TUM Institute for Cognitive Systems (ICS)

OpenWalker

Module Description: Foot Trajectory Generator (FTGM)

Simon Armleder, Emmanuel Dean, Florian Bergner,
Rogelio Guadarrama-Olvera, and Gordon Cheng

February 14, 2020

1 Module Description

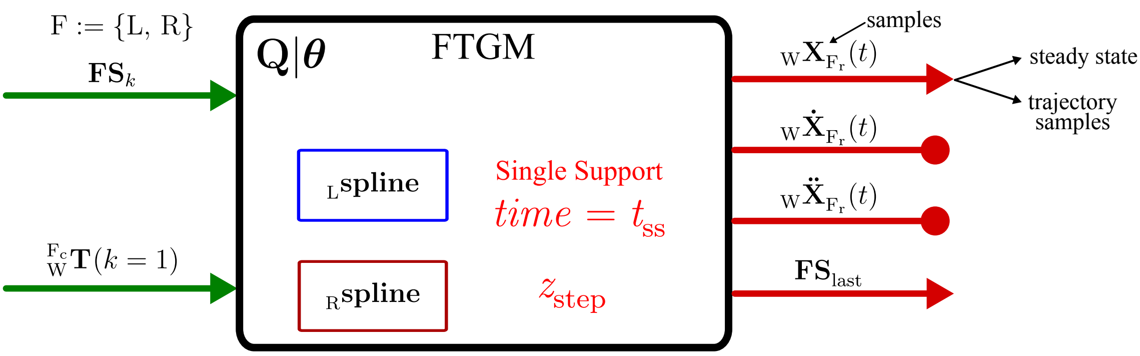

Figure 1.1: Foot Trajectory Generator: This module generates reference trajectories for the single-support phase.

The *Foot Trajectory Generator* module (FTG) constructs minimum jerk trajectories for the feet. These foot trajectories are then tracked by a controller during the single-support phase of the gait cycle. Generating smooth continuous trajectories is achieved by interpolating between the current foot pose and the next support foot pose.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 732287.

2 Module Connections

2.1 Inputs

Symbol	Name	Type	Description
${}^{L_c}_{W}\mathbf{T} \in \mathbb{R}^{4\times4}$	Left Foot Coordinate Frame	`HomogeneousTransformation`	This homogeneous transformation matrix transforms coordinates in the left foot ankle coordinate frame L to the world coordinate frame W.
${}^{R_c}_{W}\mathbf{T} \in \mathbb{R}^{4\times4}$	Right Foot Coordinate Frame	`HomogeneousTransformation`	This homogeneous transformation matrix transforms coordinates in the right foot ankle coordinate frame R to the world coordinate frame W.
$\mathbf{FS}_{last}$	Next Footstep	`FootStep`	The end position of the next footstep that gets executed.

2.2 Outputs

Symbol	Name	Type	Description
${}_W\mathbf{X}_{L_r} \in \mathbb{R}^7$	Left Foot Pose	`CartesianPosition`	This vector contains the linear and angular reference position of the left foot ankle L with respect to the world coordinate frame W.
${}_W\mathbf{X}_{R_r} \in \mathbb{R}^7$	Right Foot Pose	`CartesianPosition`	This vector contains the linear and angular reference position of the right foot ankle R with respect to the world coordinate frame W.
${}_W\dot{\mathbf{X}}_{L_r} \in \mathbb{R}^6$	Left Foot Velocity	`CartesianVelocity`	This vector contains the linear and angular reference velocities of the left foot ankle L with respect to the world coordinate frame W.
${}_W\dot{\mathbf{X}}_{R_r} \in \mathbb{R}^6$	Right Foot Velocity	`CartesianVelocity`	This vector contains the linear and angular reference velocities of the right foot ankle L with respect to the world coordinate frame W.
${}_W\ddot{\mathbf{X}}_{L_r} \in \mathbb{R}^6$	Left Foot Acceleration	`CartesianAcceleration`	This vector contains the linear and angular accelerations of the left foot ankle L with respect to the world coordinate frame W.
${}_W\ddot{\mathbf{X}}_{R_r} \in \mathbb{R}^6$	Right Foot Acceleration	`CartesianAcceleration`	This vector contains the linear and angular accelerations of the right foot ankle R with respect to the world coordinate frame W.

2.3 Inter-Connections

The first input of the FTG is connected to the output of the *Foot Step Planner* (FSP) which provides information about the next foot step to be executed. The second input of the FTG is connected to the *Forward Kinematics Module* (FKM). This connections provides the current pose of the left and right foot ankle with respect to the world coordinate frame.

The outputs of the FTG contain the interpolated feet trajectories tracked during the single-support phase. This includes the reference foot ankle position, velocity and acceleration. The FTG output is connected to the *Foot Compliant Module* (FKM) and *Command Generator* (CG).

2.4 Common Methods

Several algorithms exist to construct minimal jerk foot trajectories. Traditionally, foot trajectories are generated by polynomial interpolation with start and end boundary conditions of zero velocities and accelerations.
When there are various foot constrains such as ground conditions or obstacles, the order of these polynomials is too high and may oscillate. This problem can be avoided by utilizing cubic spline interpolation [1]. With this method foot trajectories are constructed of piecewise third-order polynomials which pass though a set of control points at chosen velocities. An advantage of spline trajectories is that intermediate control points can be easily shifted to deal with various obstacles during the stepping motion.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 732287.

References

[1] Verrelst, Bjorn and Stasse, Olivier and Yokoi, Kazuhito and Vanderborght, Bram, Dynamically stepping over obstacles by the humanoid robot HRP-2. 6th IEEE-RAS International Conference on Humanoid Robots, 2006.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 732287.