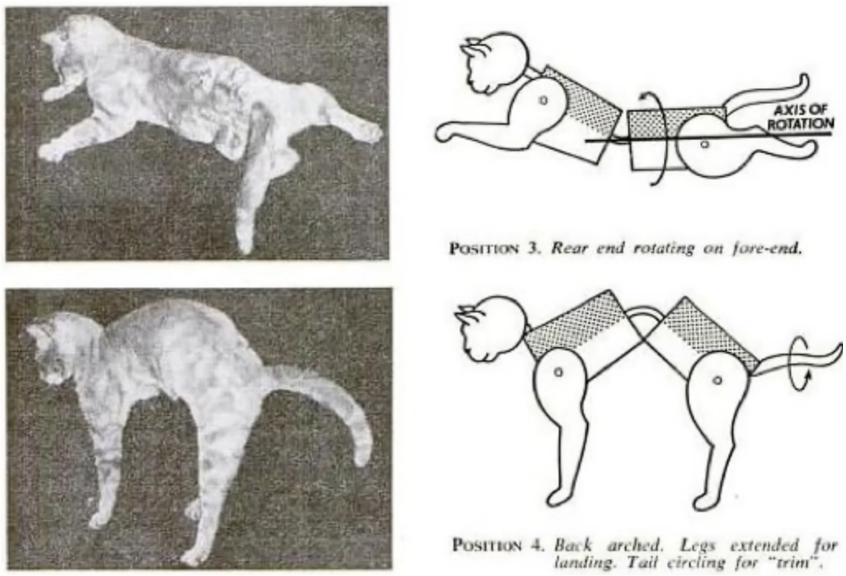
Landing Like a Cat: Aerial Self-Righting for Amphibious Robots via Active Spine Control

Description

Have you ever watched a cat fall? Even if dropped upside down, it miraculously twists mid-air to land perfectly on its feet. This biological marvel is known as the "Righting Reflex." It is not magic; it is a masterclass in conserving angular momentum.
We aim to grant this capability to next-generation quadruped robots. Using a Flexible Active Spine, the robot must detect its orientation during the split-second airborne phase (e.g., after a high jump) and vigorously twist its torso to correct its attitude before impact.
We reject the idea of adding "band-aid" hardware. We do not want heavy reaction wheels or external stabilizers. We believe in Bio-Efficiency: utilizing the robot's own body mass and structure to achieve complex control maneuvers, just like an animal.



Position 3. *Rear end rotating on fore-end.*

Position 4. *Back arched. Legs extended for landing. Tail circling for "trim".*

Background

Kane's Cat This is a classic problem in mechanics, often called "Kane's Cat." The challenge is to rotate a falling body without pushing against anything external. By cyclically bending and twisting its spine, the robot can generate internal reaction torques. Essentially, by twisting the front of its body one way, the rear rotates the other way, allowing it to net-zero its orientation errors.
Existing jumping robots often rely on heavy internal flywheels or tails to stabilize themselves. While effective, these components are "Dead Weight"—they consume battery and payload capacity but serve no purpose when the robot is just walking or standing.
The Multi-Purpose Spine We propose using an Active Spine. On the ground, it flexes to increase running speed and stride length. In the air, it acts as a high-speed attitude controller. One mechanism, multiple functions, zero wasted weight.

Technische Universität München

TUM School of Computation, Information and Technology

Lehrstuhl für Robotik, Künstliche Intelligenz und Echtzeitsysteme

Supervisor:
Prof. Dr.-Ing. Alois Knoll

Advisor:
Qian Huang M.Sc.

Type:
MA,SA,BA

Research area:
Deep Reinforcement Learning, Robotics, Sim-to-Real, Locomotion

Programming language:

Python (PyTorch), C++ (Deployment)

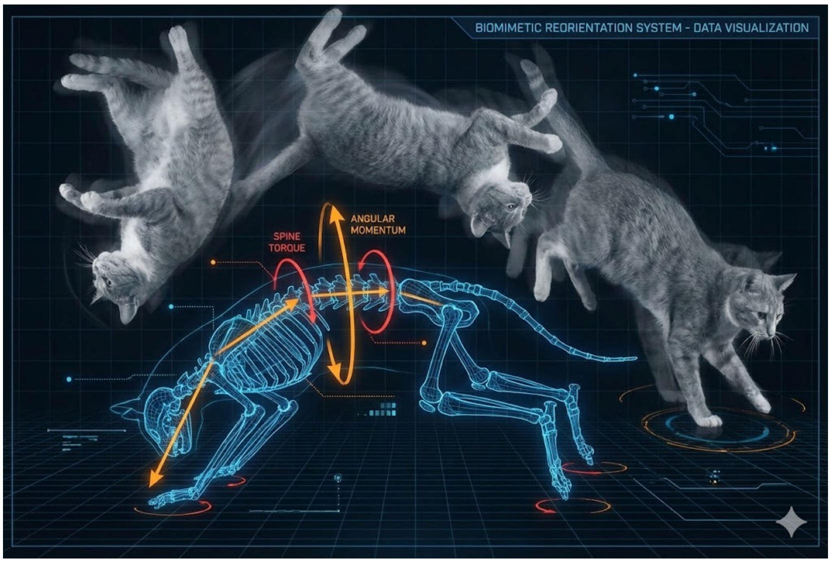
Requirements:
High self-motivation and passion for AI-driven robots; At least six-month working time; (Optional) Experience with Python and Deep Learning frameworks ro Physics Simulators (NVIDIA Isaac Sim, MuJoCo)

Language:
English

For more information please contact us:

E-Mail: qian.huang@tum.de

Internet: www.ce.cit.tum.de/air



Technische Universität München

TUM School of Computation, Information and Technology

Lehrstuhl für Robotik, Künstliche Intelligenz und Echtzeitsysteme

Tasks

1. Conceptual Modeling (The Physics):
·Analyze the mechanics of free-falling bodies.
·Understand Conservation of Angular Momentum conceptually: How does bending the "waist" of the robot affect its roll and pitch? You will map out the relationship between spine shape and body orientation.
2. Simulation Setup:
Build a simplified robot model with a flexible spine in a physics engine (e.g., MuJoCo or Isaac Sim).
Implement a control policy (using Trajectory Optimization or Reinforcement Learning). Your goal is to train the robot to "panic" correctly—finding the exact sequence of twists needed to land flat on its feet.
3. Sim-to-Real:
If time permits, we will move to a physical drop-test. You will mount a prototype torso on a test rig and verify if the motors are fast enough to reorient the body in real-time.

What You Will Gain

Dynamics Intuition: You will develop a deep "gut feeling" for how multi-body systems move and rotate in 3D space.

Modern Control: Gain hands-on experience with state-of-the-art tools like Model Predictive Control (MPC) or Deep RL in a dynamic environment.

Bio-inspiration: Learn the engineering art of translating complex biological behaviors (cat reflexes) into clean, efficient engineering solutions.

Mentorship & Support

This topic, which focuses on designing for advanced robotic control, may sound challenging. However, you will not be starting from scratch.
Your mentor (Ph.D. Student) has extensive research experience in this specific domain and has already established a solid foundation for this project. We are fully prepared to provide comprehensive, step-by-step guidance to ensure you get up to speed quickly. You will receive dedicated, hands-on support throughout the entire research and implementation process.
This is a unique opportunity to tackle a high-impact problem with expert, full-time mentorship.

For further discussion on specific tasks, welcome to direct contact me via email.