Pre-defined Ranges of Parameters for Walking Styles on Bipedal Robot with Pelvis-located Actuation

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The role of pelvis in being a significant contributor to walking is evident from biomechanics [1] and embodied movement analysis [2]. In the light of this importance, a biped model has been proposed in past that considers the simplified effect of human pelvis. In the current work, a range of parameterized trajectories for this simulated pelvis have been investigated such that they result in feasible gaits. With this formal approach of exploring the gaits, it will be easier to classify different walking styles for this biped model.

Modeling of human-pelvis-inspired Biped Model:
The proposed biped model in the past consists of an actuated compass walker with a simulated pelvis on top. The simulated pelvis consists of a prismatic mechanism moving the mass \( M_0 \) forward and backwards. The modeling is done traditionally using Euler Lagrange modeling in two phases of walking [3].

The resulting equations:

Swing Phase:

\[
\begin{align*}
D \ddot{q}_s + C_s(q_s, \dot{q}_s) + G_s &= \Gamma_s \\
\Gamma_s &= \begin{bmatrix} 0 \\ \tau \\ F \end{bmatrix} = Bu \\
\dot{x}_s &= f_{model}(x_s(t), u(t)) \\
&= D_s^{-1}(-C_s \dot{q}_s - G_s + Bu)
\end{align*}
\]

Strike Phase:

\[
x_s(t_f) = \Delta(x_s(t_f))
\]

\( \Delta : \) pre-impact state \( \rightarrow \) post-impact state

Gait Design Parameters to Gait Generation:

For generating a variety of gaits, varying the gait parameters identified in Fig. 3 can give rise to a range of feasible gaits by using trajectory optimization problem formulation chalked out in Fig. 4.

Parameter-defined Trajectories for Gaits:

Following a systematic approach, Pelvic Shift (PS) can be defined as a Fourier series approximation:

\[
PS(t) = a_0 + \sum_{i=0}^N (a_i \cos(\pi t) + b_i \sin(\pi t))
\]

A set of trajectories has been identified using the Fourier Series approximation where \( N = 2, a_1, a_2 \in [-0.78, 0.78] \) and \( b_1 = b_2 = 0 \) such that pelvic distance \( d_1 \) is within 2 m. For each of these trajectories then, feasibility has been investigated using the formulation in Fig. 4 over a range of TL (step length) \([0.05, 0.55] \). The resulting number of gaits is presented in Fig. 6.

By this exhaustive investigation, a gait library is developed. It is observed that for smaller step length (TL), more movement patterns in pelvis are allowed generating more gaits. From human perception perspective, we want to investigate if these gaits are visually distinguishable from each other too.

References: