Improving Naturalness of Locomotion of Many-Muscle Humanoids

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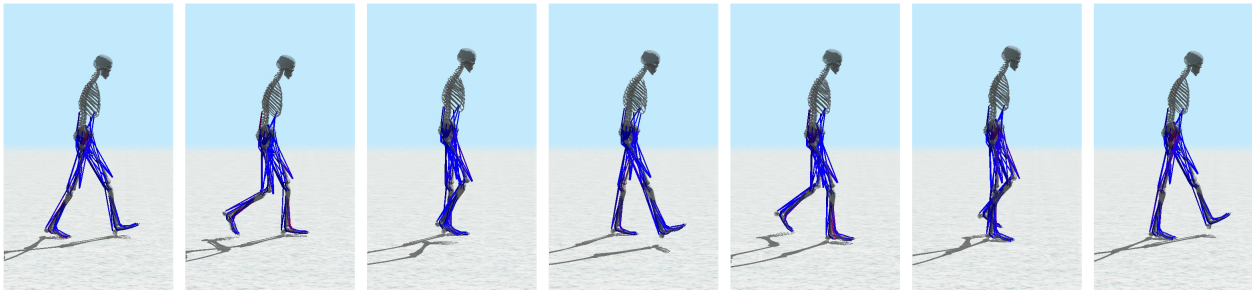

Figure 1: *Simulation of normal walk with muscle activation minimization.*

1 Introduction

For many decades, researchers have worked on the simulation of biped locomotion such as human walking. As simulation models have evolved, the simulation using a musculoskeletal model has also become possible [Lee et al. 2014]. Since the number of muscles of models they use is greater than the number of DoF of the models, the optimization problem is undetermined. In order to solve this problem, they use the 2-norm of muscle activations as an objective of optimization and minimize it. However, to obtain more realistic simulation results, real mechanisms of human movement should be applied.

In spite of development of the humanoid locomotion simulation, it is still not natural enough due to the lack of knowledge in the mechanisms of human movement. Discussions about this topic have been made, and many people believe that human movement tries to minimize one of the followings; muscle activation, derivatives of muscle activation, joint torque, derivatives of joint torque, metabolic energy expenditure or some combination of these. In this study, we did experiments for each minimization case and compared the results of kinematic data and energy consumption.

2 Our Approach

We used many-muscle controller and a simulator presented by Lee et al.[2014] They simulated biped locomotion using the musculoskeletal model. To control locomotion of the musculoskeletal models, they used muscle contraction dynamics and quadratic programming. In quadratic programming, they minimized muscle activation.

Firstly, we conducted an experiment under joint torque minimization, and compared the result with activation minimization case. There was no noticeable difference on kinematic data. One major difference was the amount of energy consumptions during the simulation. Energy consumption of joint torque minimization case was higher than that of activation minimization case.

Secondly, we did an experiment with metabolic energy expenditure minimization. We designed metabolic energy expenditure as an activation weighted by the muscle mass. In case of muscle activation minimization, all the muscles treated as they have same muscle size. By weighting with their mass, we could consider muscle forces which is proportional to muscle size in optimization process. There was no significant difference on kinematic data between activation and metabolic energy expenditure minimization cases as well. Energy consumption of this case was higher than that of muscle activation case but lower than that of joint torque case.

When muscle activation minimization case, muscles of a model is relaxed completely. However, this is not the same as human movement because it is known that human generate redundant energy(muscle co-activation) to keep the body stable, which appears in joint torque and metabolic energy expenditure minimization cases. In joint torque minimization case, because only joint torque is minimized, muscle co-activation can be generated. In metabolic energy expenditure minimization case, a combination of minor muscle forces compensates some portion of major muscle force, so redundant activation can appear. Consequently, we are going to model the muscle co-activation considering organic relationships between muscles, rather than simply minimizing some objective. To do so, we will find weighted sum of these objectives or add new objective representing co-activation.

References

LEE, Y., PARK, M. S., KWON, T., AND LEE, J. 2014. Locomotion control for many-muscle humanoids. *ACM Trans. Graph. 33*, 6 (Nov.), 218:1–218:11.

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