Spring 2020

控制系統
Control Systems

Unit 70
Overview of Control System Design

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NTU-EE

Mar 2020 – Jul 2020

Course Outline

- 1: Overview and Introduction
- 2: Dynamic Models
- 3: Dynamic Response
- 4: Feedback Analysis
- 5: Analysis & Design: Root Locus
- 6: Analysis & Design: Bode Plot
- 7: State-Space Design
- 8: Digital Control
- 9: Nonlinear Systems
- 10: Case Study

- 建模 **Modeling**
- 分析 **Analysis**
- 設計 **Design**
- 統整分析與設計

Course Outline

- 1: An Overview and Brief History of Feedback Control
- 2: Dynamic Models
- 3: Dynamic Response
- 4: A First Analysis of Feedback
- 5: The Root-Locus Design Method
- 6: The Frequency-Response Design Method
- 7: State-Space Design
- 8: Digital Control
- 9: Nonlinear Systems
- 10: Control System Design:

  Principles and Case Studies

- 信號與系統

- 線性系統
- 數位控制
- 非線性系統

Three Layers of Control Tasks

- Top Layer:
  - For Multiple Agents (Group of Vehicles, Cars, Drones)

➢ 方向盤
➢ 油門煞車

➢ 位置/車道
➢ 速度/方向

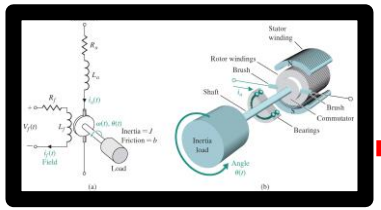
- Middle Layer:
  - For Single Agent (Single Vehicle, Car, Drone)

➢ 統整四個輪子
➢ 統整四個螺旋槳

➢ 方向
➢ 加減速

- Bottom Layer:
  - For Subsystems (Wheel, Motor, Engine, Gear Box, Braking)

➢ 控制驅動電流/電壓



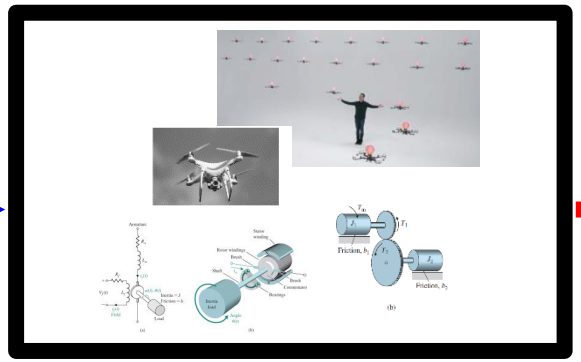
➢ 每一個輪子/螺旋槳的轉速/轉角

Plant, Input, Output, Action, Goal

Plant (P)

Ref (r)

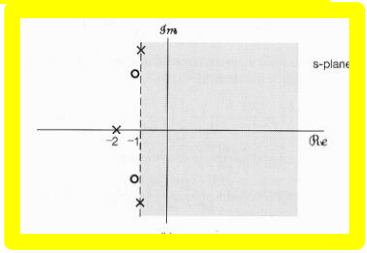
Input (u)

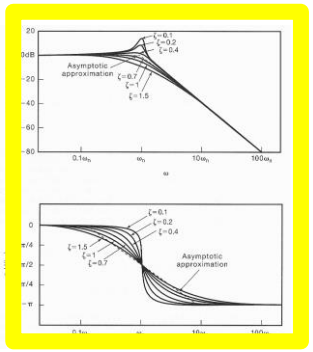


Output (y)

$$\frac{d^2y(t)}{dt^2} + 2\frac{dy(t)}{dt} - 3\,y(t) = 5\,u(t)$$

$$P(s) = \frac{Y(s)}{U(s)} = \frac{5}{s^2 + 2s - 3}$$



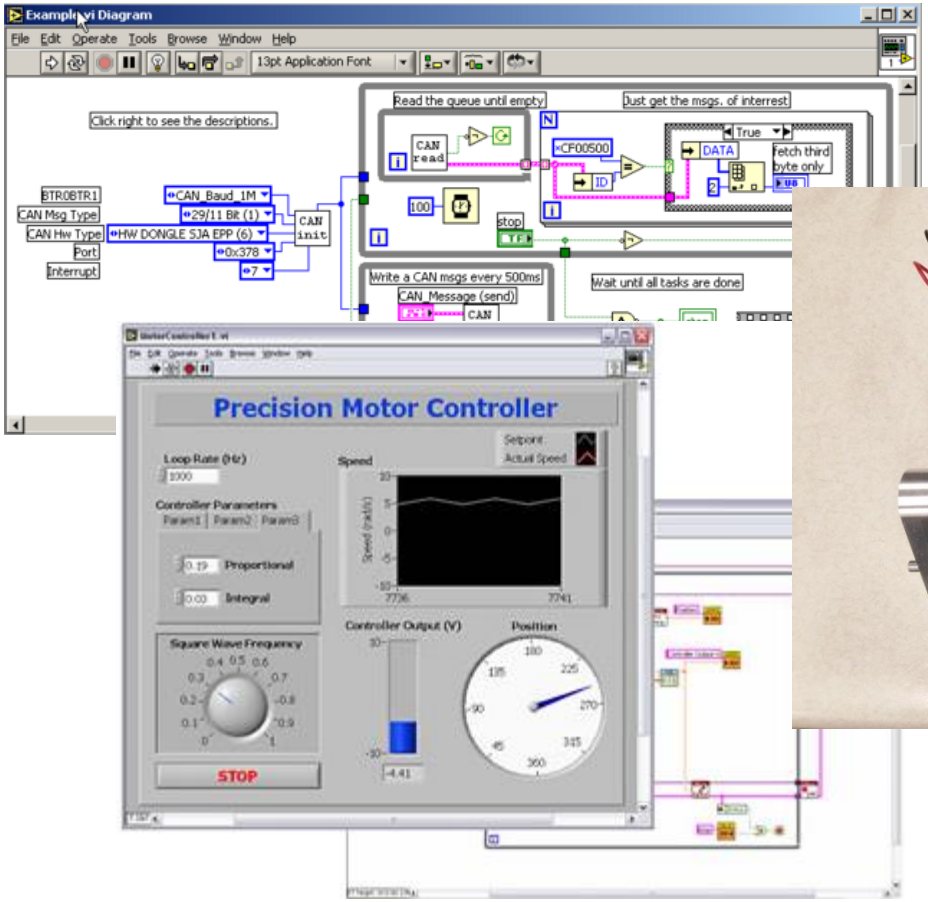


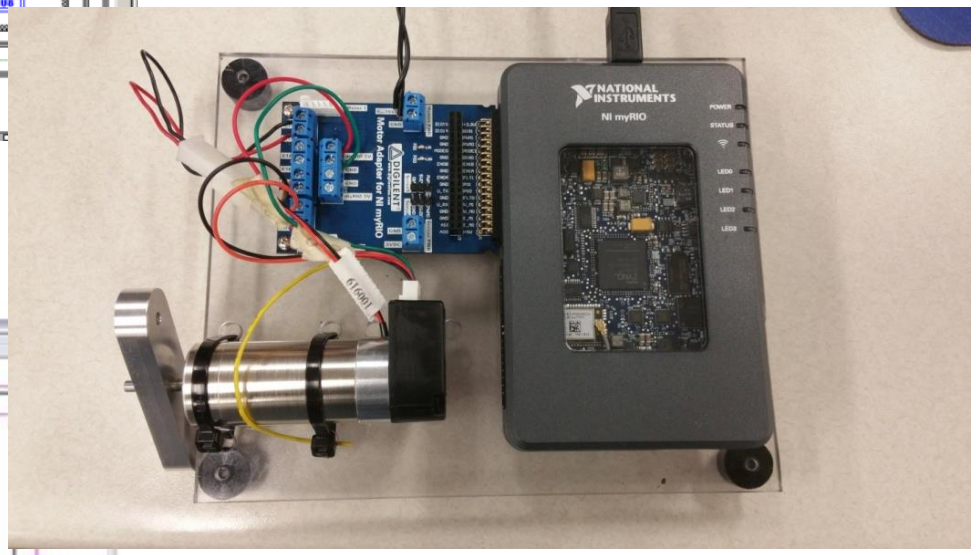
Controller

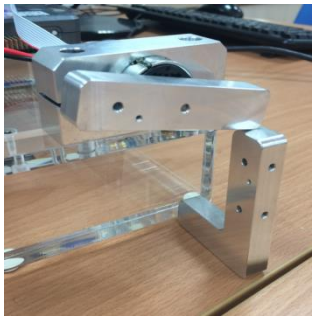
$$\frac{d^2y(t)}{dt^2} + 4\frac{dy(t)}{dt} + 3\,y(t) = 3\,r(t)$$

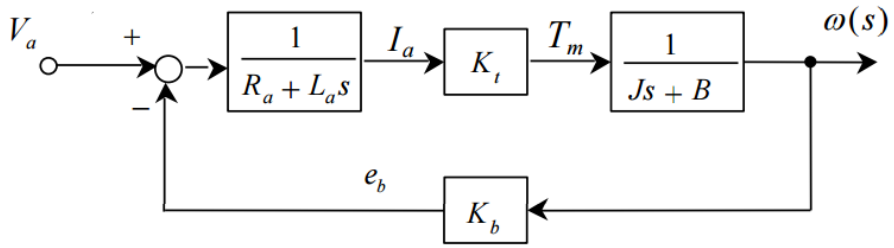
$$G(s) = \frac{Y(s)}{R(s)} = \frac{3}{s^2 + 4s + 3}$$

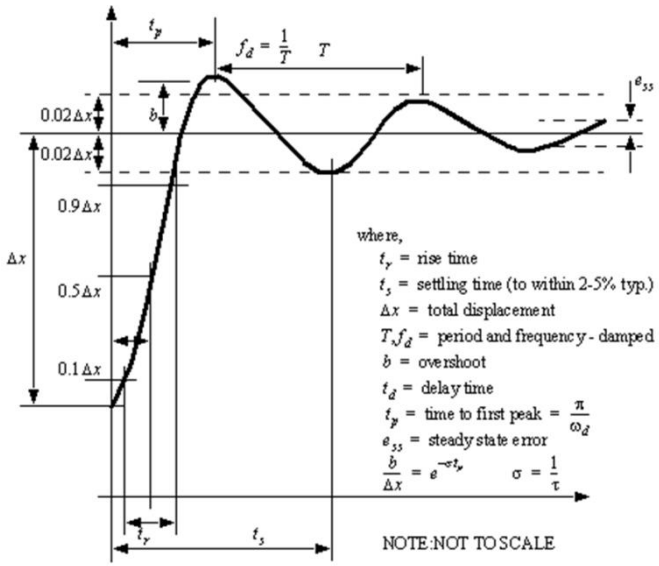
1. Model
2. Response
3. Analysis
4. Feedback
5. Control

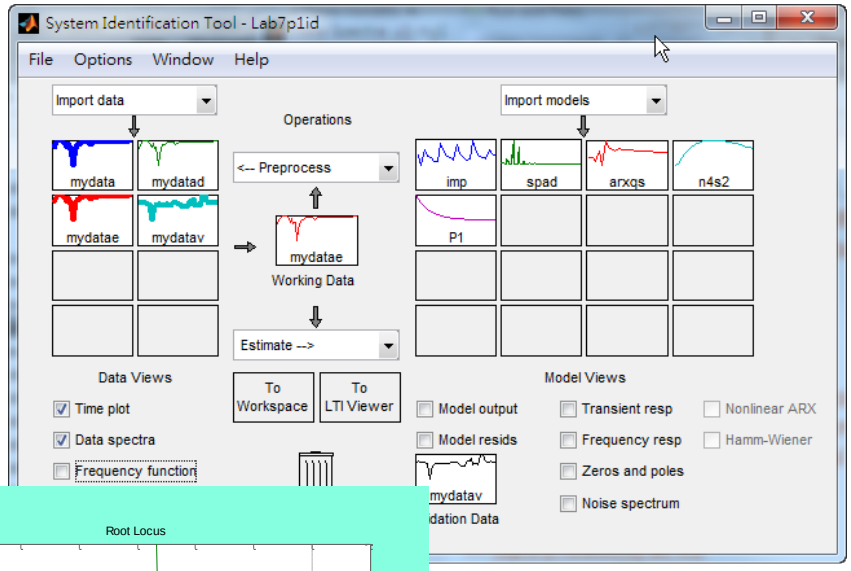

Example.vi Diagram
File Edit Operate Tools Browse Window Help
13pt Application Font
Click right to see the descriptions.
Read the queue until empty
Just get the msgs. of interrest
CAN read
0CF00500
DATA
ID
True
Fetch third byte only
100
stop
BTR0BTR1
CAN Msg Type
CAN Hw Type
Port
Interrupt
CAN_Baud_1M
29/11 Bit (1)
HW DONGLE SJA EPP (6)
0x378
7
CAN init
Write a CAN msgs every 500ms
CAN_Message (send)
CAN
Wait until all tasks are done
Precision Motor Controller
Loop Rate (Hz)
1000
Speed
Setpoint
Actual Speed
Controller Parameters
Param1 Param2 Param3
0.19 Proportional
0.00 Integral
Square Wave Frequency
Controller Output (V)
Position
STOP
-4.41

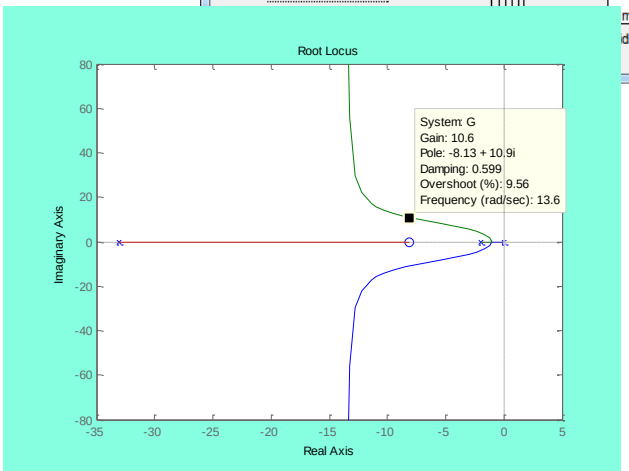

NATIONAL INSTRUMENTS
NI myRIO




V_a
+
−
$\frac{1}{R_a + L_a s}$
I_a
K_t
T_m
$\frac{1}{Js + B}$
$\omega(s)$
e_b
K_b


t_p
$f_d = \frac{1}{T}$
T
e_{ss}
$0.02\Delta x$
b
$0.02\Delta x$
$0.9\Delta x$
Δx
$0.5\Delta x$
$0.1\Delta x$
where,
t_r = rise time
t_s = settling time (to within 2-5% typ.)
Δx = total displacement
T, f_d = period and frequency - damped
b = overshoot
t_d = delay time
t_p = time to first peak = $\frac{\pi}{\omega_d}$
e_{ss} = steady state error
$\frac{b}{\Delta x} = e^{-\sigma t_p}$
$\sigma = \frac{1}{\tau}$
t_r
t_s
NOTE:NOT TO SCALE

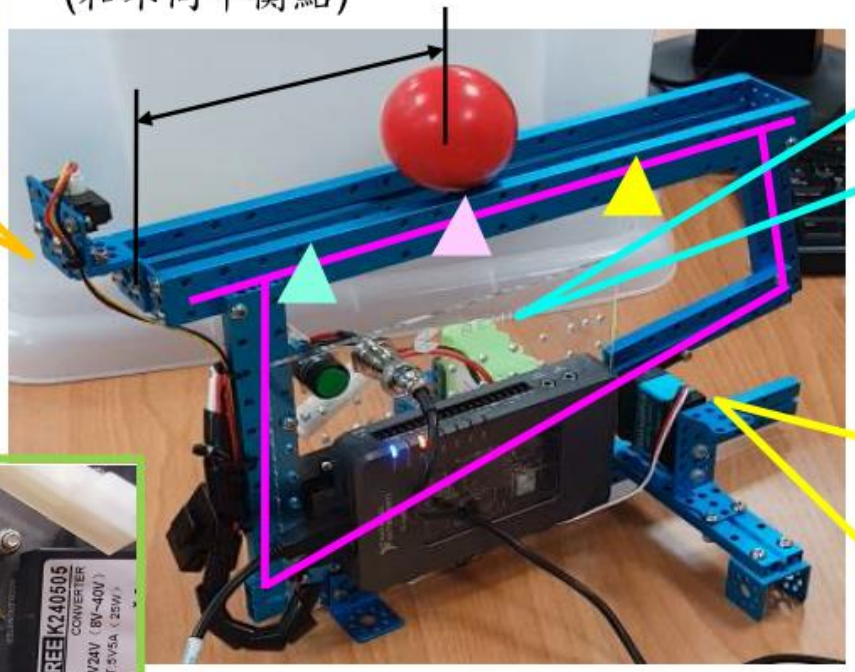

System Identification Tool - Lab7p1id
File
Options
Window
Help
Import data
mydata
mydatad
mydatae
mydatav
Operations
<-- Preprocess
mydatae
Working Data
Estimate -->
Import models
imp
spad
arxqs
n4s2
P1
Data Views
Time plot
Data spectra
Frequency function
To Workspace
To LTI Viewer
Model Views
Model output
Model resids
Transient resp
Frequency resp
Zeros and poles
Noise spectrum
Nonlinear ARX
Hamm-Wiener
mydatav
dation Data


Root Locus
System: G
Gain: 10.6
Pole: -8.13 + 10.9i
Damping: 0.599
Overshoot (%): 9.56
Frequency (rad/sec): 13.6
Imaginary Axis
Real Axis
80
60
40
20
0
-20
-40
-60
-80
-35
-30
-25
-20
-15
-10
-5
0
5

平衡手臂 (Balance Arm)

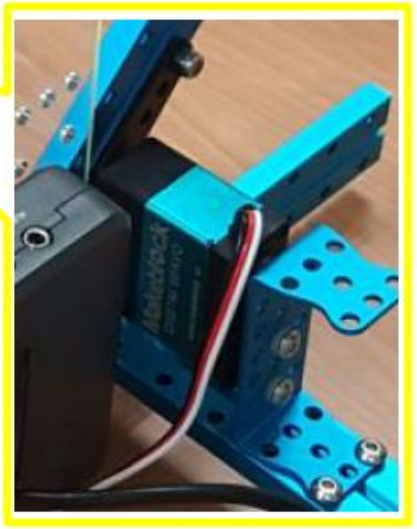
紅外線距離
感測器

四連桿平衡機構
(和不同平衡點)



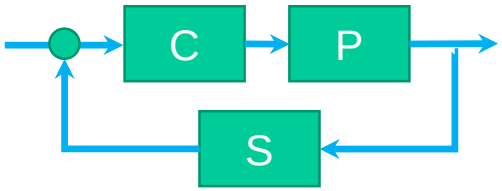
電池

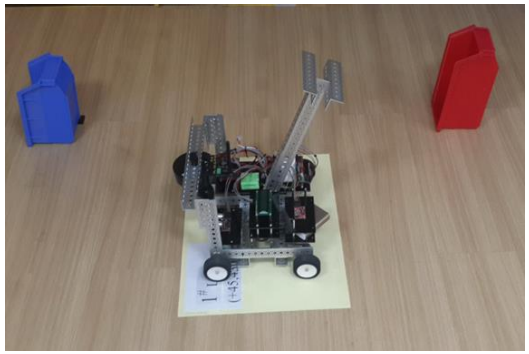
驅動馬達

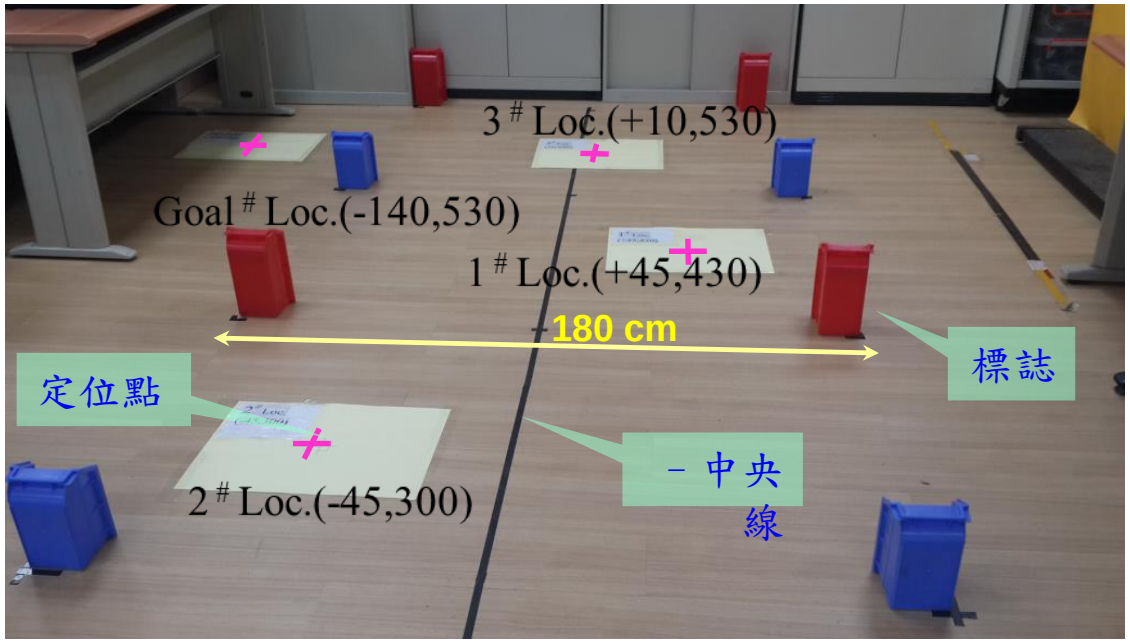


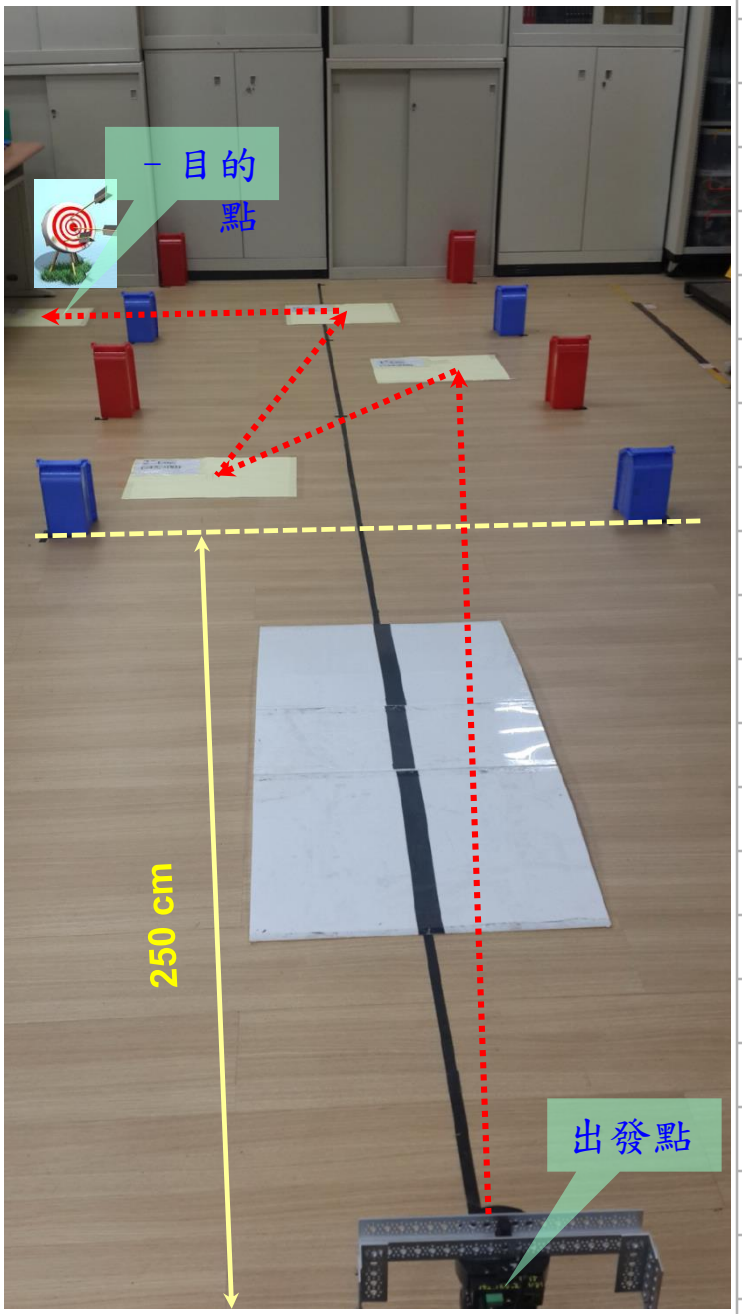
myROI 控制器

自動控制實驗

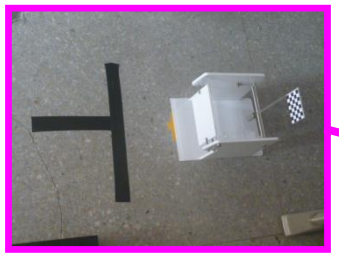

C
P
S

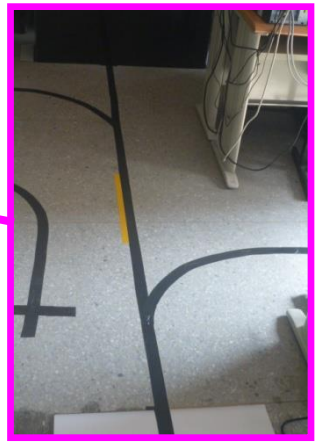


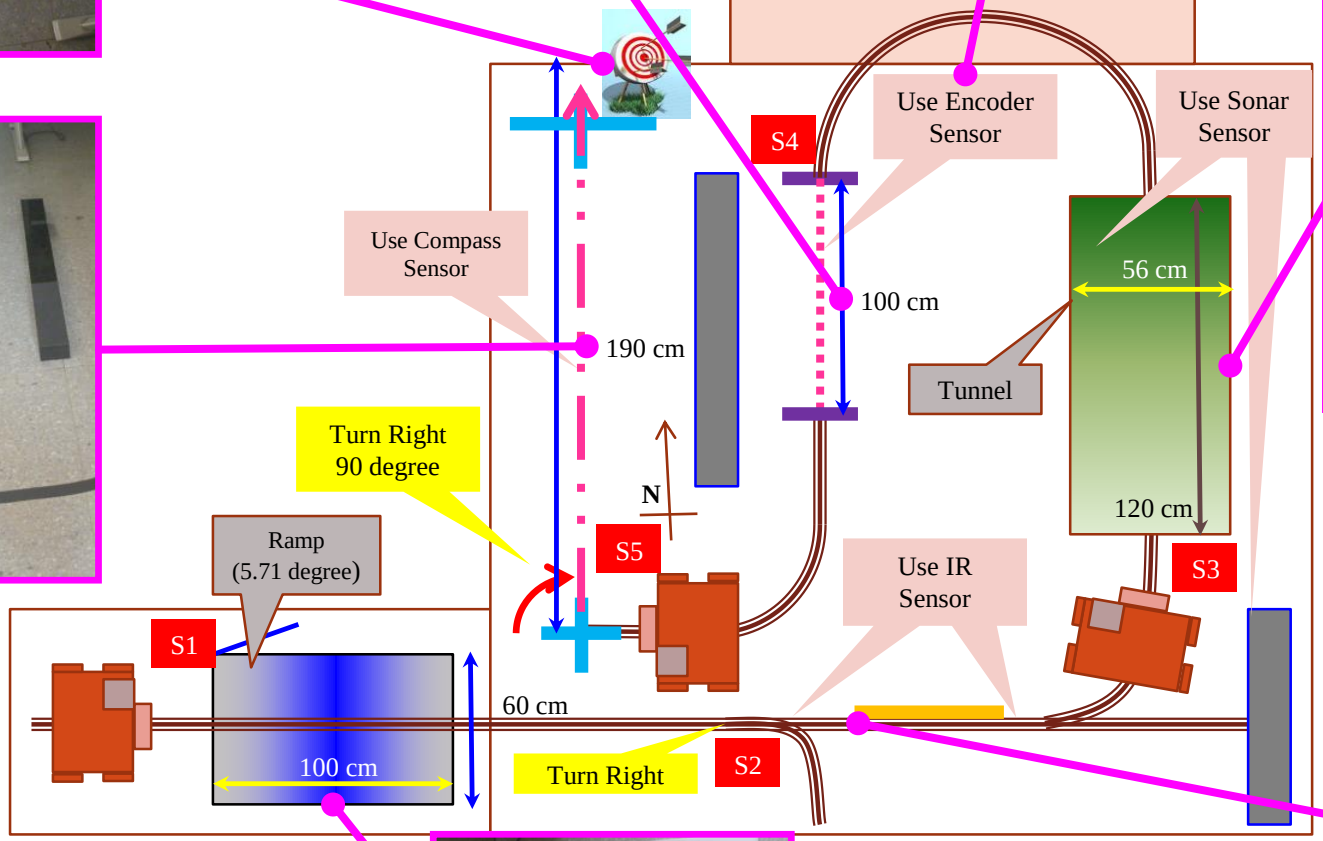

3# Loc.(+10,530)
Goal# Loc.(-140,530)
1# Loc.(+45,430)
180 cm
定位點
標誌
中央線
2# Loc.(-45,300)


目的點
250 cm
出發點

自動控制實驗



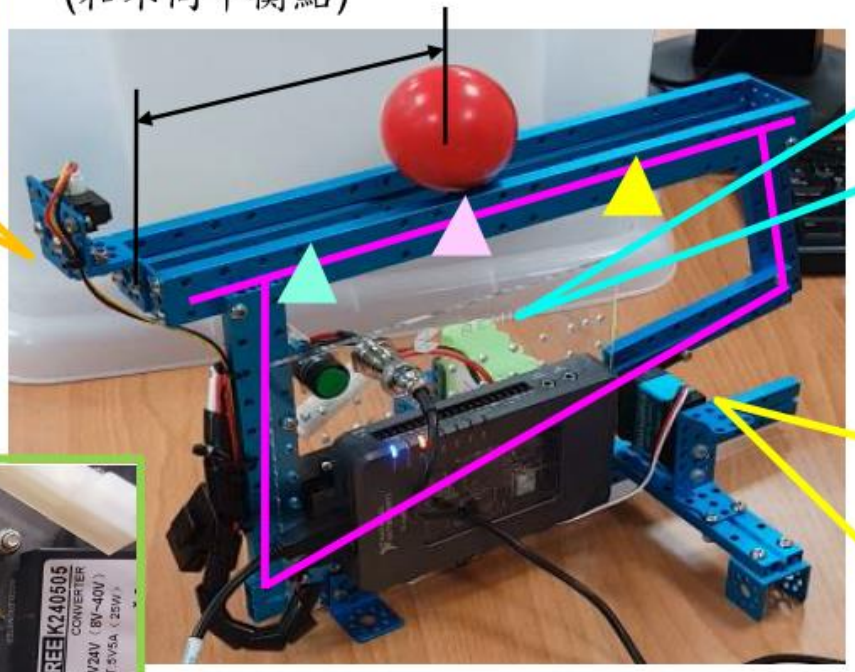



S4
Use Encoder Sensor
Use Sonar Sensor
Use Compass Sensor
100 cm
190 cm
56 cm
Tunnel
120 cm
Turn Right 90 degree
N
S5
Ramp (5.71 degree)
S1
S3
Use IR Sensor
60 cm
100 cm
Turn Right
S2

平衡手臂 (Balance Arm)

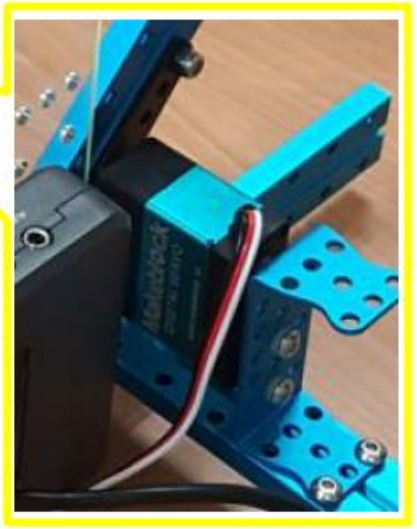
紅外線距離
感測器

四連桿平衡機構
(和不同平衡點)



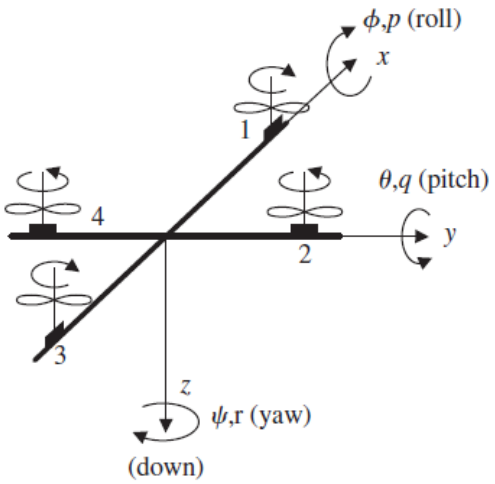
電池

驅動馬達

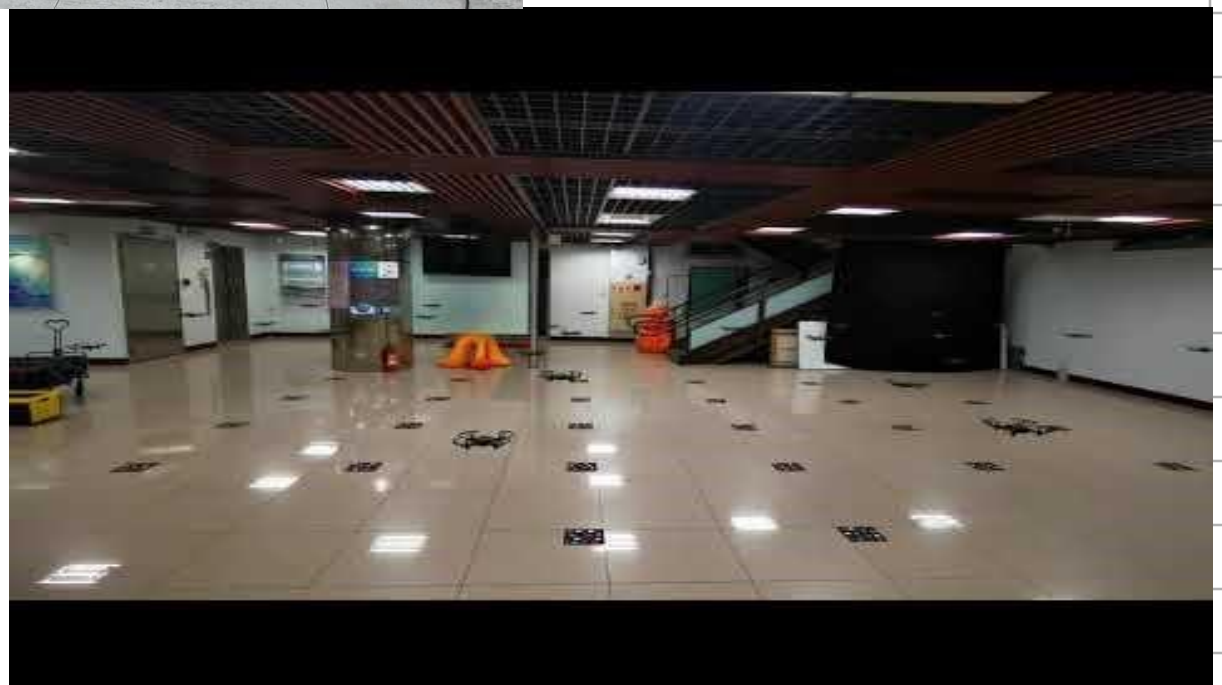


myROI 控制器

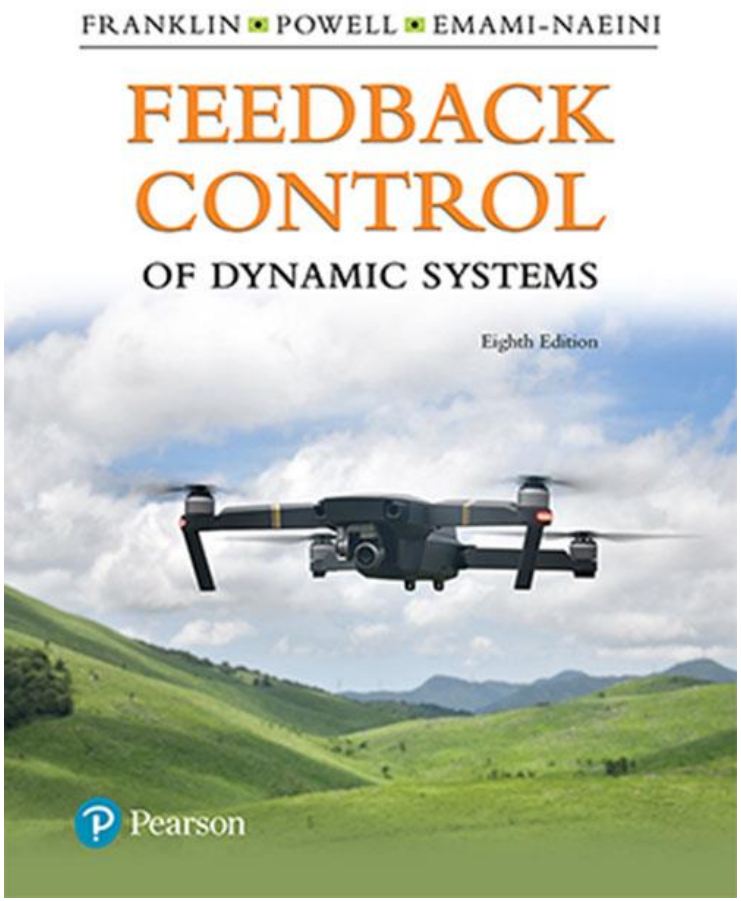
專題研究：Quadrotor Drone (Unmanned Aerial Vehicle, UAV)



專題研究： Quadrotor Drone (Unmanned Aerial Vehicle, UAV)



期末專題報告：e.g., Quadrotor Drone (UAV)



10.5 Control of a Quadrotor Drone

Drones, or Unmanned Aerial Vehicles (UAVs) are aircraft that are pilotless. They can be either controlled from the ground or are completely autonomous and have onboard control algorithms that primarily determine their path. Some are winged aircraft, and some are helicopters that rely on one or more rotor blades for lift. Drones are being developed for a very large number of applications. Some of the many examples of current use are aerial photography and video, surveillance, security/police work, search and rescue, farming, defense, and, of course, entertainment. Many other applications are being investigated from package delivery to flying cars. More general research includes optimization of onboard control, artificial intelligence, and swarming approaches where