Identification of Reflex Control Parameters in Human Walking

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Summary

This study aimed to identify feedback control laws for human walking. Parameters of a reflex controller were found by optimizing a musculoskeletal simulation to track human gait data across perturbed and unperturbed gait cycles. Although the simulation maintained balance, it did not replicate human responses to perturbations, particularly at the ankle joint. The findings suggest that the reflex controller must be improved for more human-like walking control.

Introduction

Humans have a remarkable capacity to maintain balance while walking. While there have been computational models that explain human walking with reflexes [1], those models were not informed by human data. These reflex models have since been implemented in the SCONE software [2] for movement optimization. Typically, reflex control parameters are optimized without data tracking, to perform predictive simulations of human gait, using objectives such as minimal metabolic energy expenditure [3].

We have recently performed a series of experiments in which humans were systematically perturbed to elicit reactive responses [4]. Here, we present a scripted workflow using SCONE to perform parameter identification of reflex control laws by tracking data from these experiments.

Methods

Data from one participant was used. The experiment consisted of 30 minutes of treadmill walking, with about one in six gait cycles perturbed through rapid acceleration and deceleration of the belt [4]. Perturbation timing was randomly selected to occur at one of eight discrete time points in the gait cycle (10% to 80% of stance). Motion data were ensemble averaged and rearranged into a shortened trial in which each perturbation occurred once, and perturbed gait cycles were separated by two unperturbed gait cycles. SCONE version 2.2.1.2726 was used. Lua code was written to generate the perturbations, and to compute a tracking objective for the optimization:

$$J = \sqrt{\frac{1}{63}\sum_{i=1}^{9}\sum_{j=1}^{7}\frac{1}{T_i}\int_0^{T_i}\left({q_{ij}}^{\mathrm{sim}(t)} - {q_{ij}}^{\exp(t)}\right)^2 dt}\,,$$

computed over all perturbation types (one unperturbed and eight perturbed) and seven kinematic variables.

Simulations were performed with the H0914M_osim model, which has nine degrees of freedom (DOF), and seven Hill-type muscle-tendon units in each leg [5]. The neural control model, ControllerGH2010v9.scone, was based on [1], with 22 parameters. We allowed SCONE to run for approximately 24 hours before ending the optimization.

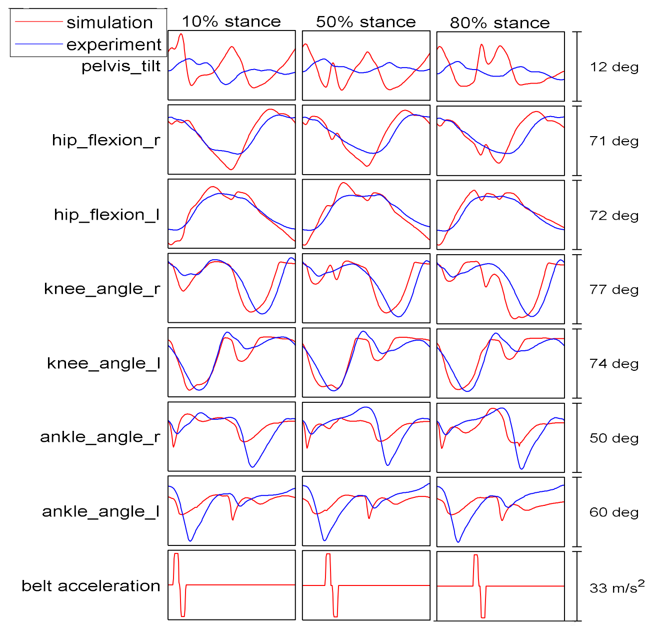

Figure 1: Measured and simulated angles during gait cycles with perturbations at 10%, 50%, and 80% of stance phase.

Results and Discussion

Figure 1 shows the result of the 24-hour optimization. Comparison between simulation and experiment shows that the simulation, while maintaining balance, did not respond to perturbations in the same way as the human participant, especially at the ankle joint. This is not entirely surprising since the reflex model [1], with only 22 parameters, does not nearly represent the full complexity of human walking control.

The SCONE workflow was, overall, successful. Computation time had to be limited, due to the time-consuming single-shooting method for parameter optimization and may have resulted in sub-optimal results.

Conclusions

The workflow was successful, and may have applications in designing human-like locomotion in robots, as well as in identifying abnormal control parameters in patients with neurological disorders. However, a more complex reflex model may be needed to produce human-like perturbation responses.

References

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