Capture Point Dynamics-(Englsberger et al.)

Overview

This project implements a **humanoid walking controller based on Capture Point (CP) dynamics**, as proposed by **Englsberger et al.** in *“Bipedal Walking Control Based on Capture Point Dynamics”*.

The controller is modeled and validated using **MATLAB/Simulink** and is intended as an **educational, reproducible reference implementation**.

Motivation

Humanoid walking control is challenging due to:

- Underactuated dynamics
- Limited support polygon
- Balance constraints (ZMP / CoP)
- Sensitivity to disturbances and modeling errors

The Capture Point framework provides an **intuitive and mathematically elegant way** to stabilize walking by directly controlling the unstable component of the LIPM dynamics.

Objectives

- Implement the **Capture Point based walking controller** described in the reference paper
- Model humanoid walking using the **Linear Inverted Pendulum Model (LIPM)**
- Validate controller performance in **MATLAB/Simulink**
- Visualize walking behavior using:
  - Center of Mass (CoM)
  - Capture Point (CP)

- Zero Moment Point (ZMP)

Reference Paper

This implementation is based on:

1. Bipedal Walking Control Based on Capture Point Dynamics

J. Englsberger, C. Ott, M. A. Roa, A. Albu-Schäffer, G. Hirzinger

2. Integration of vertical COM motion and angular momentum in an extended Capture Point tracking controller for bipedal walking

Johannes Englsberger, Christian Ott

Control Architecture

The implemented control loop follows the structure proposed in the paper:

1. Compute CoM position and velocity
2. Calculate Capture Point
3. Apply CP control law to compute desired ZMP
4. Project ZMP to support polygon
5. Track ZMP using a lower-level controller

This cascaded structure separates **balance control (CP)** from **motion execution (ZMP / kinematics)**.

How to Run the Simulation

Step 1: Open MATLAB

Set the project root as the MATLAB working directory.

```
Englsberger_controller
```

Step 2: Initialize Parameters

Run the initialization script:

```
ref_cp.m
```

Step 3: Open Simulink Model

```
cp.slx
```

Step 4: Run Simulation

Click **Run** in Simulink.

Outputs & Visualization

Simulation results can be analyzed using Simulink scopes:

- CoM position and velocity
- Capture Point trajectory
- ZMP trajectory

Snapshots and plots are available in:

```
Snapshots_englcp
```

Key Features

- Intuitive Capture Point based stabilization
- Exponential stability guarantee
- Explicit ZMP constraint handling
- Suitable for push recovery and online footstep adaptation