PREDICTION OF HUMAN WALKING BASED ON SIMPLE GAIT DESCRIPTORS

Lei Ren[1], Richard Jones[2] and David Howard[2]

[1] School of Physical Sciences and Engineering,
King's College, London, WC2R 2LS, UK
lei.ren@kcl.ac.uk

[2] Centre for Rehabilitation & Human Performance,
University of Salford, Salford, M5 4WT, UK
d.howard@salford.ac.uk

Key Words: *Gait prediction, inverse dynamics, optimisation*

Introduction

Gait prediction has many potential applications including the investigation of: motor control objectives in gait; the impact of musculoskeletal structure and injury on movement coordination; and the effect of assistive devices on locomotion performance [1]. In this study, an inverse dynamics multi-segment model was combined with optimisation techniques to simulate normal human walking in the sagittal plane on level ground. Walking is formulated as an optimal motor task, subject to multiple constraints, with minimisation of mechanical energy consumption being the performance criterion. All segment motions and ground reactions were predicted from only three simple gait descriptors: walking velocity, cycle period and double stance duration.

Methods

The human body is modelled as a dynamic coupled multi-segment system containing seven segments: the right and left thighs, shanks, and feet together with a HAT segment (head, arms and trunk). The segments are connected by frictionless hinge joints, and the model accounts only for segment motions in the sagittal plane. The foot is modelled as a rigid body with a curved surface rolling on the ground without slipping.

Segment angles are used to define the motion of the model. During walking, the motion of the stance ankle can be determined by the shape of the plantar surface of the stance foot and its orientation. Thereafter, the motion of each body segment can be derived based on the topology of the model, the segment angles and the stance ankle motions. An inverse dynamics method is employed to calculate the joint kinetics and mechanical energy expenditure during walking. As the ground reactions are initially unknown, the inverse dynamics algorithm is based only on segment motions, where a linear transfer assumption is used to solve the indeterminacy problem during the double support phase [2].

The gait prediction problem is formulated as the following optimisation task: find segment trajectories that achieve the specified gait parameters, whilst minimizing energy cost, and satisfying the constraints associated with walking. The optimisation scheme was implemented in the MATLAB (Mathworks, MA, USA) programming environment using the SQP (Sequential Quadratic Programming) optimisation algorithm. The three input gait descriptors (walking velocity, cycle period and double stance duration) were obtained from gait measurement data for one subject (age: 38years, weight: 101.7kg, height: 178cm), where the averaged values from four repeated normal walking trials were used.

Results and Discussion

       To find optimal solutions (local minima), the minimization was repeated with different random initial values. Several local minima were obtained (Figure 2), and it was found that the solution with the lowest energy consumption (Figure 2(d)) yields the most realistic gait pattern.
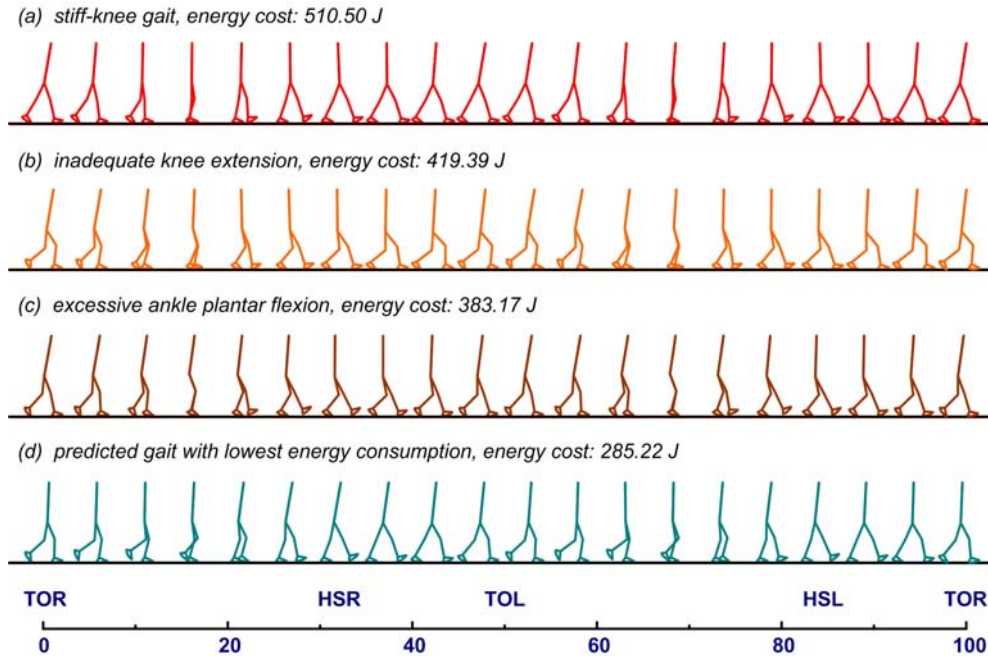

Figure 2: Some typical optimization results (local minima)

Quantitative comparisons of predicted gait data with gait measurements show that the model reproduced the significant characteristics of normal gait in the sagittal plane (Figure 3). The simulation results suggest that minimising energy expenditure is a primary control objective in normal walking. However, there is also some evidence for the existence of multiple concurrent performance objectives.
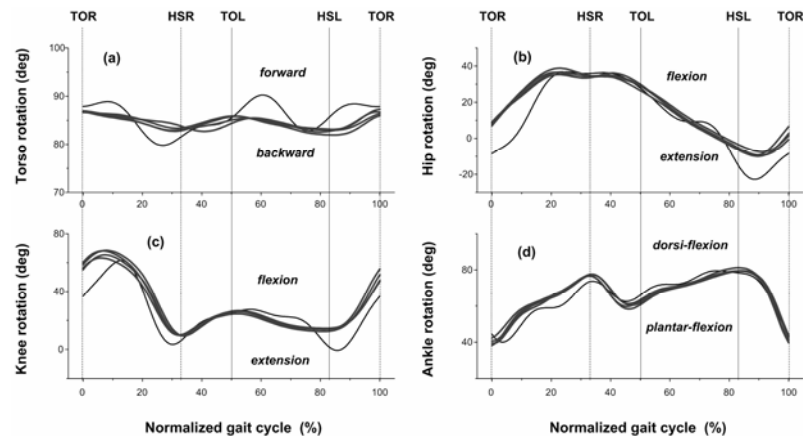

Figure 3: Comparison of predicted (single line) and experimental (set of 4 lines)

References
1. Pandy MG., *Annu. Rev. Biomed. Eng.,* 3, 245–273, 2001.
2. Ren L., Jones R. and Howard D., *J.Biomech.,* 40 (2007) 1567–1574.