A New Lower Body Model using Global Optimisation Techniques

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Introduction

It is now more than ten years since the Davis/Kadaba (DK) gait model for the lower body was published [1] [2]. Since then it has gained almost universal acceptance in the gait community as the "standard" model for calculating joint kinematics and kinetics. However, the anthropometric method of establishing the location of the joint centres has been questioned, some papers claiming that the modelled hip joint centres could be misplaced by as much as 40 millimetres compared to their real locations [4]. Also, the model is very reliant on accurate marker placement on bony landmarks. We have developed a new model, OLGA (Optimised Lower-limb Gait Analysis), which globally optimises joint centre locations and segment orientations using data from the entire walking trial instead of basing the estimation of centres on vector algebra on a frame by frame basis which is the case for the DK model.

The Model

The mathematics used in OLGA's algorithms is very complex and it is beyond the scope of this paper to present the model in any mathematical detail. This paper describes the concepts of the model only.

Many people who have tried to locally or globally optimise joint centre locations have found that the final estimates end up being very unreliable [3] [5]. One major aim of OLGA is to obtain repeatable and reliable results.

Furthermore, any model which aims to replace the current standard model will always need to produce equivalent or more accurate results regardless of the patient's pathology. A fundamental concept of the new model is that the DK model will be used to establish the starting point for an iterative procedure which will only improve the joint centre locations and segment orientations if it can reliably do so.

The method used by OLGA to determine data quality relies on the movement measured by the DK model. It is assumed that the DK model provides a reasonable estimate of the range of movement for the different segments. This estimate is used to establish a confidence measure for the quality of the measured marker data. In other words, the outputs from the DK model are used to weigh the input marker data.

All this information is used by the optimisation algorithm to establish confidence ellipsoids around its globally optimised joint centre positions. The confidence ellipsoid indicates how certain the model is that a joint centre location has been iteratively improved. Along with the segment orientations and joint centre locations, this is an output of the model.

Finally it should be pointed out what global optimisation in OLGA's context means. Instead of trying to improve the positions of the joint centres separately, the algorithm looks at the lower body structure as a whole and will therefore optimise all the lower limb joint centre positions as part of the same iterative procedure, subject to different constraints for the different joint types. Furthermore, the model's marker set is very flexible so that additional markers can be added to aid tracking and improve accuracy.

Methodology and Results

We processed several trials from three different subjects, two normal and one pathological, through the Vicon Plug-in Gait implementation of the DK model as well as through OLGA. We chose to concentrate on the hip joint centres initially as these are very close to mathematical ball-and-socket joints. All the trials were captured with the standard DK model marker set, and we chose the distance between the calculated hip joint centre and the knee marker as an indication of the quality of the modelled hip joint centre location. The knee marker, when accurately placed, will experience less skin movement than other markers and will thus remain fairly equidistant from the hip joint centre.

The following table contains the results. The measurements are in millimetres and are from a typical trial for each subject.

	DK Left	DK Right	OLGA Left	OLGA Right
Normal Subject 1	412.8±4.9	412.7±5.6	409.0±2.6	408.9±2.2
Normal Subject 2	396.6±5.6	397.5±4.2	386.8±2.2	387.4±1.6
Pathological Subject	300.1±2.2	286.2±3.6	292.1±1.3	277.7±2.2

The results show a significant decrease in the standard deviation when processed with OLGA, which indicates a more accurately modelled hip joint centre. The repeatability for the same-subject trials was very good, and all processed trials showed similar results to the ones above.

Discussion

The initial version of OLGA has been completed, but we still intend to develop and improve it further to make sure that all the goals are met. Once development has been completed, the next steps are testing and validation. First, the finished model needs to be tested on a variety of normal and pathological gait trials so that we can get an indication as to whether the model works reliably and whether it really does output more accurate results than the DK model. After that, the intention is to collaborate with independent gait labs in order to clinically validate the model.

References

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