Using optimal control to investigate potential improvements in whole-body walking generation for the Humanoid Robot HRP-2

Formulation of the Problem:

The Humanoid Robot HRP-2

The rigid multi-body model is established in the open-source software package - DYNAMOD. Inspired by the idea of minimizing the symbolic model equations and transforming them to C-Code (HuMAnS[15]), DYNAMOD is based on 6D spatial DAE-System of dynamic model with contact constraints

\[ \mathbf{q} = \mathbf{v} \]

\[ M(q) \dot{q} + N(q, \dot{q}) + C(q) + G(q) = F(q, \dot{q}, p) \]

\[ \mathbf{G} \mathbf{q} = \mathbf{0} \]

Inelastic impact constraint - velocity discontinuity equation

\[ G(q,p) = 0 \]

\[ \mathbf{a} \mathbf{q} = \mathbf{0} \]

Dynamic Modeling - DYNAMOD

As the pure symbolic model equations are handled directly any parameterizations of the model is easily applicable. Further more the model logic is accessible to symbolic or automatic differentiation.

Currently the software package is build on top of the commercial algebra package Maple[12].

Case Study: Walking

Objectives used for case study

- Min Joint Torque
- Max Postural stability
- Min Joint Velocity
- Max Efficiency
- Max Forward Velocity

Case Study: Overstepping

Multiple studies of HRP-2 overstepping large obstacles have been previously made.

- Static study [17]: 24 cm
- Dynamic study [11]: in consideration 25 cm
- Dynamic study [14]: in reality: 15 cm

Based on optimal control optimization we could extend the overstepping performance by using the whole-body dynamic:

- Obstacle contact point: 38.1 cm
- Obstacle tip height: 44.8 cm
- Obstacle diameter: 11 cm
- Step length: 0.154 m
- Step width: 0.517 m
- Step time: 4.784 s