UNIVERSITÉ DE LORRAINE

POLYTECH NANCY

Identification of linear models for dynamical MIMO systems

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Categories of systems

Systems can be categorized by the number of inputs and outputs they have

- Single Input Single Output (SISO)

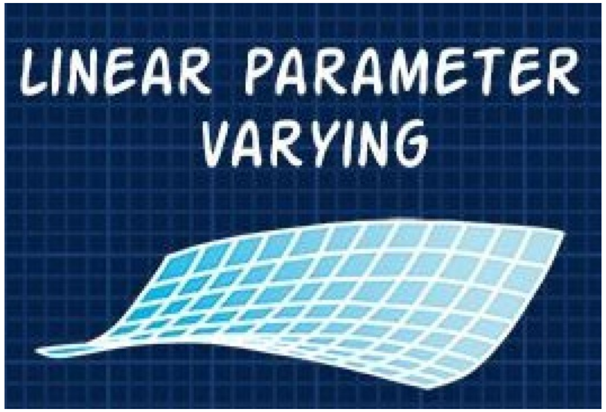
(a) QUBE-Servo 2 with Inertia Disc Module

- Single Input Multiple Output (SIMO)

- Multiple Input Single Output (MISO)

- Multiple Input Multiple Output (MIMO)

Linear continuous-time models



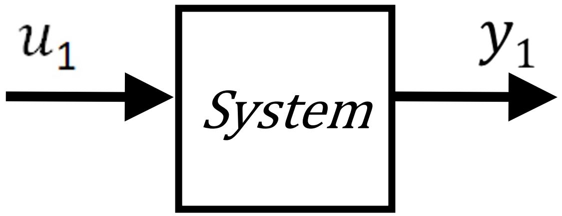
$$G(s, v(t)) = \frac{K(v(t))}{1 + T(v(t))\, s}$$

Single input systems

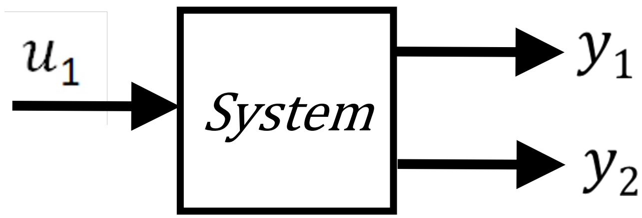
Single-input systems have a single control input

Depending on the number of outputs, sub-categories include:

- Single-input, single-output (SISO)
- Single-input, multi-output (SIMO)

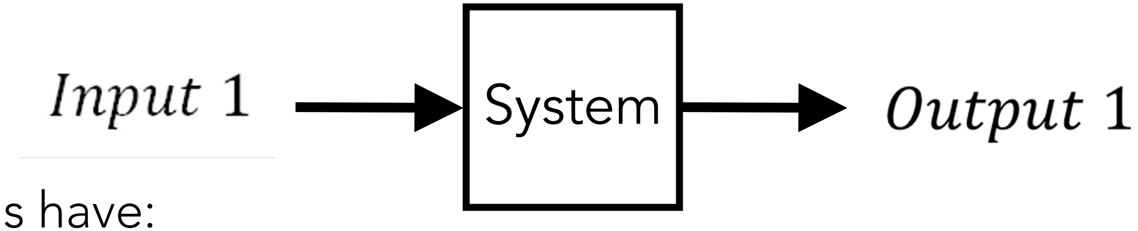


SISO



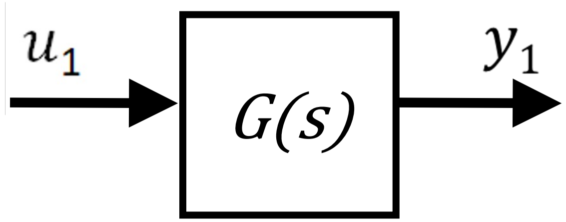
SIMO

Single Input Single Output (SISO) systems



SISO systems have:

- A single actuating element
- A single sensing element



Typically modeled using ***transfer functions***

Relatively simple control system

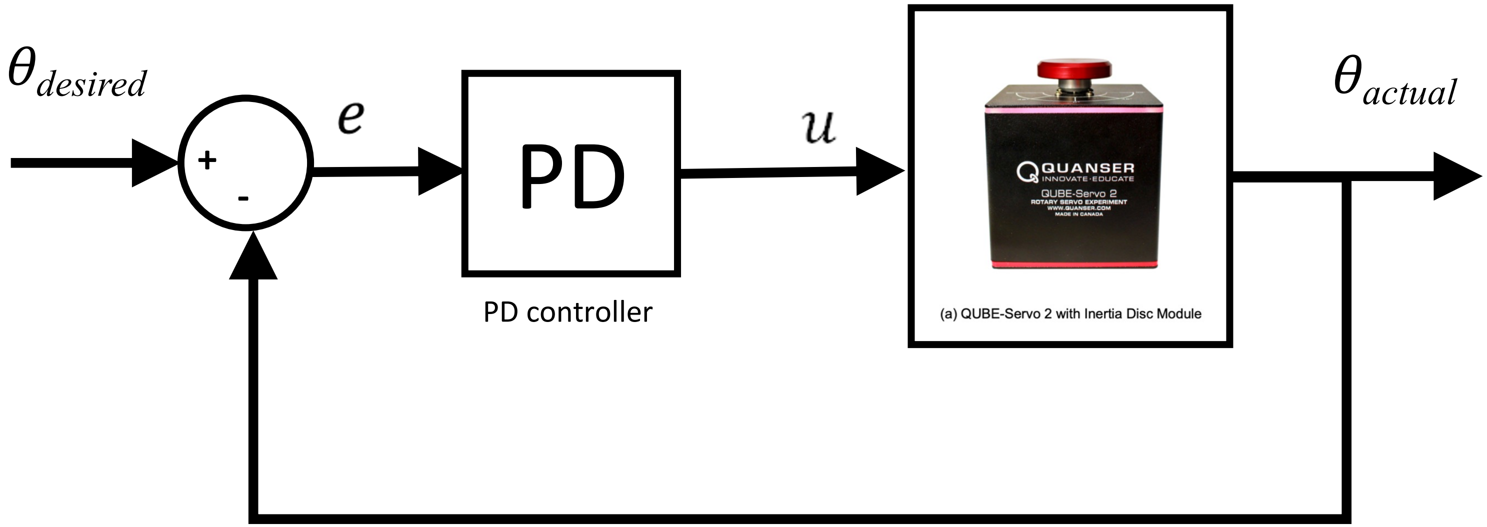
- Mainly ***PID control***, but also on-off control

Examples include:

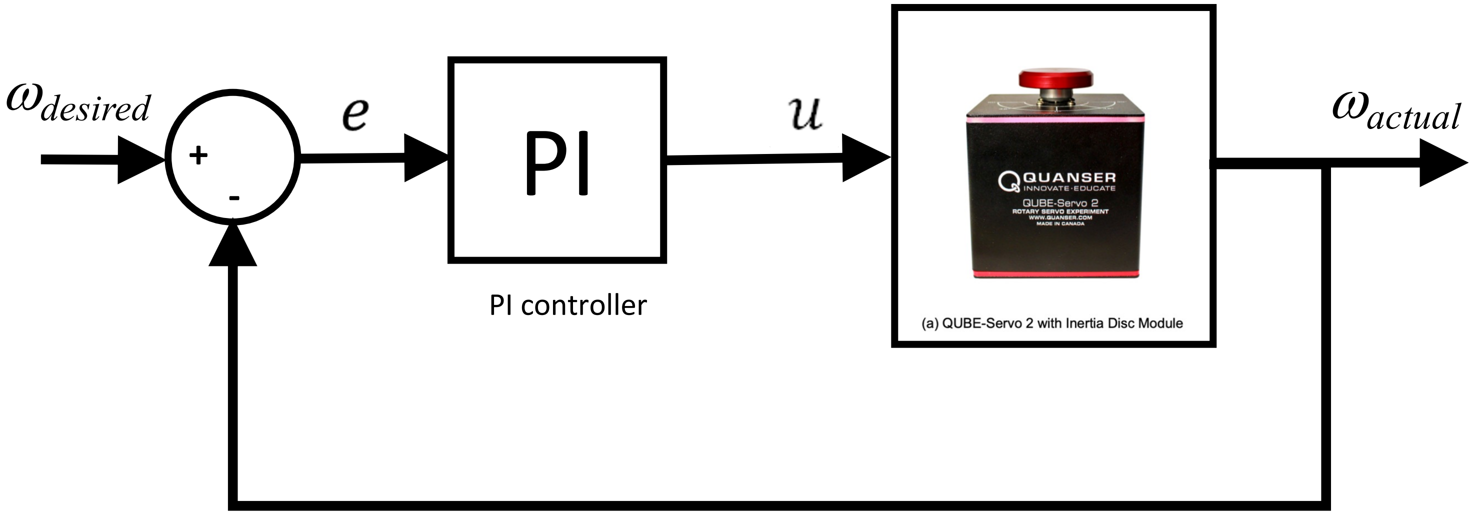
- Angular position control of the QUBE servo 2 inertia disc
- Angular velocity control of the QUBE servo 2 inertia disc


(a) QUBE-Servo 2 with Inertia Disc Module

Example: PD control of the inertia disc angular **position**



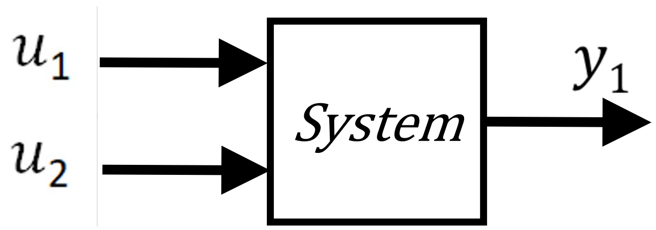
Example: PI control of the inertia disc angular **velocity**



Multi input Single output (MISO) systems

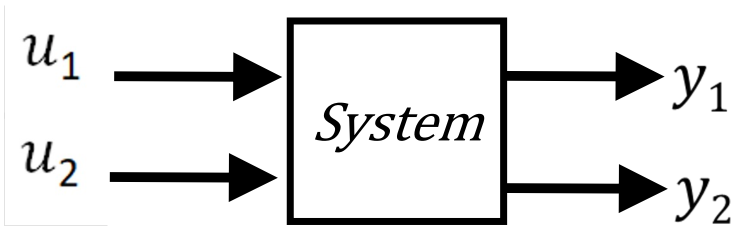
Multi-input single output systems have multiple control inputs and one single output

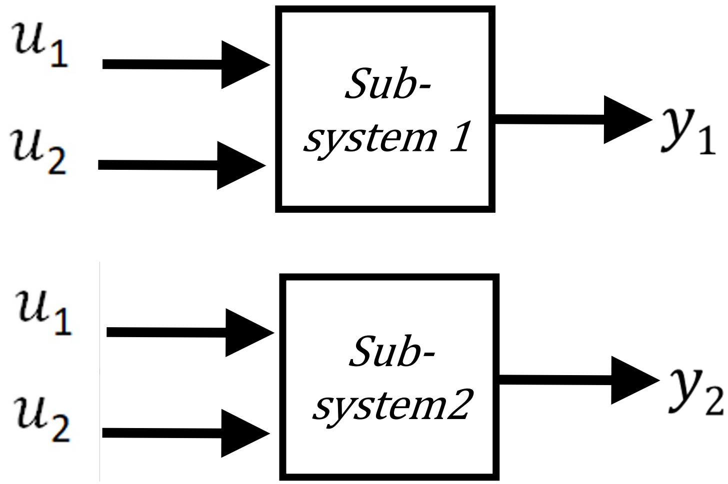
- ➢ *quite rare*



MISO

In certain cases, MISO systems can be modeled as multiple SISO systems





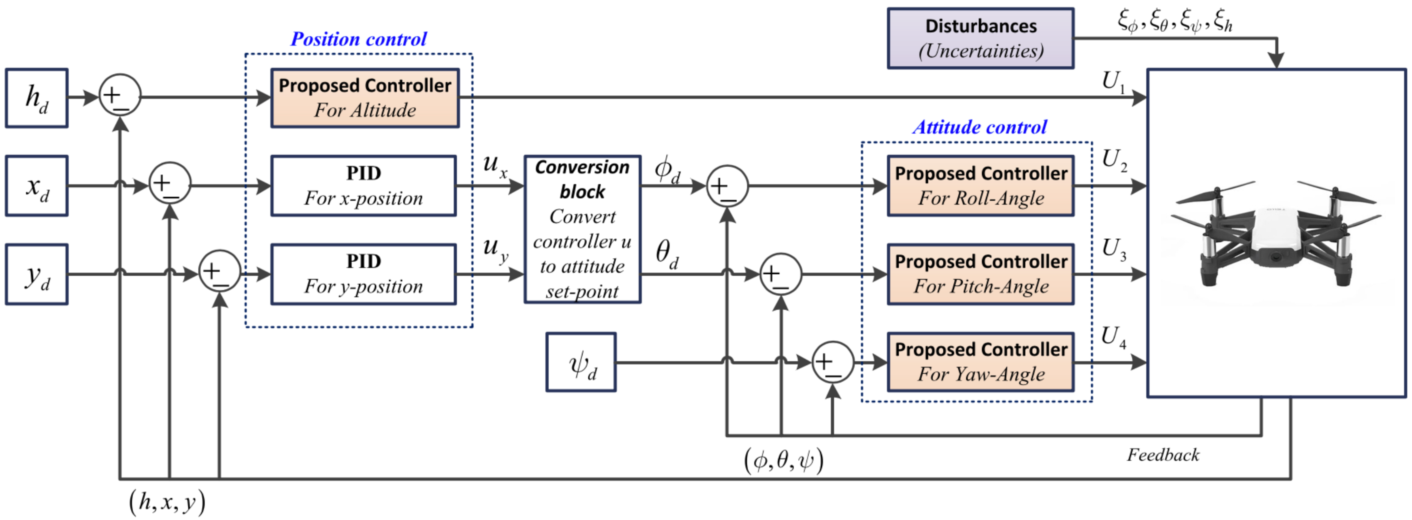
SISO vs. MIMO

In certain cases, MIMO systems can be modeled as multiple SISO systems

- Why? SISO systems are easier to model and control !
- Easier to tune multiple SISO systems, instead of a single MIMO system

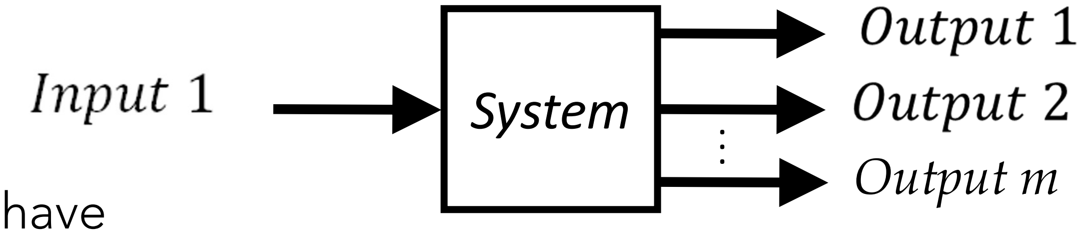
Examples include:

➢ Drone attitude control



When? Nonexistent or negligible coupled dynamic – **Not always possible !**

Single Input Multi Output (SIMO) systems



SIMO systems have

- Single actuating element
- Multiple sensing elements
- Known as *under-actuated systems*

Typically modeled using ***state-space models***

More advanced control systems

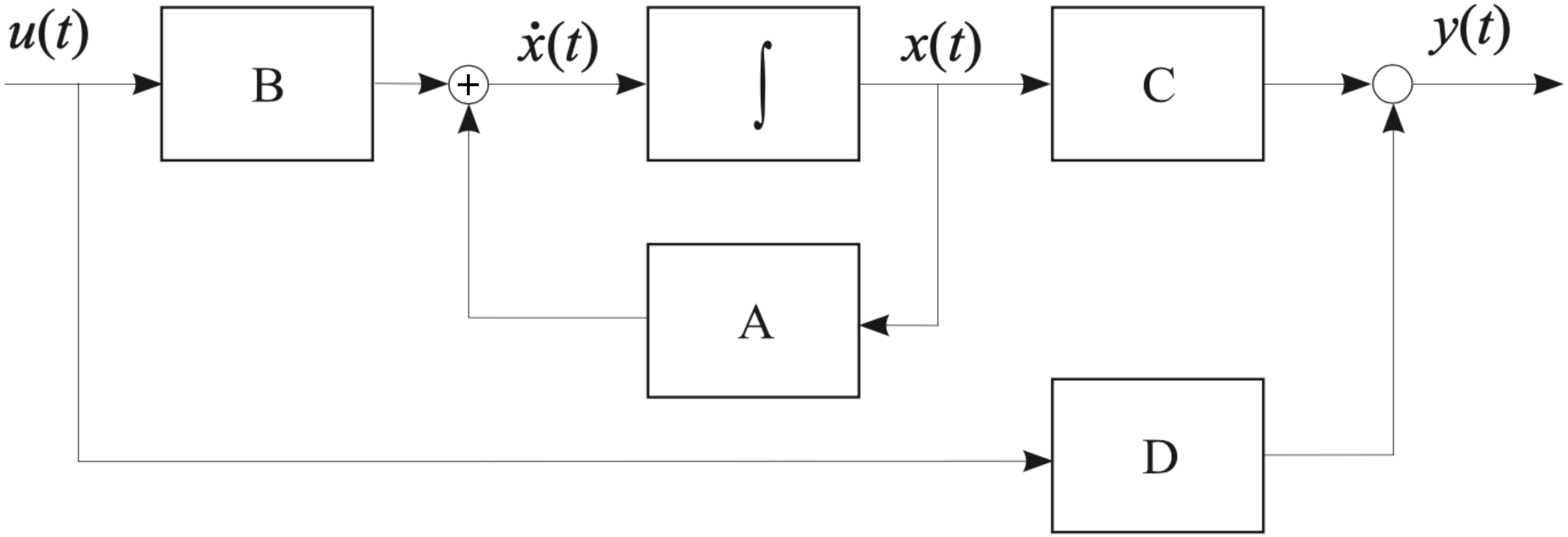
- ***LQR control***

Examples include:

- Inverted pendulum, tower crane
- Flexible robotic arm

Continuous-time linear state-space model

$$\dot{x}(t) = Ax(t) + Bu(t)$$
$$y(t) = Cx(t) + Du(t)$$



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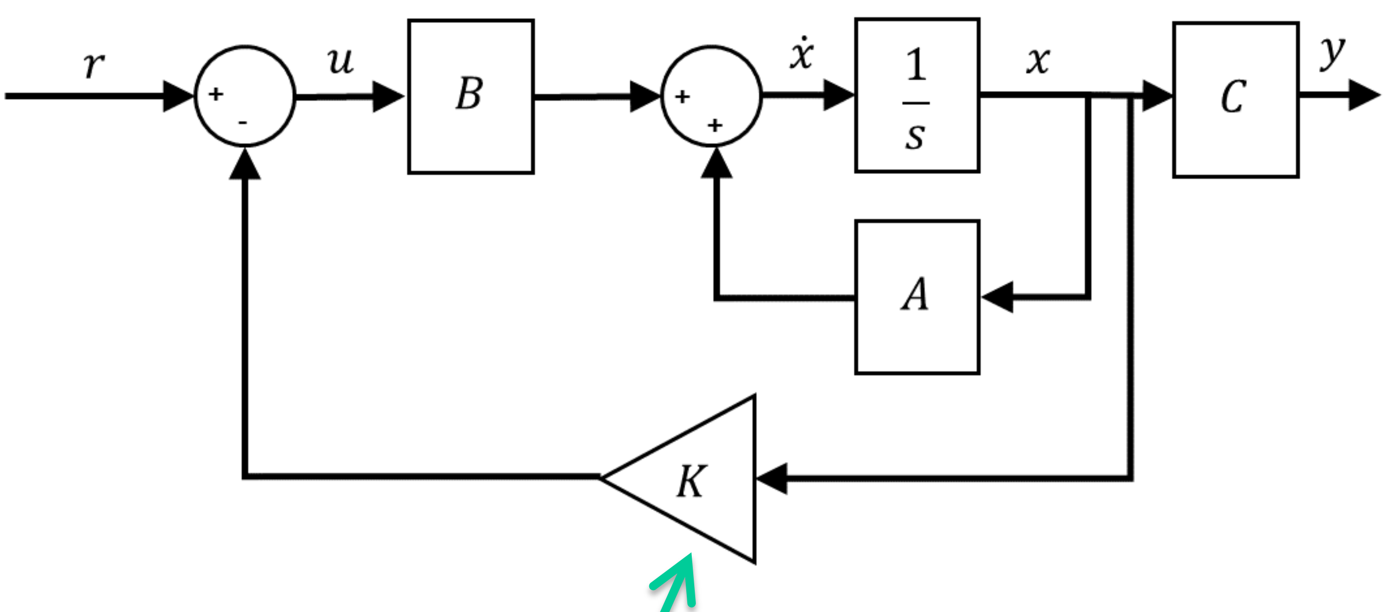
State-feedback control



Use pole placement or LQR
control design

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Example: Canadarm

Arm is made of several ***flexible*** links and motorized joints

- Each link/joint represents a SIMO system modeled using ***state-space***

Coupled dynamics

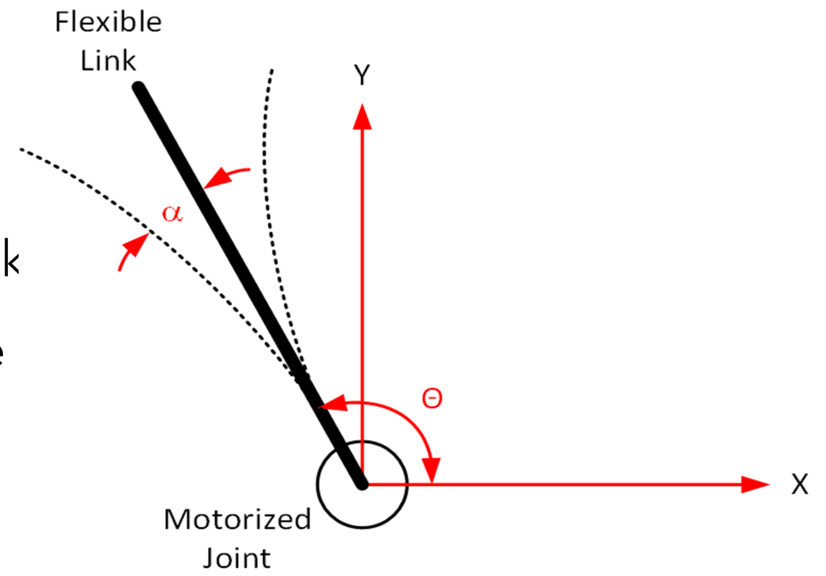
- Joint movement/flexible link dynamically affect each other

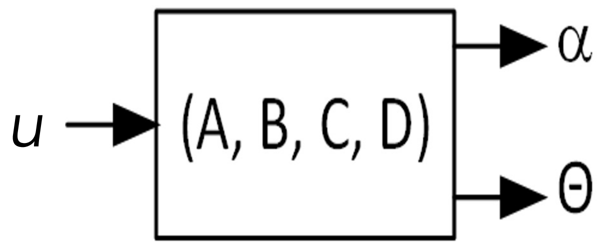
We will study the identification and control of a flexible robot link

Identification of a state-space model for a SIMO flexible link

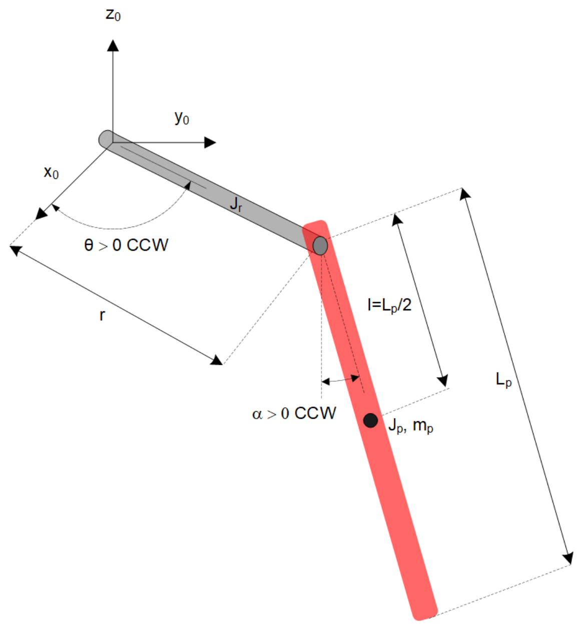
It is a 1 input - 2 outputs (SIMO) system

- $u(t)$: the motor voltage
- $\alpha(t)$: the angle deflection of the flexible link
- $\theta(t)$: the angular position of the servo base



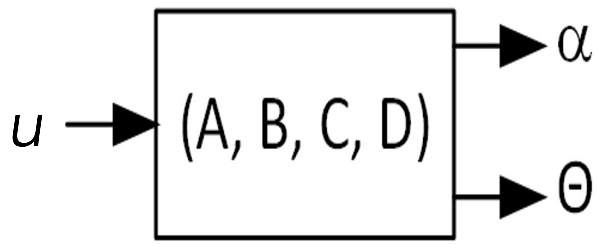


Identification of a state-space model for a tower crane



Motions of a rotary pendulum are similar to that of a tower crane. It is a 1 input - 2 outputs system

- *u(t)*: the motor voltage
- α*(t)*: the angular position of the pendulum
- θ*(t)*: the angular position of the servo base/arm



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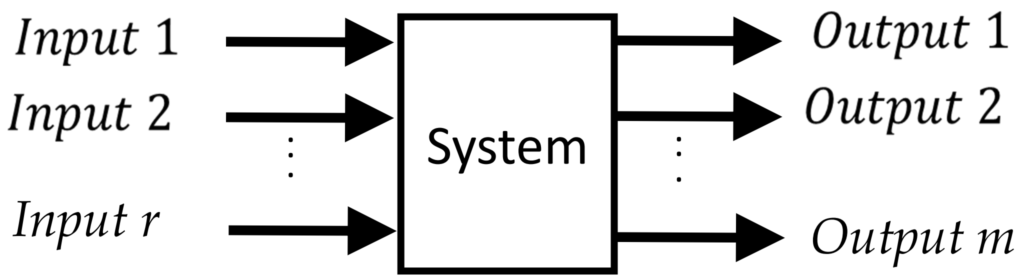
Multi-Input Multi-Output (MIMO) Systems



MIMO systems have

- Multiple actuating elements
- Multiple sensing elements

Typically modeled using *state-space models*

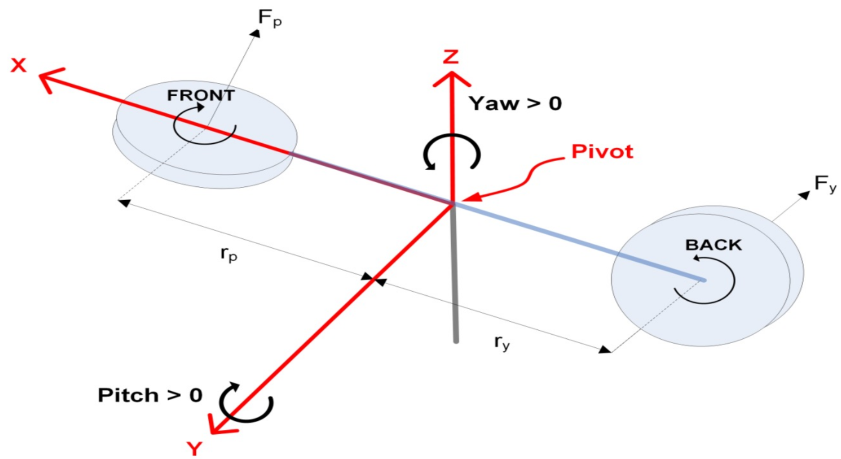
Advanced control systems are required

- *LQR control*,...

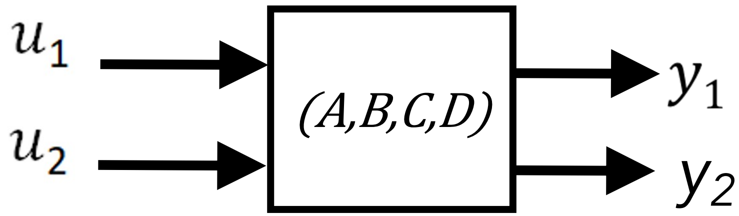
Examples include:

- Dual-rotor AERO helicopter

Example: 2 inputs - 2 outputs AERO helicopter



- Two inputs
  - Front rotor thrust
  - Read rotor thrust
- Two outputs *(no roll)*
  - Pitch
  - Yaw
- Coupled dynamics
  - Pitch/yaw affect each other



We will study the identification and control of the AERO helicopter