Student names: ... (please update)

Instructions: Update this file (or recreate a similar one, e.g. in Word) to prepare your answers to the questions. Feel free to add text, equations and figures as needed. Hand-written notes, e.g. for the development of equations, can also be included e.g. as pictures (from your cell phone or from a scanner). ***This lab is graded.*** *and needs to be submitted before the* ***Deadline : 05-06-2018 Midnight****.*
You only need to submit one final report for all of the following exercises combined henceforth.
Please submit both the source file (.doc/*.tex) and a pdf of your document, as well as all the used and updated Python functions in a single zipped file called final_report_name1_name2_name3.zip where name# are the team member's last names. Please submit only one report per team!*

Locomotion

In the previous lab you explored the reflex model with the mouse fixed in air. By changing the muscle activation gains you were able to produce a stable gait behavior based on the four phases described by [1]. In the current model the mouse will no longer be fixed but it can move around in three dimensions.

Important to note the differences in [1] and the mouse model. The morphology of mouse and cat are different, the parameters used for musculo-skeletal properties are completely different from [1]. Do not be surprised to see results different from [1]. Also the mouse model is new and currently being developed. Please report if you find any bugs and please point out any interesting behaviors that you may observe during the exercises.

Now you can explore how the reflex model behaves under different conditions and study the locomotion behavior.

In the current model we explore three important quantities during the stance phase in the reflex model,

- Coupling between the legs : This ensures that one of the hind legs lifts-off from the ground only when the other leg is in stance phase. This coupling can be enabled or disabled by the setting the variable reflexes::COUPLING to either True or False in the mouse.py controller file at any instant of time. In the current model we tuned the parameters to produce locomotion for the coupling case. During the exercises you will observe how this influences the overall model.
- Hip extension rule : During the stance phase, this reflex parameter determines the angle of the hip extension at which the stance phase terminates and enters the lift-off phase. This reflex parameter can be enabled or disabled by the variable reflexes::HIP_EXTENSION_RULE to either True or False in the mouse.py controller file at any instant of time.
- Ankle unloading rule : During the stance phase, this reflex parameter terminates the stance phase when the force in soleus muscle drops below a threshold value and enters the lift-off phase. This reflex parameter can be enabled or disabled by the variable reflexes::ANKLE_UNLOADING_RULE to either True or False in the mouse.py controller file at any instant of time.

Download the updated model from the git repository along with the controller files. In the new files, you can replace the muscle activation constants that you tuned from the previous lab in the current reflexes.py file.

Data logging The current model now saves additional entities during the simulation. They are,

- Trajectory of the left and right right hind foot
- Ground contact detection for the left and right hind foot
- Muscle activations and tendon forces from left and right hind limb muscles
- Joint angular positions from left and right hind limb

Use Results::load_data.py file to read and plot the data saved in Results

Questions

yes we do

7c. With the previously tuned reflex model, report if you observe a stable gait or not with the 3D model for at least 2 seconds of simulation time? If you do not observe a stable gait then tune the muscle activation constants (Kx) in the reflexes.py file to obtain stable gait. Report the changes in muscle activation constants if any. Plot and explain the joint angles of hip, knee and ankle joints from left and right hind limbs. Plot the muscle activations of either left or right hind limb. Explain how the muscle activity correlates with the different phases of gait. Plot the ground contact of both left and right hing feet. Use Results::load_data.py files to see how to load the data at the end of the simulation. Use subplots to make your plots and plot both left and right joint angles in each subplot. See the example given in Results::load_data.py (Note : You need to press revert button in Webots to save the data.). Also compute and report the duty factor of the model

7d. Now explore the coupling between the hind legs of the mouse. In mouse.py disable coupling at the beginning of the simulation. Plot the joint angles similar to the one before and explain the gait you observe without coupling. What happens to the gait when you start the simulation with coupling and then turn it off/disable it after 1.0 second of simulation?. To do this you can use an *if* condition in the mouse.py::run and you can obtain the current simulation time using the Webots robot class method self.getTime(). Why is there a difference in behavior in the above two cases and can it be improved by re-tuning the parameters in the model?

7e. Explore the robustness of the model with coupling under different terrains and small perturbations. Use cmc_mouse_uphill.wbt and cmc_mouse_downhill.wbt world files to simulate uphill and downhill climbing scenarios. In the world files you can change the inclination of slope by changing the rotation field in Floor Solid → Floor Group → Hill Transformation → rotation. Report the different conditions under which the model is explored. Show one set of joint angles plot and ground contact plot for one condition of up hill and down hill scenario. With the same plots explain how the gait frequency changes with respect to the terrain. Apply small perturbations to the model using the Webots GUI and show how the gait recovers using the ground contact plots of hind limbs.

As mentioned earlier, two main reflexes used in the model for stance termination are hip extension rule and ankle unloading rule. To explore, the role of each we start the simulation with all couplings and reflexes enabled. At time == 1. we can start disabling each of the rules and then look at the behavior of the model

7f. Is one type of reflex rule more important than the other to generate stable locomotion? To explore the differences first disable the hip extension rule at 1 second of simulation time and observe the models gait. Do the same by disabling the ankle loading rule at 1 second of simulation time and observe the models gait. If you do not observe any differences in gait can you explain how the coupling parameter is responsible for the stability? Disable the coupling parameter to see the models performance. Would re-tuning the model parameters help in stabilizing the model without coupling?

7g. How do the reflex rules perform under different terrains. Use cmc_mouse_uphill.wbt and cmc_mouse_downhill.wbt world files to simulate uphill and downhill climbing scenarios. Use the default slope of 0.08 **rad. Show the joint trajectories and ground contacts while each of the reflex parameters is disabled. Using the observations from 8b describe if having the combined reflex rule helps in stabilizing the model better.**

In the coming weeks the goal will be to explore the above scientific questions but also now by varying other the reflex parameters in the system and tuning to the model to perform better even under uncoupled condition. More details will be discussed later

Discussion Questions

These questions require only a discussion and no implementation of any model is expected.

a. What would be the potential benefits of adding a CPG to the locomotor circuit? Try to relate to literature as much as possible.

b. How could the model be extended? (e.g. more or less detailed models, 3D, full body, more sensory modalities, inclusion of more brain parts, ..., discuss, no need to implement). Try to relate to literature as much as possible.

c. Which type of additional experiments could be done (with the current model, and with extended models) and what would be your predictions? Discuss, no need to implement. Try to relate to literature as much as possible.

REFERENCES

1. *Computer Simulation of Stepping in the Hind Legs of the Cat: An Examination of Mechanisms Regulating the Stance-to-Swing Transition* : Orjan Ekeberg and Keir Pearson. Journal of Neurophysiology 2005 94:6, 4256-4268 download link