Modern Control Theory

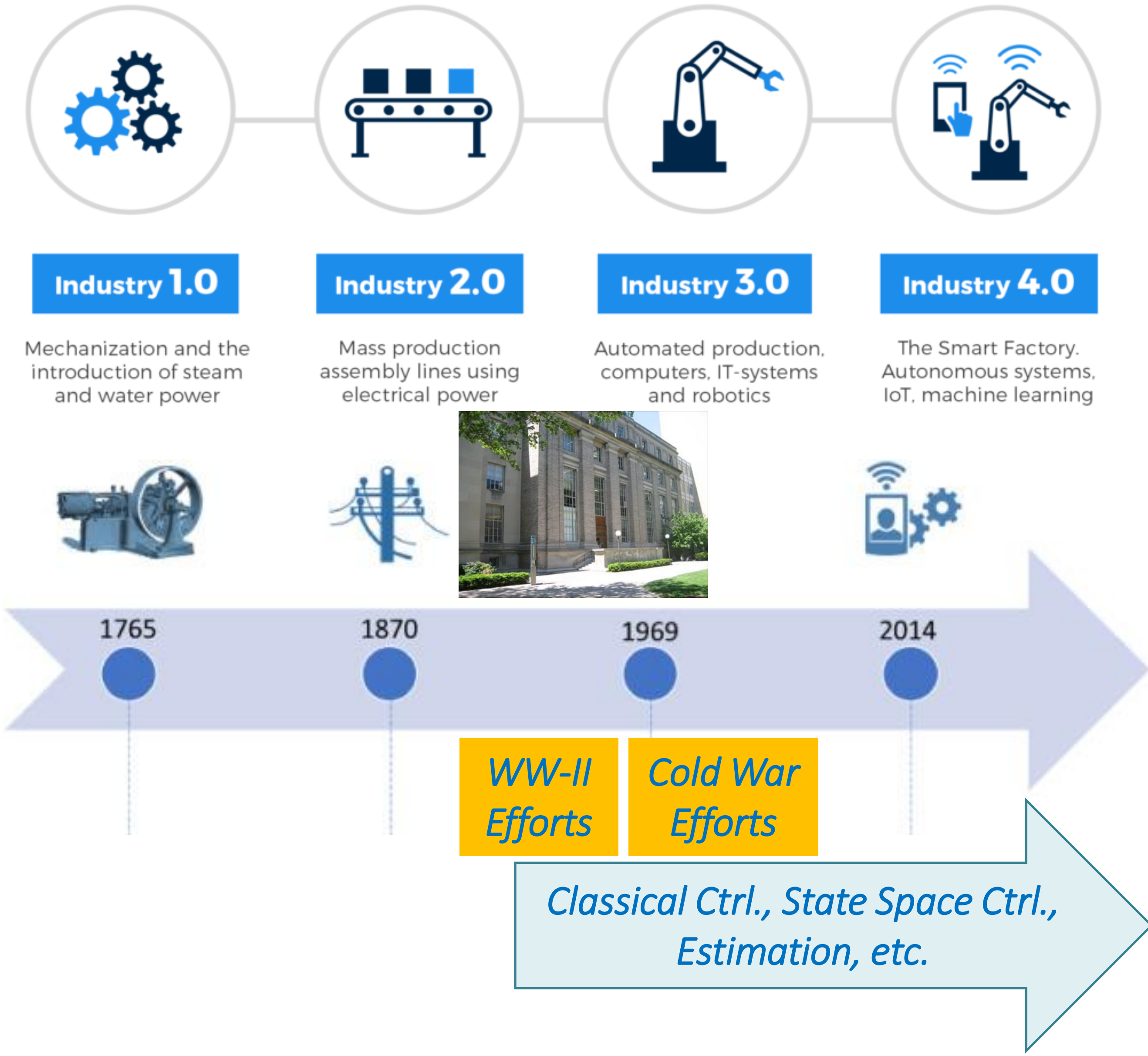
Lecture No. 1

- Why re-learn Control Theory & Feedback ?
- Classical Controls & their Limitations
- Why State Space ?
- Concepts behind State Space Theory
- The Big Picture :

  - State Feedback
  - State Estimation
  - Virtual Sensoring, Monitoring, Diagnostics, Prognostics

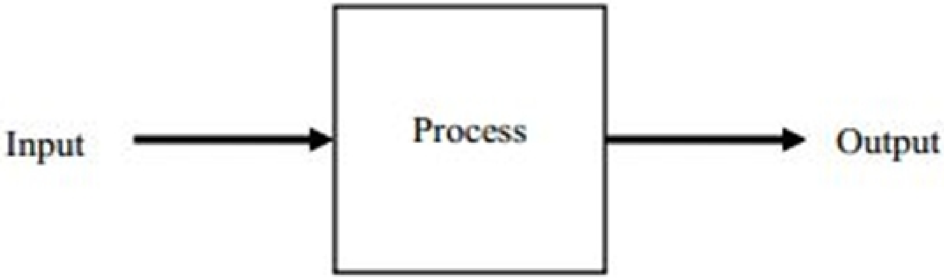
The Four Industrial Revolutions

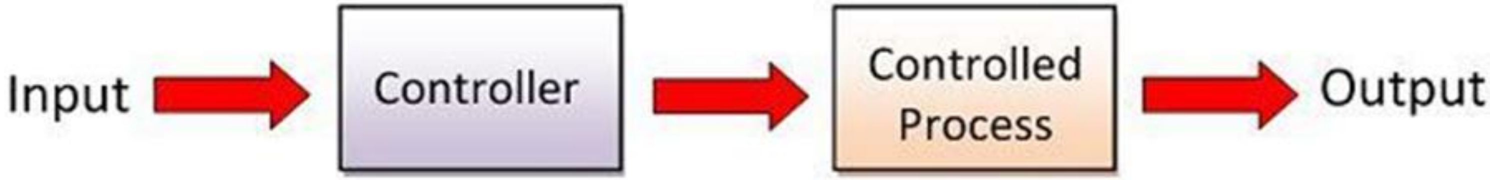
The Control Revolution

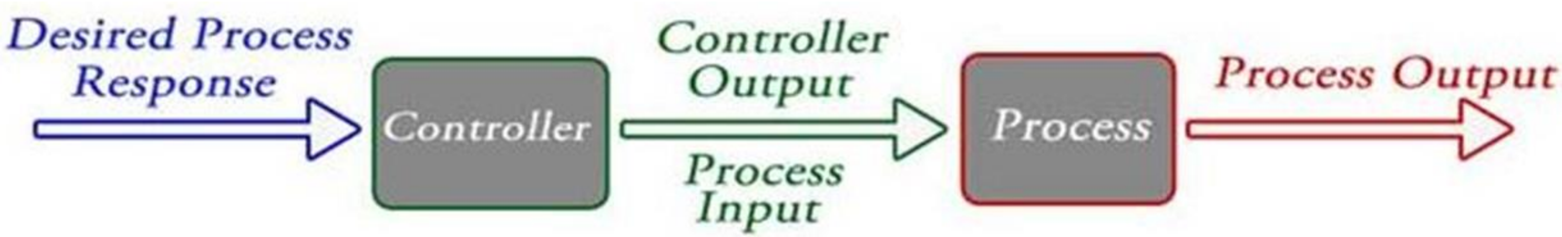


The Growth of Control Engg. vis-à-vis Industrial Revolutions

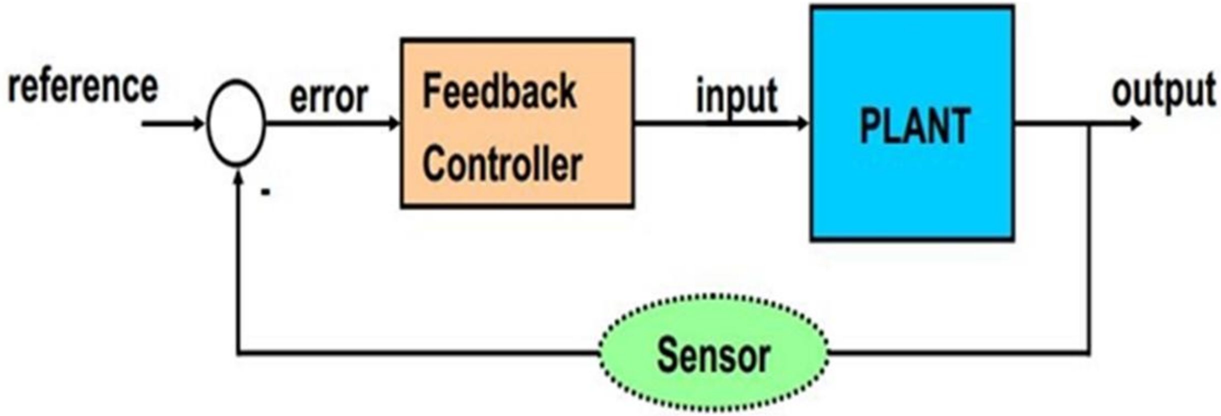
Why Control ??

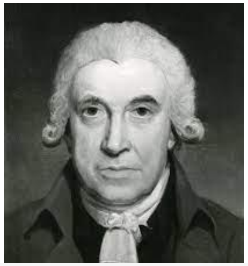

Input
Process
Output

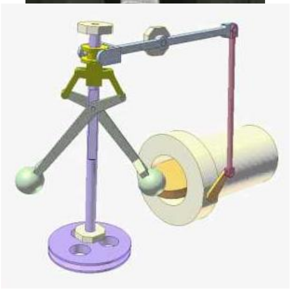

Input
Controller
Controlled Process
Output

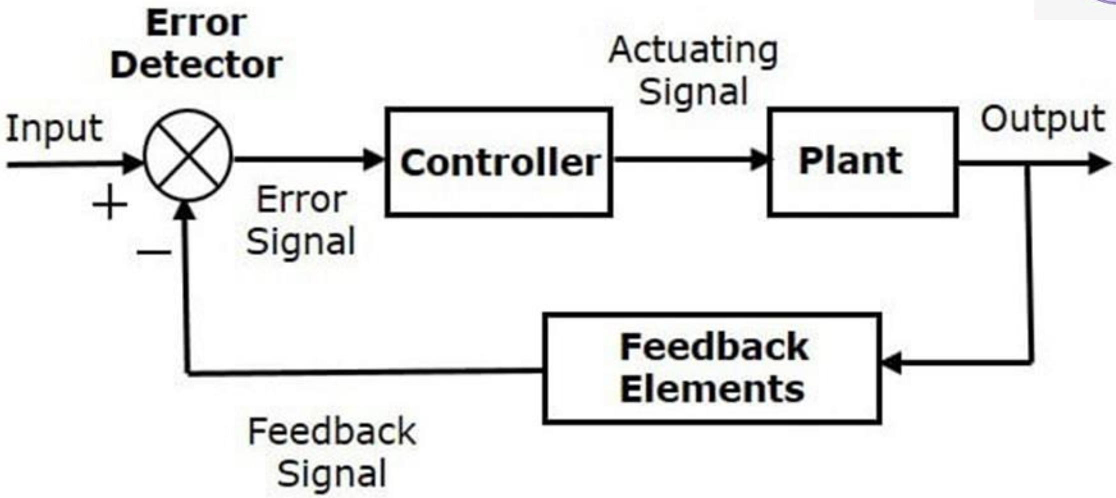

Desired Process Response
Controller
Controller Output
Process Input
Process
Process Output

Why have feedbacks ?









The ODE as a first step towards understanding
the Transient & Steady State Characteristics of a Dynamic System

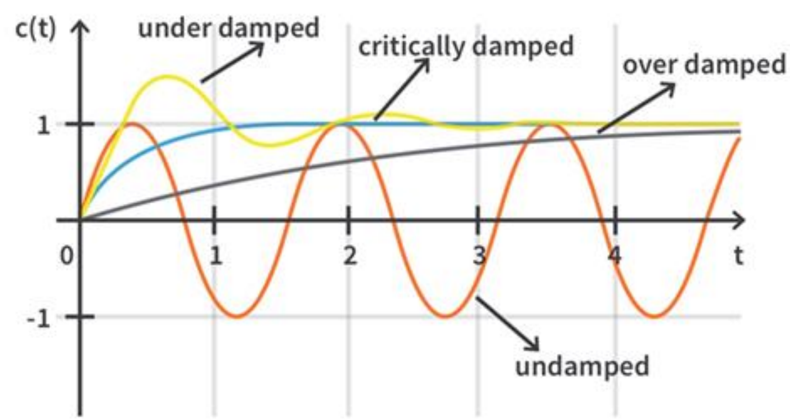
$$\frac{d^2y}{dt^2} + P_1\frac{dy}{dt} + P_0 y = Q(t)$$

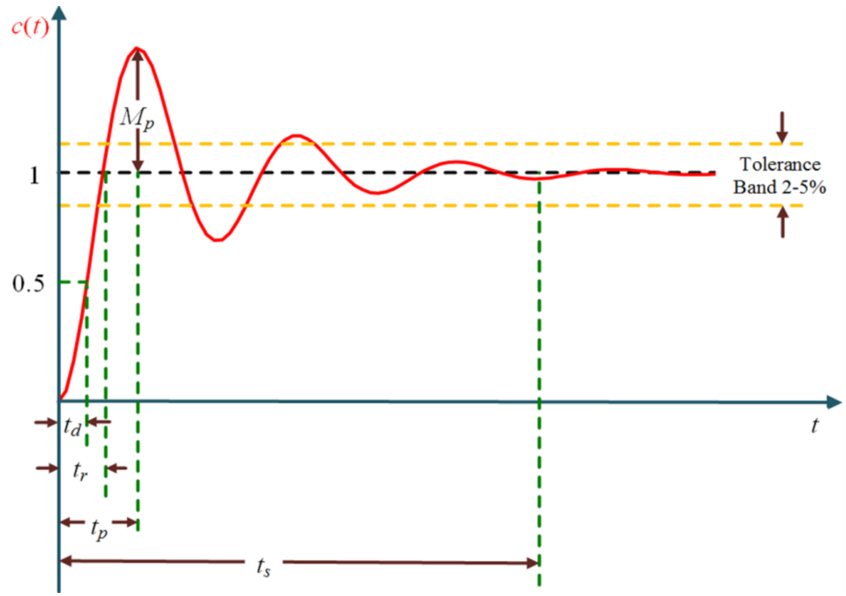
Non - homogeneous equation

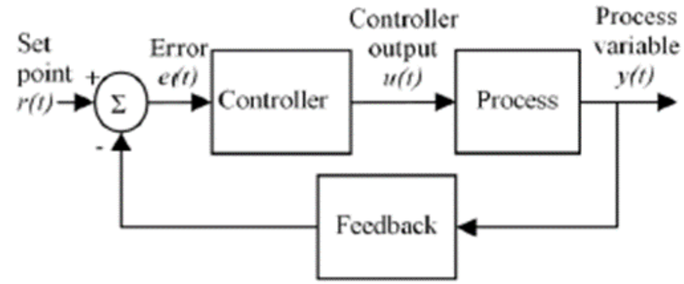
$$y'' + p(x)y' + q(x)y = r(x)$$

$$\frac{d^2y}{dt^2} + P_1\frac{dy}{dt} + P_0 y = 0$$

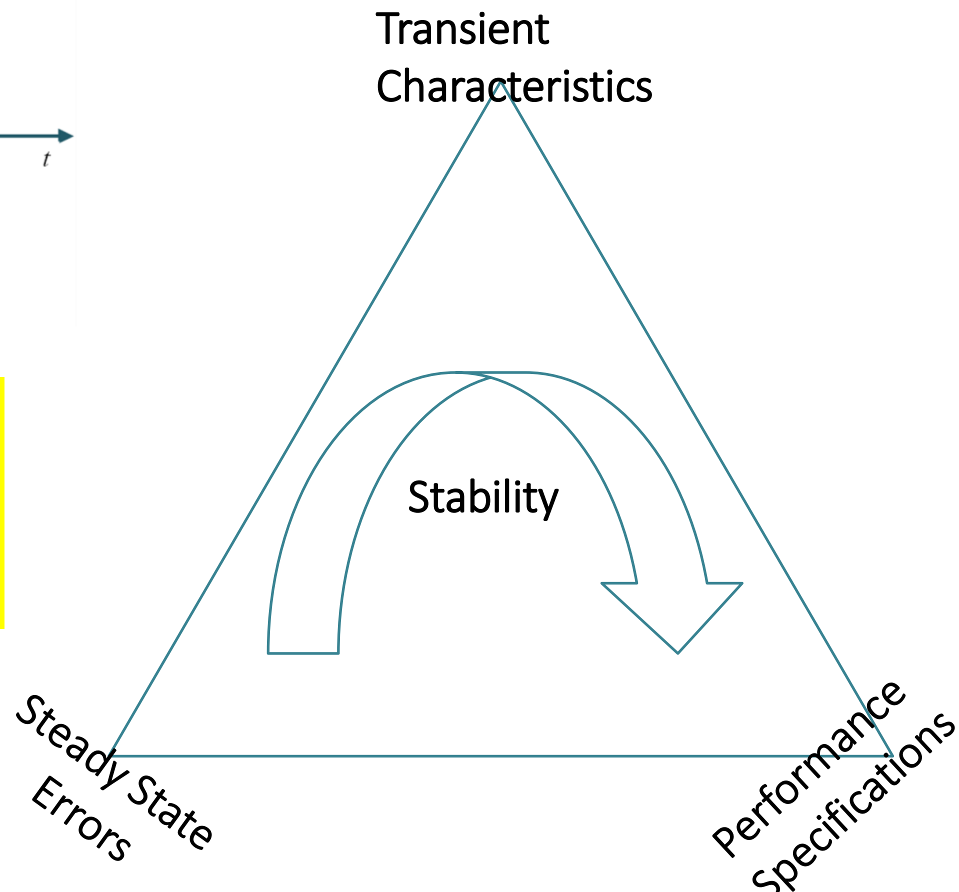
Homogeneous equation

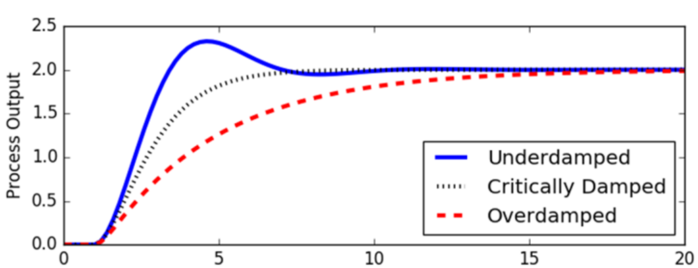






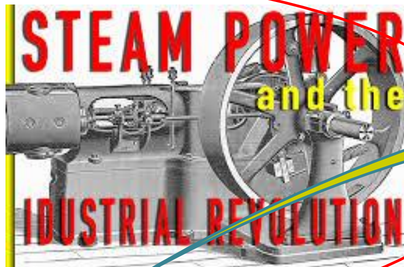
Handling Transients & Steady State Errors, while ensuring Stability and Adherence to Performance Specifications





$$\lim_{t\to 0^+} f(t) = \lim_{s\to\infty} sF(s) = f(0^+)$$

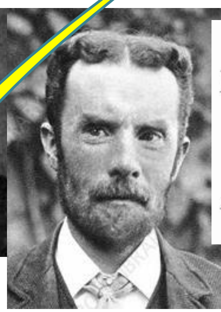
Some of the Wizards of Controls, who helped shape our lives



Posterior, Likelihood, Prior

$$P(A|B) = \frac{P(B|A) * P(A)}{P(B)}$$

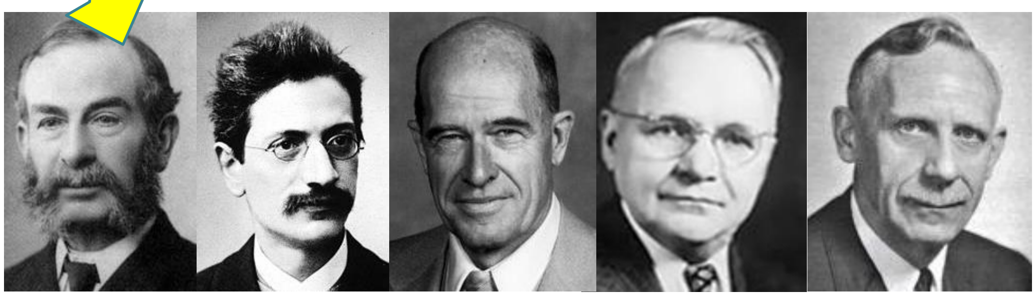
Evidence

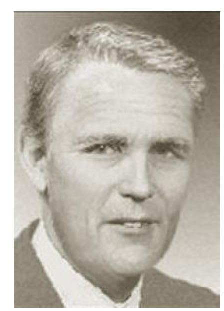


$$Y(s) = \frac{s+1}{s(s^2+4s+4)} = \underset{(1^{st})}{\frac{A}{S}} + \underset{(3^{rd})}{\frac{B}{(s+2)}} + \underset{(2^{nd})}{\frac{C}{(s+2)^2}}$$

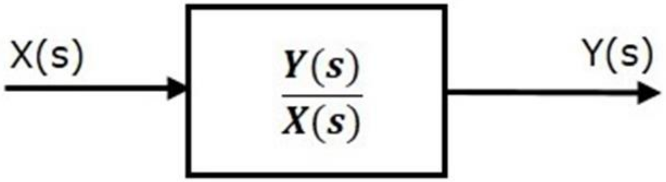
$$A_k = \lim_{s \to r_k} (s - r_k)^m Y(s)$$

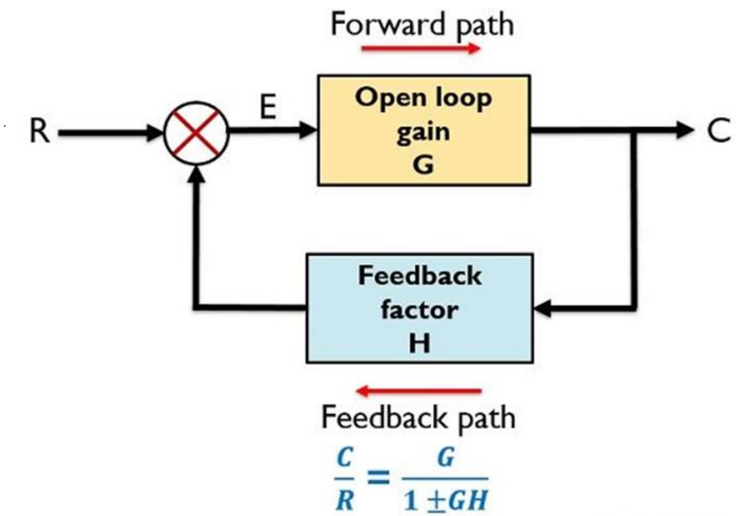
(repeated root, highest order where order = m)

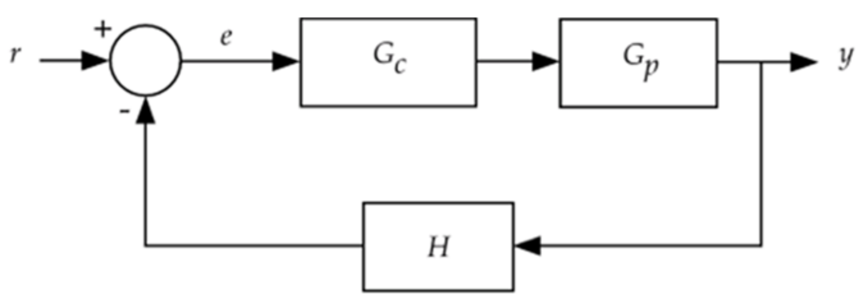




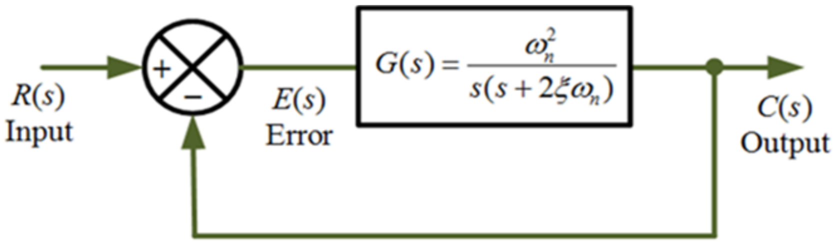
The Transfer Function Approach

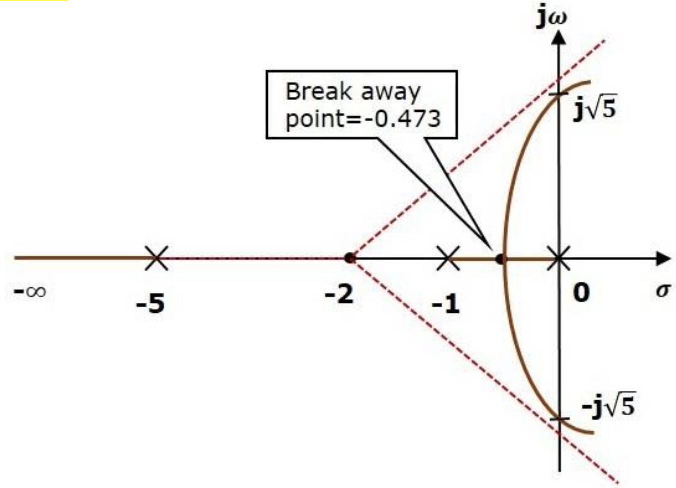


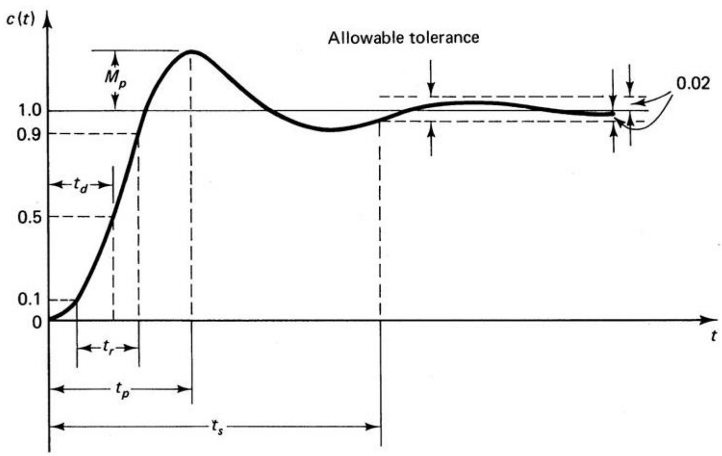




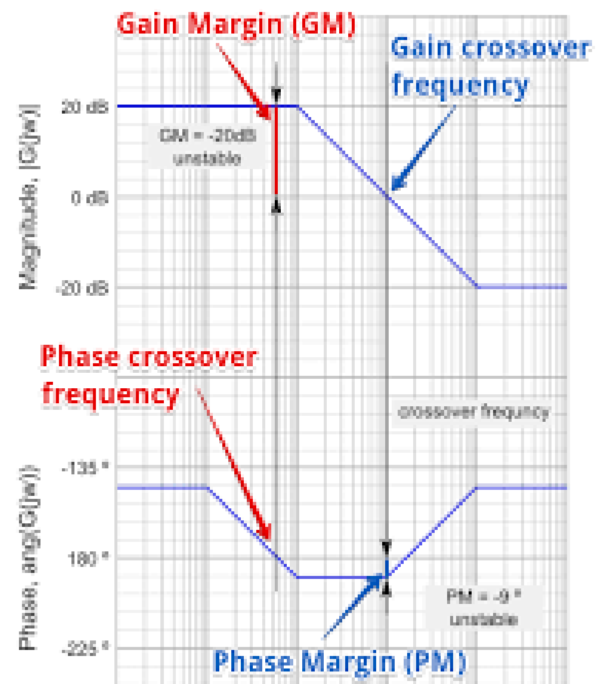
Some of the Typical Classical Control Techniques



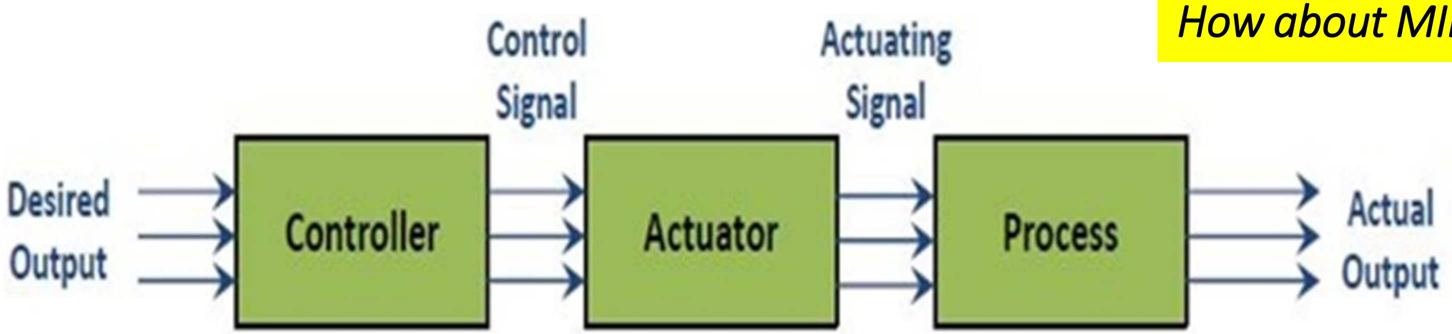


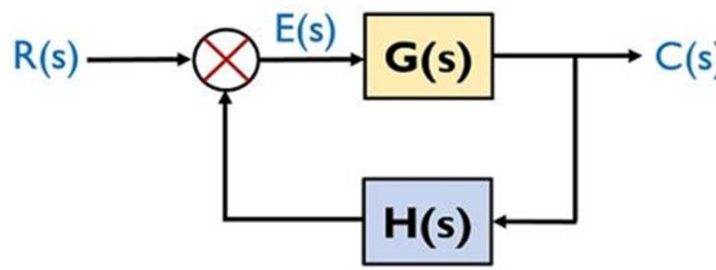


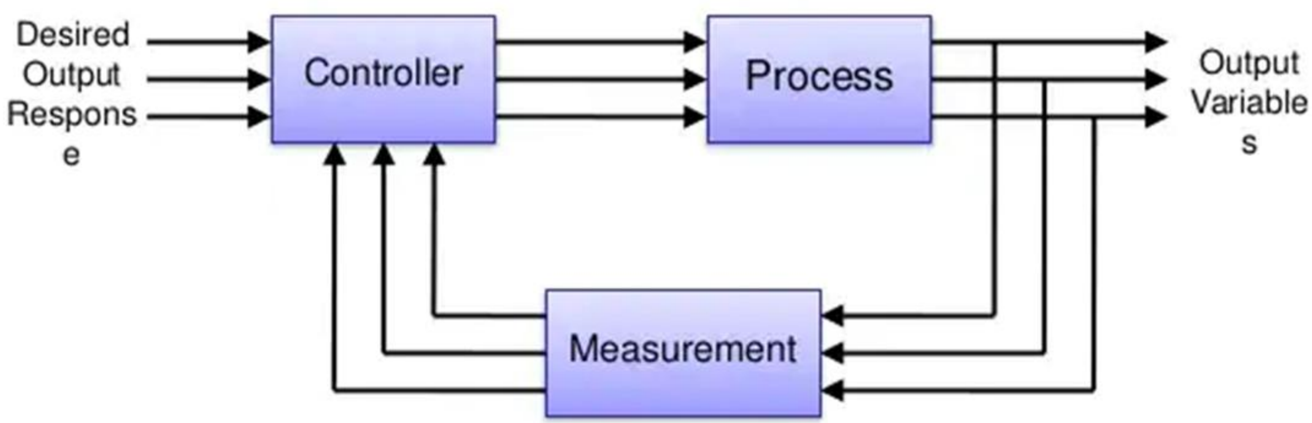
s^6	a_0	a_2	a_4	a_6
s^5	a_1	a_3	a_5	0
s^4	$\dfrac{a_2a_1 - a_0a_3}{a_1} = A$	$\dfrac{a_4a_3 - a_2a_5}{a_3} = B$	$\dfrac{a_4 \cdot 0 - a_6a_5}{a_5} = a_6$	0
s^3	$\dfrac{a_3A - a_1B}{A} = C$	$\dfrac{a_5B - a_3a_6}{B} = D$	0	0
s^2	$\dfrac{BC - AD}{C} = E$	$\dfrac{a_6D - B \cdot 0}{D} = a_6$	0	0
s^1	$\dfrac{DE - Ca_6}{E} = F$	0	0	0
s^0	$\dfrac{E \cdot 0 - a_6F}{F} = a_6$	0	0	0



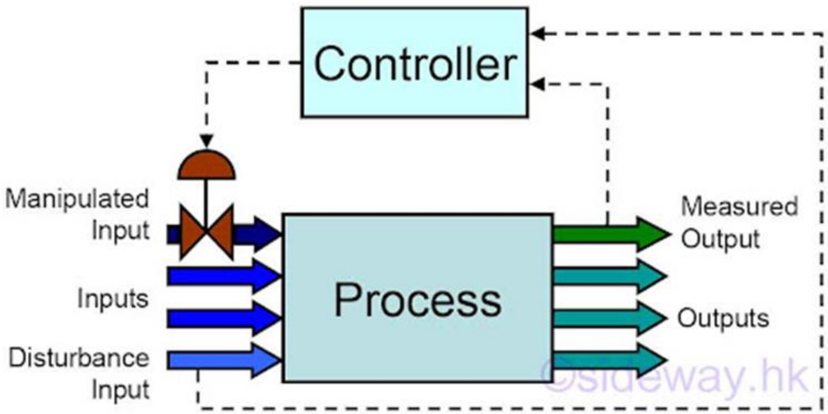
How about MIMO Systems

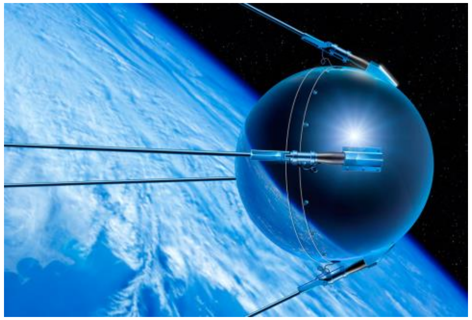


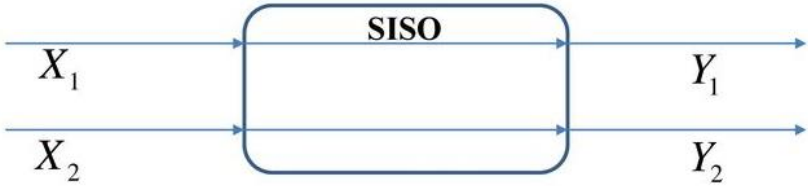


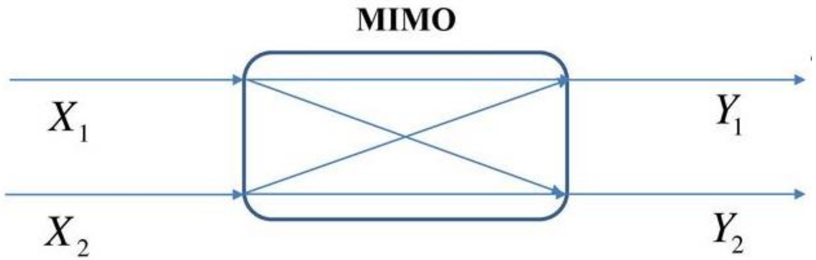


Limitations of the Transfer Function Approach for Multi Variable Problem Solving









Initiation to the Domain of Modern Controls

IFAC
INTERNATIONAL FEDERATIO
OF AUTOMATIC CONTROL

High Order Differential Equation

↓

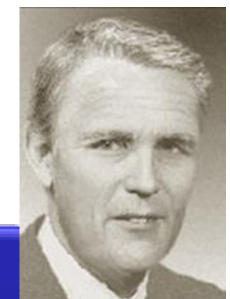
A Set of Simultaneous First Order Differential Equations

↙ ↓ ↘

Numerical Solution

Matrix Equation

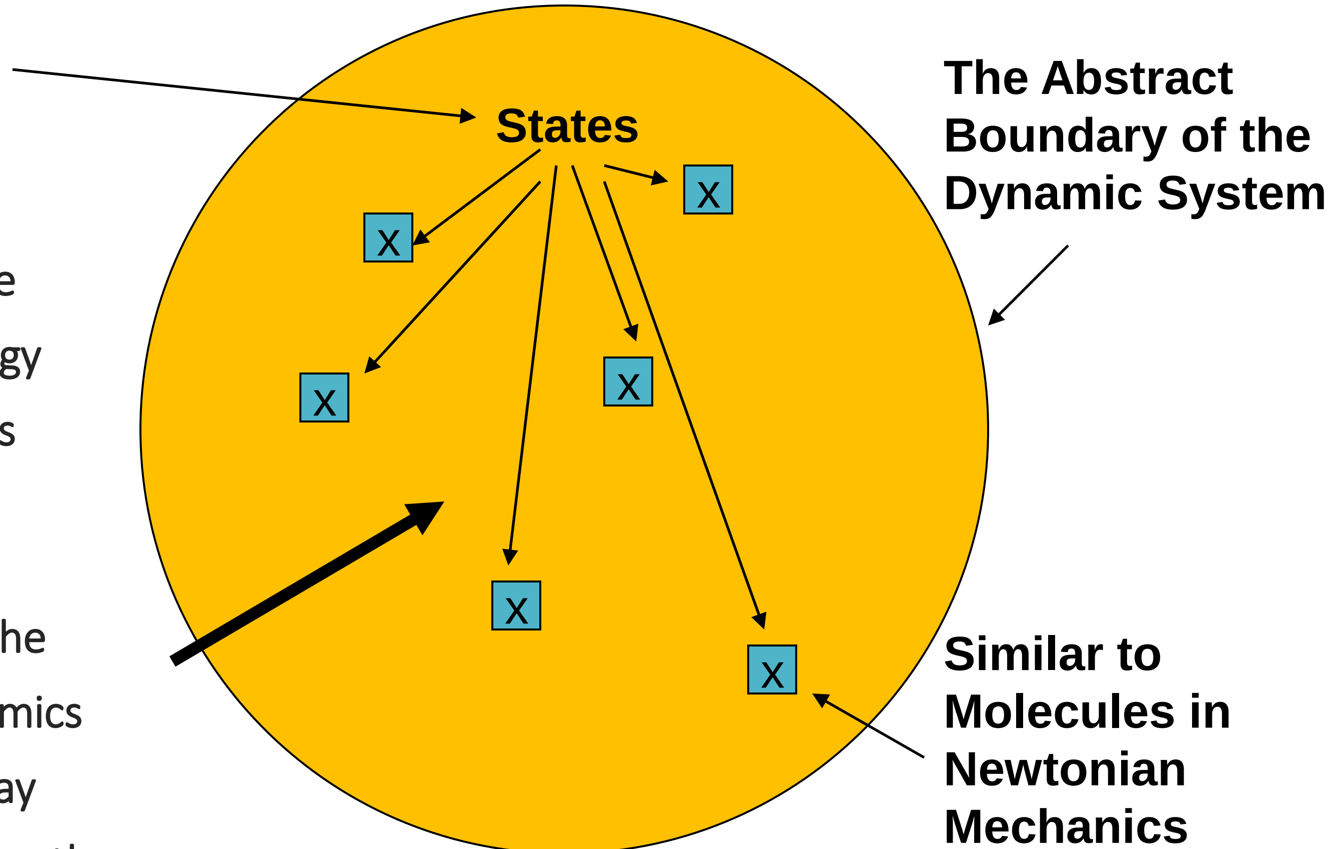
State Space (Control System)



Visualizing the State Space Framework

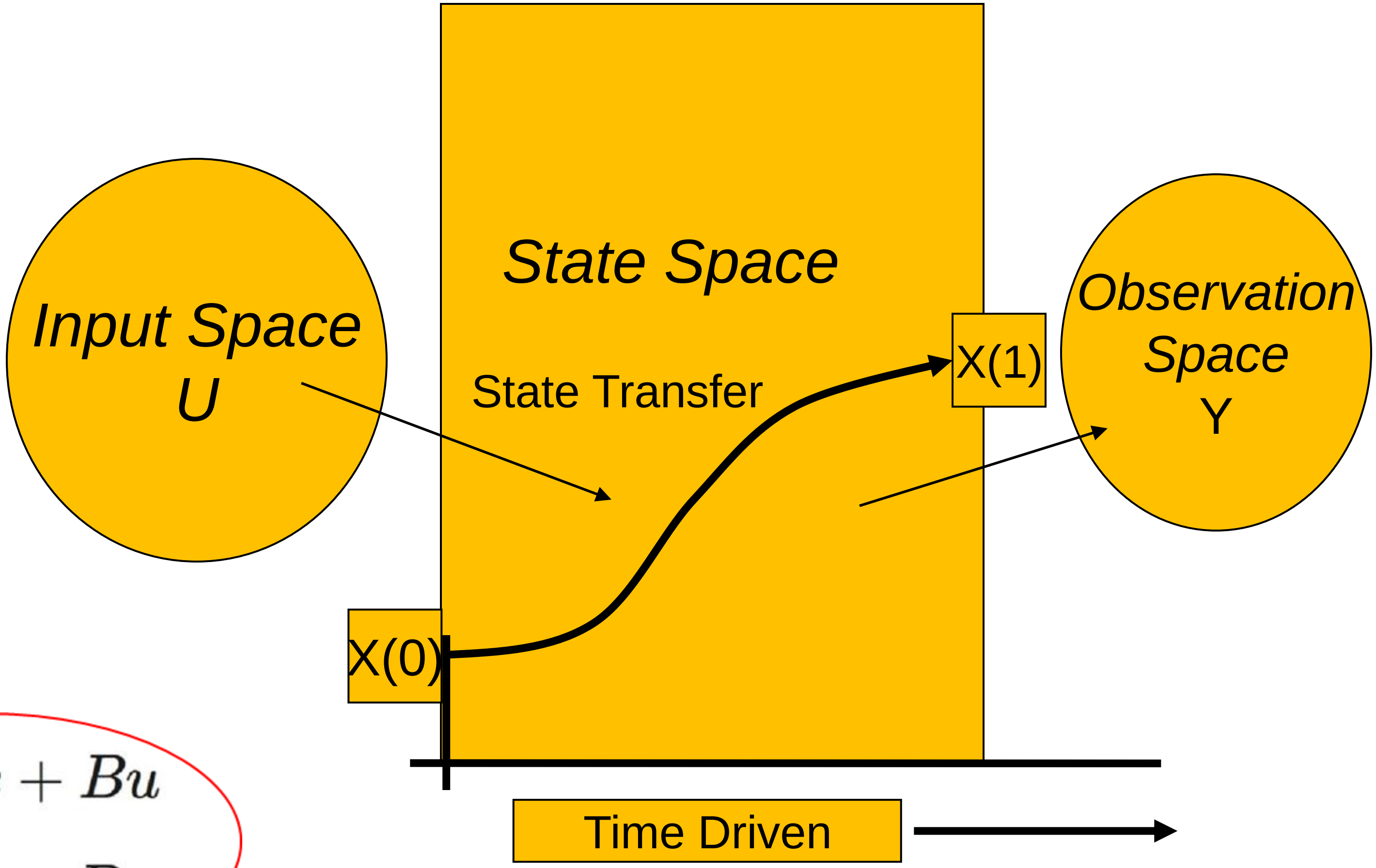
Any Dynamic System comprises of internal variables, termed as States

No. of States, Same as Order of the System --- effectively the Number of Energy Storing Elements in the System



Knowledge of the Position & Dynamics of the States, may Completely define the System Dynamics

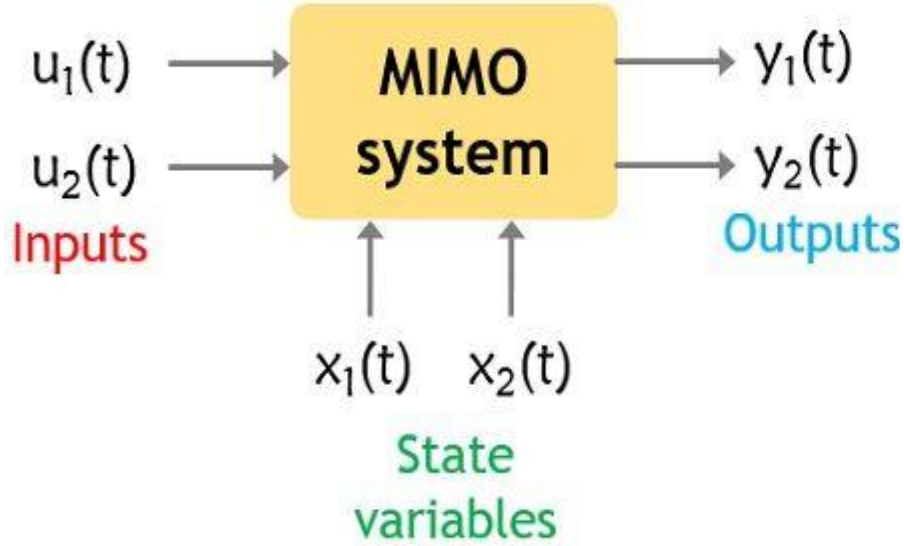
The Concept of State Transfer

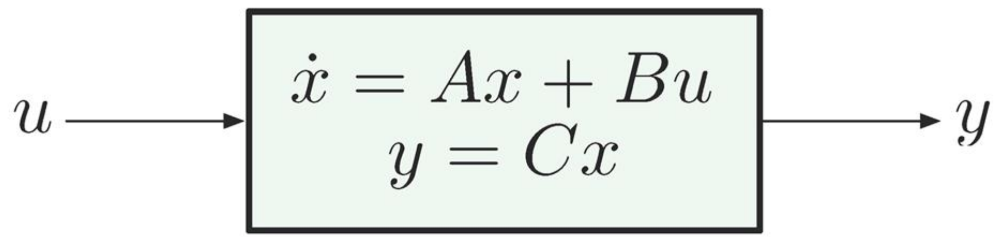


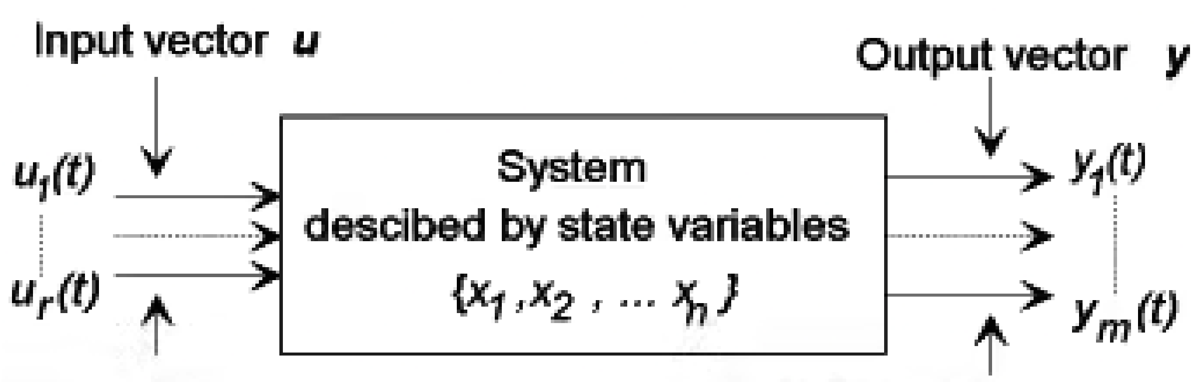
$$\dot{x} = Ax + Bu$$

$$y = Cx + Du$$

Casting MIMO Systems in the State Space Framework







Question Time

Thank You