Introduction

Contact-aware Control, Lecture 1

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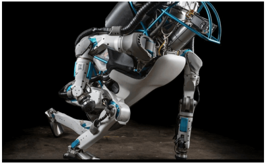
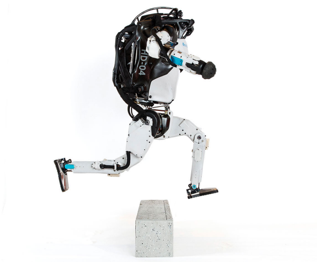
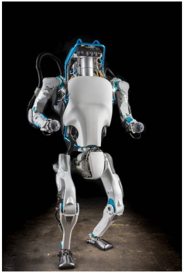
Motivation

Dynamics depends on contact







What do you find different between those poses in terms of mobility of the robot?

Contact in Robotics

There are a number of areas where changes in contact interaction between the robot and the environment is part of normal operation of the robot:

- walking robots;
- collaborative robots;
- robots performing tooling and other operations which do not involve moving the operated objects.

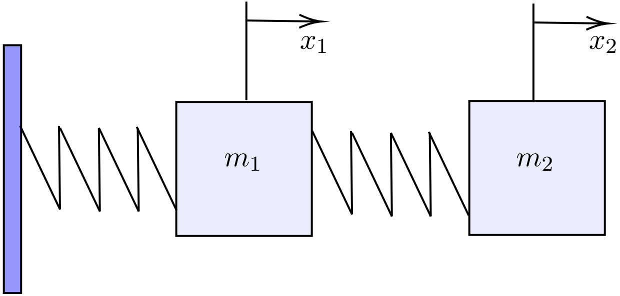


Figure 1: Two body oscillator diagram

This is an example of a system that you know how to describe:

$$\begin{cases} m_1\ddot{x}_1 = k_1 x_1 + k_2(x_2 - x_1 - l_{12}) \\ m_2\ddot{x}_2 = -k_2(x_2 - x_1 - l_{12}) \end{cases} \tag{1}$$

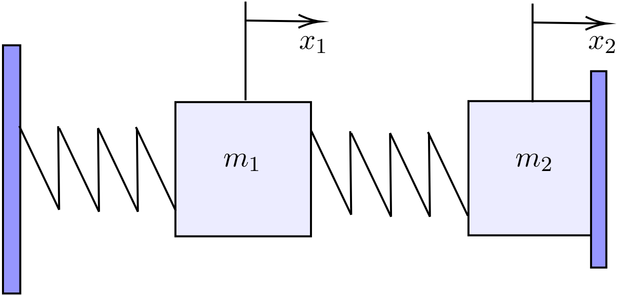


Figure 2: Two body oscillator diagram

Now we add a constraint:

$$x_2 = \text{const} \tag{2}$$

How do we describe this one?

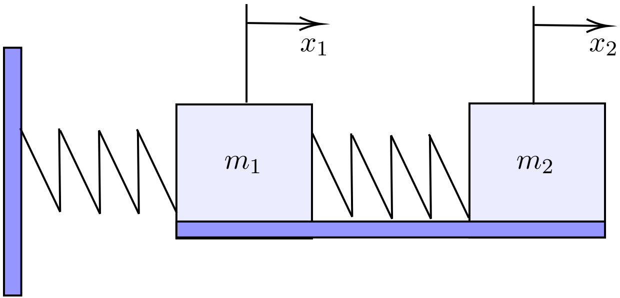


Figure 3: Two body oscillator diagram

Now we add a different constraint:

$$x_2 - x_1 = \text{const} \tag{3}$$

How do we describe this one?

Motivating example

Two body oscillator, part 4

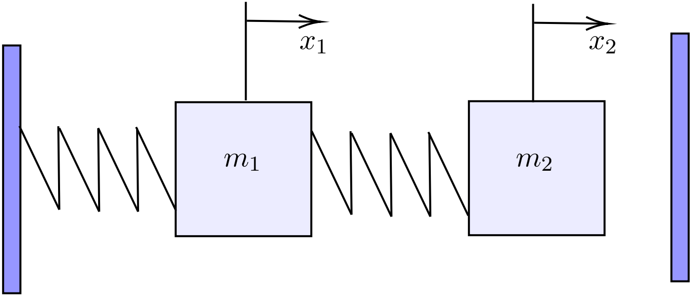


Figure 4: Two body oscillator diagram

Previously we saw *equality constraints*. Now we add *inequality constraints*, or *unilateral constraints*:

$$x_2 \leq 1 \tag{4}$$

This is an even more complicated example than the previous one. Think about why.

This course

Content

In this course we will:

- learn how to describe systems with different types of constraints, how to automatically generate equations for them;
- learn how to simulate them;
- learn control methods for those systems;
- understand methods for analysis of those systems;
- learn how to do planning for systems with constraints;
- learn how describe certain systems with constraints as a normal ODE, and when it is possible;
- ...and many other useful things.

This course

Tools we will use and learn

We will use important and interesting tools, which will be useful for your further studies and professional work:

- symbolic computation and auto-differentiation;
- linear algebra, projectors, change of coordinates via fundamental subspaces and other tools;
- numeric optimization: convex optimization, quadratic programming, second order cone programming;
- linear control, non-linear control: LQR, CTC, inverse dynamics, stable error dynamics, and other concepts;
- path planning with mixed-integer optimization;
- ...and many other useful tools.

Homework

Try to write dynamic equations for the cases with equality constraints.

Lecture slides are available via Moodle.

You can help improve these slides at:
github.com/SergeiSa/Contact-Aware-Control-Slides-Fall-2020

Check Moodle for additional links, videos, textbook suggestions.