Implementing adhesion forces for a neuromechanical model of Drosophila Melanogaster : NeuroMechFly

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Supervised by:
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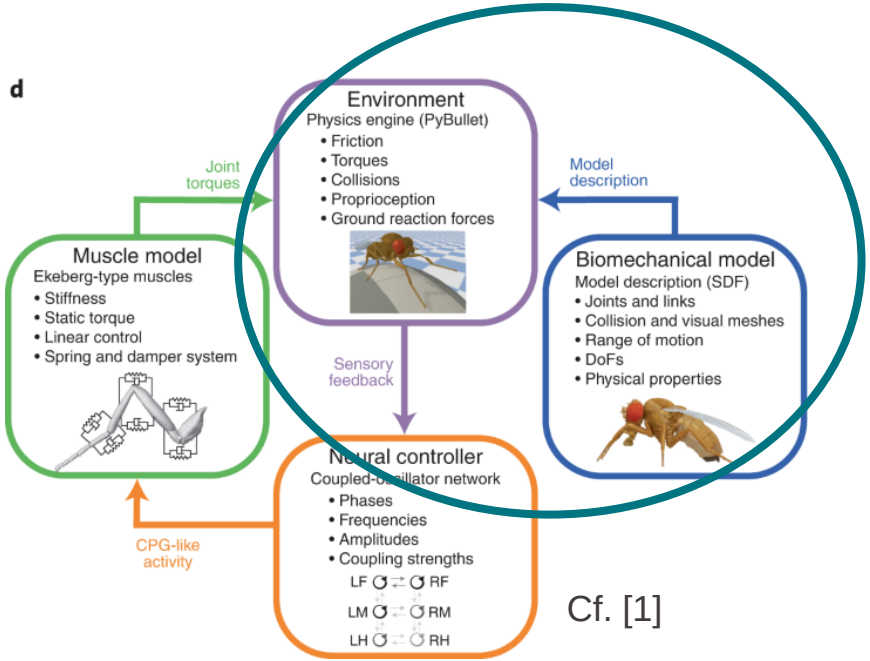
Bachelor
Project
Midterm
presentation

SV 2.715 – 27.03.2023

Model of Adult Drosophila Melanogaster: NeuroMechFly

- **Biomechanical model:**
  - 7 DoF per leg are required for replay leg kinematics
  - Currently run on Pybullet
- **Utility:**
  - Allows to measure contact forces and torques (i.e. ground reaction forces)



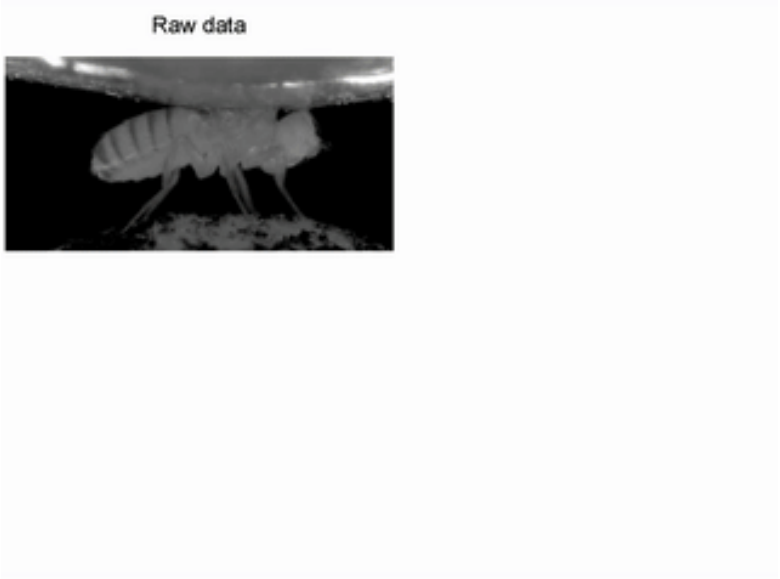
Cf. [1]

NMF on Pybullet vs MuJoCo vs IsaacGym

- **Pybullet:**
  - **Uses SDF files**
  - Allows for collision detection (rigid and soft dynamics)
  - Inverse kinematics
- **MuJoCo:**
  - Uses XML files instead of SDF files
    - Actuators (i.e. position, velocity for each joint, **adhesion**)
- **IsaacGym:**
  - Rendering is more time consuming.
  - Runs on GPU

Experimental SetUp studied for the project

- **Focus:**
  - Fly walking on ball treadmill surface (not flat terrain)
  - Ball velocity tracking data exists (FicTrac) for kinematic replay



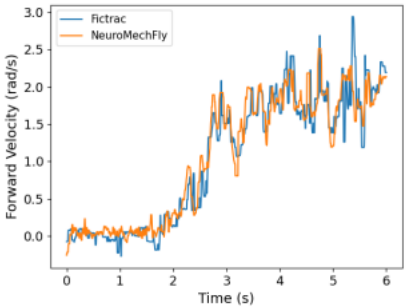
https://github.com/NeLy-EPFL/NeuroMechFly/blob/main/docs/images/km_walking.gif

- **Initial conditions:**
  - Stretch pose
  - Drosophila is tethered at thorax

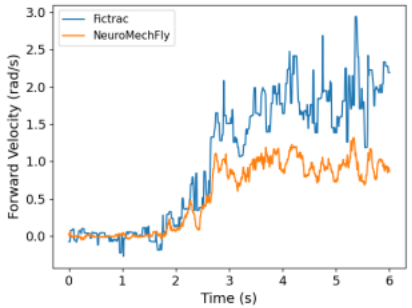
- **Aim:**
  - Similar/ higher correlation performance as NeuroMechFly on Pybullet
  - Assume that with these parameters remain fixed when adding adhesion
- **Parameters to tune:**
  - **Friction force on the ball**
  - During position control : **KPGain** -> influences contact profile
  - Relative ball position
  - Stiffness of joints and damping of the joints
- **How?**
  - **Grid search (2 phases) (even partition) or asynchronized hyperparameter optimization**

Part 1: Tune parameters for ball locomotion in MuJoCo

- **Accuracy measurement:**
  - Comparing ball rotation velocities to the FicTrac raw data using MSE and Spearman correlations
- **Expectations:**
  - **Similar performance (not able to follow high frequency components) (cf. Bryan Gotti)**



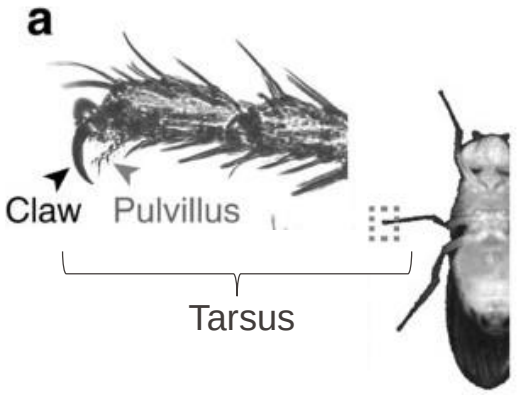
(a) PyBullet

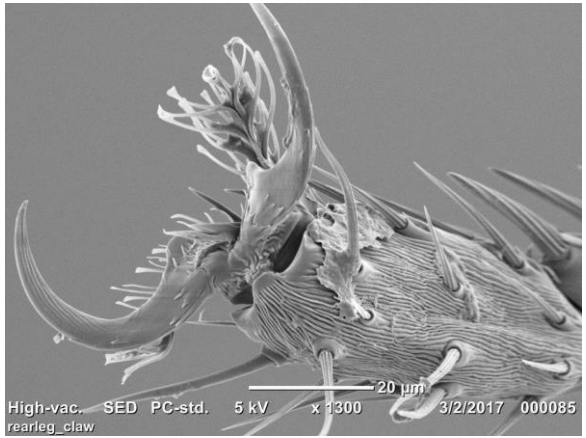


(b) Optimal grid search configuration

Cf. Bryan Gotti

- **Physiology:**
  - Adhesion allows the fly to climb [1]
  - one pretarsus suffices the fly to hang for >1 s [1]
- **Model: When should adhesion apply?**
  - **No adhesion:** When fly leg is in swing
  - **Adhesion:** When fly is in contact to ball



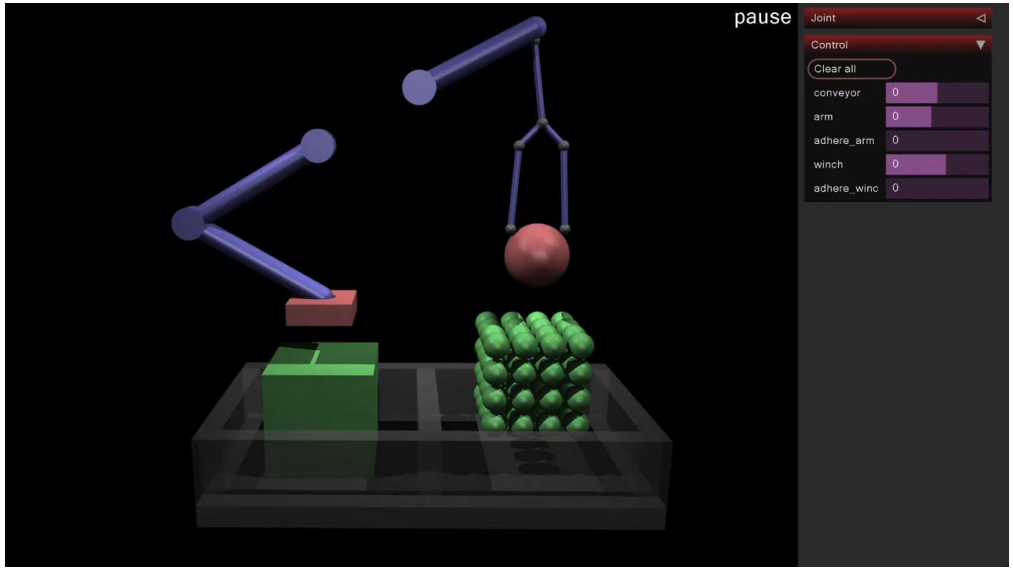


https://pbs.twimg.com/media/C58Ks8fU0AAwcFH.jpg

Part 2: Implement Adhesion Forces

Adhesion in MuJoCo

- **MuJoCo vs Pybullet**
  - MuJoCo allows to add an adhesion actuator



Cf. [3]

- **Accuracy measurement:**
  - Comparing ball rotation velocities to the FicTrac raw data using MSE and Spearman correlations

- **Expectations:**
  - **Improved reaction to high frequency changes**

Part 3: Verify Adhesion Forces

Laetitia Schwitter

Gantt Chart – Until week 6

Project Start Date:

Bachelor Project: Implement adhesion forces in a neuromechanical model of adult Drosophila melanogaster

Activity	Status	Feb		Mar			
		20-Feb	27-Feb	06-Mar	13-Mar	20-Mar	27-Mar
		WEEK 1	WEEK 2	WEEK 3	WEEK 4	WEEK 5	WEEK 6
Project	In progress						midterm presentation 27 March
SetUp/ Administration	Completed						
Literature introduction	Completed						
Install Softwares	Completed						
Part 1: Tune parameters for Ball locomotion	In progress						
Verify correct 3D collision implementation in MuJoCo	In progress						
Contacts tuning in MuJoCo for both floor and ball surface	In progress						
Identify how to trace specific positions on the ball and leg in MuJoCo for calculations	In progress						
Identify necessary ball and fly parameters in PyBullet and how they can be accessed	In progress						
Part 2: SetUp Adhesion Forces	Not started						
Research on adhesion/ friction forces	In progress						
Create a theoretical model for Adhesion forces specific to D. Melanogaster	Not started						
Implement model in code (Adhesion On/ Off switch)	Not started						
Part 3: Validate Adhesion Forces	Not started						
Compare ball displacement in the simulation and in the real fly	Not started						
Adjust Adhesion Forces / Parameters, possibly go back to task #12	Not started						
Part 4: Presentation / Report	Not started						
Write-up Report	Not started						
Prepare Presentation	Not started						

Gantt Chart

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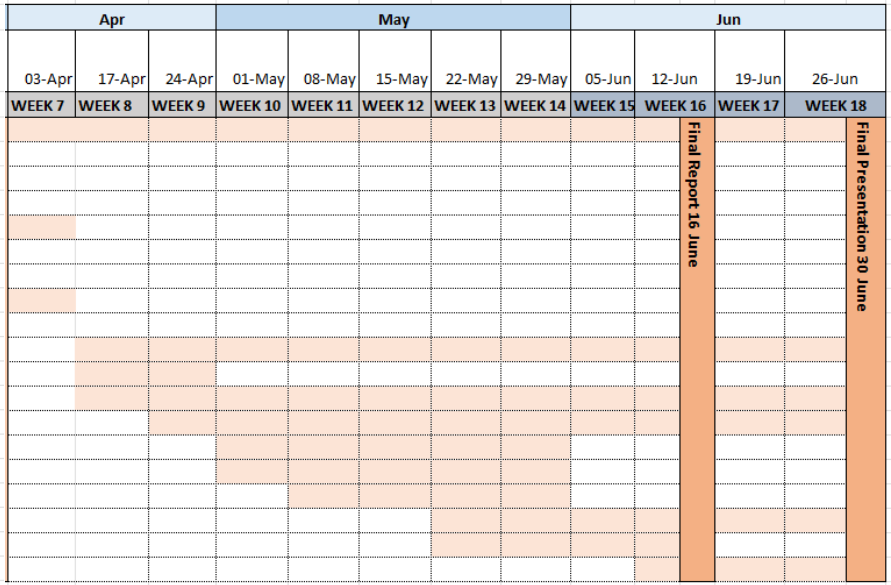

Current difficulties

- Extracting and overwriting the parameters from MuJoCo for hypermeter tuning
- Adapting IsaacGym code to MuJoCo
- Choosing the exact parameters to change

Progress

- Familiarize with MuJoCo, Pybullet, IsaacGym
- Adapting IsaacGym code to MuJoCo

References

- **[1]** Lobato-Rios, V., Ramalingasetty, S.T., Özdil, P.G. *et al.* NeuroMechFly, a neuromechanical model of adult *Drosophila melanogaster*. *Nat Methods* **19**, 620–627 (2022). https://doi.org/10.1038/s41592-022-01466-7
- **[2]** Ramdya, P., Thandiackal, R., Cherney, R. *et al.* Climbing favours the tripod gait over alternative faster insect gaits. *Nat Commun* **8**, 14494 (2017). https://doi.org/10.1038/ncomms14494
- **[3]** "XML Reference#." *MuJoCo Documentation*, https://mujoco.readthedocs.io/en/stable/XMLreference.html#actuator-adhesion.