Karlsruhe Institute of Technology

Institute of Engineering Mechanics
Chair for Dynamics / Mechatronics

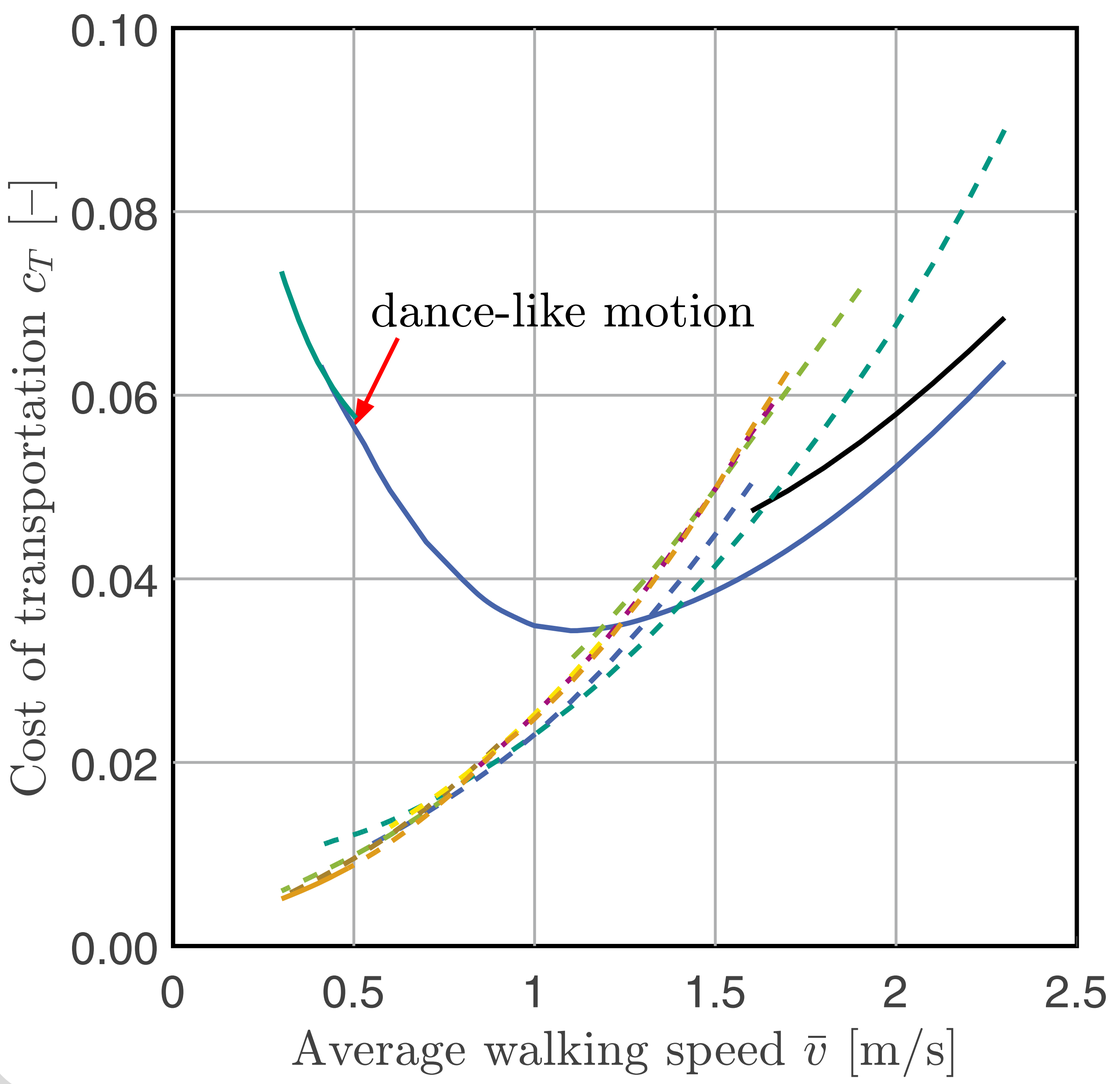
Dance-like motions in optimal walking

Ulrich J. Römer, Alexander Fidlin

Summary

Gait generation for bipedal robots via gradient-based optimization may result in local optimality of the solution. We have applied a gradient-based energy efficiency optimization method to a seven degree of freedom robot model with rolling feet. The convergence to several solutions in a wide speed range proves the coexistence of local optima with more or less similar energy expenditure. The optimal gait depends on the average walking speed. There are several different stable and unstable gaits which become optimal different speeds, respectively. An examination of locally optimal gaits reveals dance-like motions which indicate some optimality in human dancing.

Energetically optimal walking gaits



- Seven segment walker with rigid feet and hybrid zero dynamics-based controller*
- Single support phase + impact of swing foot
- Periodic walking: limit cycle of hybrid system
- Gait generation: optimization of cost of transportation (energy input per distance)

$$c_T = \frac{1}{mgL} \sum_{i=1}^{6} \int_0^T \max\left(P_{\mathrm{el},i}, 0\right) \mathrm{d}t$$

$$P_{\mathrm{el},i} = \underbrace{c_{\mathrm{stat}} u_i^2}_{\text{heat losses}} + \underbrace{u_i \dot{q}_i}_{\text{mech. work}}$$

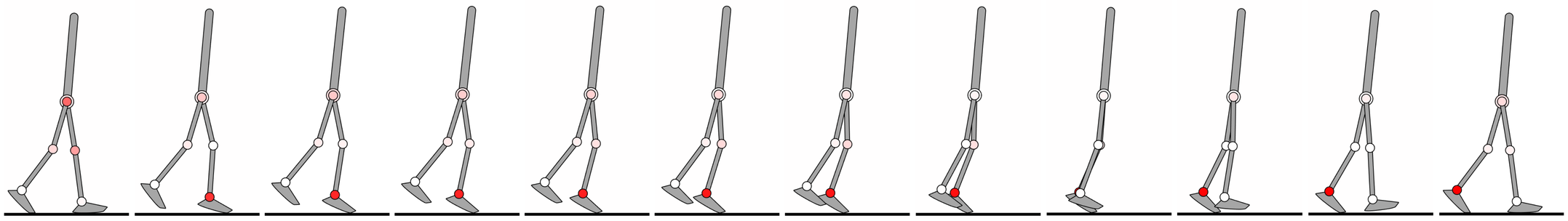
u_i: joint torques, $\dot{q}_i$: joint velocities

- Results
  - 11 different gaits (local optima)
  - existence restricted to specific speed intervals
  - many gaits with similar cost of transportation
  - solid/dashed lines: stable/unstable limit cycles
  - suboptimal slow gaits: dance-like motions

*) Martin, A. E., Post, D. C., and Schmiedeler, J. P. (2014). Design and experimental implementation of a hybrid zero dynamics-based controller for planar bipeds with curved feet. *Intl. J. Robot. Res.*, 33(7): 988-1005.

Dance-like motion

Locally optimal slow gait



Slowfox: basic step

Source: *Basic Foxtrot Demo (Music) by Mirko & Alessia*, https://www.youtube.com/v/d6p46E1Zlss (22.06.2017)