40	mm	$L_{min} = d \times N_t$	12.00	mm
Torsion stress			Spring length		
$\tau = \sigma \times 0.33$	17.49	kg/mm^2	$ML = \pi \times D_m \times N_t$	669.16	mm
Initial tension					
$P_0 = \frac{\pi \times d^3 \times \tau}{8 \times D_m}$	0.25	kg			
Load					
$P = l \times K$	1.3333	kg			
Spring constant					
$K = \frac{G \times d^4}{8 \times (OD - d)^3 \times N_e}$	53.33368	N/m			

ENGINEERING FOR MANKIND KAIST

Theory



ω = 60 rpm -> K< 118.44 N/m necessary

$\Rightarrow$ Our K value : 53.33 N/m

r =2.114

Theory :

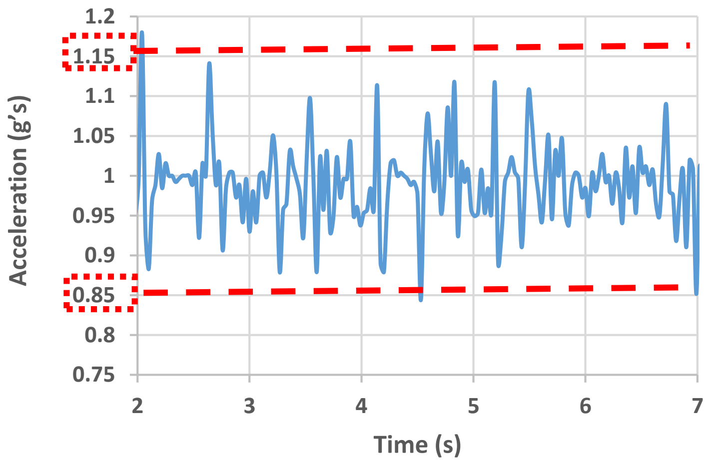
$$\frac{X_{after}}{X_{before}} = -10dB \approx 0.316$$

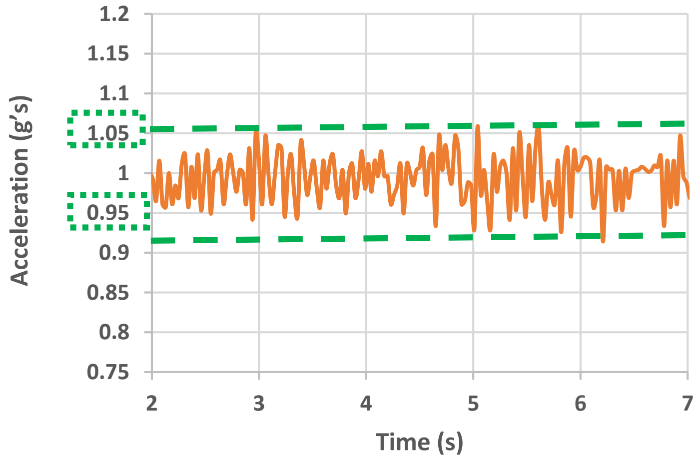
Experiment:

$$\frac{X_{after} \times {\omega_n}^2}{X_{before} \times {\omega_n}^2}$$

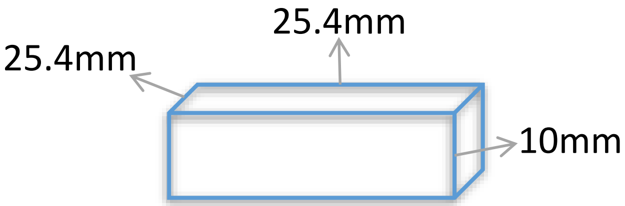
$$\frac{X_{after}}{X_{before}} = \frac{0.05}{0.15} \approx 0.33$$

Experiment





ENGINEERING FOR MANKIND KAIST



Without fan or fin

$$T_f = \frac{T_s + T_\infty}{2}$$

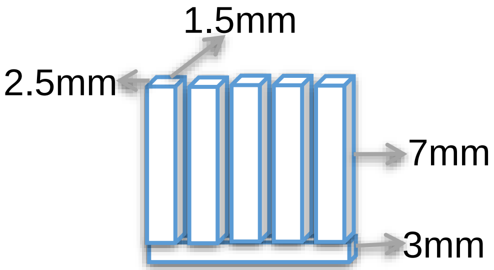
$$L = \frac{A_s}{P}$$

$$Ra = G_r P_r = \frac{g\beta(T_S - T_\infty)L^3}{\upsilon\alpha} P_r$$

$$Nu = 0.54 Ra^{\frac{1}{4}} = \frac{hL}{k}$$

$$\therefore h = 8.97\ {}^{W}/_{m^2.K}$$

$$q = hA\Delta T = 0.323W$$



With fin

$$Ra = G_r P_r = \frac{g\beta(T_S - T_\infty)L^3}{\upsilon\alpha} P_r$$

$$Nu = 0.54 Ra^{\frac{1}{4}} = \frac{hL}{k}$$

$$\therefore h_{side\ 1} = 33.20\ {}^{W}/_{m^2.K}$$

$$\therefore h_{side\ 2} = 29.66\ {}^{W}/_{m^2.K}$$

$$q = M\tanh(mL) = 0.323W$$

$$q = kA\frac{T_s - T_b}{t}$$

$$T_b = 36.7°C$$

$$T_s = 36.71°C$$

With fan

$$r = 70mm, flow\ rate = 0.0108\ {}^{m^3}/_{s},$$

$$V = 0.7\ {}^{m}/_{s}$$

$$Re_x = \frac{Vx}{r}$$

$$Nu = \frac{h_x x}{k} = 0.664 Re_x^{\frac{1}{2}} Pr^{\frac{1}{3}}$$

$$\therefore h_x = 20.5\ {}^{W}/_{m^2.K}$$

$$q = hA\Delta T = 0.323W$$

$$T_s = 31.8°C$$

Free convection

$$Ra_L = \frac{g\beta}{\nu\alpha}(T_s - T_\infty)L^3$$

$$Nu_L = 0.54Ra_L^{\frac{1}{4}} \quad 10^4 < Ra < 10^7$$

$$q'' = \dot{E}/A_{surface}$$

$$q'' = h(Ts - T\infty)$$

$$Ts = ?$$