Master's Thesis : Reinforcement Learning for Modelling Human Escape Behavior

Uzay Gökay, Yonatan Hutabarat, Dominik Bach
Hertz Chair for Artificial Intelligence and Neuroscience (CAIAN)
University of Bonn

May 2025

Context & Motivation

Escaping from danger is a fundamental survival behavior, shaped by neural, biomechanical, and ecological constraints. Human motor control in these moments is life-preserving, rapidly orchestrating coordinated muscle activations to enable escape from threat. Understanding the biomechanical and neural principles underlying these escape behaviors has implications for neuroscience (e.g. stress and panic responses), rehabilitation (e.g. retraining gait after injury), prosthetics (e.g. fall avoidance controllers), and animation (e.g. lifelike NPCs in VR). However, investigating human escape strategies is challenging due to ethical and practical limitations in experimental settings.

With recent advances in physic-based simulation and reinforcement learning (RL), we can now train agents to mimic human-like behavior. Classical models of behavior often rely on simplified joint-torque controllers or hand-crafted kinematic rules, which capture what the body does but not how muscles work together. Recent advances in muscle-level reinforcement learning [1–4] show that we can learn controllers that not only reproduce human motion but also generate physiologically realistic muscle activation patterns, closely matching EMG data, using motion-capture sequences.

Project Goals

In this project, you will work with a large motion capture dataset of human escape behaviors and develop an RL agent that :

- **Imitates human escape behavior** (sprinting, dodging, crouching, etc.) to drive a lower- or full-body avatar via muscle-length set-points and PD → force → activation dynamics.
- **Fine-tunes that policy** in a simulated "threat environment," where a predator or falling object pursues the agent, by optimizing a survival-based reward (reach safe house vs. get caught).

What You'll Learn

- Hands-on experience with MuJoCo for real-time, muscle-level simulation.
- Bridging data-driven imitation and goal-driven RL in embodied AI.

- Scientific communication: benchmarking, ablations, and delivering clear, reproducible code.

Candidate Profile

- Strong programming skills in Python (experience with PyTorch and hands-on experience with reinforcement learning is a plus).
- Basic familiarity with MuJoCo is required (familiarity with control theory and/or biomechanics is a plus).
- Enthusiasm for interdisciplinary research at the intersection of AI, neuroscience, and robotics.

To apply: Please send your CV and transcript to `u.goekay@uni-bonn.de`.

References

[1] Yusen Feng, Xiyan Xu, and Libin Liu. Musclevae: Model-based controllers of muscle-actuated characters. In *SIGGRAPH Asia 2023 Conference Papers*, pages 1–11, 2023.

[2] Kaibo He, Chenhui Zuo, Chengtian Ma, and Yanan Sui. Dynsyn: dynamical synergistic representation for efficient learning and control in overactuated embodied systems. *arXiv preprint arXiv:2407.11472*, 2024.

[3] Pierre Schumacher, Daniel Häufle, Dieter Büchler, Syn Schmitt, and Georg Martius. Dep-rl: Embodied exploration for reinforcement learning in overactuated and musculoskeletal systems. *arXiv preprint arXiv:2206.00484*, 2022.

[4] Merkourios Simos, Alberto Silvio Chiappa, and Alexander Mathis. Reinforcement learning-based motion imitation for physiologically plausible musculoskeletal motor control. *arXiv preprint arXiv:2503.14637*, 2025.