Automated Markerless Analysis of Human Walking and Running by Computer Vision

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Introduction

Very often, analysis of gait kinematics exploits invasive data acquisition techniques, e.g. attaching a goniometer and accelerometer, using a multiple exposure camera technique [Murray67] with reflective, and markers [O'Malley93] on the subject's body. These can be expensive, laborious and inconvenient. More importantly they encumber the natural manner of walking and running. Human walking and running is a highly sophisticated system involving multiple factors interacting simultaneously. Naturally, it is difficult to model human locomotion realistically. A considerable amount of work (in biomechanics) seeks to model human walking [Mochan80], running [McGeer90] or both [Alexander92] aiming to understand or explain the mechanism underlying these movements, but not for realistic modelling or imitation.

We have developed an automated non-contact and markerless analysis system using computer vision techniques. A structural motion model derived from forced coupled oscillators, which can describe the spatio-temporal characteristics of human running and walking gaits [Yam02], serves as the basis of an evidence gathering technique used to extract leg motion. Naturally, concern over marker movement is now replaced by concern of the features extracted. In this respect, evidence gathering approaches have known optimal performance, especially in respect of noise and occlusion.

Method

The fronto-parallel views of 20 healthy subjects (5 females and 15 males, age:22-45, weight:45-100kg, height:156-192cm) walking (2.8-5.5km/h) and running (6.5-13.9km/h) normally on a treadmill at their preferred speeds are filmed with a digital camera. The video clips are digitised into image files. Edge maps are obtained via the Sobel edge detector. Temporal template matching that considers the whole sequence of edge maps is applied to extract the motion of a whole gait cycle. The structural motion model serves as the basis of this evidence gathering technique. The length of the thigh and lower leg, their absolute rotation angles and the hip's motion can be extracted and computed simultaneously. These measurements can then be used for further analysis. The process is automatic following pre-selection of some control parameters.

Results and Discussions

Fig. 1 shows the extracted rotation angles of a subject's thigh (when walking) and lower leg (when running) superimposed on manually labelled data. The gross motions are captured well and appear very close to the manual labelled data which could however be erroneous. **Fig. 2a** shows an image with the extracted motion superimposed. This technique extracts the front of the legs and we shall later determine its relationship to the conventional labelling on the bone structure. Due to temporal (1/2 period) and spatial (sequence of oscillation) symmetry, this technique can extract both legs, and hence handle self-occlusion. Here, only the thigh and lower leg rotation are considered, with potential extension to ankle rotation.

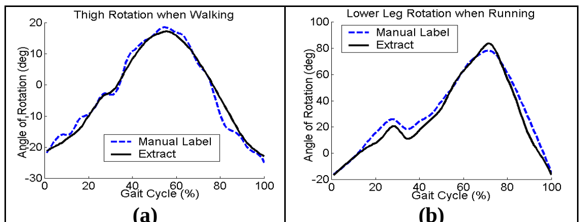

Fig. 1: Automatically extracted absolute angles of (a) thigh when walking and (b) lower leg when running.

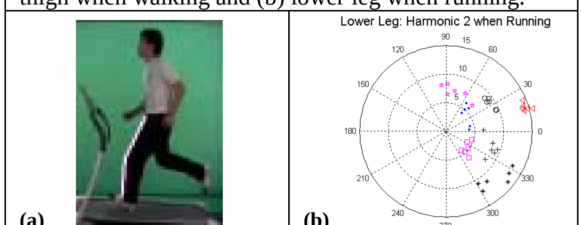

Fig. 2: (a) Automatically extracted leg motion; (b) phasor plot of lower leg rotation when running; different symbols represent different subjects.

Fig. 2b shows the 2nd harmonic Fourier description for lower leg motion. It suggests individuality, in that people's movement clusters in different places. Experimentation shows that running actually has more variability than walking. The capability to extract individual characteristics in gait patterns suggests that it is indeed appropriate for future investigation in analysis of gait biomechanics. This non-contact, markerless and automated feature extraction process is invariant to gait mode (walking or running) and speed, so is feasible for analysis, especially with a large subject population.

References

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