

# Introduction

## Contact-aware Control, Lecture 1

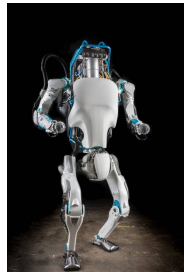
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# Motivation

Dynamics depends on contact



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

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.

# Motivating example

## Two body oscillator, part 1

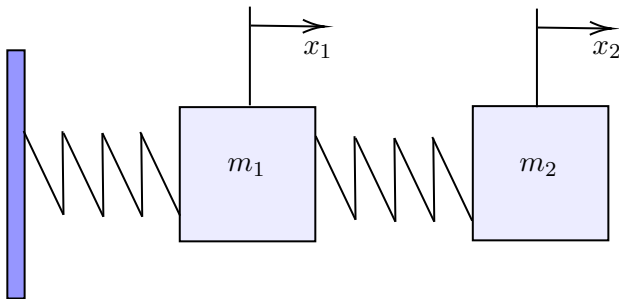


Figure 1: Two body oscillator diagram

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

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

# Motivating example

## Two body oscillator, part 2

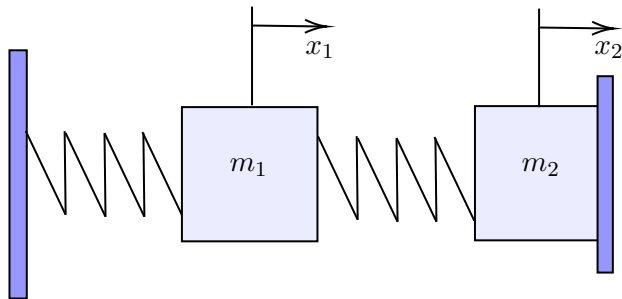


Figure 2: Two body oscillator diagram

Now we add a constraint:

$$x_2 = \text{const} \quad (2)$$

How do we describe this one?

# Motivating example

## Two body oscillator, part 3

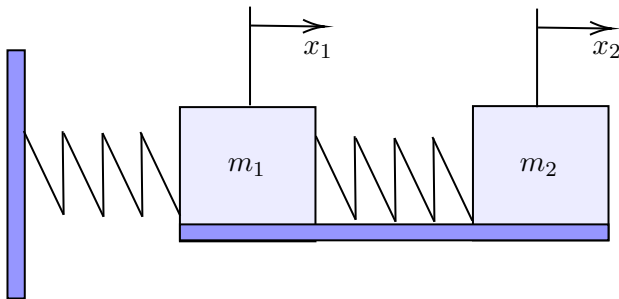


Figure 3: Two body oscillator diagram

Now we add a different constraint:

$$x_2 - x_1 = \text{const} \quad (3)$$

How do we describe this one?

# Motivating example

## Two body oscillator, part 4

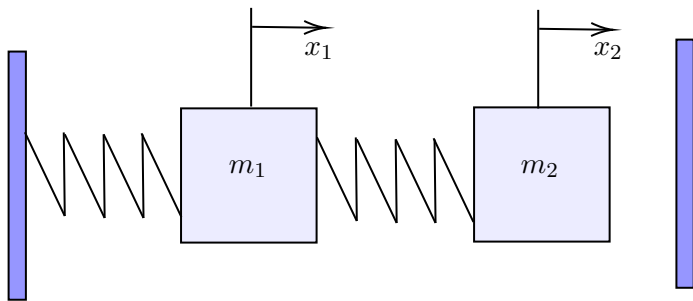


Figure 4: Two body oscillator diagram

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

$$x_2 \leq 1 \quad (4)$$

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



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](https://github.com/SergeiSa/Contact-Aware-Control-Slides-Fall-2020)

Check Moodle for additional links, videos, textbook suggestions.