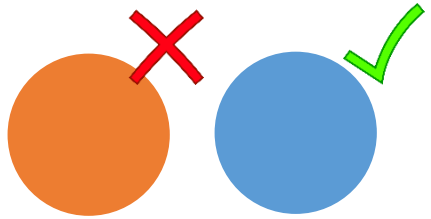
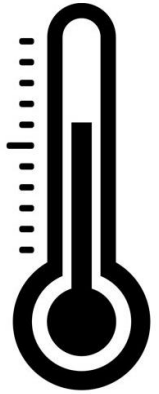
PROBLEM DEFINITION

MISSION: Create mobility system to deliver three blue balls into the basket

Side quests





What do we know & What should we do

- Design / Manufacture
  - Ball collecting system
  - Integrated configuration
- Heat transfer
  - Temperature Control
  - Energy Management
- Dynamics
  - Vibration Control
  - Optimized Mobility
- Control
  - Controlling Mobility System
  - Image Recognition
  - Path Planning

Design - Ball Collecting

Brainstorming

Grab with arm	Point contact / Line contact Top grabbing / Side grabbing Plane Contact (Glove)
Sticking	Glue Piercing
Sweeping	Net on arm Golf ball collector Pinball
Suction	Vacuum holder
Scooping	Tossing the boll Shovel type arm

Design - Ball Collecting

Evaluation – Decision Matrix

- **Grab with arm**
- **Sticking**
- **Sweeping**
- **Suction**
- **Scooping**

	Weight	Grab	Sticking	Sweeping	Suction	Scooping
Mass	6	S	+	+	-	S
Efficiency	8	S	+	+	-	S
Time	8	S	+	+	+	S
Reliability	8	S	-	S	S	-
Safety	5	S	-	S	-	S
Creativity	5	S	+	+	+	+
Aesthetic	1	S	+	-	+	S
Feasibility	10	S	-	+	-	-
Durability	6	S	-	+	S	S
Total		0	-1	42	-15	-13

Design

Concept generation (TRIZ)

1. If we use many motor, system reliability is good but Energy, Complexity is High.

2. Collecting ball is easy when collector area is large, but energy increases

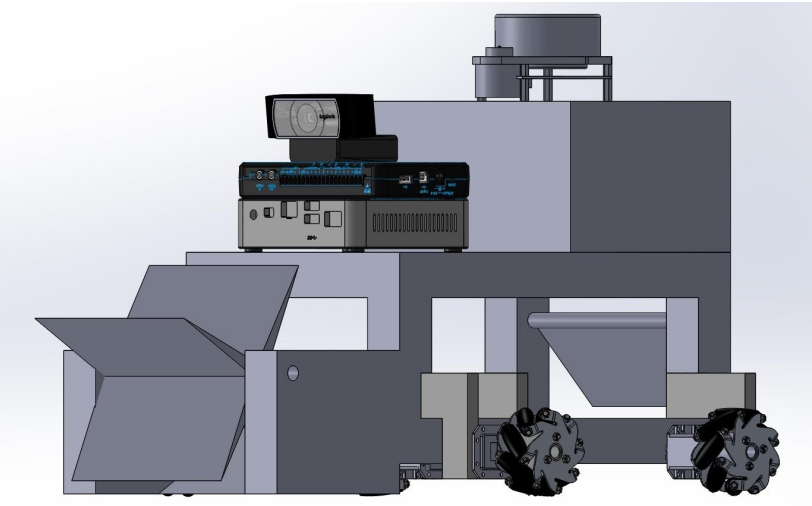
-Reliability & Energy

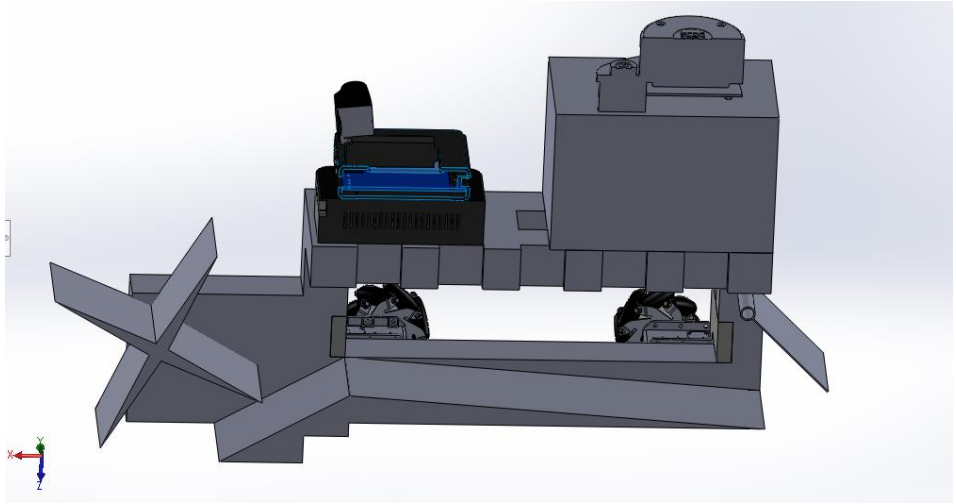
11. Beforehand Cushioning
19. Periodic Action
21. Skipping
27. Cheat Short - Living

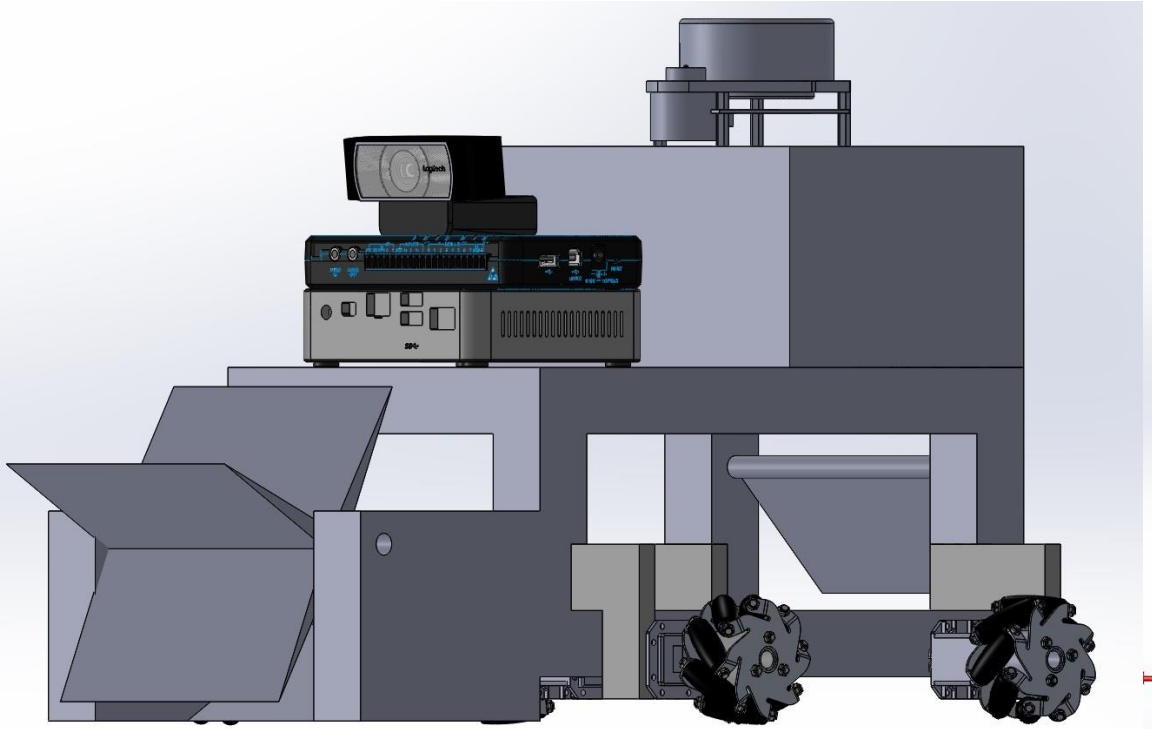
-Area of moving object & Energy

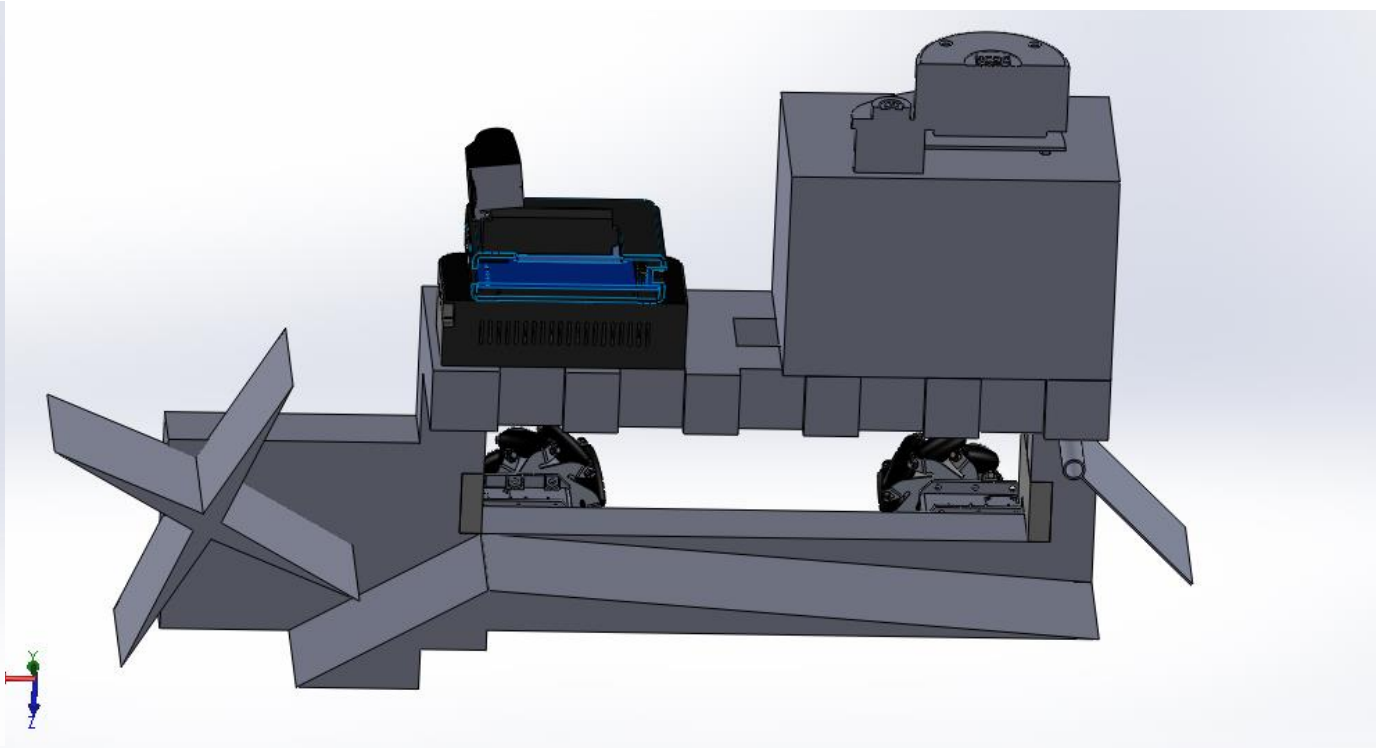
9. Preliminary Action
19. Periodic Action
29. Pneumatic and Hydraulic
32. Color Changes

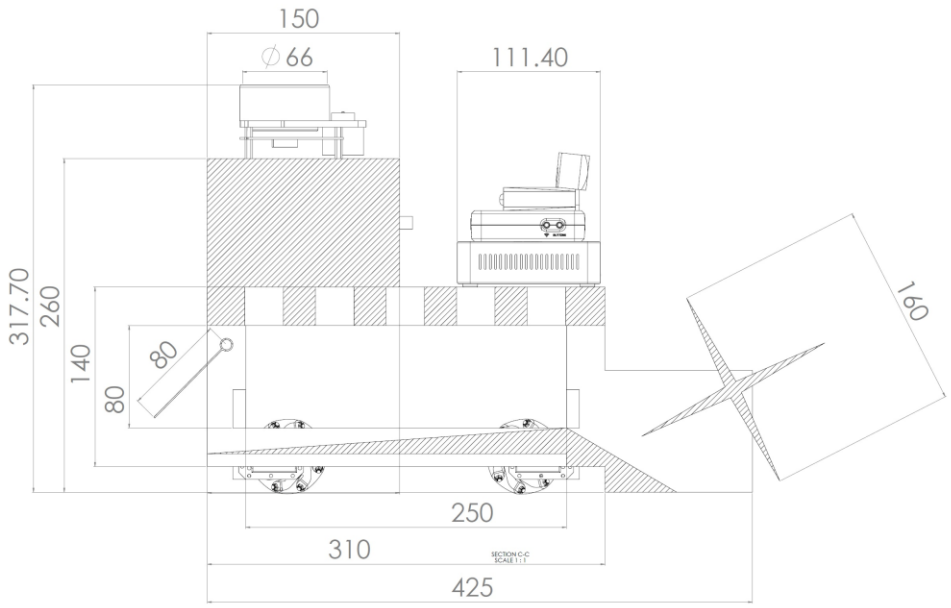
Rotating Sweeper





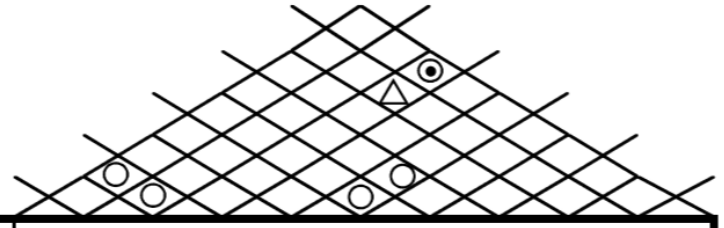





150
∅66
111.40
317.70
260
140
80
80
160
250
310
425

Design

◉ 9
○ 3
△ 1



What		student	position of camera	position of lidar	damping factor of suspension	cooler's thermal efficiency	speed of motors	size of sweeper	size of dropping gate	the number of motors	frame thickness	density of material
		who	How									
		↑	↑	↑	↑	↓	↓	↑	↓	↓	↓
			m	m		℃/s	rpm	m^3	m^3	개	m	kg/m^3
Recognize the ball	distinguish two colors	15	◉	◉								
	vibration reduction	7	△	△	◉		○					
control temperatue	decreasing temperature	15				◉	○			○		
	low energy usage	10					◉	○		○	○	◉
ball mechanism	pick up the ball	15						◉				
	drop the ball	13							◉			
mission time	path finding	10	○	◉								
	motor control	15					◉			◉		
	importance		11.9	16.1	4.4	11.4	20.1	11.4	8.1	14.5	2.1	6.2
	Target(Delighted)		0.3	0.3						6		
	Threshold (Disguested)		0.2	0.2						7		

Significant Specifications

-Speed of motors spec has most significant effect on performance.

-The number of motor affects temperature control and motor control

-Camera/Lidar location affects Path planning and Image identification

Energy Management

Least Energy consumption

Mechanical Energy (Main motor) $60W$

+

Electrical Energy $50W$

20% of energy heats up battery

$$q_{battery} = hA(T - T_\infty)$$

$$h \sim 20W/Km^2$$

$$A \sim 0.1m^2$$

$$(T - T_\infty) \sim 10K$$

80% efficiency assumed

Intel Nuc : 25W (idle)

NI myRIO : 14W

RPLidar, DFR0315 : 4W

Logitech HD pro webcam :3W

Temperature control

Cooling Mechanism (Passive)

1. Fin

2. Thermal Conducting vent

3. Design factors

Temperature control

Cooling Mechanism (Passive)

1. Fin

2. Thermal Conducting vent

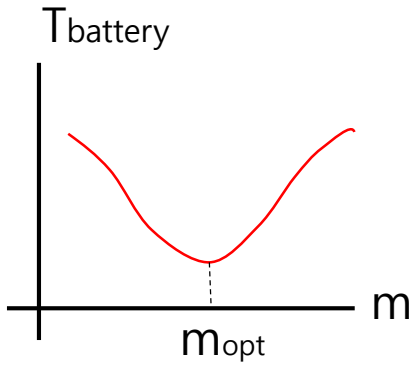
3. Design factors

$$q_{battery} = f(E) \text{ (increasing function)}$$

$$T_{battery} = T_{\infty} + \frac{q_{battery}}{\eta_o h A_t}$$

Assume: $q_{battery} \propto m$ (increasing function)

$$A_t \propto m\text{^}(\frac{2}{3})$$



$$\left.\frac{dT_{battery}}{dm}\right|_{m_{opt}} = 0$$

$$m_{cooler,opt} = m_{opt} - m_{sys,\,w/ocooler}$$

Temperature control

Cooling Mechanism (Active)

Fan

Coolant (Fluid)

ICE Pack

JT Expansion

	Weight	Fan	Coolant	ICE Pack	JT Expansion
Mass	6	S	-	S	+
Efficiency	8	S	+	+	+
Maintenance	3	S	-	-	-
Reliability	8	S	+	+	+
Safety	10	S	-	-	-
Creativity	5	S	S	-	+
Aesthetic	1	S	+	-	+
Feasibility	10	S	-	-	-
Durability	6	S	S	-	-
Cost	2	S	-	+	-
Total		0	-11	-17	0

Vibration Control

Naïve analysis

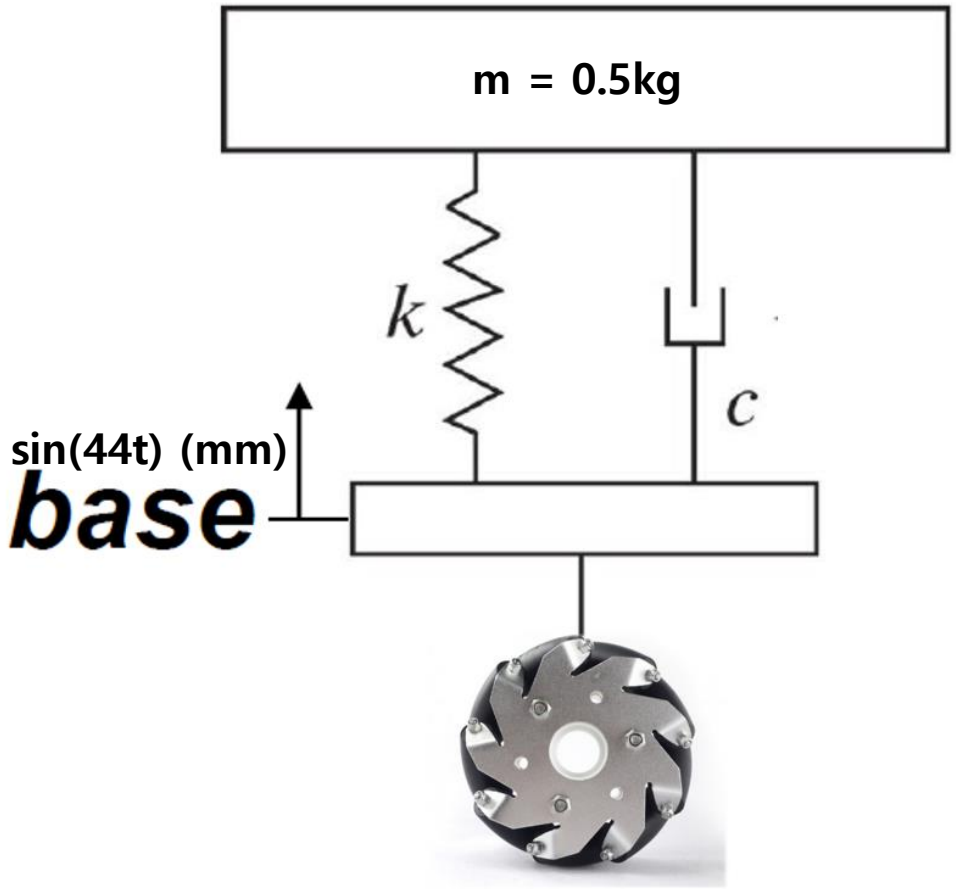
Angular velocity: 55rpm (5.8rad/s)
Base Vibration's Angular frequency: 44 rad/s

Equation of motion:

$$m\ddot{x} = \sum F = -k(x - y) - c(\dot{x} - \dot{y}) \text{ or}$$

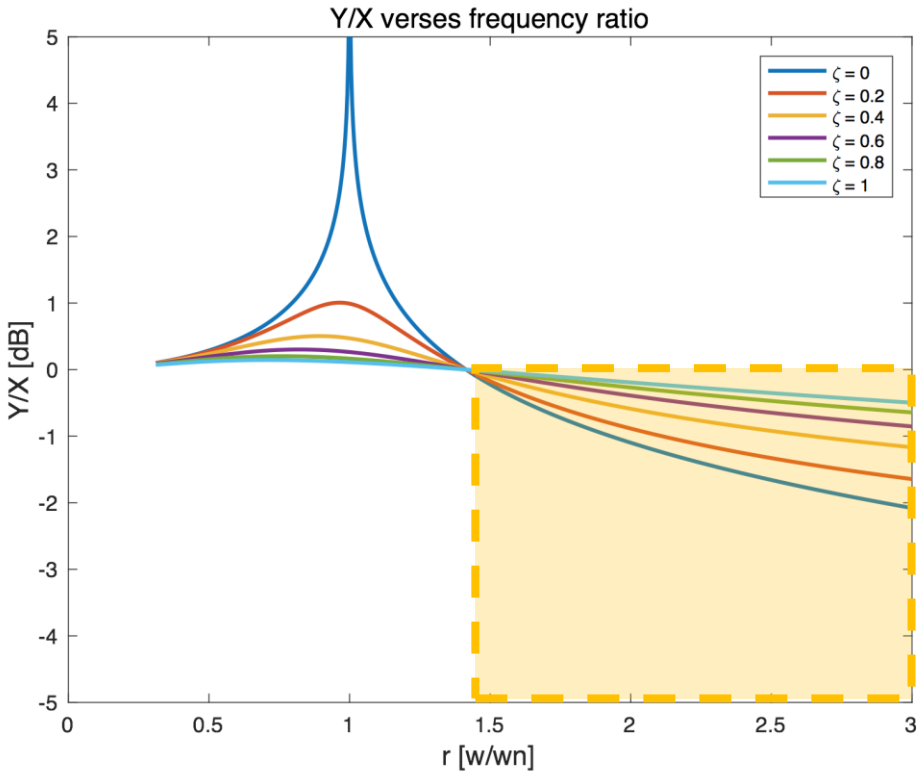
$$m\ddot{x} + c\dot{x} + kx = c\dot{y} + ky$$

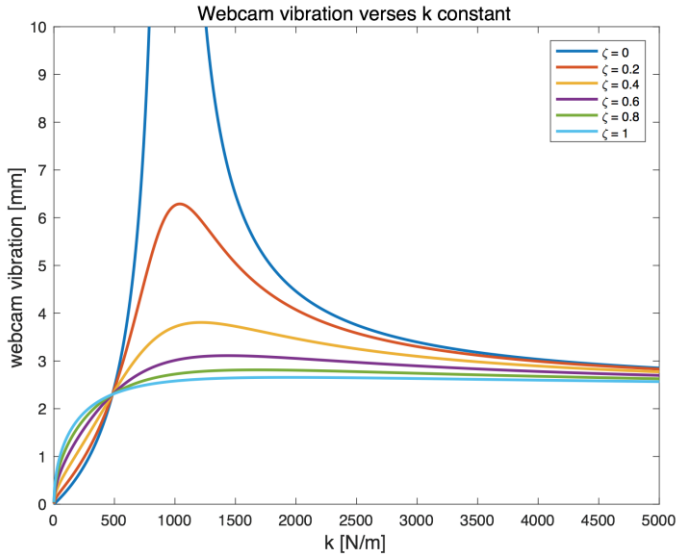
m = 0.5kg
y = 2.3 sin(44t) (mm)

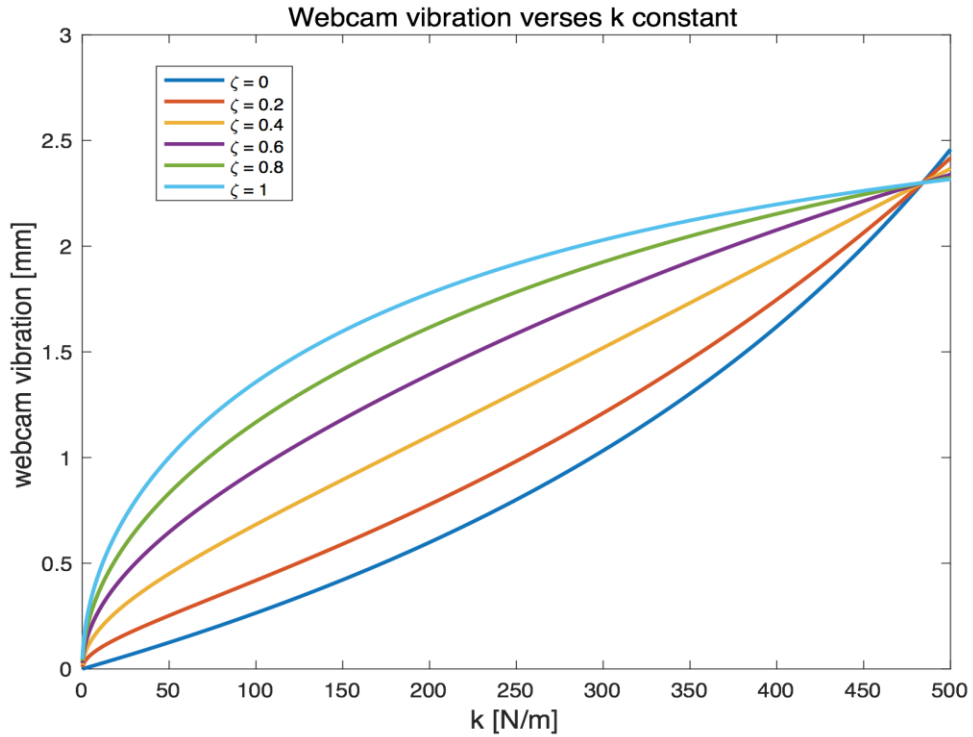


Vibration Control

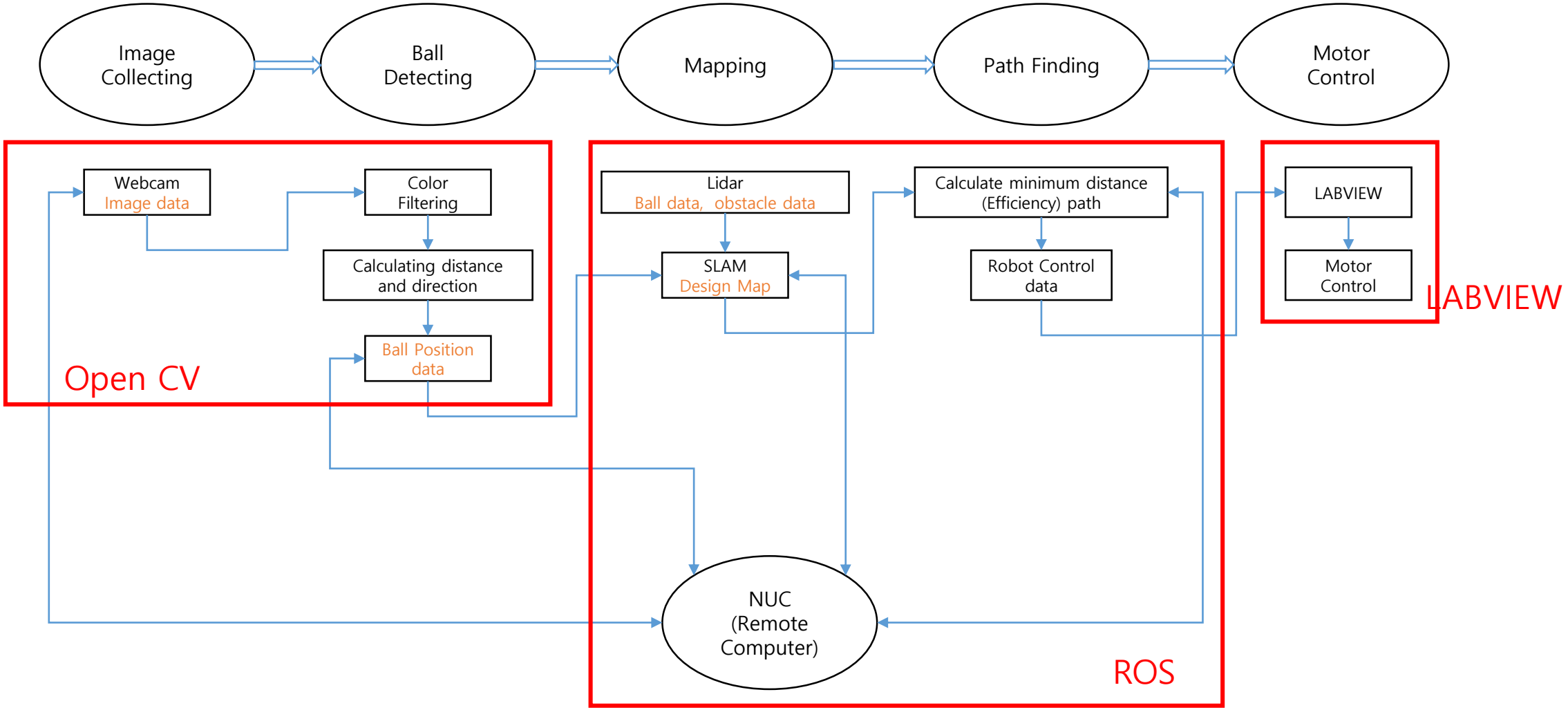
$$\frac{X}{Y} = \sqrt{\frac{1+(2\zeta r)^2}{(1-r^2)^2+(2\zeta r)^2}}$$







OpenCV/ ROS / LabView Integration

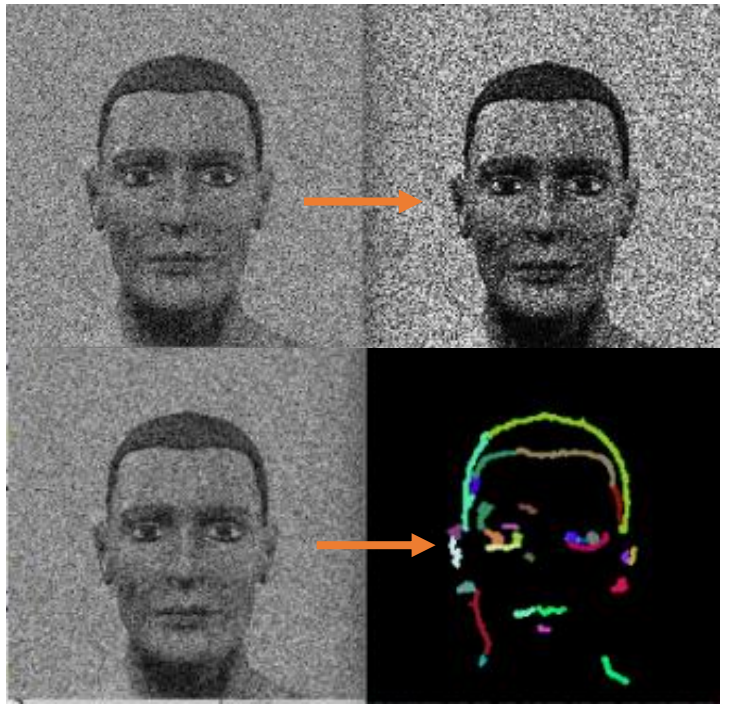


OpenCV

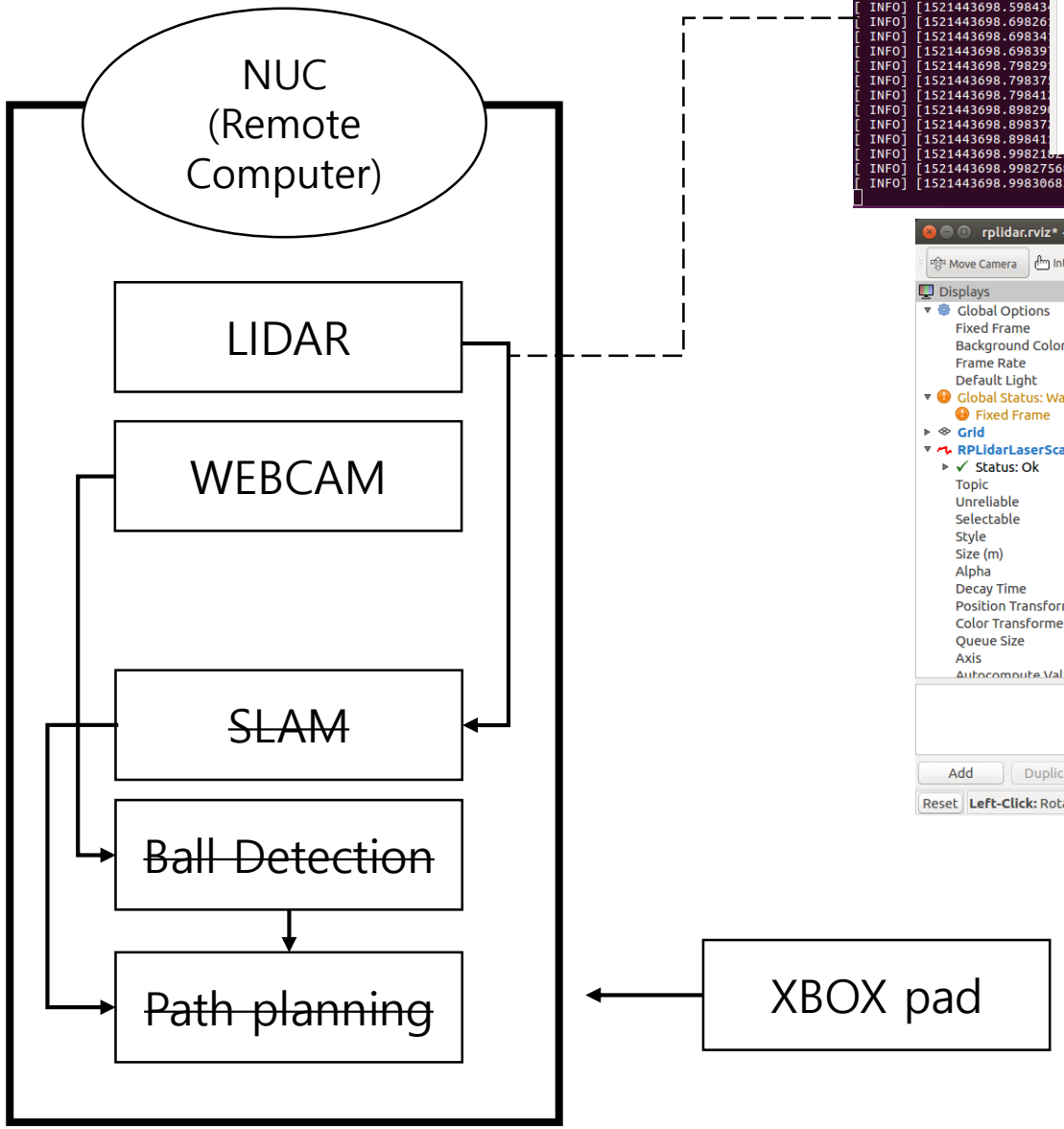
Functions

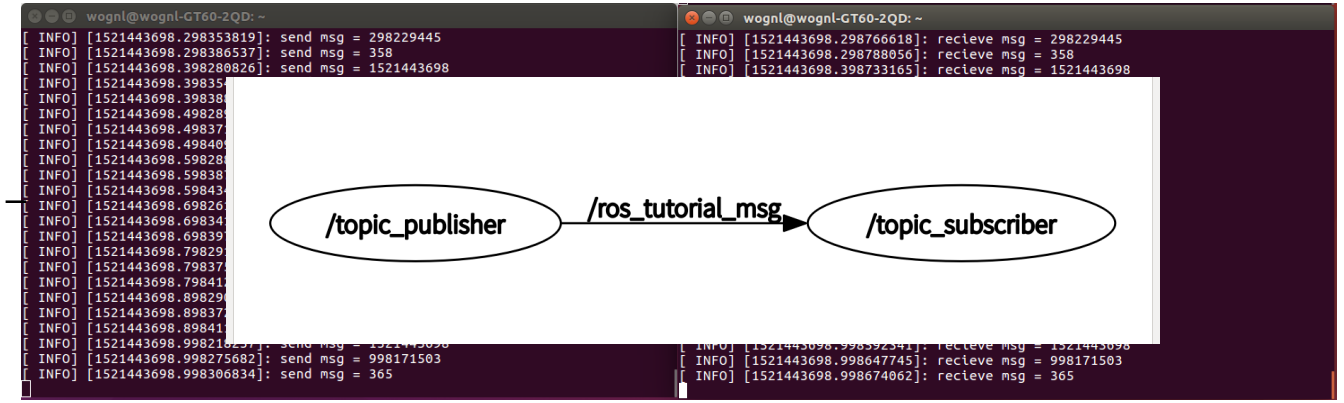
-Detect & Locate Ball
-Determine Color
-Reduce Noise

-Help Motion Analysis and Object Tracking
-Camera Calibration
-2D Reconstruction



ROS


NUC
(Remote
Computer)
LIDAR
WEBCAM
SLAM
Ball Detection
Path planning
XBOX pad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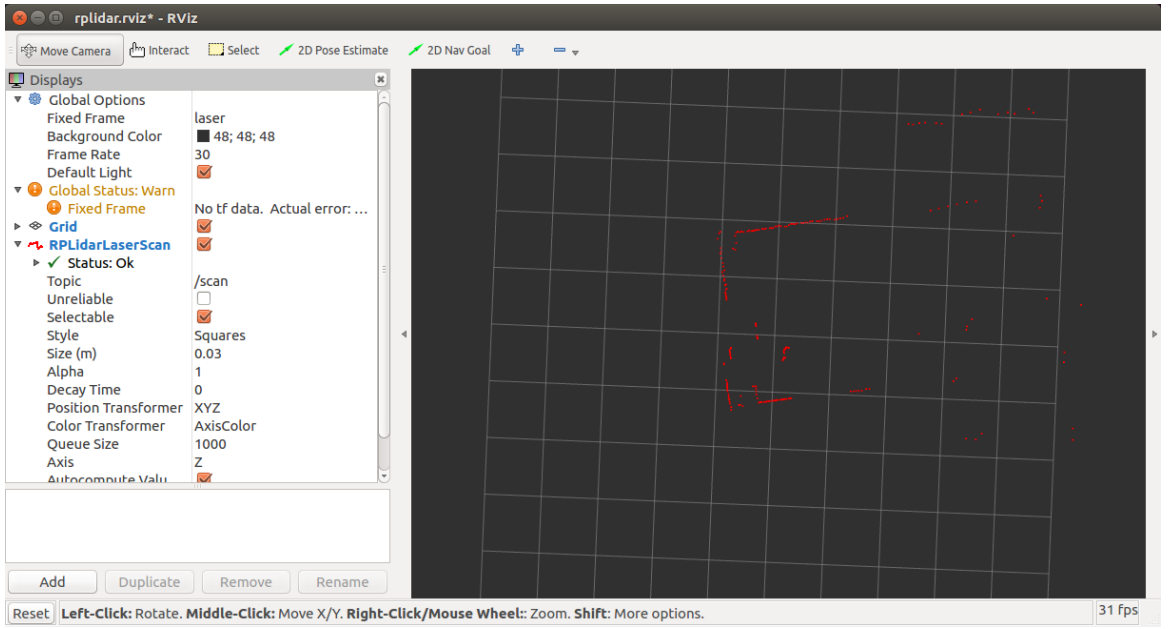
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Move Camera
Interact
Select
2D Pose Estimate
2D Nav Goal
Displays
Global Options
Fixed Frame laser
Background Color 48; 48; 48
Frame Rate 30
Default Light
Global Status: Warn
Fixed Frame No tf data. Actual error: ...
Grid
RPLidarLaserScan
Status: Ok
Topic /scan
Unreliable
Selectable
Style Squares
Size (m) 0.03
Alpha 1
Decay Time 0
Position Transformer XYZ
Color Transformer AxisColor
Queue Size 1000
Axis Z
Add
Duplicate
Remove
Rename
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
31 fps


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:: +0.000,+0.000) LT:+0.000 RT:+0.000 U:0 D:0 L:0 R:0 A:
0 B:0 X:0 Y:0 Bk:0 St:0 LB:0 RB:0 LS:0 RS:0
eased: 1 -> 0 -> 0d left[1936287828] trigger pressed: 1
(q)uit (r)umble
[1936287828] button triggered: Y
[1936287828] button triggered: A
[1936287828] button released: B
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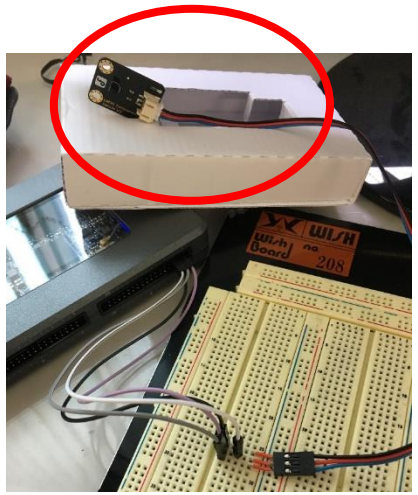
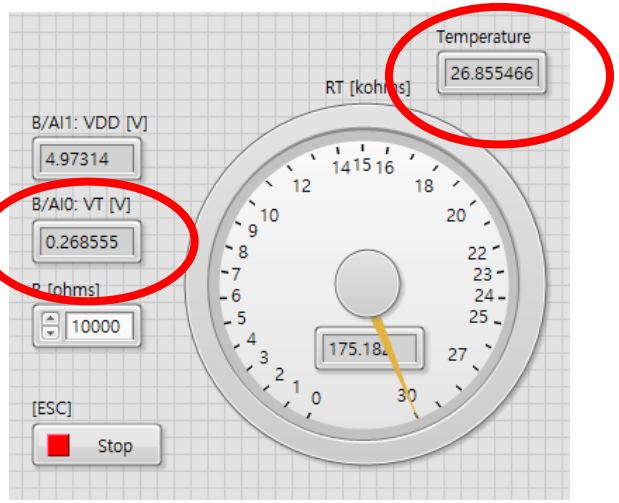
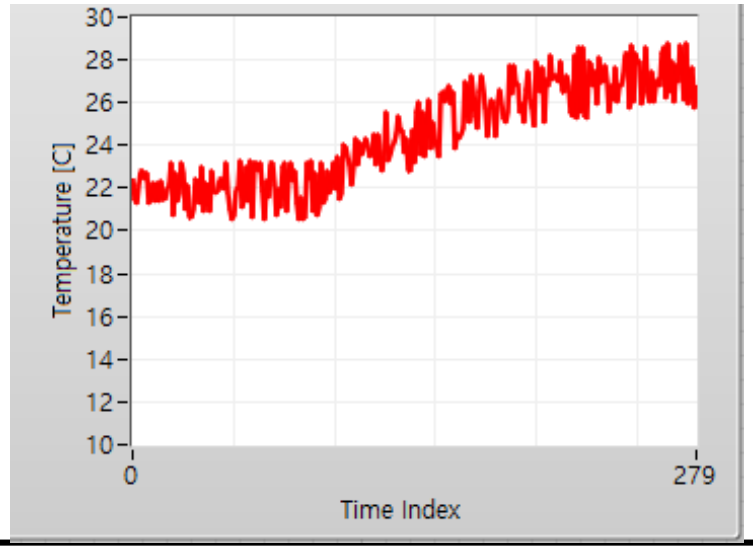
[1936287828] button released: X

LabView

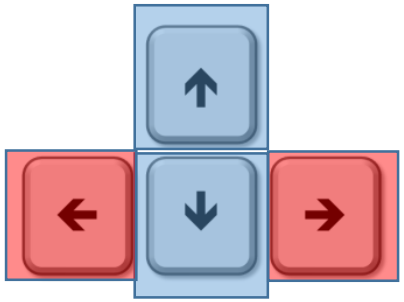
Temperature Sensor

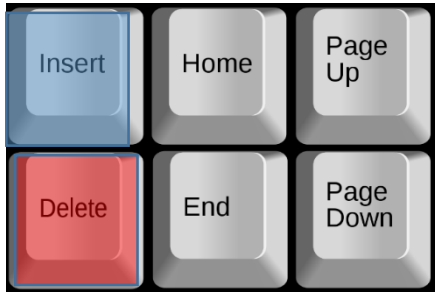






TCP/IP Connection





TCP/IP