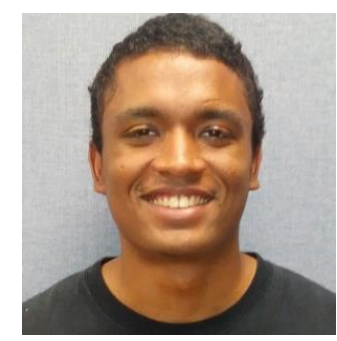
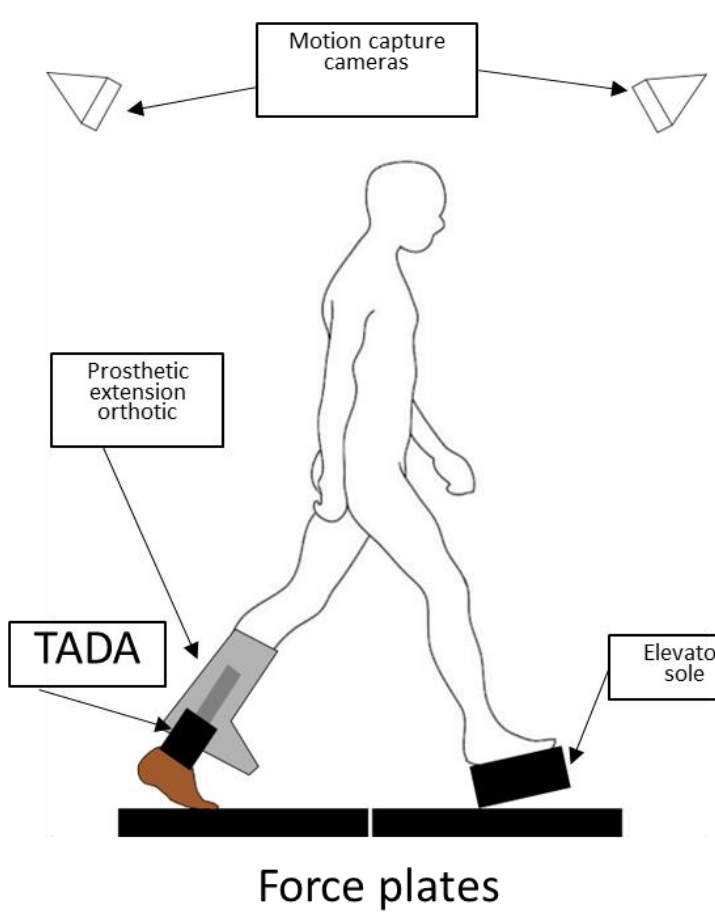


Exploration of semi-active control laws for the Two Axis aDaptable Ankle (TADA)

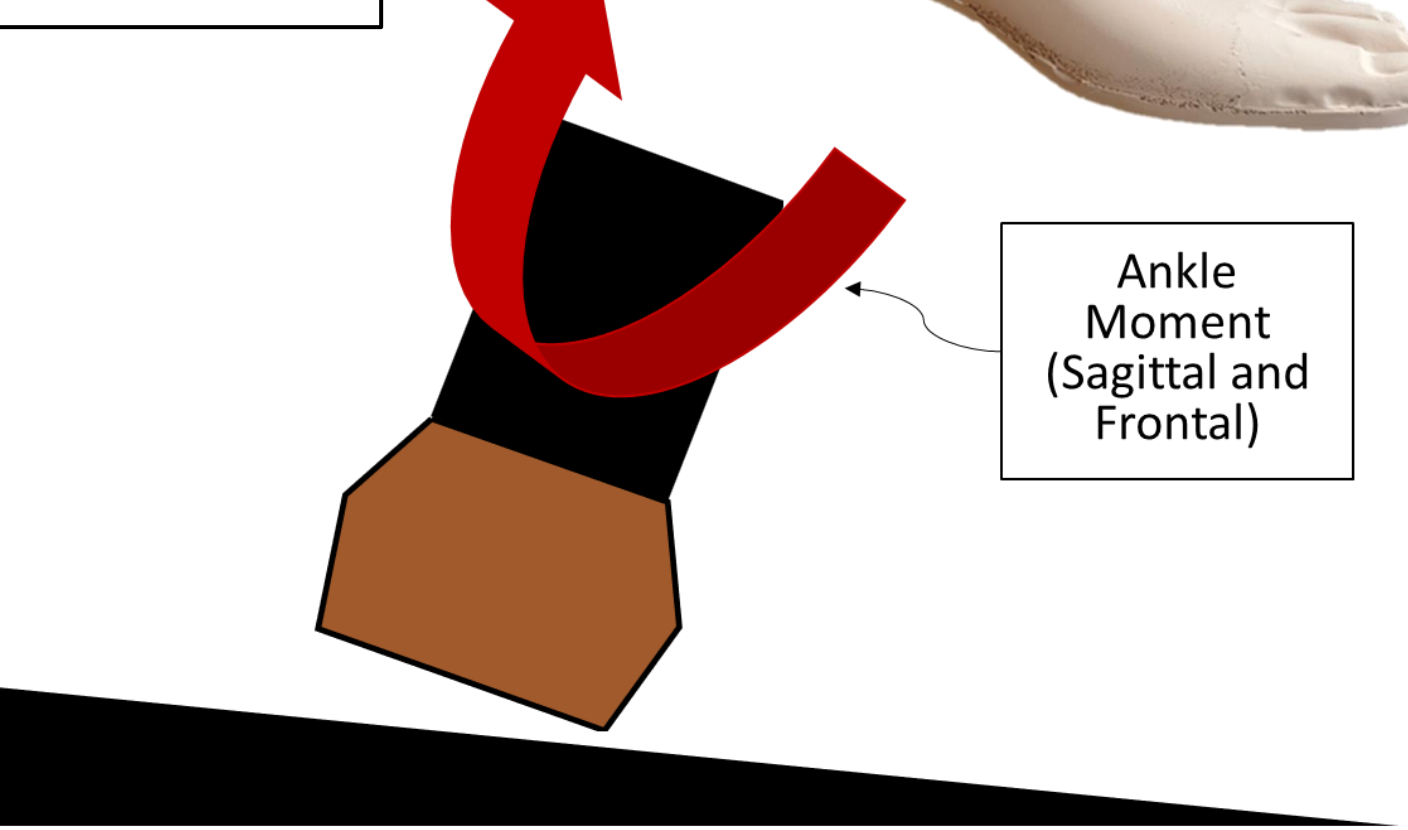
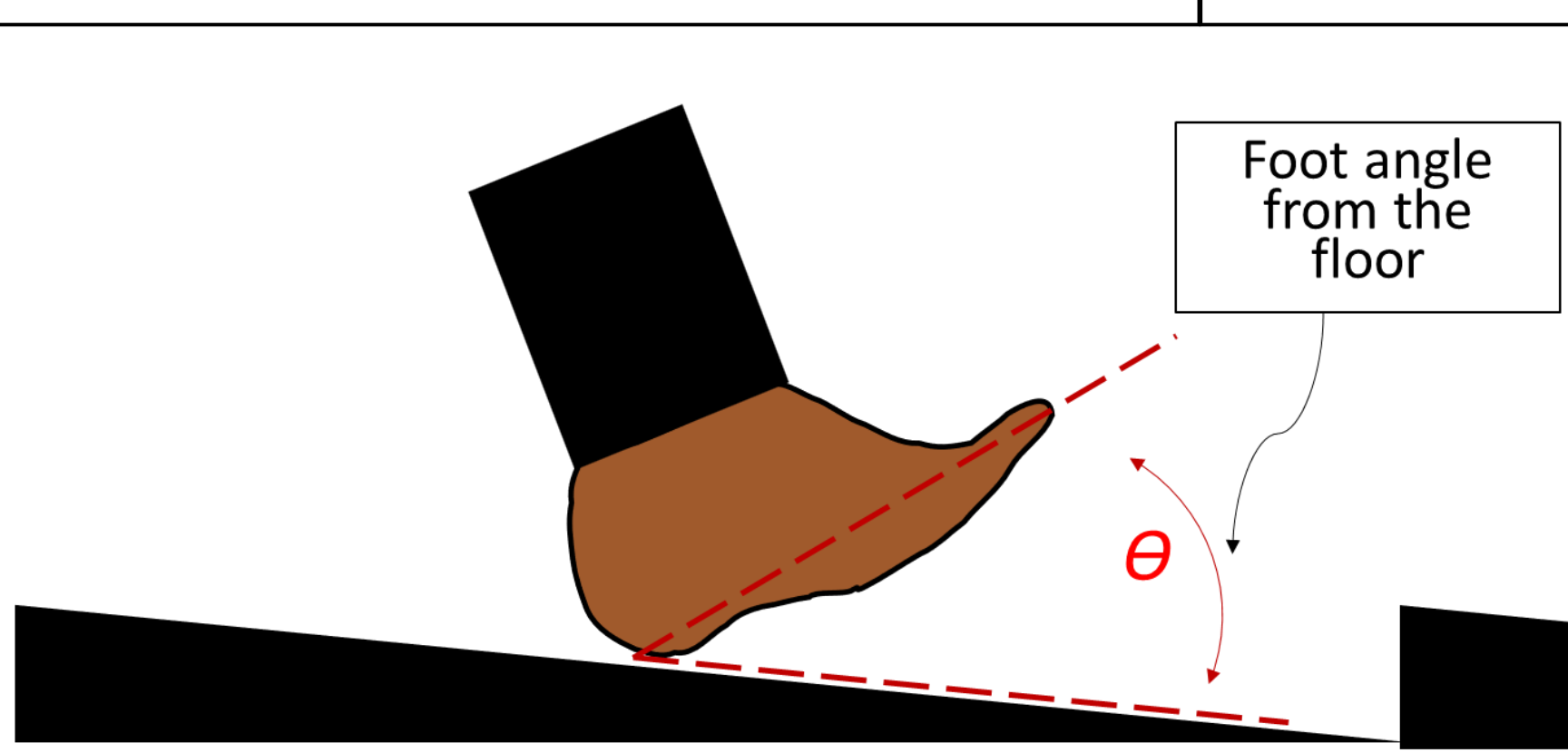
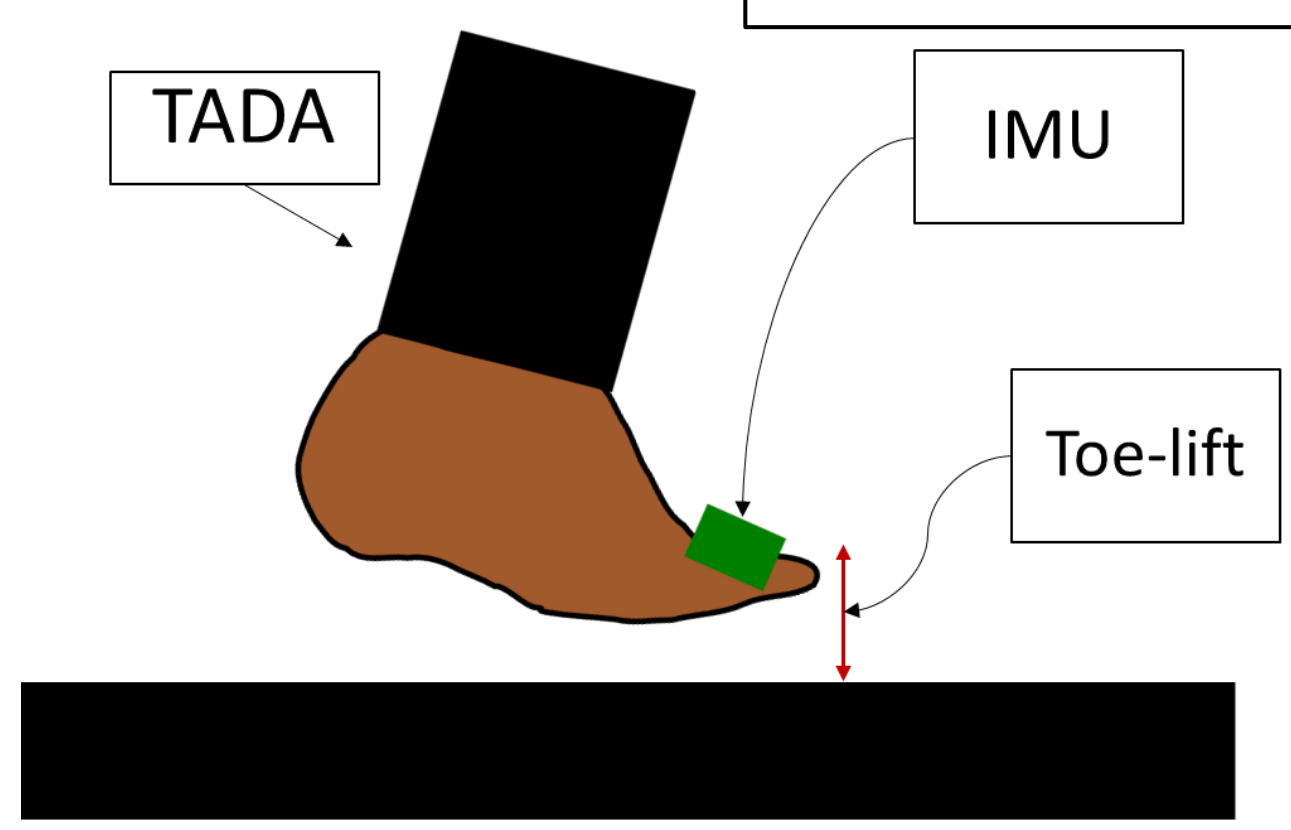
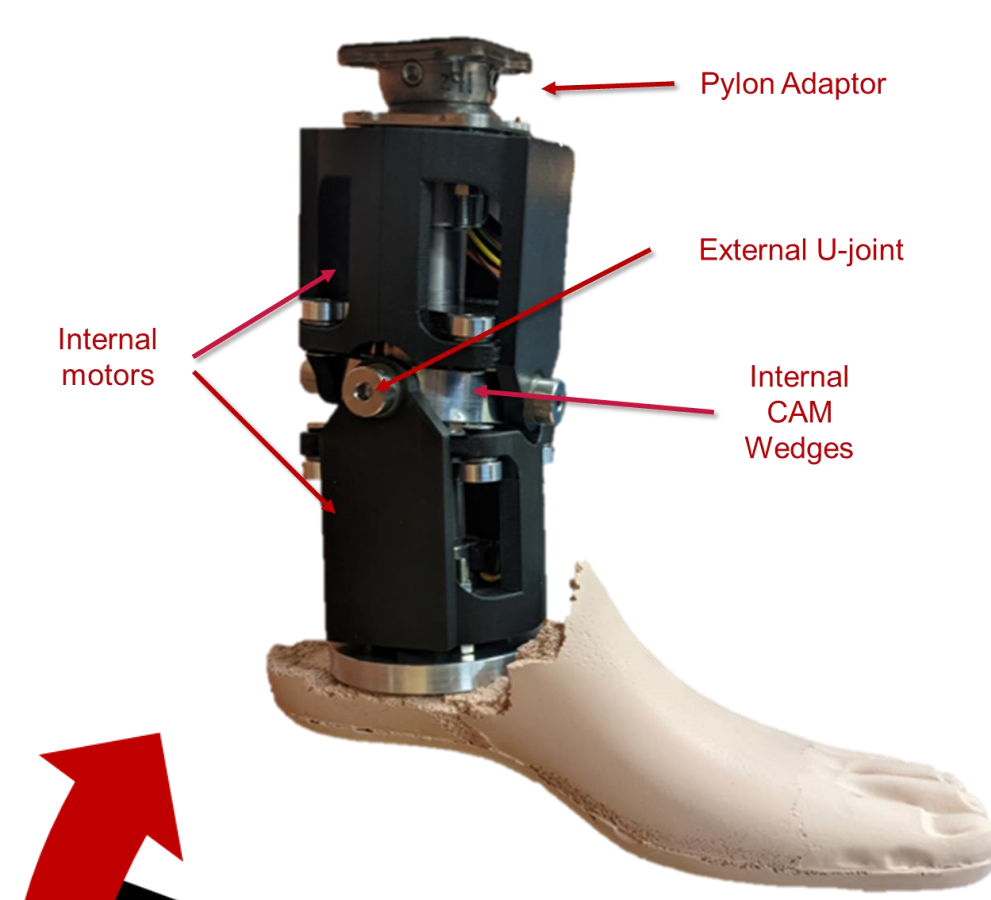


Kieran Nichols
Advisor: Peter Adamczyk
Co-author: Becca Roembke



- TADA: semi-active (moves in swing) ± 10 deg sagittal and/or frontal
- Method: walk at a self-selected speed using TADA angles of neutral angle (90° dorsiflexion and no eversion), plantarflexion (PF), dorsiflexion (DF), eversion (EV), and inversion (IV)
- Sensing: IMU – encoders – load cell (F_z , M_x , M_y)

- ### How to control a semi-active prosthetic ankle?
- Ideal Swing phase trajectory?
 - Right way for the TADA to adapt to the slope?
 - Optimal ankle angle control to lower ankle moment?



Toe-lift control

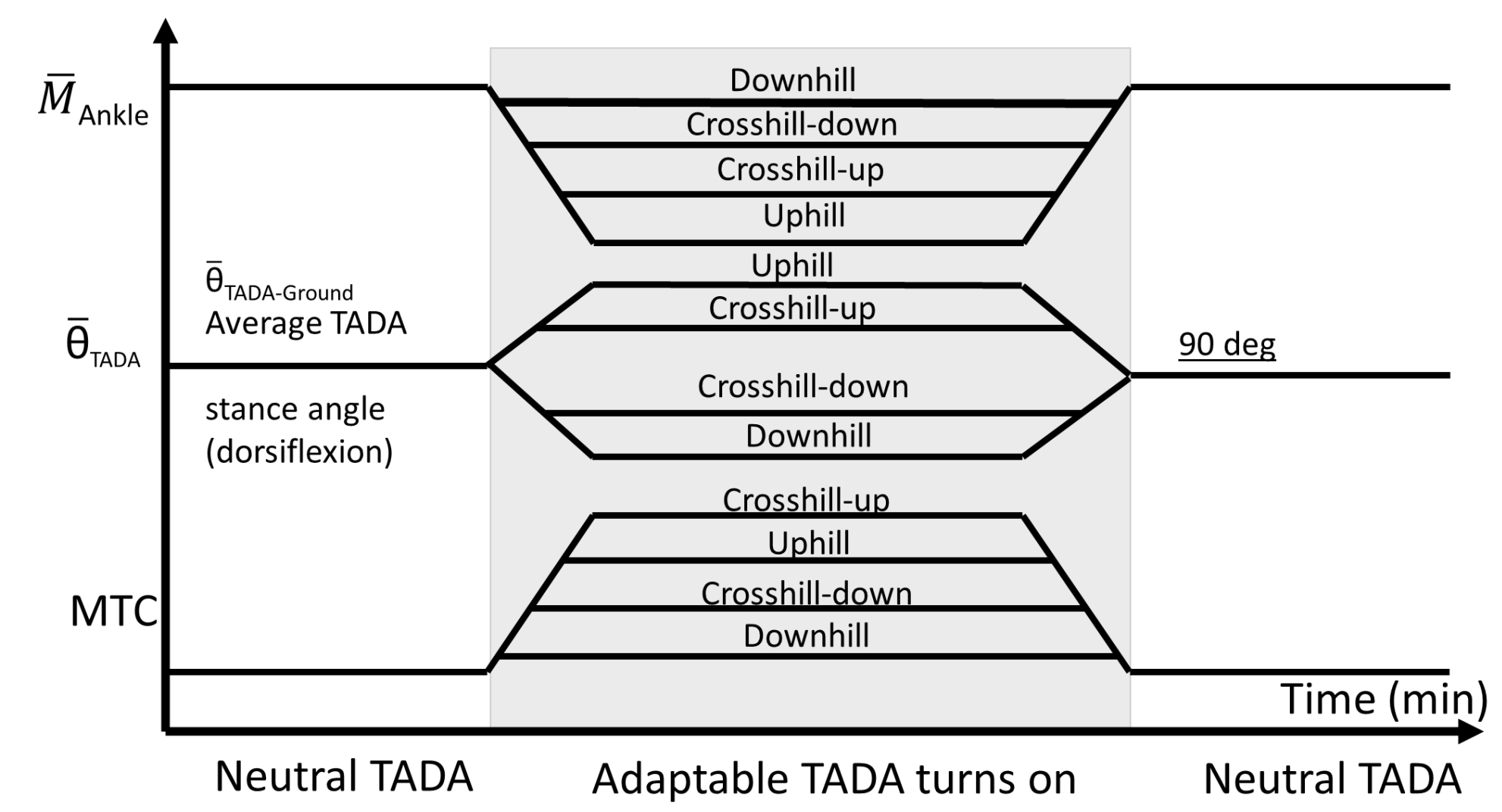
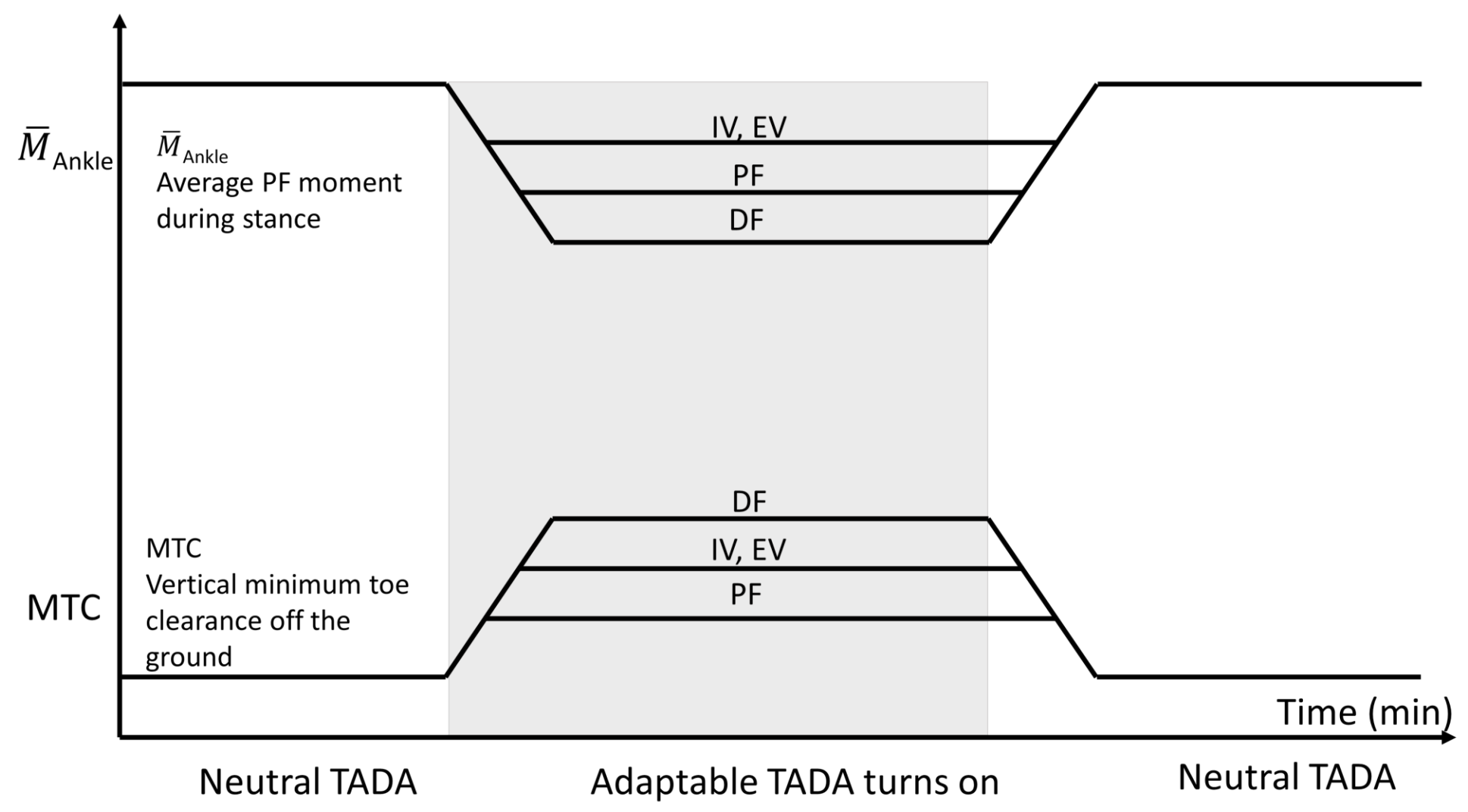
Anticipatory Slope-Adapting Control

Moment-Targeting Control

- ### Toe-Lift Control
- Initial tuning of mid-swing ankle angle to user-preference
 - Evaluate minimum toe clearance (MTC)
 - MTC is lower on passive prostheses¹ and a lower MTC contributes to tripping²
 - Does active dorsiflexion of the TADA raise the MTC?

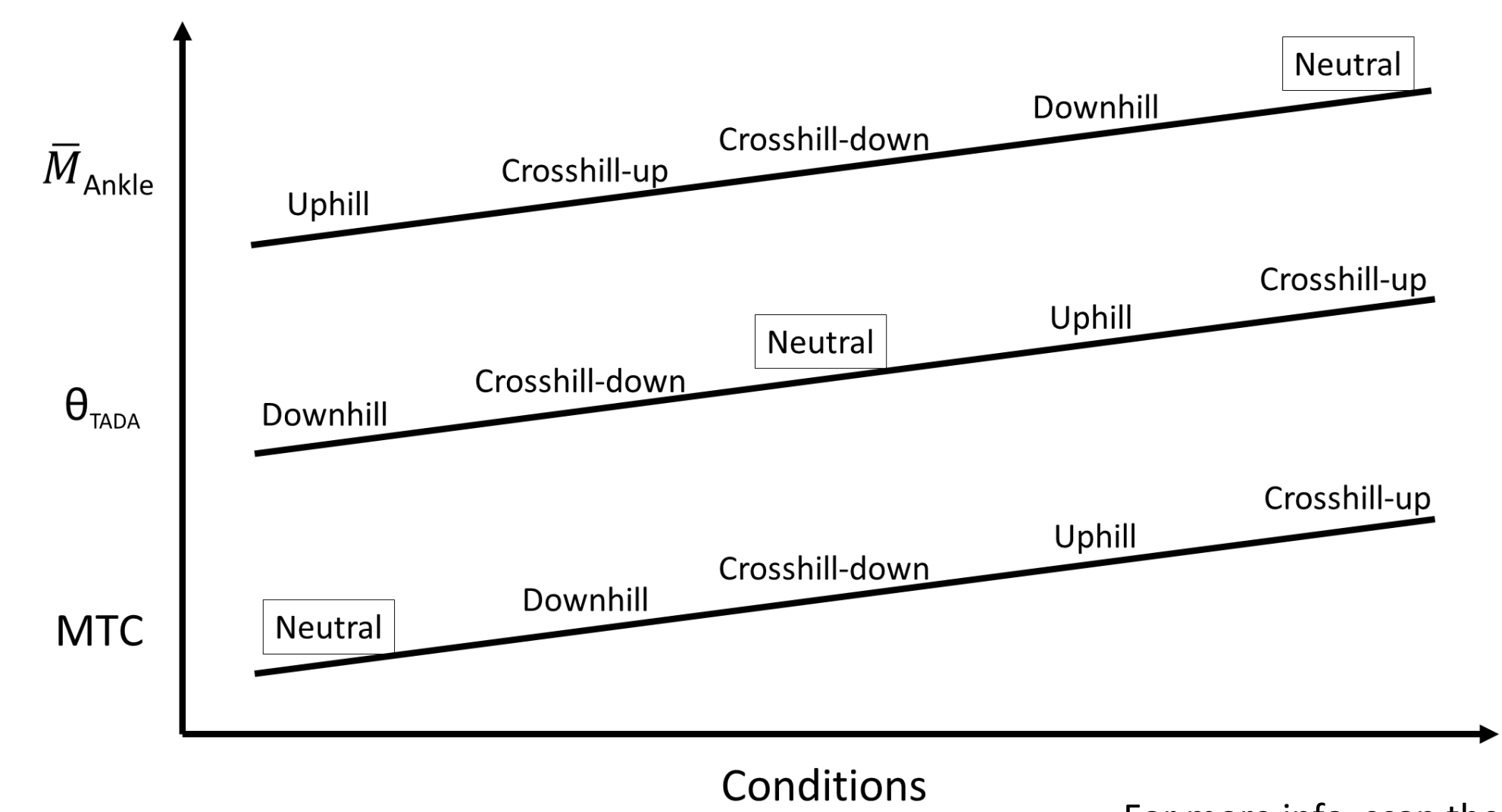
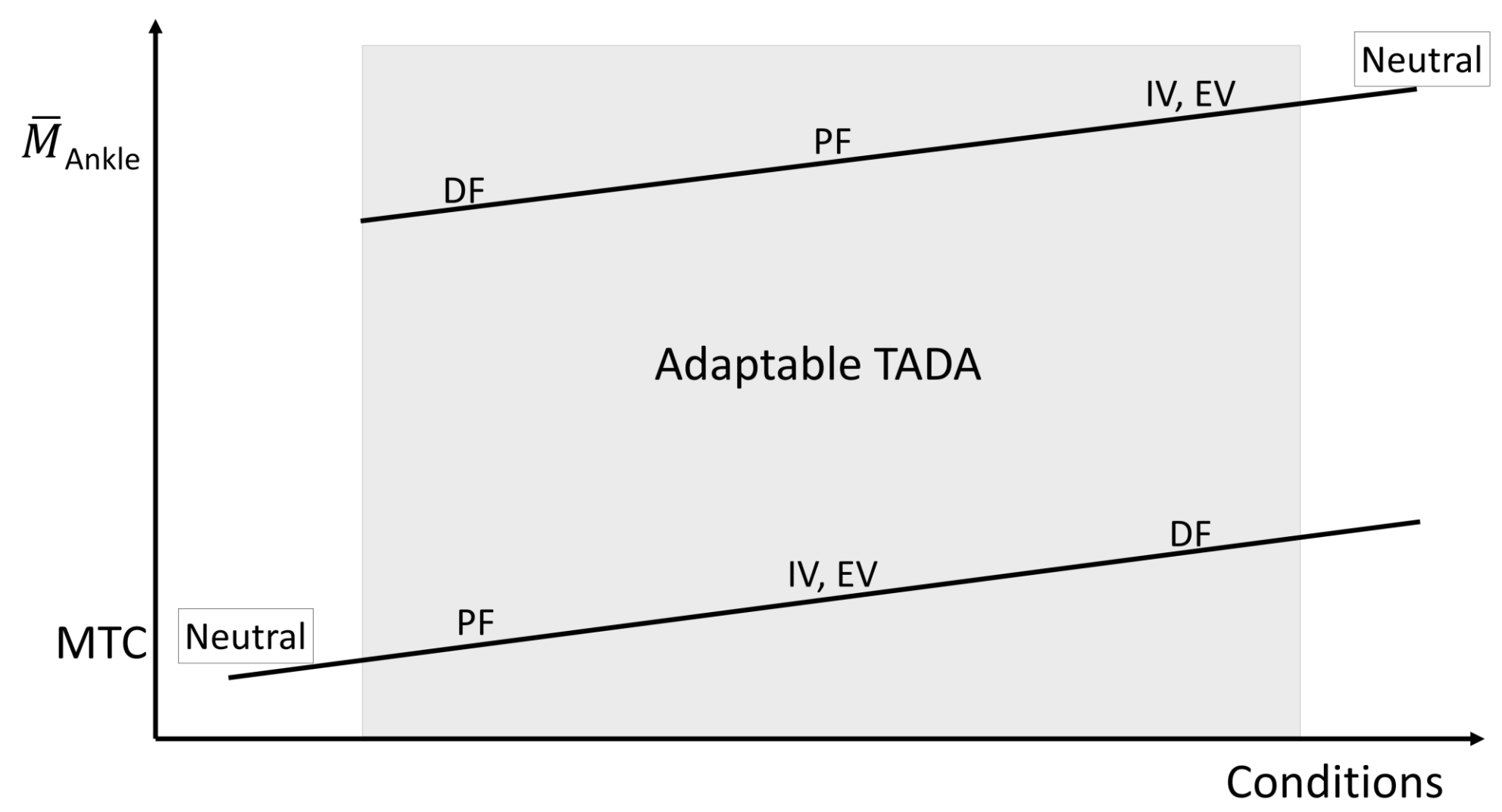
- ### Anticipatory Slope-Adapting Control
- Initial tuning of stance angle to user-preference
 - Evaluate average ankle moments
 - High average ankle moments in prostheses may contribute to knee injuries
 - Does preferred stance angle has lower peak ankle moments?

- ### Moment-Targeting Control
- Initial tuning of stance angle to a chosen multiple (0.5-0.95) of average ankle moment from neutral TADA walking
 - Evaluate resulting ankle angles
 - Do ankle angles with targeted lower moments have similar values to intact side or non-disabled ankle angles?



- Lab tests with non-disabled persons
- Validation study for TADA ankle moment and minimum toe clearance

- Outdoor tests with persons with transtibial amputations
- Walk in square laps on a sloped surface



- ### Remaining Challenges
- Sensing terrain
 - Remembering slope
 - Optimizing preference
 - Predictive and volitional control
 - Human-in-the-loop optimization
 - Osseointegration bi-directional neural interface

- ### References
- 1) Johnson, L., De Asha, A. R., Munjal, R., Kulkarni, J., & Buckley, J. G. (2014). Toe clearance when walking in people with unilateral transtibial amputation: effects of passive hydraulic ankle.
 - 2) Wu, A. R., & Kuo, A. D. (2016). Determinants of preferred ground clearance during swing phase of human walking. Journal of Experimental Biology, 219(19), 3106-3113.
- ### Acknowledgments
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