Viability and Global Stability of a Task-Regulated Compass Walker

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Overview

Fall risk ⇔ **dynamic stability** of walking.

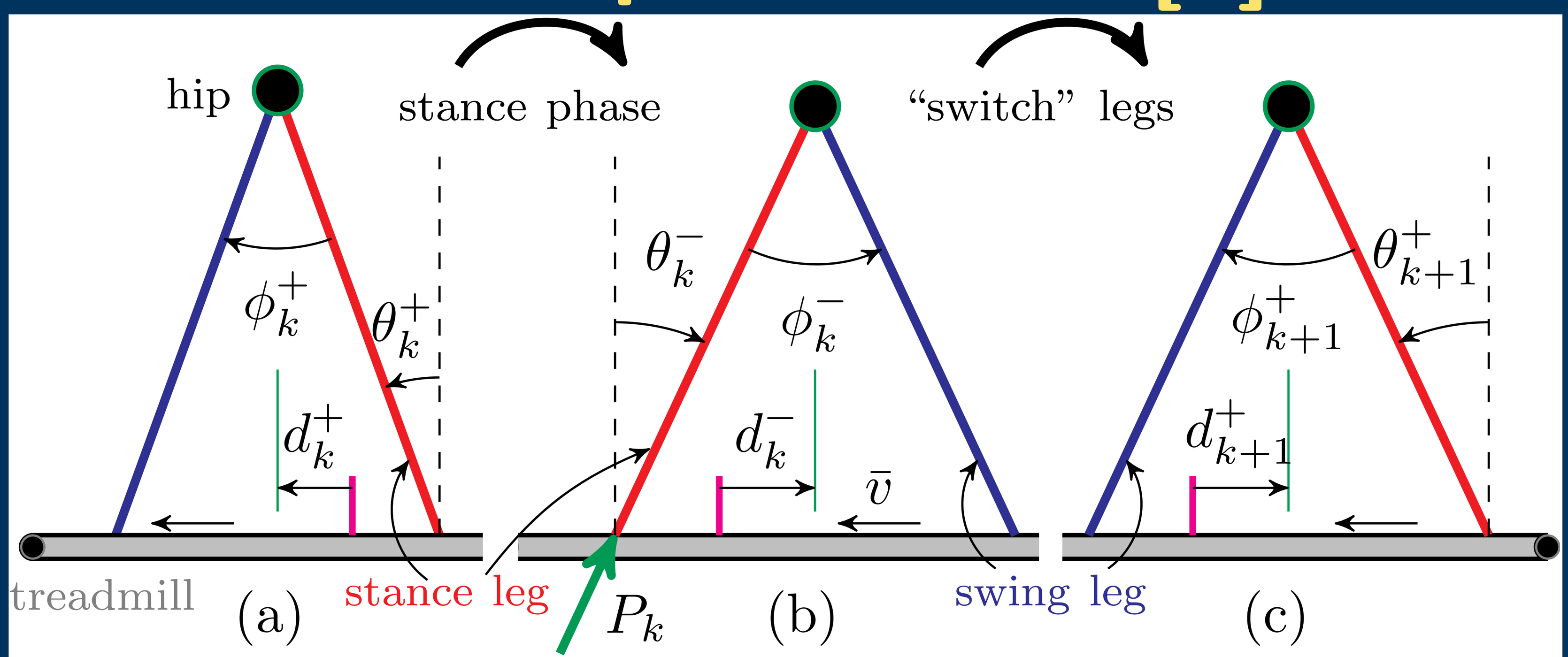
Hierarchical schema for biological movement:

Control to remain **viable** (avoid failure).
Regulation to achieve **task-level goals**.

Humans exploit **task-level redundancies** [1, 2]; perhaps to minimize their fall risk?

We study the effect of regulation strategies on **global stability** of the simplest dynamic walker in its **viable region**.

Powered compass walker [3]



Hybrid Poincaré map: $\mathbf{x}_{k+1} = \boldsymbol{F}(\mathbf{x}_k; P_k)$.

Step speed: $V_k = L_k / T_k$

Absolute position: $d_k^- = d_k^+ + L_k - \bar{v} T_k$

Task-level regulation: $\mathcal{O} \in \{V, d^-\}$

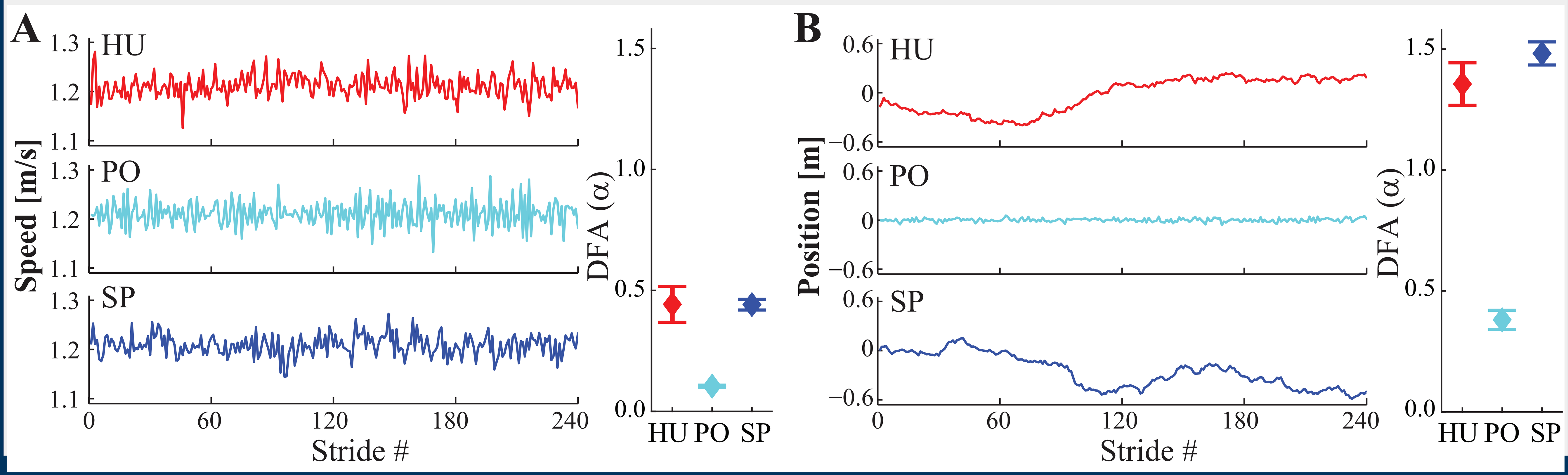
$$P_k^{\text{opt}} := \underset{0 \leqslant P \leqslant P_{\max}}{\operatorname{argmin}} \left[\mathcal{O}_{k+1}(\mathbf{x}_k; P) - \mathcal{O}^*\right]^2$$

Open-loop: $P_k = P^*$; **Regulated:** $P_k = P_k^{\text{opt}}$.

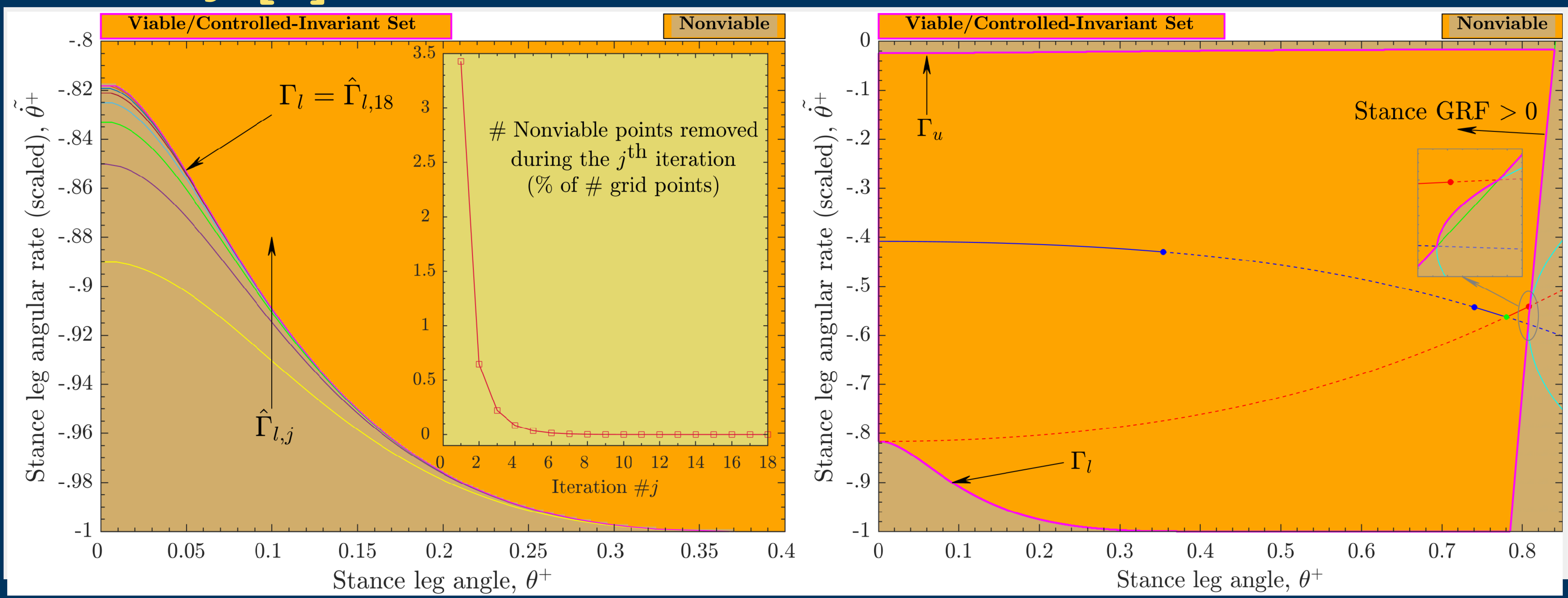
References

[1] Dingwell et al. (2010). *PLoS Comput Biol*, **6**: e1000856.
[2] Dingwell JB and Cusumano JP. (2015). *PLoS One*, **10**: e0124879.
[3] Kuo AD. (2001). *ASME J Biomech Eng*, **124**: 113–120.
[4] Zaytsev et al. (2018). *IEEE Trans Robot*, **34**(2): 336–352.

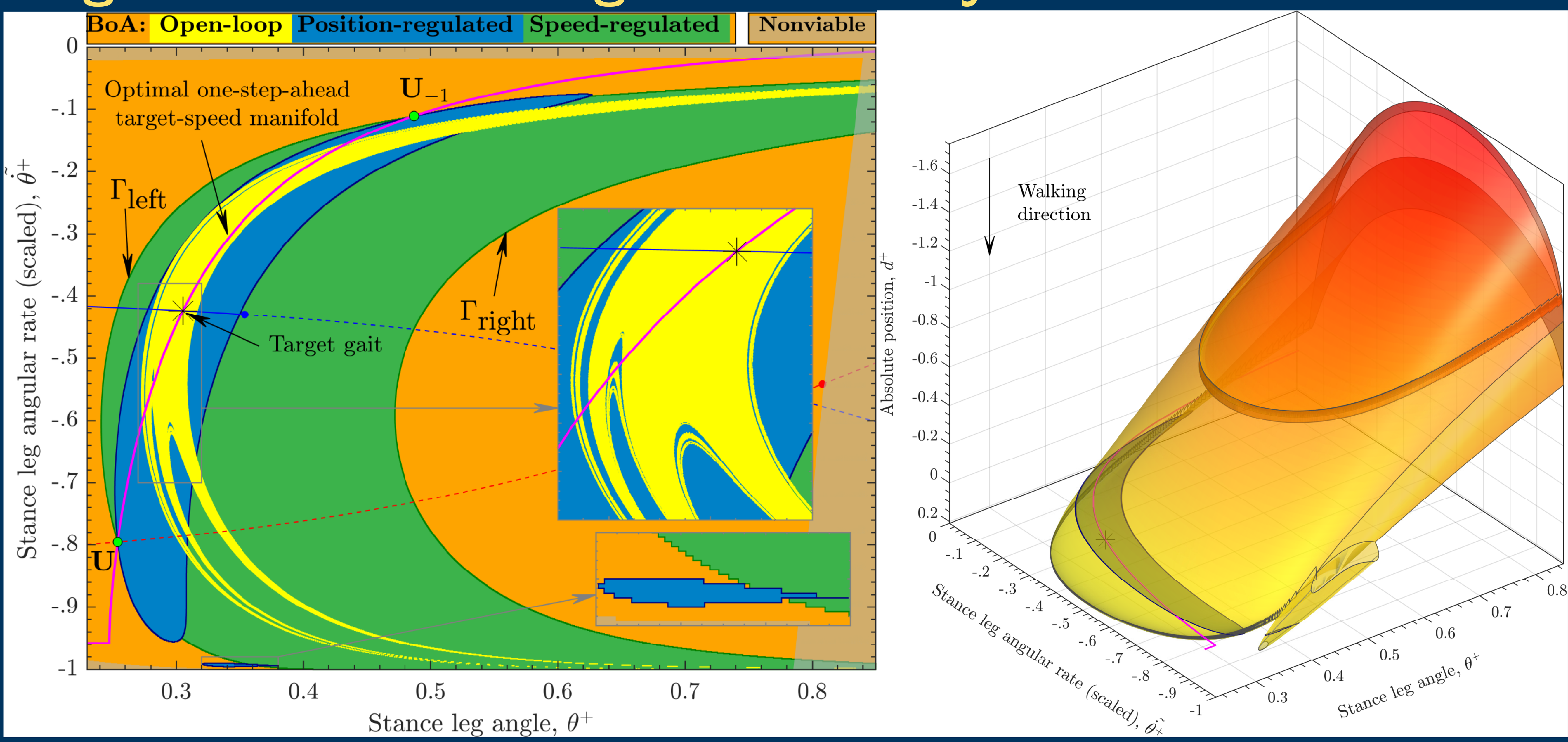
Humans regulate speed while treadmill walking [1, 2]



Viability [4]: fall avoidance via control invariance



Regulation enhances global stability: basins of attraction



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