Developing a Walking Controller for a Three-link 2D Biped

Jessica Lanini, Andrea Di Russo, Dimitar Stanev, Laura Paez,
Ramachandran Vivek, Mehmet Mutlu and Auke Ijspeert
{jessica.lanini - andrea.dirusso - dimitar.stanev - laura.paez - ramachandran.vivek - mehmet.mutlu}@epfl.ch

Start: 24/09/2019 - Deadline: 20/12/2019

Introduction

I am sure by now you have seen many legged robots. The question is, if I give you a legged robot how would you make it walk? Where do you start? Of course, there is an interface where you can receive sensory data and send commands, but will you start by sitting and sending commands and see what happens? No. So, what is the starting point? The starting point is to model, then design control and finally simulate. The whole point of the mini-project is to realize the following **Control Design Pipeline**:

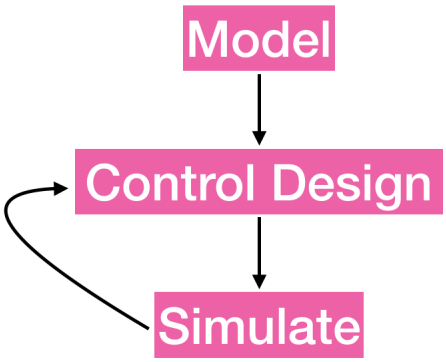

Figure 1: **Control Design Pipeline**

In order to understand the main principles behind the control design, we will work with a simple model: the **Three-link 2D Biped**, as represented in Fig. 2.

The project will be divided into three main parts:

- Modelling and visualization of the 3-link;
- Solving the equations of motion of the 3-link biped (simulation);
- Design of two different walking controllers, evaluate the resultant gaits and compare the performances.

You are asked to **develop these three parts and report your methods, results and observations in a final report**.

You are asked to structure your report according to the following sections which will be evaluated with the corresponding percentages:

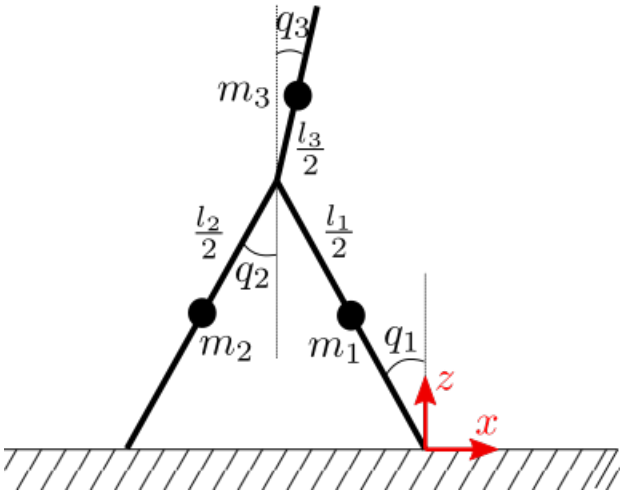

Figure 2: **Three Link Biped**

- Introduction : 3%
- Methods : 5%
- Results : 40% (kinematics and dynamics: 10%; controllers: 30%)
- Discussion : 50%
- Conclusion : 2%

In this lecture we will get started with the first point, that is *Modelling and visualization of the 3-link*. This will be done by understanding what a "Model" is and how to develop the kinematic and dynamic equations.

What is a "Model"?

What do we mean by model? We mean developing kinematics and dynamics from a simplified model (e.g., urdf: Universal Robot Description Format) of the real robot. Normally, for complex robots like the COMAN robot with 31 actuators, we do not do this from scratch and there are softwares that convert (reduce) the mechanical design (CAD files) to simplified models (urdf or srdf). There are software or libraries that symbolically or numerically calculate the kinematics and dynamics (for instance, Robotran calculates the kinematics and dynamics symbolically, while RBDL does the same thing numerically). Software such as Gazebo take the urdf and internally calculate the kinematics and dynamics numerically, also solve the dynamics and presents a graphical simulation of the real robot. However, it is always good to do all this process from scratch yourself; indeed the goal of the modeling part of the miniproject is to implement the kinematics and the dynamics of a 3-link biped. In order to get familiar with such an implementation let us start with implementing the equations of motion of the double pendulum represented in Fig. 3, that can be considered as a simplified version of the 3-link biped.

Exercise 1.1: Equations of motion of the double pendulum

In this exercise (NOT GRADED) you are asked to derive the equations of motion of the double pendulum and write them in the document "double_pendulum_start.mlx".

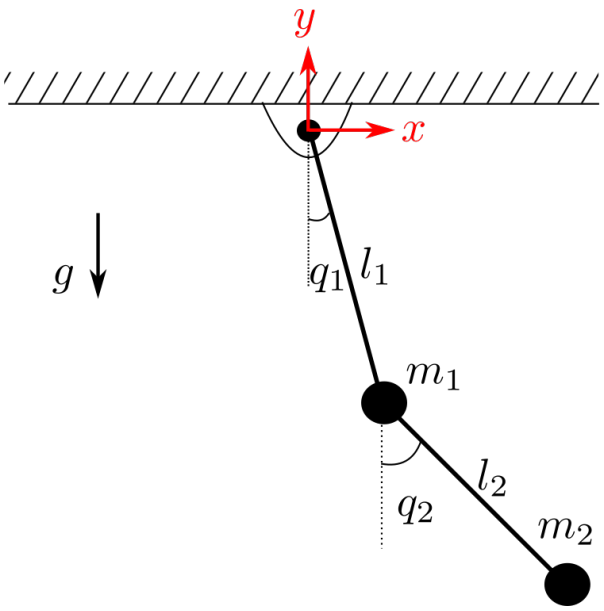

Figure 3: **Double Pendulum**