Karlsruhe Institute of Technology

Institute of Engineering Mechanics
Chair for Dynamics / Mechatronics

A novel analytical foot rollover model for planar walking

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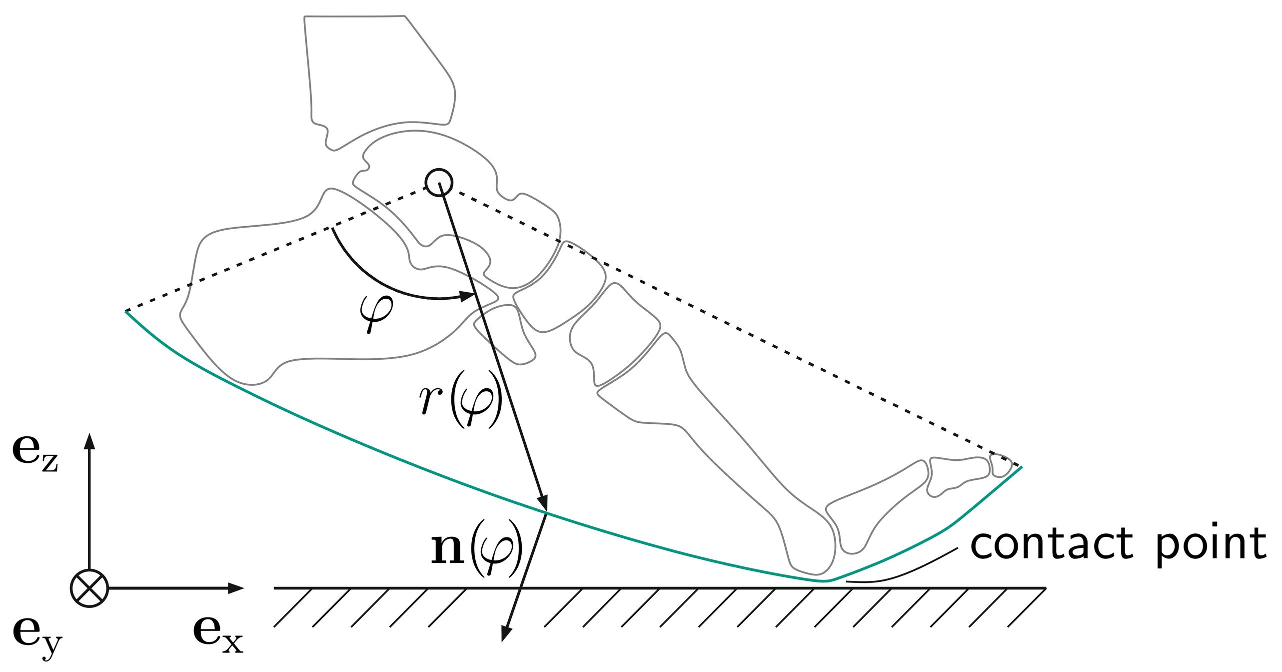
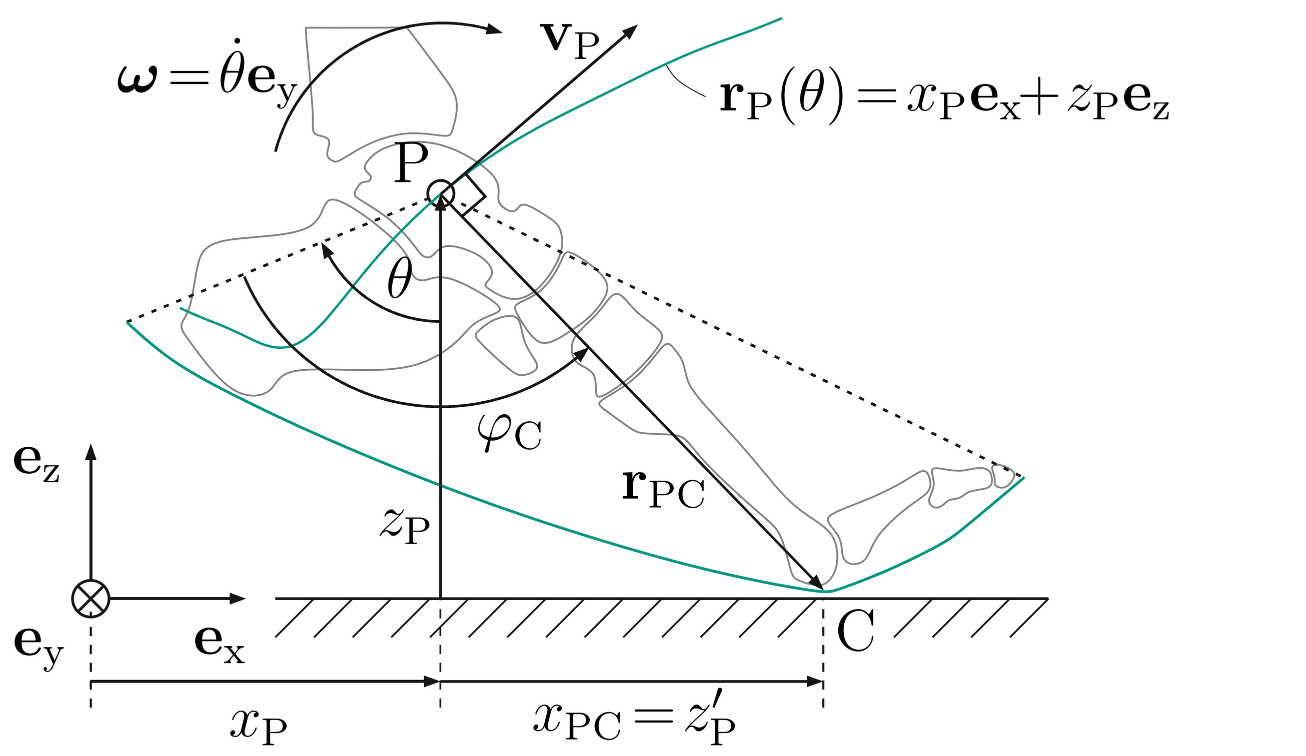
Motivation: established foot rollover model



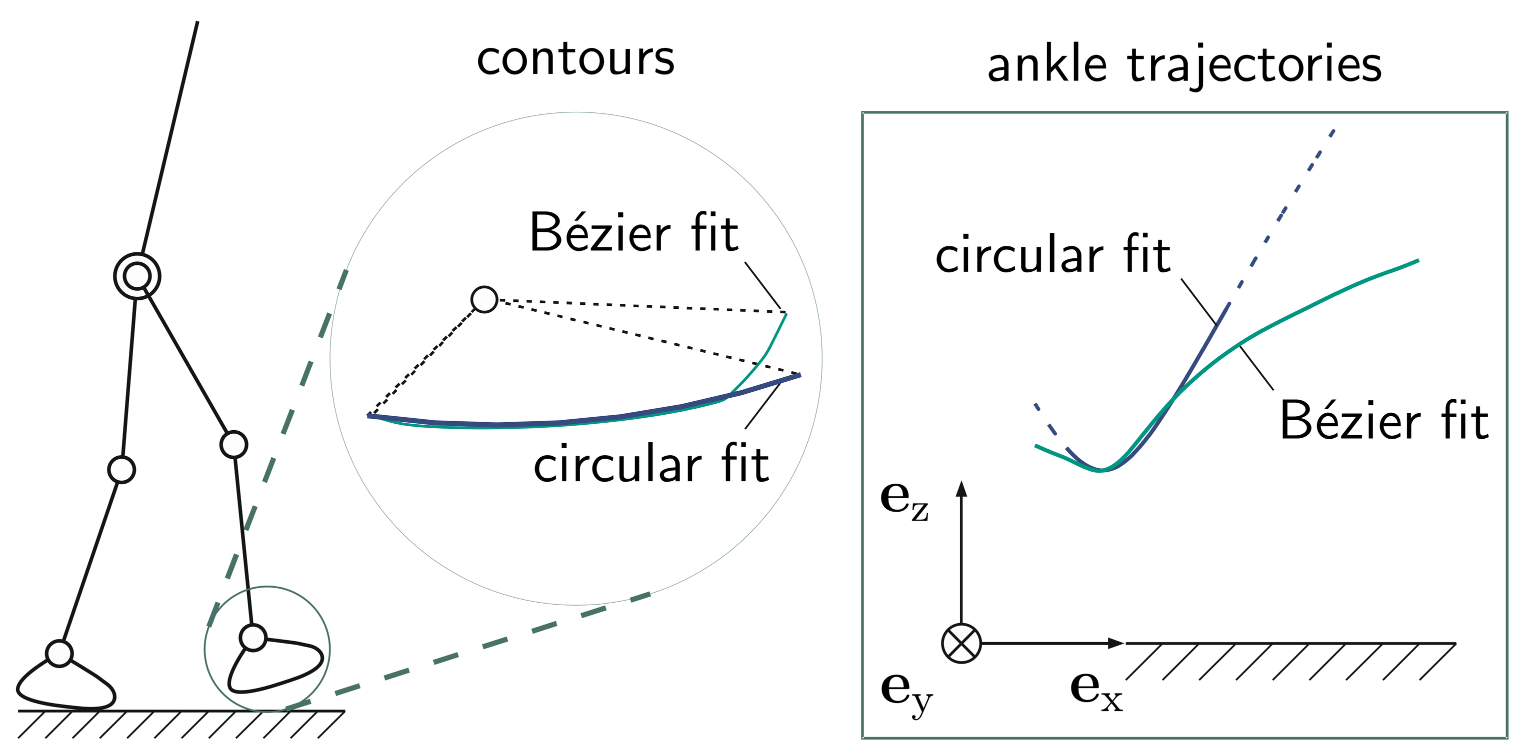
- Rigid (convex) feet model rolling kinematics
- Established parameterization: radius $r(\varphi)$
- Contact point: implicit problem $\mathbf{n}(\varphi)\cdot\mathbf{e}_z = -1$
- Dynamics: differential algebraic equation (DAE) of index 2
- Simulation:
  - Contact point iteration
  - Time integration of DAE

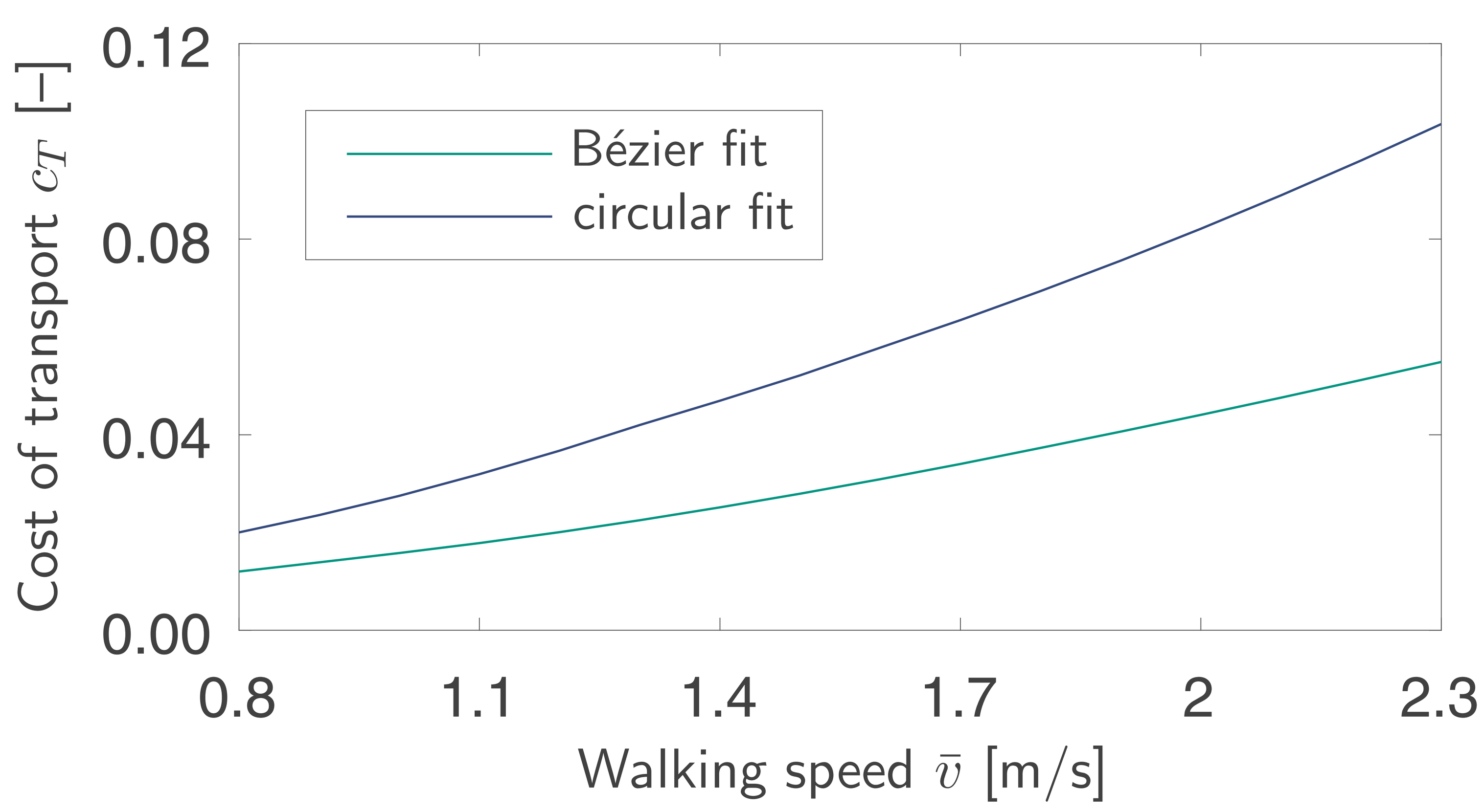
Novel foot rollover model



- Parameterization: ankle trajectory $\mathbf{r}_P(\theta)$ with orientation θ
- Velocity: in tangential direction $\mathbf{v}_P(\theta)$
- Contact point: explicit solution $x_C = x_P + z_P'$
- Dynamics: ordinary differential equation (ODE)
- Simulation:
  - Contact point via explicit equation
  - Time integration of ODE

Example parameterizations





- Seven segment walker with rigid feet and hybrid zero dynamics-based controller*
- Single support phase + impact of swing foot
- Gait generation via optimization of cost of transport (input of mechanical work)

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

- Two ankle trajectory parameterizations:
  - circular foot contour
  - Bézier polynomial (fit to human data**)
- Comparison of both parameterizations:
  - Model & controller complexity identical
  - Contours/rollover shapes very similar
  - Significant influence on c_T
  - Bézier fit (human data) ≈45% better

*) 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.

**) Hansen, A. H., Childress, D. S., and Knox, E. H. (2004). Roll-over shapes of human locomotor systems: effects of walking speed. *Clin. Biomech.*, 19(4): 407-414.