Hybrid Control of Systems with Poorly Defined Relative Degree: The Ball-on-Beam Example

Authors: Adam T. Simmons

and John Y. Hung

Auburn University, ECE Department

Outline

- The Idea / Problem
- Relative Degree
- The Ball-on-Beam Example
- Traditional Nonlinear Control Design
- Linear Control Design
- Hybrid Approach
- Discussion

Incremental Overlays you Say...

For this slide, I will give a brief example of how to do incremental slide overlays. First, we skip a small step, and go into the next part.

Incremental Overlays you Say...

For this slide, I will give a brief example of how to do incremental slide overlays. First, we skip a small step, and go into the next part.

The next part can involve equations and or pictures

$$x^2 + y^2 = z^2$$

But, might not have a solution.

Incremental Overlays you Say...

For this slide, I will give a brief example of how to do incremental slide overlays. First, we skip a small step, and go into the next part.

The next part can involve equations and or pictures

$$x^2 + y^2 = z^2$$

But, might not have a solution.

Finally, the last part of the slide can again have a picture:

$$H(s) = \frac{A(q)}{B(q)}$$

The Problem

- Traditional Nonlinear Design Techniques will not work for systems with poorly defined relative degree.
- SOLUTION: Could a hybrid approach create a more reasonable control effort?

What is Relative Degree?

- **Poorly Defined** means the relative degree is not the same for all state values.
- **Relative Degree** = the number of differentiations of the output variable required to reveal the control input in the result.

Relative Degree, Linear

- Linear Systems with Relative Degree r

$$\frac{Y(s)}{U(s)} = \frac{b_o s^m + b_1 s^{m-1} + \cdots + b_m}{s^n + a_1 s^{n-1} + \cdots + a_n}$$

Equations

Linearization of a Ball-on-beam System

$$\dot{x}_1 = x_2 \quad (1)$$

$$\dot{x}_2 = \frac{mgx_3}{\left(m + \frac{I_{ball}}{r^2}\right)} \quad (2)$$

$$\dot{x}_3 = x_4 \quad (3)$$

$$\dot{x}_4 = \frac{\tau - C_d x_4 + gmx_1}{(I_{beam} + I_{ball})} \quad (4)$$