

NU Presentation Template

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Presentation

A. Uthor

Introduction

Background

Another
subsection in
the
Introduction
section

Analytical
optimization

Conclusion

[Introduction]

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- 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.

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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

Body: $\ddot{x}_b = \frac{u}{m_b} - g,$

Foot: $\ddot{x}_f = -\frac{k_g}{m_f} x_f - g - \frac{u}{m_f},$

Stroke: $0 \leq x_b - x_f \leq s,$

ICs: $(x_b, \dot{x}_b, x_f, \dot{x}_f) \big|_{t=0} = (s, v_0, 0, v_0)$

Presentation

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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

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

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

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

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

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!

Presentation

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Introduction

Conclusion



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)