Neuromuscular Reflex Models with Inverse Dynamics

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1 Introduction

Biologically inspired controllers and actuators have been explored for controlling animated characters as well as humanoid robots. One such class of controllers are Neuromuscular Models (NMM) developed in [2]. These are policy-based neuromechanical controllers where the actuation forces are a result of simulated muscles with human-like neural delay, which leads to torque patterns that incorporate biomechanical constraints. It is a common observation in robotics that manually designed, policy-based controllers, as are seen in for example the Big Dog, are often more robust than model-based optimization controllers. But policy-based methods are hard to apply to tasks with steering or footstep targets, which is a capability provided by model-based controllers. This has been exploited in the recent DRC trials and details can be seen in [3].

In this work, we analyse the robustness of the neuromuscular models on a 2D model of the Sarcos Primus humanoid robot, by adding ground height variations and mass and torque disturbances. We find that the neuromuscular model is very robust to torque and mass disturbances, and can walk over ground disturbances of up to ± 3 cm. The next step is to combine this with a model-based optimization controller that explicitly takes the dynamics of the robot into account and allows it to do more general tasks.

2 Neuromuscular reflex based model

The conceptual basis of a neuromuscular controller is a spring-mass model. The spring mass model is capable of integrating running and walking into one model. Geyer, et al successively substitute springs with segmented legs, controlled using muscles. They also add a trunk and simple swing phase laws, as described in [2]. The final model consists of two 3-segment legs controlled by seven Hill-type muscles and a trunk, controlled by two Hill type muscles. Each muscle has its own neural stimulus function for swing and stance phases that generate muscle torques. Details of these can be found in [2].

We modified the mechanical structure and muscle time delays to match that of the Sarcos Primus humanoid.

This modified model was able to walk on flat ground, as shown in Figure 1. This model was also found to be robust to time delays (long, medium and short), but sensitive to ground height disturbances. To improve performance over disturbances, we perform optimization over a random sequence of ground disturbances. Our experiments on the original model and the optimized model and the corresponding results can be found in the next section.

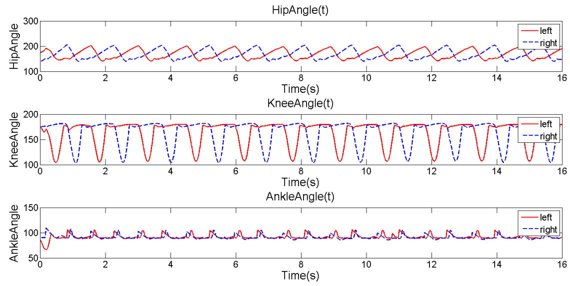

Figure 1: Joint angles over time, showing stable walking on flat ground with no disturbances, for a model with Sarcos masses and 3ms time delays, using the original parameters given in [2].

3 Preliminary results

We ran the now-optimized model under three different conditions:

- Varying ground height, where ground height was varied randomly between ± 0.01m to ± 0.03m. The corresponding performances of the optimized model and the original model from [2] can be seen in Figure 2.
- Varying torque disturbances at each joint (ankle, knee, and hip). Each joint experiences a randomly varying torque profile upto ± 5Nm.The corresponding performances of the optimized model and the original model from [2] can be seen in Figure 3.
- Changing masses. In order to test some notion of sensitivity to model accuracy, we varied the masses of the robot limbs from 50% of the original to 150%. These results are shown in Figure 4.

4 Combining neuromuscular models with Inverse Dynamics

Policy-based methods like neuromuscular models [2] and Raibert controllers [4] can generate trajectories that are robust to modelling errors and slight disturbances in the environment. However, they have some inherent shortcomings

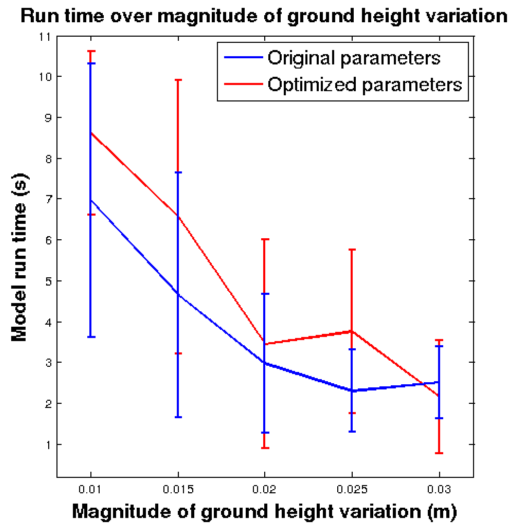

Figure 2: Robustness to ground height disturbances

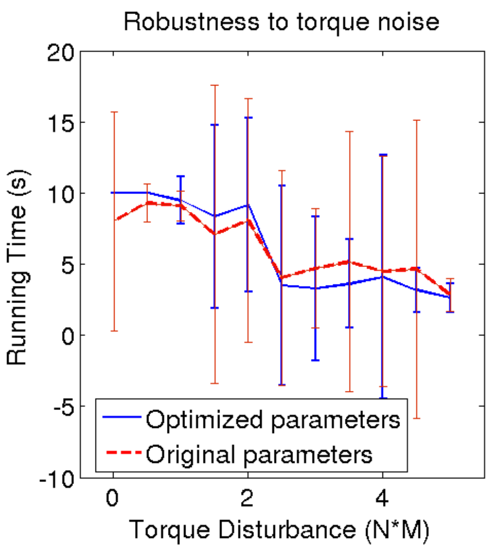

Figure 3: Robustness to Torque

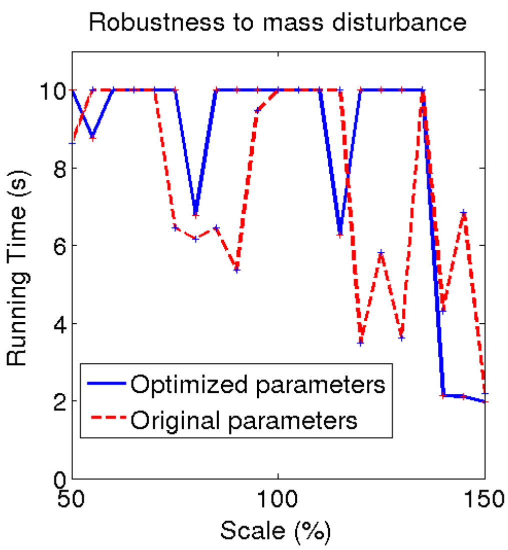

Figure 4: Model robustness to variations in limb mass.

such as, lack of a steering angle and footstep location in the case of neuromuscular models. These shortcomings of these models make it difficult to apply them on real robots.

Thus, combining policy based methods with optimization based methods can be useful for generating walking trajectories that are robust, stable and can be made to superimpose tasks like hand movements, which are not generated by the NMM. We describe a way of combining these two methods below.

A popular way of solving the problem of inverse dynamics is by formulating it as a quadratic programming problem that minimises a cost subject to constraints, for example, in [3] and [1]. The cost function could be tracking a Cartesian space COM trajectory, while the constraints could be torque limits, friction cones, etc.

If we have a desired torque provided from some external model, for example, the NMM, we can force our optimizer to follow the desired torque as closely as possible, by incorporating a cost term in our optimization.

This can allow us to generalize our policy-based controllers to solve more general problems, and make optimization-based controllers more robust. We need to perform experiments to test our hypothesis and observe the results of such a set up.

5 Acknowledgements

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References

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