NU Presentation Template

List of author names

Northwestern University

author@institution.edu

May 1, 2019

- You can present plain text,
- equations, such as $\dot{x} = f(x, u)$, and
- you can cite references like [1] and [2],
- but using BibTeX is harder than with other LaTeX document classes.

This is a "block"

The block contains information I want to emphasize.

You can create multiple columns. This is one.

Caption: and you can put figures in columns

This is another column.

Another block

$$f_g = \begin{cases} 0 & \text{if not in contact,} \\ -k_g x_f & \text{if in contact and foot is sinking,} \\ [0, -k_g x_f] & \text{if in contact and foot is stationary.} \end{cases}$$

Block 3

$$\begin{aligned} \text{Body:} \quad & \ddot{x}_b = \frac{u}{m_b} - g, \\ \text{Foot:} \quad & \ddot{x}_f = -\frac{k_g}{m_f} x_f - g - \frac{u}{m_f}, \\ \text{Stroke:} \quad & 0 \le x_b - x_f \le s, \\ \text{ICs:} \quad & (x_b, \dot{x}_b, x_f, \dot{x}_f)\big|_{t=0} = (s, v_0, 0, v_0) \end{aligned}$$

Soft landing problem $\rightarrow$ optimal control problem, solve with Pontryagin's Maximum Principle [3].

- cost function $J(x, u, t)$, dynamics $\dot{x} = f(x, u)$,
- state constraints $h(x) \leq 0$, terminal constraints $\psi(x(T)) = 0$, T is free

Pontryagin's Maximum Principle (PMP), 1956

Given

$$\mathcal{H} = p^\top f(x, u) + \nu^\top h(x),$$

$$\dot{x} = \frac{\partial \mathcal{H}}{\partial p}^\top = f(x, u),$$

$$\dot{p} = -\frac{\partial \mathcal{H}}{\partial x}^\top = -\frac{\partial f}{\partial x}^\top - \frac{\partial h}{\partial x}^\top \nu, \text{ and}$$

$$p(T) = \left.\frac{\partial J}{\partial x}^\top\right|_T - \left.\frac{\psi}{\partial x}^\top\right|_T \lambda,$$

the optimal control satisfies

$$\mathcal{H}(u^*) = \min_{u_{\min} \leq u \leq u_{\max}} \mathcal{H}(u).$$

Insights from PMP

- $\mathcal{H}$ linear in $u \rightarrow$ bang-bang control is optimal until foot stops
- switching times determined by zeros of switching function: $a + b\cos(\omega(T - t)) + d\sin(\omega(T - t))$, where $\omega = \sqrt{\frac{k_g}{m_f}}$
- once foot stops, $u \in [-m_f g, -k_g x_f - m_f g]$

Assume only 1 switching event before foot stops.
Result: bang-bang-boundary control

$$u^* = \begin{cases} u_{\max}, & 0 \leq t < t_1, \\ u_{\min}, & t_1 \leq t < t_2, \\ u_b, & t \geq t_2, \end{cases}$$

Saw some of the things you can do with the Beamer package

Such as

- Blocks
- Equations
- Figures
- Columns

Lastly

- I hope you find this useful.
- I certainly have.

second-to-last caption

the last caption!

J. J. Aguilar and D. I. Goldman.
Robophysical study of jumping dynamics on granular media.
Nature Physics 12, 273-283 (2016).

C. M. Hubicki, J. J. Aguilar, D. I. Goldman and A. D. Ames.
Tractable terrain-aware motion planning on granular media: an impulsive jumping study.
In 2016 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), pages 3887-3892, Oct 2016.

L. S. Pontryagin.
The mathematical theory of optimal processes.
CRC Press, 1987 (originally published in 1956)