

MATLAB & SIMULINK

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Signals and Systems Applications

AGENDA

- 1 WHAT ARE THEY?
- 2 INVERTED PENDULUM
 - System Equations
 - Transfer Function
 - What to do with it?
- 3 DIGITAL SIGNAL PROCESSING
 - Sound Signal Processing
 - Image Signal Processing

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WHAT ARE THEY?

MATLAB

MATRIX LABORATORY

MATLAB is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation.

- Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration
- 2-D and 3-D graphics functions for visualizing data
- Functions for integrating MATLAB based algorithms with external applications and languages, such as C, C++, Fortran, JavaTM, etc.
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SIMULINK

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Simulink allows modeling, simulation, and analysis of dynamic systems. It enables you to pose a question about a system, model the system, and see what happens.

- Aerospace and Defense
- Automotive
- Communications
- Electronics
- Signal Processing
- Medical Instrumentation
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MATLAB & SIMULINK

Essentially, prototyping tools

A MUST KNOW for any serious engineer!

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2 INVERTED PENDULUM

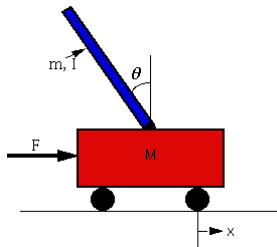
- System Equations
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INVERTED PENDULUM

SYSTEM EQUATIONS



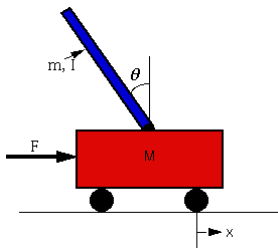
SYSTEM EQUATIONS

A non-linear system governed by the differential equations:

$$\begin{cases} (M + m)\ddot{x} + b\dot{x} + ml\ddot{\theta} \cos \theta - ml\dot{\theta}^2 \sin \theta = F \\ (I + ml^2)\ddot{\theta} + mgl \sin \theta = -ml\ddot{x} \cos \theta \end{cases}$$

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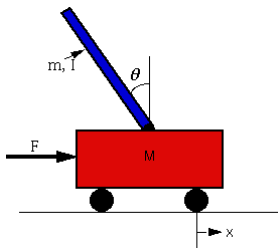
SYSTEM EQUATIONS



- Non-linear equations
- No general theory
- No systematic analysis method
- Better to linearize

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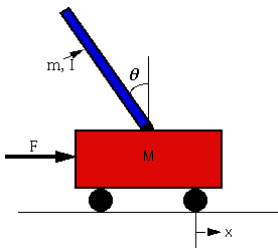
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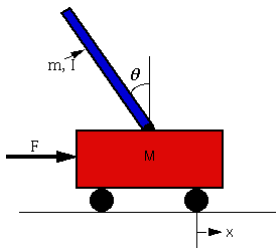
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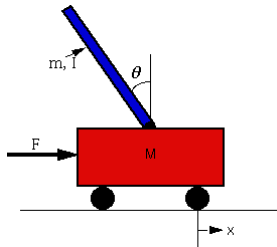
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INVERTED PENDULUM

LINEARIZED SYSTEM EQUATIONS



LINEARIZED SYSTEM EQUATIONS

If θ is small, we can make the system linear:

$$\begin{cases} (I + ml^2)\ddot{\theta} - mgl\theta = ml\ddot{x} \\ (M + m)\ddot{x} + b\dot{x} - ml\ddot{\theta} = x \end{cases}$$

INVERTED PENDULUM

TRANSFER FUNCTION

Ok! Differential equations and blablabla...
...but what linear system theory has to do with it?

- Consider the system with null initial state
- Apply Laplace Transform to obtain algebraic linear equations:

$$\begin{cases} (I + ml^2)\Theta(s)s^2 - mgl\Theta(s) = mX(s)s^2 \\ (M + m)X(s)s^2 + bX(s)s - ml\Theta(s)s^2 = X(s) \end{cases}$$

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TRANSFER FUNCTION

Ok! Differential equations and blablabla...
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- Solve to find $H(s) = \frac{\Theta(s)}{X(s)}$:

$$H(s) = \frac{\frac{ml}{q}s}{s^3 + \frac{b(l+ml^2)}{q}s^2 - \frac{(M+m)mg l}{q}s - \frac{bmg l}{q}}$$

where $q = [(M + m)(l + ml^2) - (ml)^2]$

INVERTED PENDULUM

TRANSFER FUNCTION

Set the parameters...

- $M = 0.5kg$
- $m = 0.2kg$
- $b = 0.1N/m/sec$
- $l = 0.3m$
- $I = 0.006kg \cdot m^2$

...and we have a complete model of an inverted pendulum:

$$H(s) = \frac{4.545s}{s^3 + 0.1818s^2 - 31.18s - 4.455}$$

INVERTED PENDULUM

WHAT TO DO WITH IT?

Great! But... what can I do with it?

- Simulate
- Analyze
- Experiment
- Control!

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INVERTED PENDULUM

THE INVERTED PENDULUM CONTROL PROBLEM

How about trying to balance the pendulum so that it will return to the same position after disturbance?

- Control is all about to compensate for disturbances
- The big question: how much force should I apply to keep the equilibrium of the pendulum at any moment?
- The big solution: **PID Controller**

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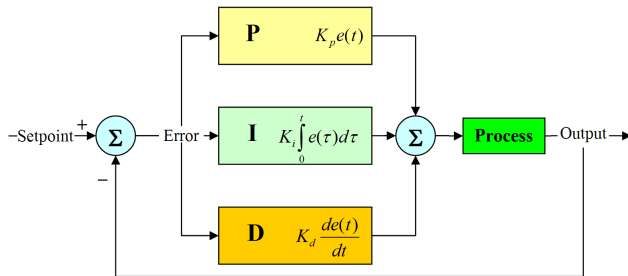
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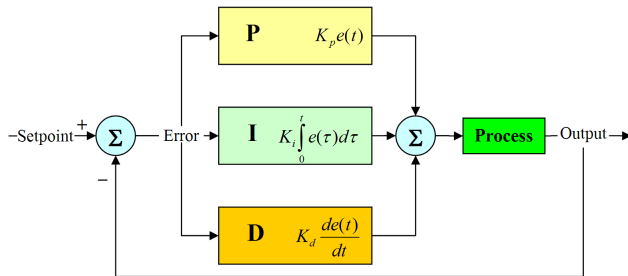
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- Don't try to understand the details (just believe me)
- See the big picture

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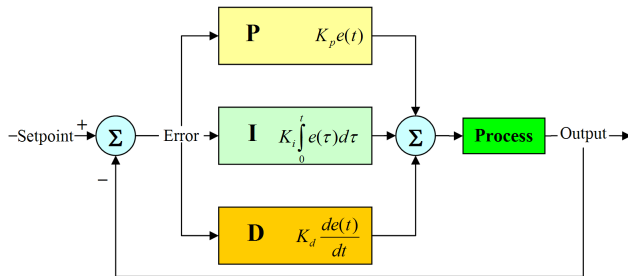
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DEMO

Now, let's put it all together at the Simulink!

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SOUND SIGNAL PROCESSING

- Very basic signal processing
- How to eliminate some noise from a music?
- Filtering the frequency content of the signal

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SOUND SIGNAL PROCESSING

Let's try it!

IMAGE SIGNAL PROCESSING

- What is a frequency in a image?
- The effect of filters in the frequency spectrum of an image

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QUESTIONS?

