Chair for Cognitive Systems
Department of Electrical and Computer Engineering
Technische Universität München

RoboCup@Home Final Project: Compliant Grasping

Team: NineAndThreeQuaters

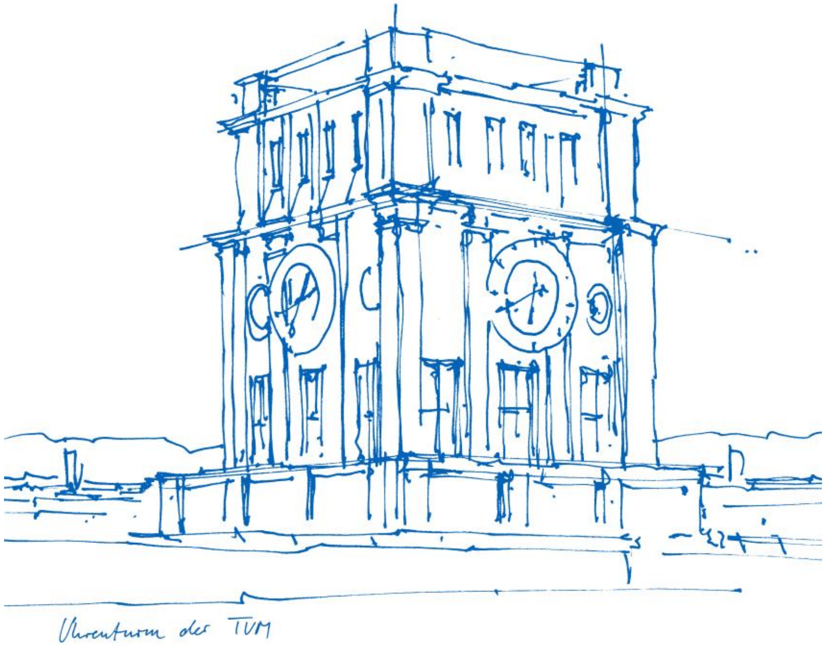
Member: Siqi Hu, Zhenyu Li, Chensheng Chen, Chenhao Wang

Technical University of Munich

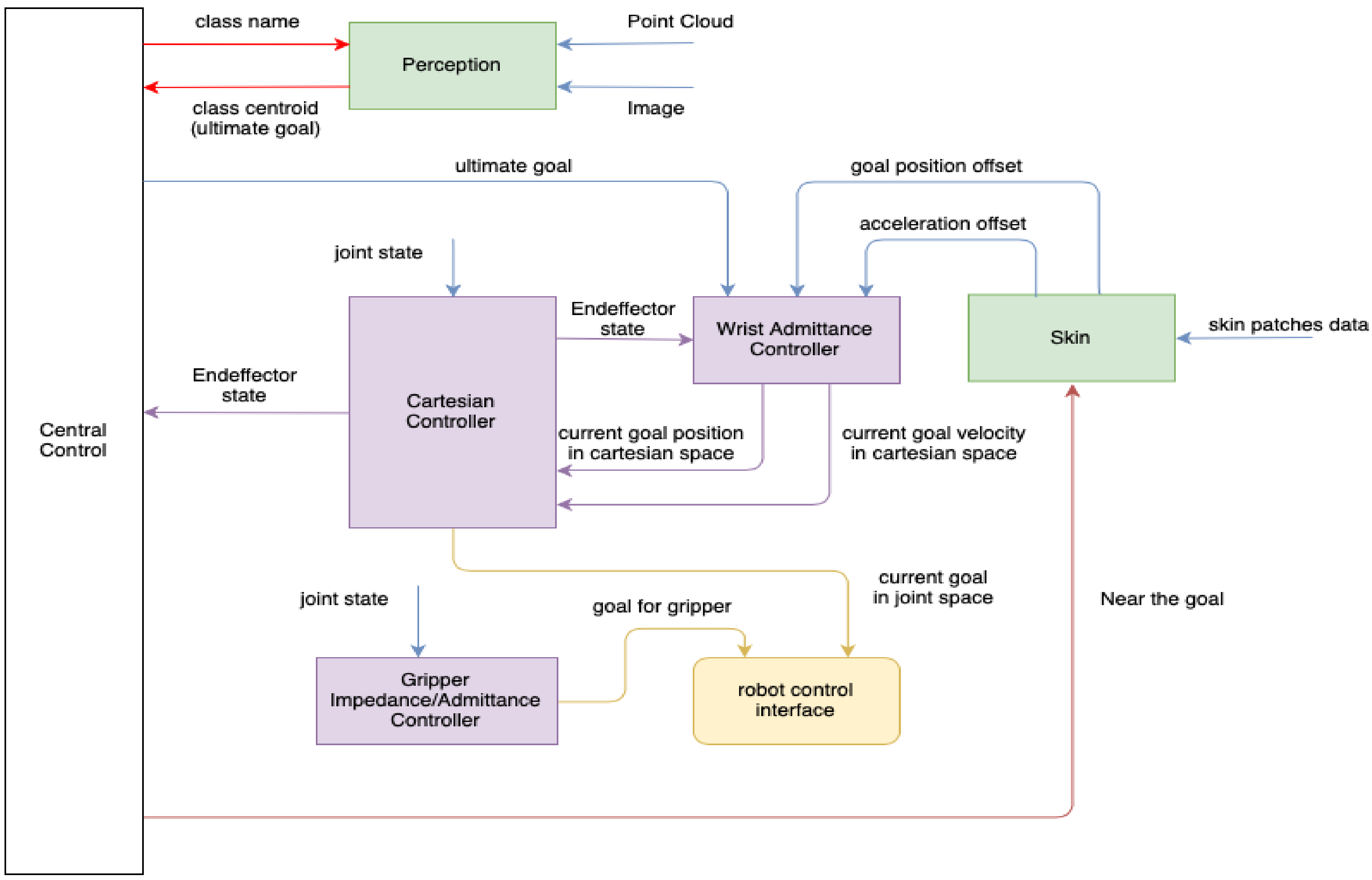
Chair for Cognitve Systems

Prof. Gordon Cheng

Munich, 08. February 2019



General Structure



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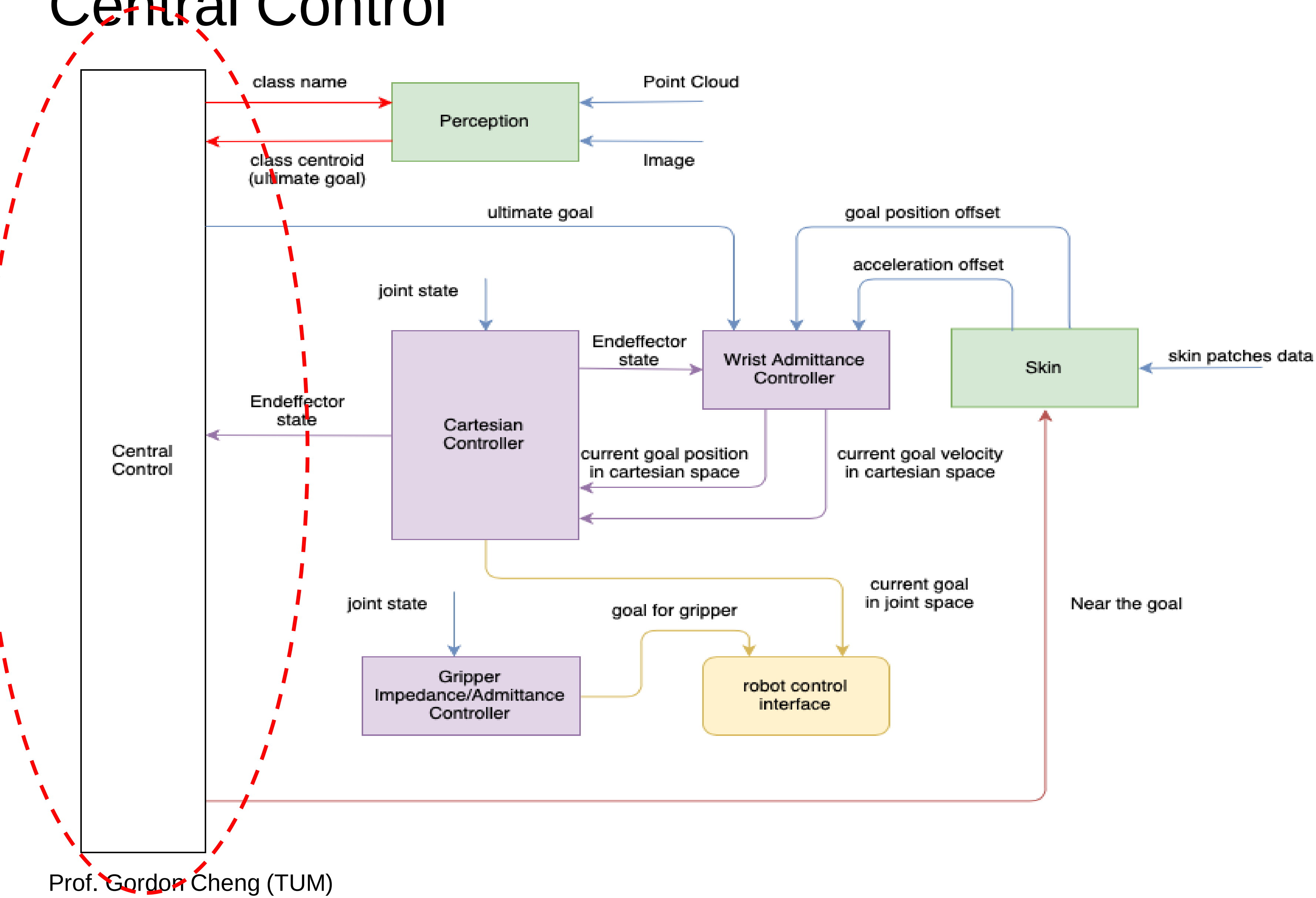
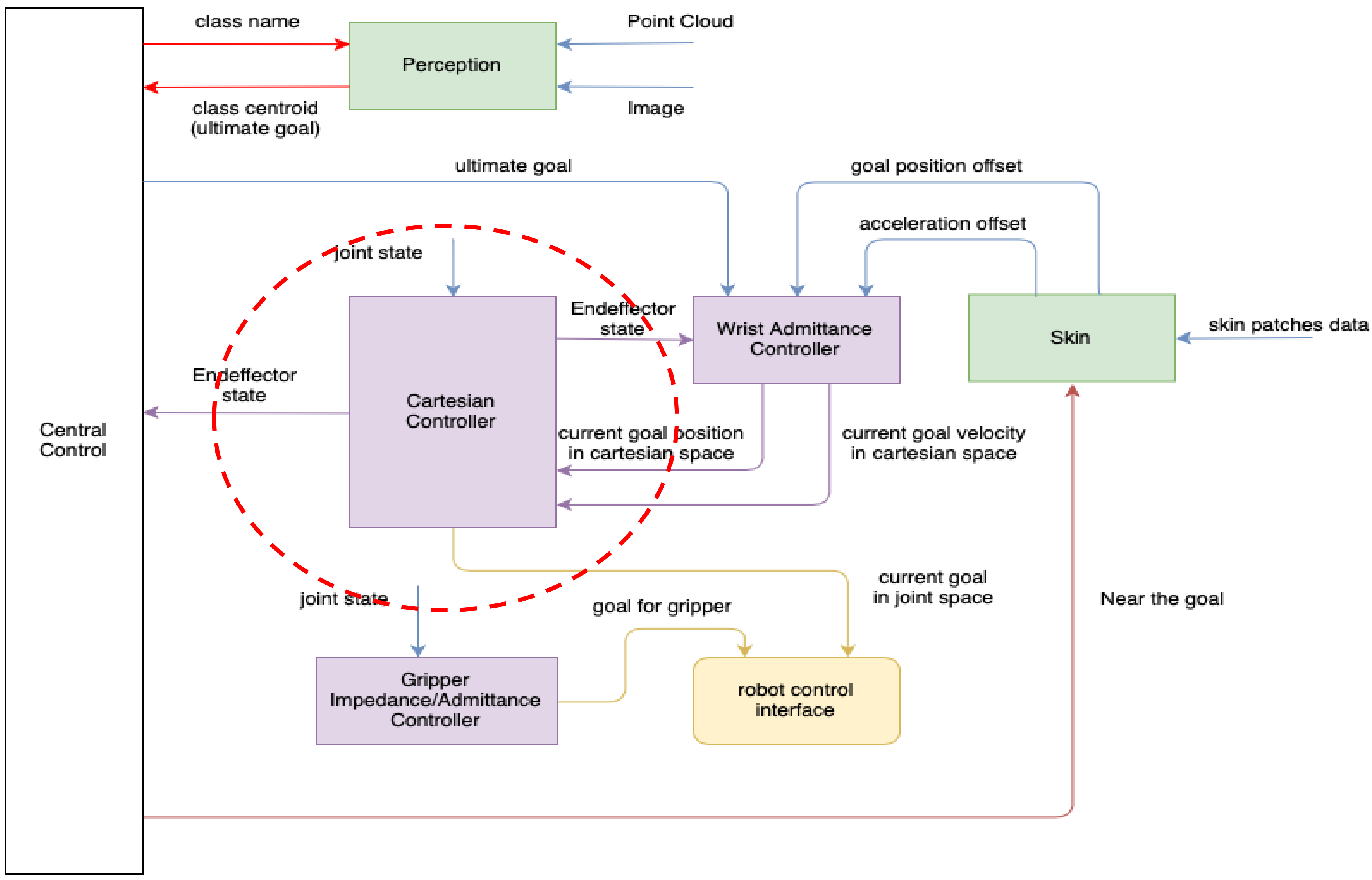
Central Control



Cartesian Controller by Siqi Hu



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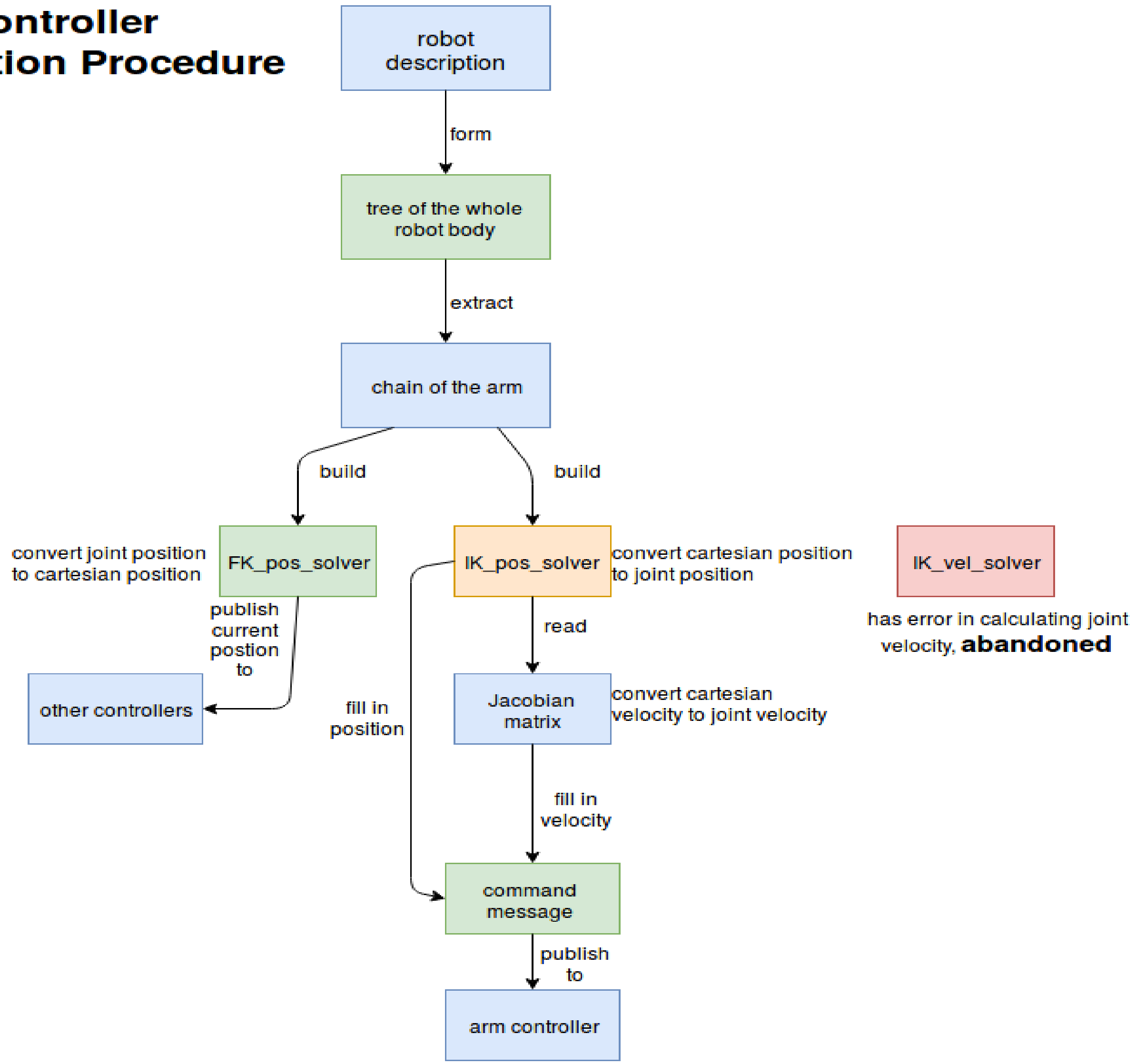
Cartesian Controller

Cartesian Controller Implementation Procedure



Cartesian Controller

Small Demo in Simulation: Set a goal in cartesian space. Convert goal position into 7 goal joint values, publish the goal joint values in order to move the end-effector to the goal.

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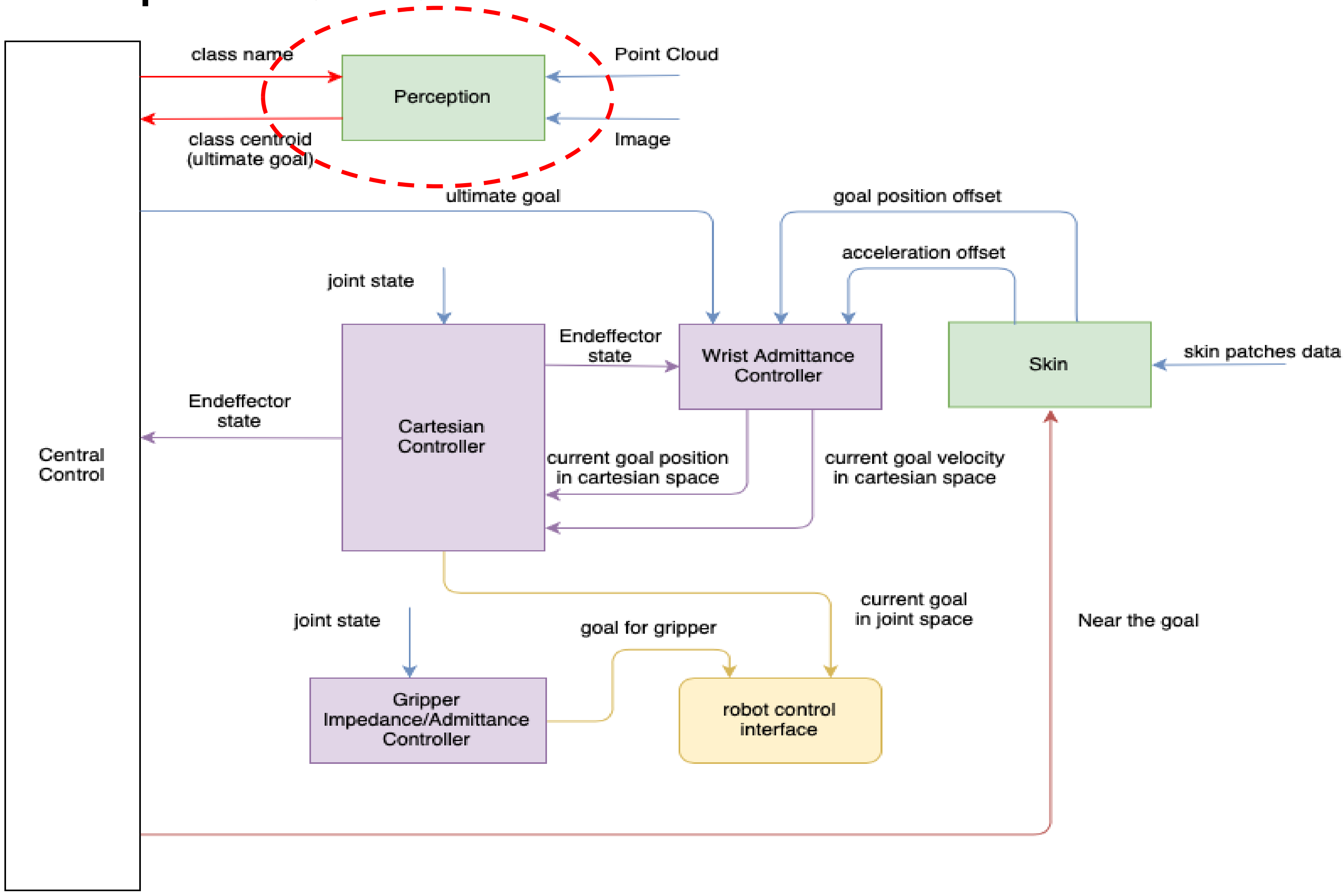
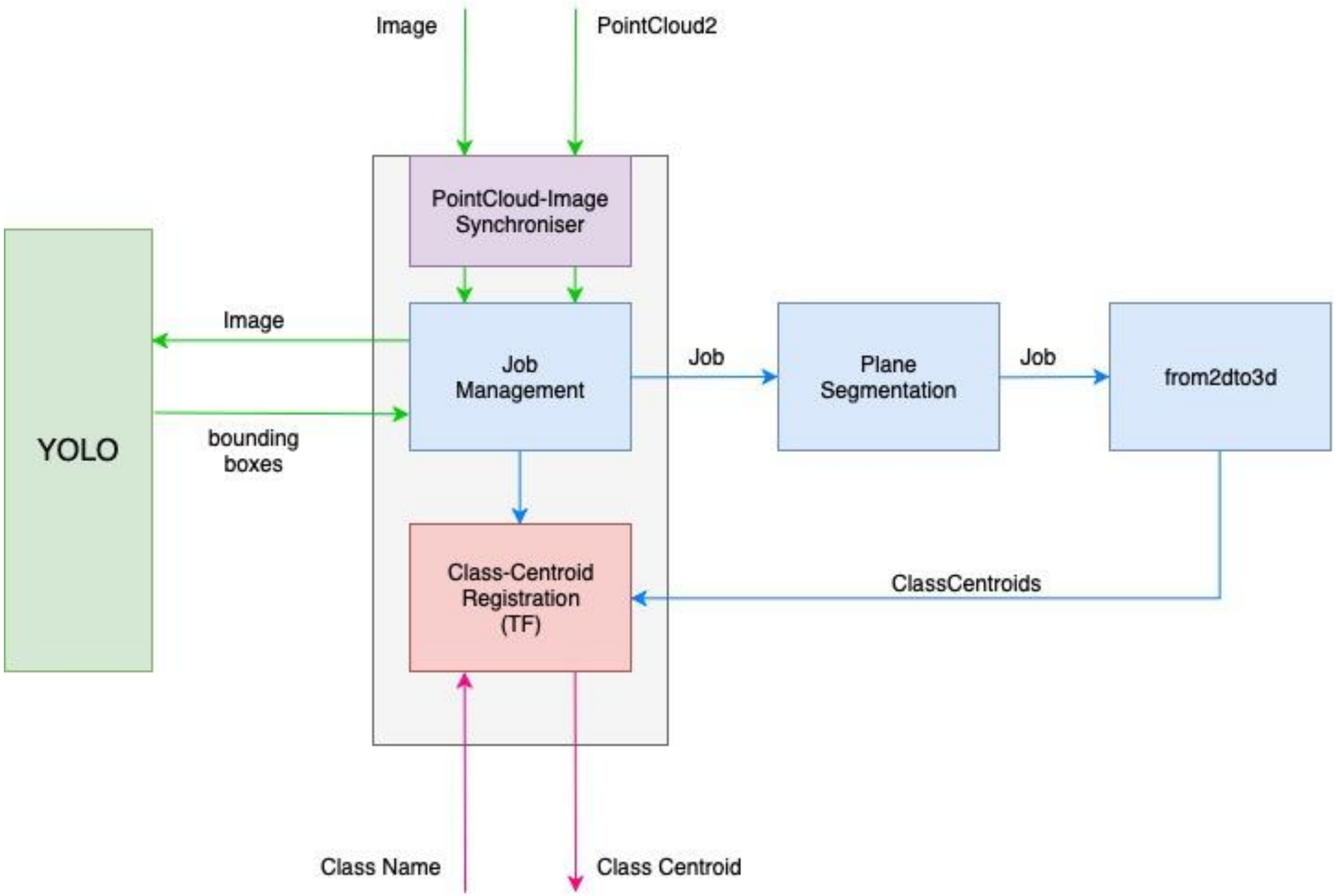
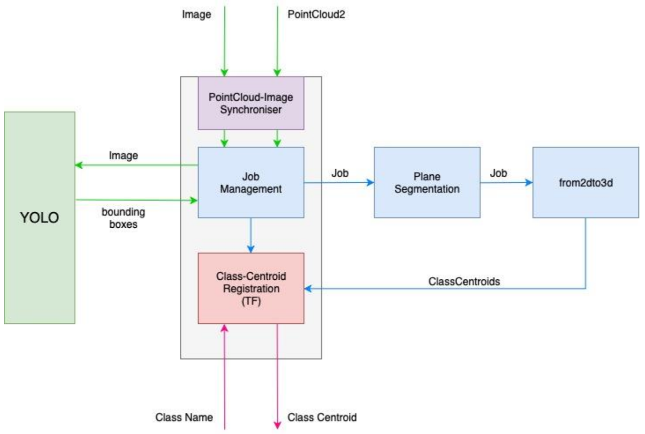
Perception by Zhenyu Li



Perception: pipeline

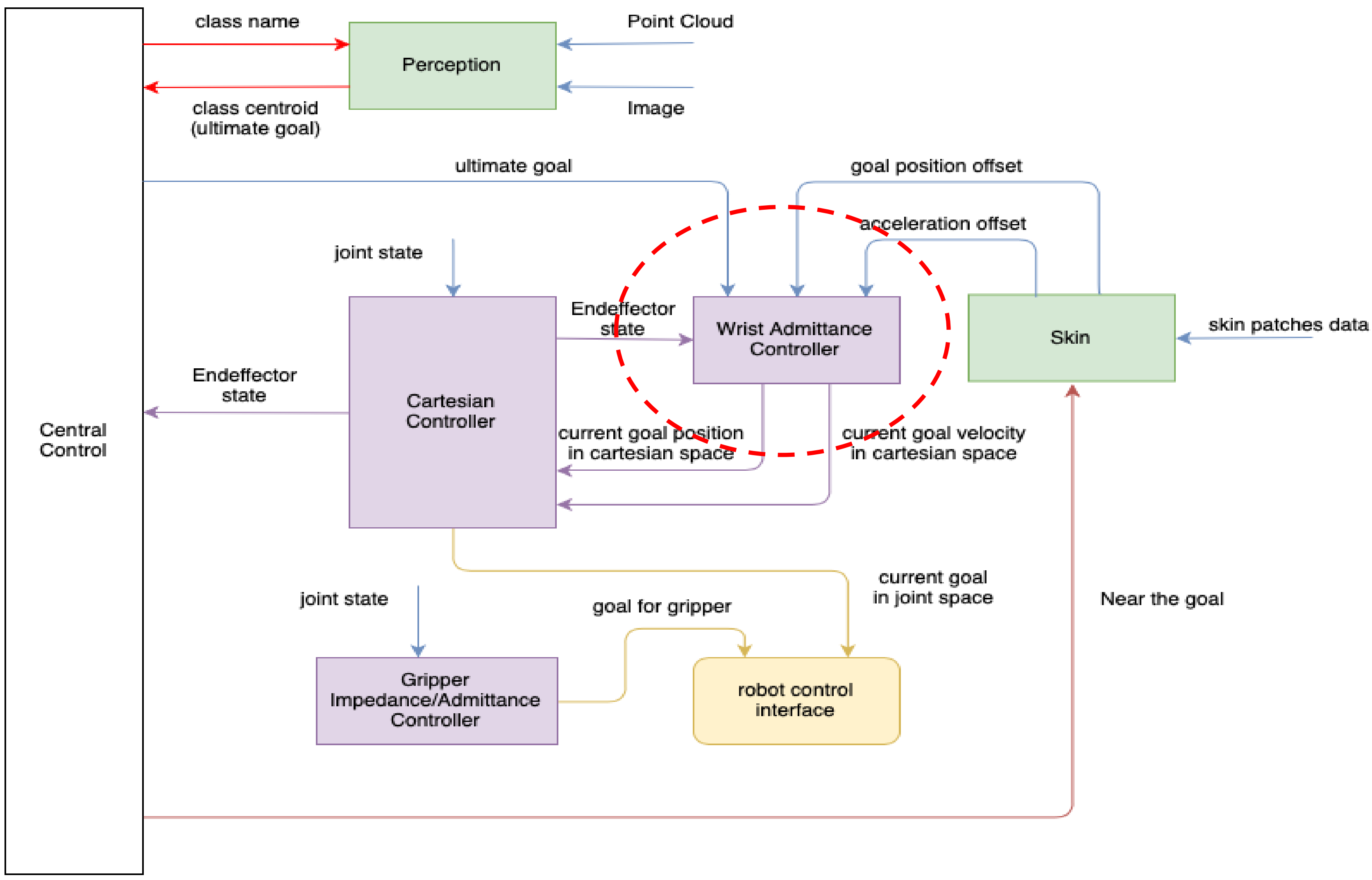


Perception: advantages



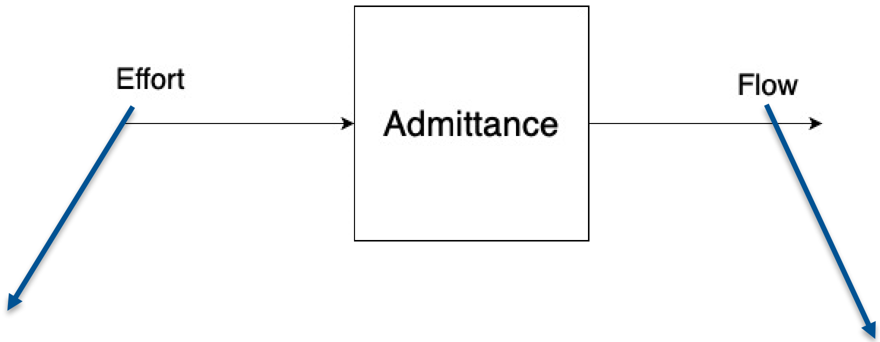
1. No need of clustering
2. Accurate centroid
3. Capable for dealing with moving scenario

Wrist Admittance Control



Wrist Admittance Control

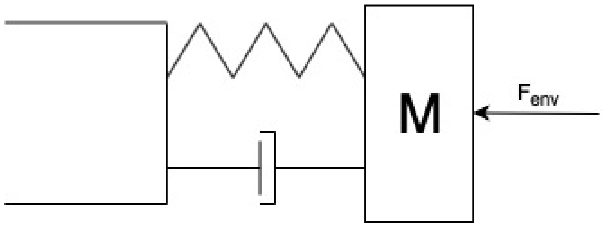
What is admittance in the field of mechanical system?



Force: control input

Velocity: control output

Wrist Admittance Control: 1-dimension



$$M\ddot{x} + D\dot{x} + K(x - x_r) = -F_{env}$$

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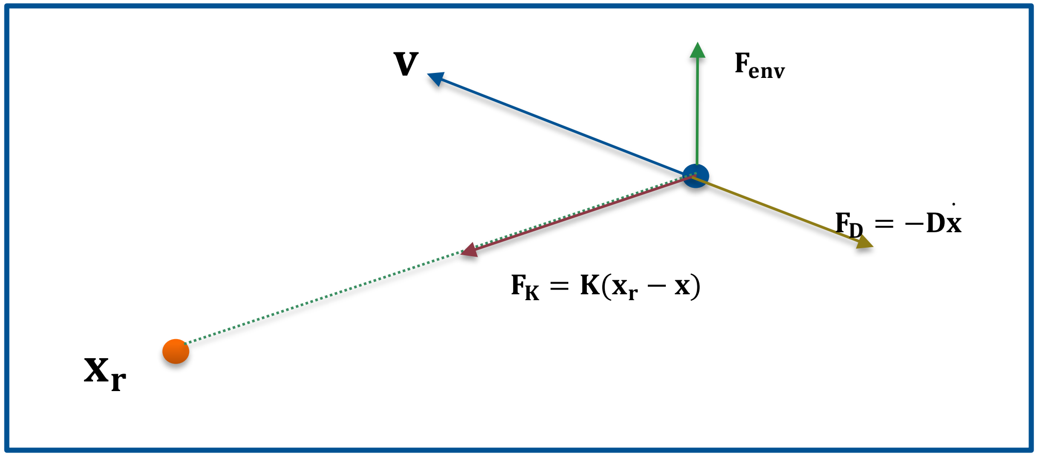
Wrist Admittance Control: cartesian space



$$\mathbf{M}\ddot{\mathbf{x}} + \mathbf{D}\dot{\mathbf{x}} + \mathbf{K}(\mathbf{x} - \mathbf{x_r}) = \mathbf{F_{env}}$$

$$\ddot{\mathbf{x}} = \frac{1}{\mathbf{M}}\left[-\mathbf{D}\dot{\mathbf{x}} + \mathbf{K}(\mathbf{x_r} - \mathbf{x}) + \mathbf{F_{env}}\right]$$

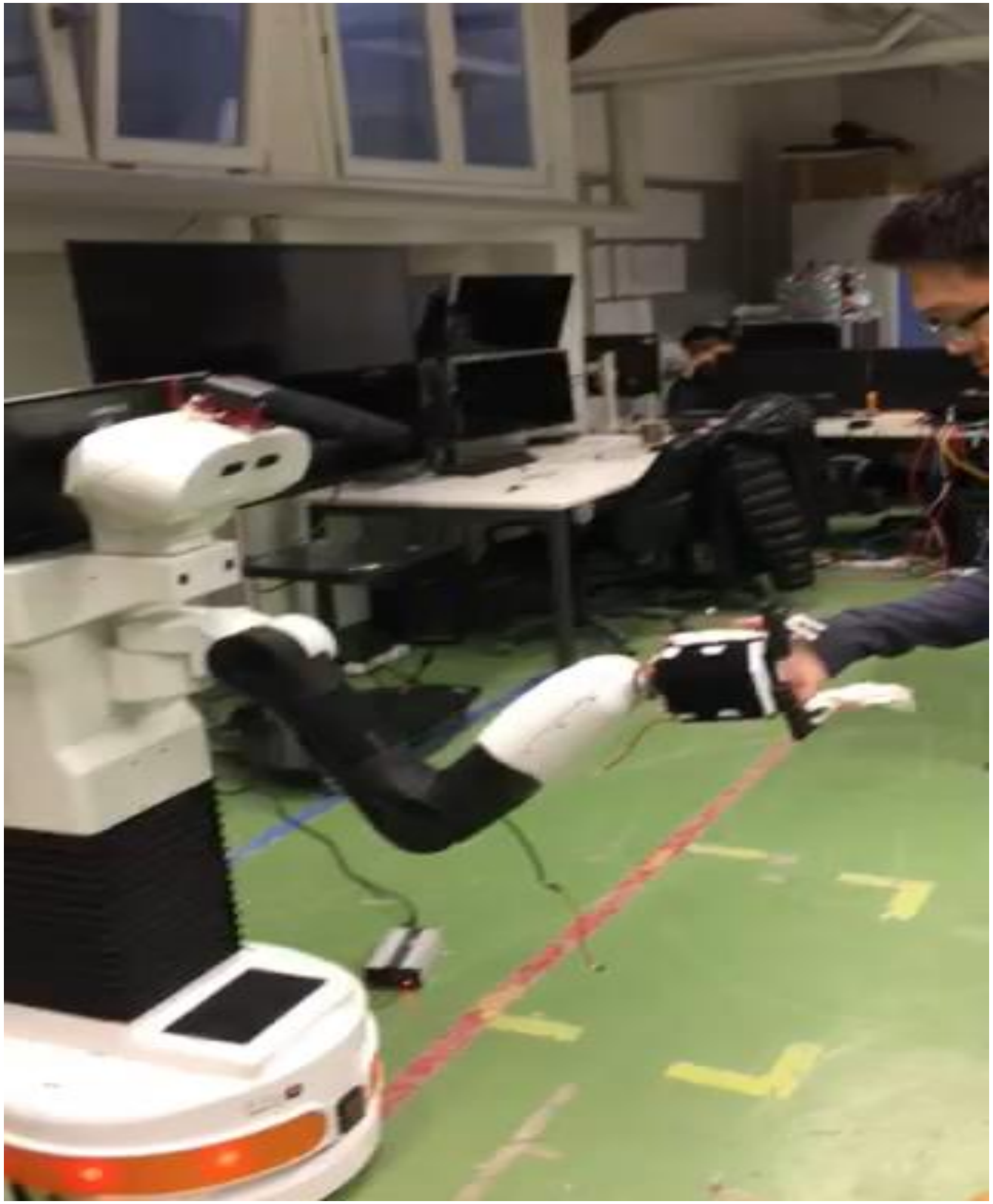
Wrist Admittance Control: cartesian space

$$\ddot{\mathbf{x}} = \frac{1}{\mathbf{M}}\left[-\mathbf{D}\dot{\mathbf{x}} + \mathbf{K}(\mathbf{x_r} - \mathbf{x}) + \mathbf{F_{env}}\right]$$

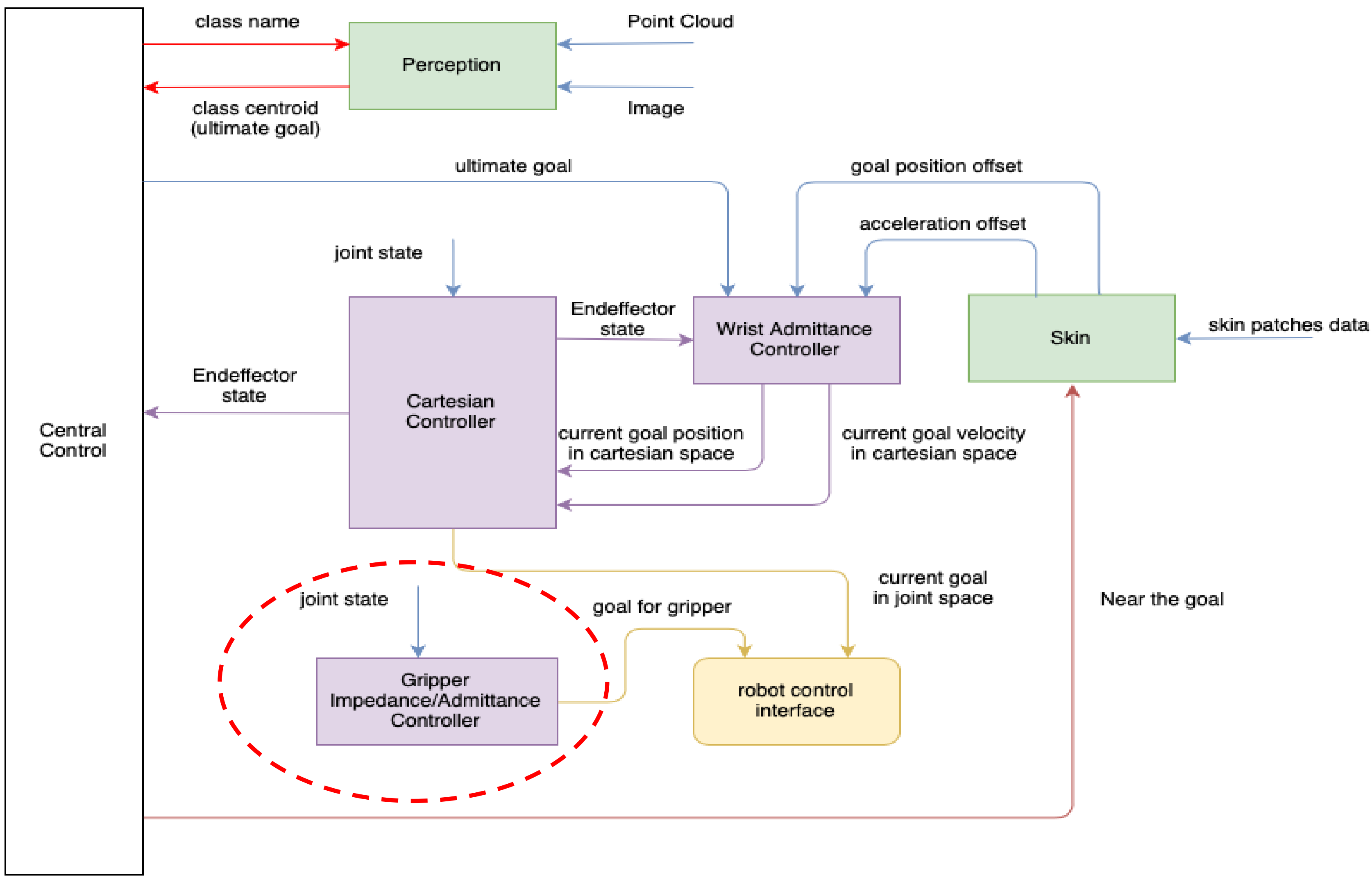
$$\dot{\mathbf{x}} := \dot{\mathbf{x}} + \ddot{\mathbf{x}}dt$$

$$\mathbf{x} := \mathbf{x} + \dot{\mathbf{x}}dt$$

Cartesian Controller

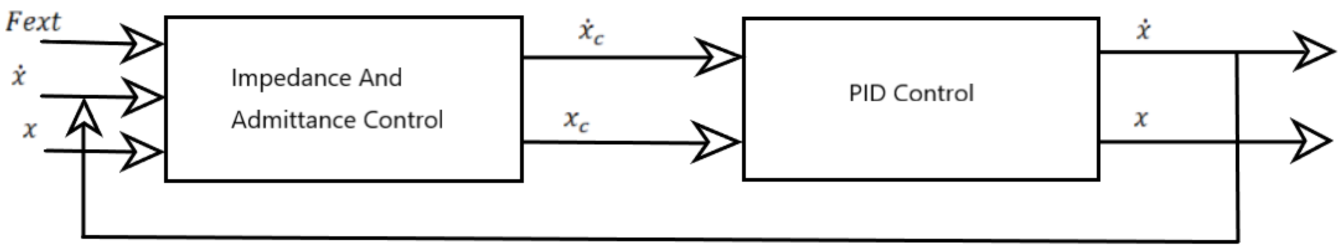


Gripper Impedance/Admittance Controller



Gripper: Impedance And Admittance Control

Control Structure:



Control Law:

Designed Property: $M\Delta\ddot{x} + B\Delta\dot{x} + K\Delta x = F_{ext}$

Target State: $\ddot{x}_d = 0$ $\dot{x}_d = 0$ $x_d = x_d$ ("grip": $x_d = 0$, "release": $x_d = 0.04$)

Control Function: $M\ddot{x}_c + B\dot{x}_c + K(x_c - x_d) = F_{ext}$ (current state: $\ddot{x}_c$, $\dot{x}_c$, x_c)

Gripper: Impedance And Admittance Control

Practical Problem:

Problem: Tiago can't use $\ddot{x}$ or force

Solution: Using $\ddot{x}$ to calculate $\dot{x}$ and x

$$\dot{x}(t + dt) = \dot{x}(t) + \ddot{x}(t + dt) * dt$$
$$x(t + dt) = x(t) + \dot{x}(t + dt) * dt$$

Problem: In each iteration, $\Delta\dot{x}(t)$ is too small → PID control can't deal with so small change and next iteration, $\dot{x}$ and x will stay the same

Solution: using $\ddot{x}_c$ to calculate virtual $\dot{x}_c$ which increases in each iteration

Gripper: Impedance And Admittance Control

Stability Analysis:

$$\ddot{x}(k+1) = \left(F_{ext} - B\dot{x}(k) - Kx(k)\right) * \frac{1}{M}$$

$$\dot{x}(k+1) = \dot{x}(k) + \ddot{x}(k+1)dt = \left(1 - \frac{B}{M}dt\right)x(k) - \frac{K}{M}dt * x(k) + \frac{F_{ext}}{M}dt$$

$$x(k+1) = x(k) + \dot{x}(k+1)dt = \left(1 - \frac{B}{M}dt\right)dt\dot{x}(k) + \left(1 - \frac{K}{M}dt^2\right)x(k) + \frac{F_{ext}}{M}dt^2$$

$$\begin{bmatrix} x(k+1) \\ \dot{x}(k+1) \end{bmatrix} = \begin{bmatrix} 1 - \frac{K}{M}dt^2 & \left(1 - \frac{B}{M}dt\right)dt \\ -\frac{K}{M}dt & 1 - \frac{B}{M}dt \end{bmatrix} \begin{bmatrix} x(k) \\ \dot{x}(k) \end{bmatrix} + \begin{bmatrix} \frac{dt^2}{M} \\ \frac{dt}{M} \end{bmatrix} F_{ext}$$

Acorrding to $|\lambda I - A| = 0 \quad |\lambda_1| < 1 \quad |\lambda_2| < 1 \Longrightarrow \begin{cases} 1 - \frac{B}{M}dt < 0 \\ \left|\frac{1}{2}\left(\frac{K}{M}dt^2 - 2 + \frac{B}{M}dt\right)\right| < 1 \end{cases}$

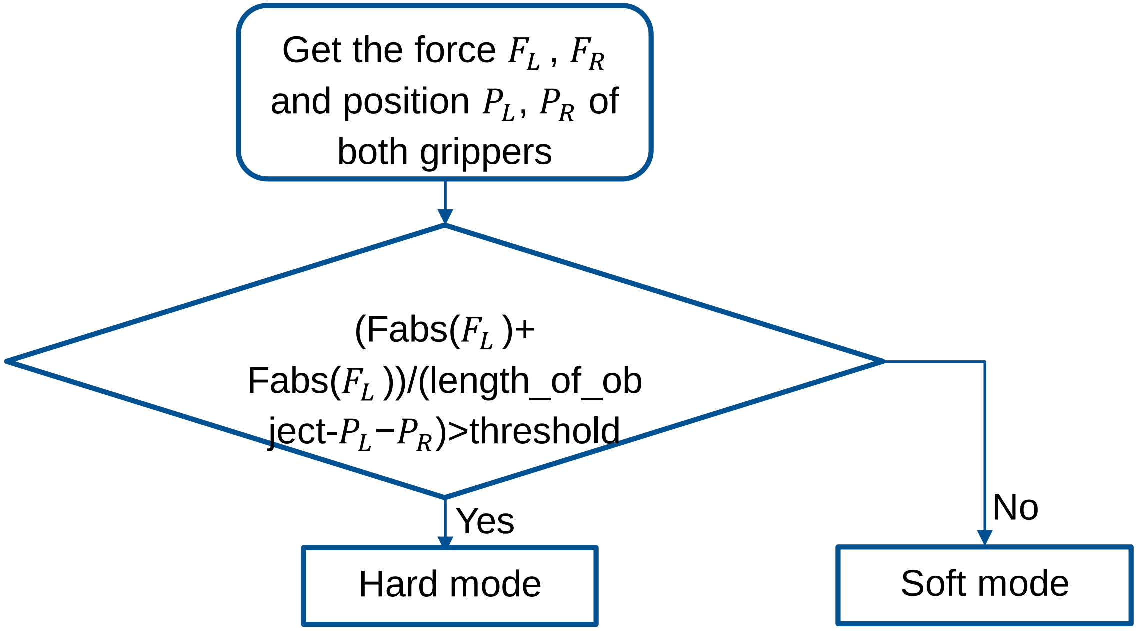
Gripper: Impedance And Admittance Control

Extension:

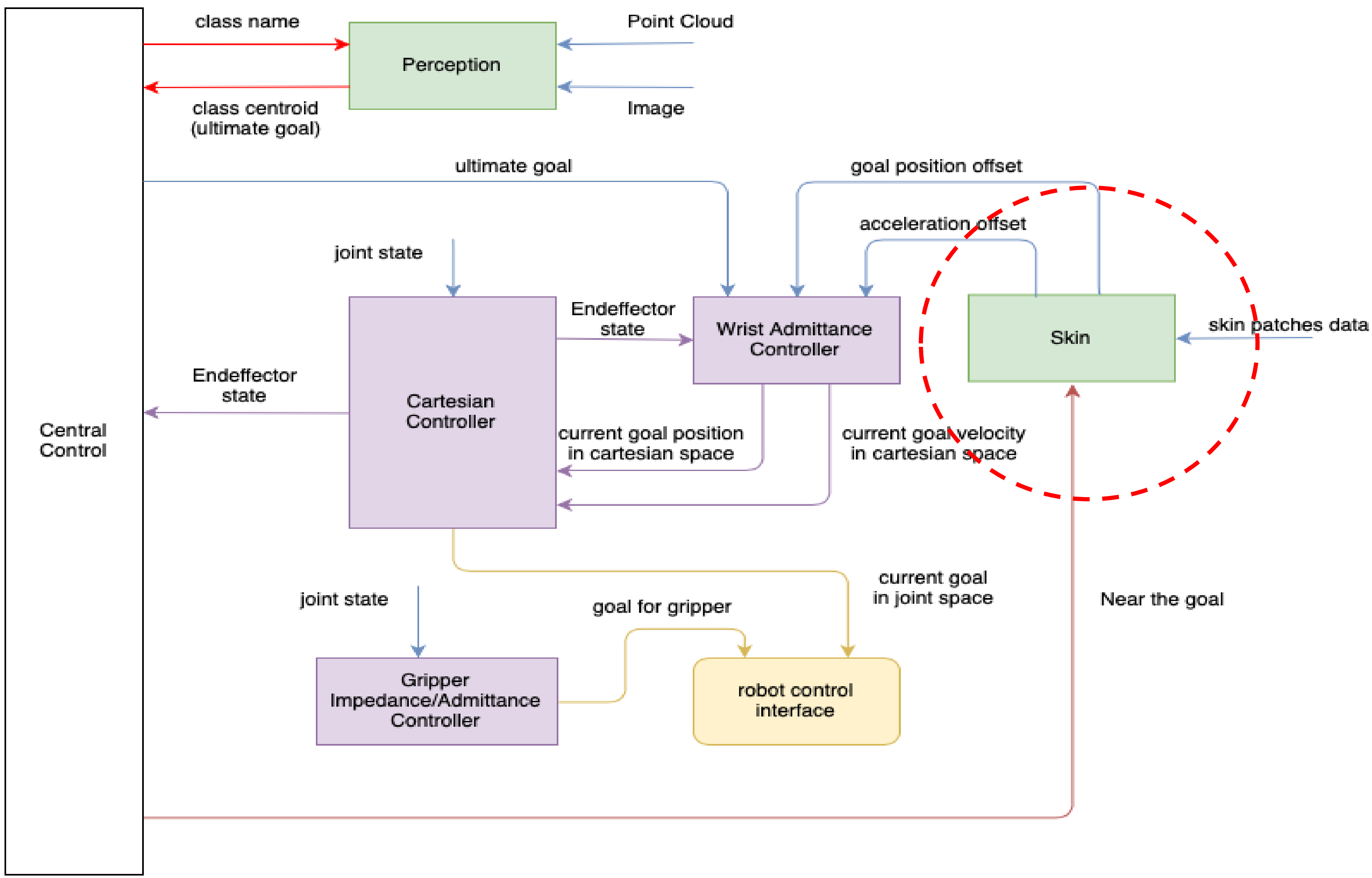
Two mode: $\begin{cases} soft\ mode \\ hard\ mode \end{cases} \Longrightarrow \quad ensure\ F_{ext}\ not\ too\ big$

$(with\ different\ parameters\ \ M, B, K)$

Using the length of object and the position of both grippers to switch the modes

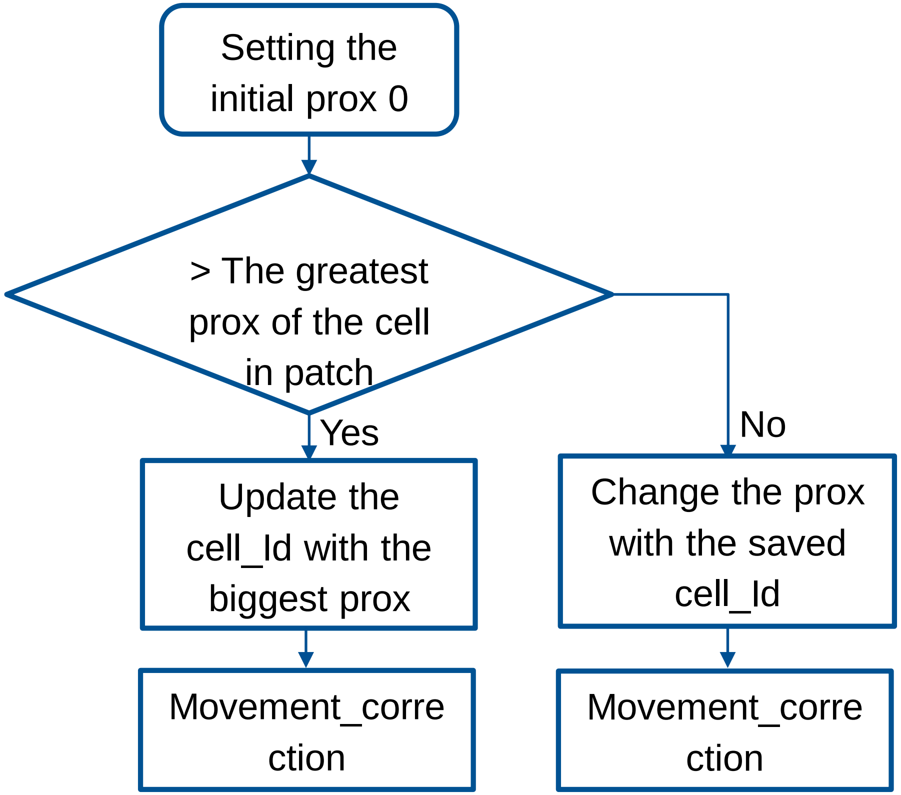


Skin: Movement Correction



Skin: Movement Correction

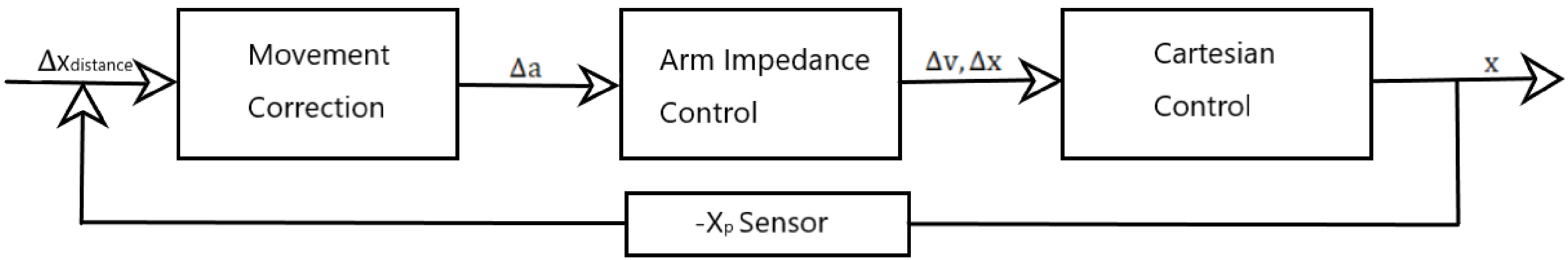
- Get data from sensor
  - Topic: /tiago/patches Every cell each time publish data
  - ⟶ Take the smallest distance from cells in one path
  - Algorithm flow of each pitch:



Skin: Movement Correction

Movement correction:

The distance between object and skin too small ⟶ give an Δa to arm controller



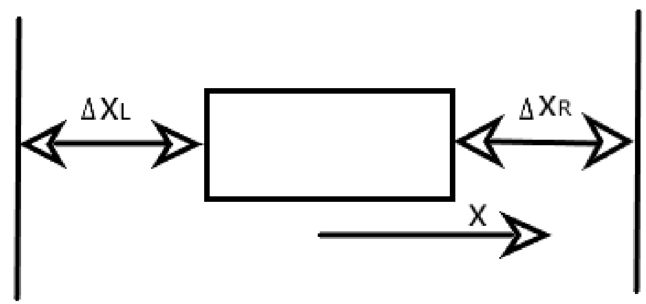
Cost function:

Assume prox = $\frac{1}{\Delta x}$

$$F = (\frac{1}{\Delta x_L})^2 + (\frac{1}{\Delta x_R})^2$$

$$\frac{\partial F}{\partial x} = -\frac{1}{2}\Delta x_L^{-\frac{3}{2}} * \frac{\partial \Delta x_L}{\partial x} - \frac{1}{2}\Delta x_R^{-\frac{3}{2}} * \frac{\partial \Delta x_R}{\partial x}$$

$$= \Delta x_R^{-\frac{3}{2}} - \Delta x_L^{-\frac{3}{2}}$$



$$\Delta \dot{x} = \Delta x_L^{-\frac{3}{2}} - \Delta x_R^{-\frac{3}{2}} \Longrightarrow prox_L^2 - prox_R^2 \Longrightarrow (\max prox_L)^2 - (\max prox_R)^2$$

$$\Longrightarrow \Delta a = w * (prox_L^2 - prox_R^2)$$

Skin: Movement Correction

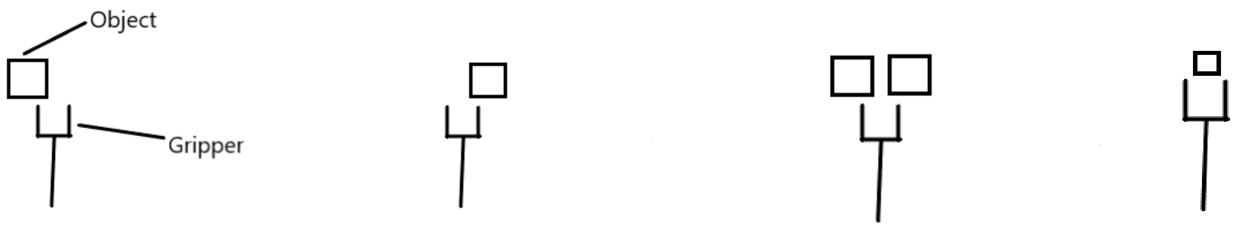
Optimizations:

1、Avoid large $\Delta a \longrightarrow$ different w for different distances

2、Estimating noise in sensor data $\longrightarrow$ discard small Δa

Position correction:

4 cases when grasp



Set goal a little right | Set goal a little left | Can't grip the object | Can grip

(1) Send Δx to arm impedance control to change the goal

(2) When arm approaches the target, open position correction

(3) Perform not good in practice because of the distance, which can be detected by sensor is too short compare to the motion of arm

Skin: Movement Correction

Temperature

Take the temperature from the patch3 and patch5

Too hot ⟶ tiago speak “hot”

Too cold ⟶ tiago speak “cold”

Practical Problem:

Plastic layer of the skin too thick

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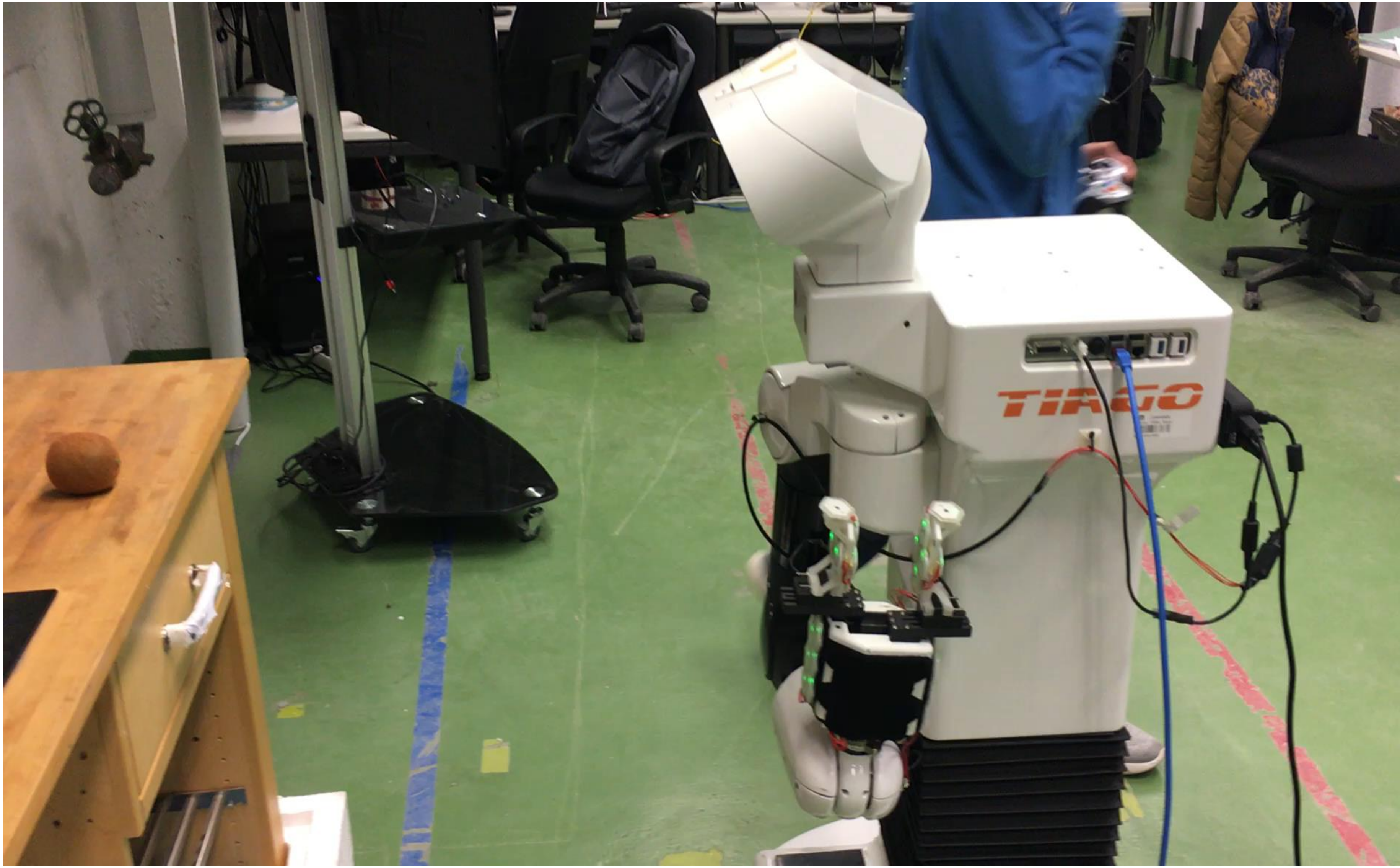

Thanks!