

Lectures on Motion Planning and Control for Underactuated Mechanical Systems

Lecture 1: Introduction

Anton Shiriaev

LIRMM, Montpellier

July 1, 2019

1. Conceptual examples
2. Topics Covered in the Course

Conceptual examples

Example

Dynamics of a simplified model of a ship is given by

$$m\ddot{x} = F \cos \theta, \quad m\ddot{y} = F \sin \theta, \quad J\ddot{\theta} = T,$$

where

- x , y and θ define the Cartesian coordinates and the orientation of the ship;
- F and T are two control variables (the total force and the torque);
- m and J are the mass and the inertia of the ship.

Task:

Find behaviors of the ship along a straight line

$$y = k \cdot x, \quad \tan \theta = k$$

Example

Dynamics of a simplified model of a ship is given by

$$m\ddot{x} = F \cos \theta, \quad m\ddot{y} = F \sin \theta, \quad J\ddot{\theta} = T,$$

where

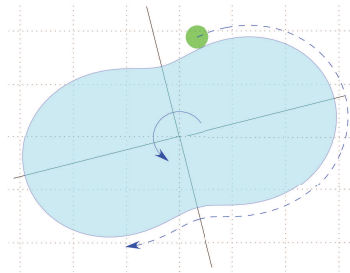
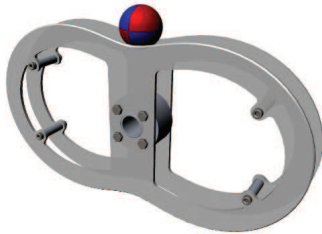
- x , y and θ define the Cartesian coordinates and the orientation of the ship;
- F and T are two control variables (the total force and the torque);
- m and J are the mass and the inertia of the ship.

Task:

Find behaviors of the ship along a circle of radius r

$$x^2 + y^2 = r^2, \quad \tan \left(\theta - \frac{\pi}{2} \right) = \frac{y}{x}$$

Examples in Dynamic Manipulation



The tasks are

- to plan a rolling of a sphere on a frame
- to design a feedback controller to stabilize a motion

Topics Covered in the Course

- Math tools for analysis of 2nd order systems

Topics

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints
- Representations of a motion of a controlled mechanical system

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints
- Representations of a motion of a controlled mechanical system
- Motion planning for mechanical systems with constraints

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints
- Representations of a motion of a controlled mechanical system
- Motion planning for mechanical systems with constraints
- Transverse dynamics, transverse coordinates and their linearization for a motion

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints
- Representations of a motion of a controlled mechanical system
- Motion planning for mechanical systems with constraints
- Transverse dynamics, transverse coordinates and their linearization for a motion
- Hybrid transverse linearization

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints
- Representations of a motion of a controlled mechanical system
- Motion planning for mechanical systems with constraints
- Transverse dynamics, transverse coordinates and their linearization for a motion
- Hybrid transverse linearization
- Controller design steps for orbital stabilization

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints
- Representations of a motion of a controlled mechanical system
- Motion planning for mechanical systems with constraints
- Transverse dynamics, transverse coordinates and their linearization for a motion
- Hybrid transverse linearization
- Controller design steps for orbital stabilization
- The case study: the Butterfly robot

- Math tools for analysis of 2nd order systems
- Modelling mechanical systems with constraints
- Representations of a motion of a controlled mechanical system
- Motion planning for mechanical systems with constraints
- Transverse dynamics, transverse coordinates and their linearization for a motion
- Hybrid transverse linearization
- Controller design steps for orbital stabilization
- The case study: the Butterfly robot
- **Perspectives, challenges and open problems**