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AN OPTIMISATION METHOD TO SIMULATE WHOLE-BODY WALKING USING ASYMMETRIC LOWER LIMBS TO SEARCH A STABLE GAIT

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ABSTRACT

Introduction

Simulation of walking is one of the main challenges in computational modelling of locomotor systems. Human or animal walking is a complex procedure where multiple muscles work coordinately to propel the body. Usually, a musculoskeletal model for simulating a walking procedure should include all the main segments (e.g. head, trunk, upper limbs, lower limbs, feet, etc.), where the lower limbs are driven using the major muscles (e.g. hamstring, quadriceps, gastrocnemius, etc.). In a forward dynamic simulation, initially muscle activities, which can be suitable for driving the model properly, are unknown and thus will be searched using mathematical optimisations, which normally work as multi-loop. Eventually, the model may be able to perform a reasonable manner similar to that of a real subject [1, 2]. The major hurdle to the forward dynamic simulation is that there are so many muscles involved in the walking process and too many parameters in each muscle, which need to be adjusted. If all muscles and parameters were considered, a simulation procedure would take a considerable amount of time (e.g. several days to months) even with the use of high performance computer. This would make it difficult to apply the technique of computer simulation in the applied fields, e.g. clinical assessment or sports exercise.

There may be some techniques that can reduce computing time during simulation. For example, employ a more efficient optimisation to allow for a faster search procedure or cut the number of simulated muscles in the lower limbs thus reducing computing workload. The former demands the development of a new algorithm while the latter may lose the similarity between the model and its real counterpart. That is to say, the former is difficult to do and the latter should be avoided in practice.

Based on the issues above, we show a new approach that can reduce computing workload whilst resaving the number of muscles in the lower limb.

Method

The method is termed “self-compared optimisation” (SCO). This means that the model is designed with asymmetry in the lower limbs (e.g. one leg with multi-muscle and the other without). Hence, in simulation, whilst one leg is driven by muscle activities the

other is driven by joint movement functions which have been collected from a real subject's walking pattern. In each optimisation loop, the simulated kinematic data (e.g. joint angles) from the muscle-driven leg is compared with the kinematic data from the other. The difference(s) between two sets of kinematic data is used as the evaluation of given muscle functions. If these differences are less than the minimum that has been obtained from previous loops, the given muscle functions will be considered as one of the best potential solutions; then the searching procedure enters the next loop until the differences reach a satisfactory range, as shown in Figure 1.

To try this method, a model with the segments of the head, trunk, upper limbs, lower limbs and feet was constructed. One side of the lower limbs was included with 12 muscles and the other without. A group of joint angles were collected from a subject who walked in a comfortably normal way. The model was built using dynamic analysis software, Madymo®, as shown in Figure 2.

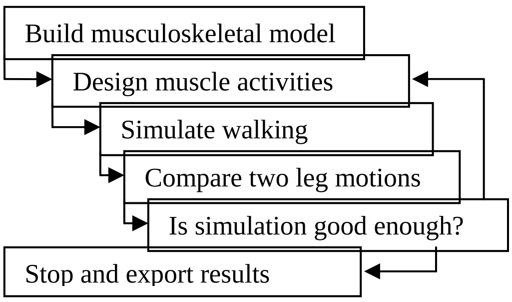

Figure 1 Flowing chart

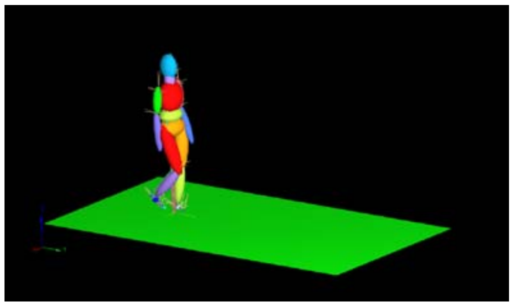

Figure 2. A musculoskeletal model in walking

Results

The results from the simulations showed that the model can walk in a similar way to that of a real subject. The differences between simulated joint angles and experimental ones were reasonably low, confirming that the proposed method is feasible and may be used in practice. From the simulated model, muscle parameters such as force, velocity etc., were easily obtained.

Discussion and Conclusion

The SCO has specific characteristics, which can reduce computing workload, i.e. increase the speed of the simulation/optimisation procedure. This is very important, especially when a simulation is carried out using a PC rather than using a giant computer system. The proposed method has a self-learning function, thus users are not required to set extra objectives. This initiative may be applied to various fields rather than just in computer modelling.

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