Automated Non-Invasive Human Locomotion Extraction Invariant to Camera Sagittal View

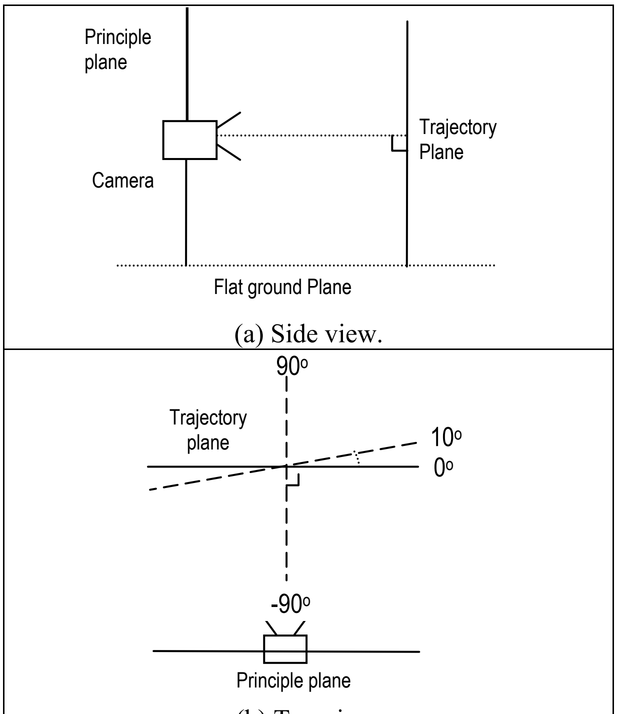
ChewYean Yam, Mark S. Nixon
Image, Speech and Intelligent System,
Electronics and Computer Science,
University of Southampton, U.K.
{cyy99r|msn}@ecs.soton.ac.uk

Introduction

Usually, gait analysis involves invasive methods during data acquisition such as attaching a goniometer or an accelerator, or using markers [1] to aid angular motion extraction. Attaching gadgets and complex wiring may encumber the natural manner of a person locomotion. Furthermore, some methods are not highly automated and introduce high cost of operation. There exists many models for human locomotion [2,3], however, they are mainly used for understanding or explaining the underlying mechanics. Also, there are many extraction techniques available, but not many are model-based. The advantages of model-based approach is that it can handle occlusion such as when one leg is occluding the other or by the bars on the treadmill, a commonly used instrument in human gait analysis. We have introduced a non-invasive method in acquiring the angular motion of the legs via motion models invariant to human walking and running gait [4], and now we are extending the technique to include trajectory invariance. This technique which originally used as the basis of a biometrics approach [5] includes the motion models for the hip, thigh and lower leg, and may be deployed for clinical applications.

Methods

The database consist of a series of synthesized human walking at various camera sagittal angles, which effectively is the trajectory angle ranging from -90° to 90° at every 10°. Figure (1) shows the setup of the camera and various planes. Motion generated by this in-house synthesizer is based on real life 3-D motion data of a subject. We have assumed that the subject is walking on a flat ground plane. Then the angle of rotation projected on the principle plane are extracted via an evidence gathering technique consisting of two phases. The first is a *temporal evidence gathering* aiming to search for the best parameters of the gross motion whilst the second stage is *local evidence gathering* aiming to extract the deviations from one's unique norm, yield precise angles of rotation in each image frame. This technique can simultaneously extract the hip, thigh, lower leg rotation and the length of each segments of the lower limb, which can in turn be used for gait analysis. This process is automatic following pre-selection of some parameters for initialisation.



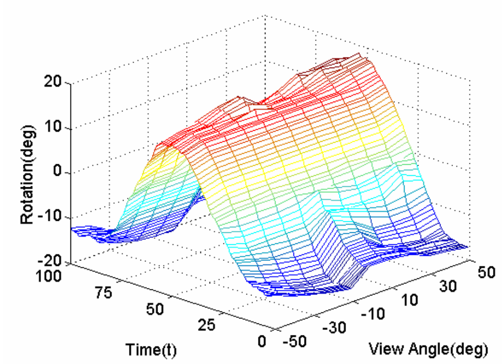
(a) Side view.

(b) Top view.

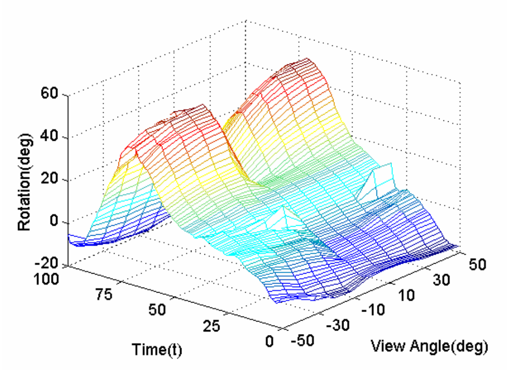
Figure (1): Setup of the camera and various planes.

Results

This feature extraction technique can precisely extract the motion for trajectory angle ranges from -50° to 50° without any parameter adjustment, but started to deteriorate when the angle gets larger. Figure (2) illustrates the automatic extraction results for the absolute angles of rotation projected on the principle plane when the synthesized human walks at various trajectory angles. Notice that the graphs changes smoothly and is symmetric at sagittal view angle = 0°.



(a) Thigh rotation.



(b) Lower leg rotation.

Figure (2): Absolute angles for the thigh and the lower leg rotation when walking at trajectory angle ranging from -50° to 50°.

Figure (3) shows the Fourier magnitude spectrum of the thigh and knee rotation extracted from various trajectory angles. The zero term harmonic is omitted as it is merely an offset. The pure dynamic of these motions are of our interest. The first harmonic of the thigh rotation and the first two harmonics of the lower leg rotation change in a linearly fashion of a sinusoidal function with the trajectory angles. The pattern is symmetric at sagittal view angle = 0°. However, the higher harmonics are of relatively small magnitude and does not follow the pattern of the lower harmonics, this is because they are mainly dominated by noise.

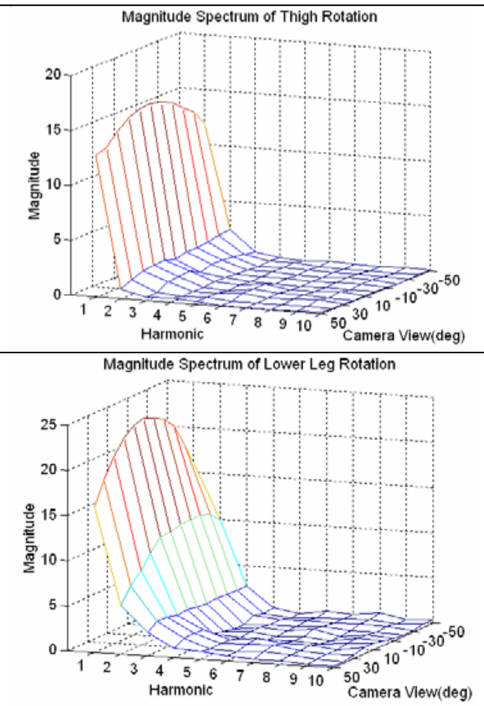


Figure (3): Magnitude spectrum for the thigh and the lower leg rotation when walking at trajectory angle ranging from -50° to 50°.

Figure (4) shows the phasor diagram of the first three harmonics of the thigh and lower leg rotation. Interestingly, the phase change pattern is also symmetry at 0°. The arrow represents the direction of phase change with trajectory angle ranging from -50° to 50° and the direction of change turns at when sagittal angle = 0°. The variation in magnitude is mainly due to the trajectory angle. Nonetheless, the variation in phase may be due to both volumetric and dynamic factors. Because this is a 2-D extraction technique and human motion is a matter of 3-D, (in fact 4-D when time is taken into account) and the hip's transversal rotation may cast an effect on the angles of motion projected on the principle plane.

The linear relationship of the magnitude spectrum and the camera sagittal view angle can be exploited conveniently in making the angular motion invariant to camera sagittal view. In other words, angular motion extracted from various trajectory angle can be mapped to the true angular motion, i.e. sagittal angle = 0° for the convenience of gait analysis, by their linear relationship. Although the phase spectrum shows similar trend, however due to the inadequacy of real life data, a precise structure is difficult to draw. Hence, a more precise model for the magnitude, phase and trajectory angle relationship shall be investigated further.

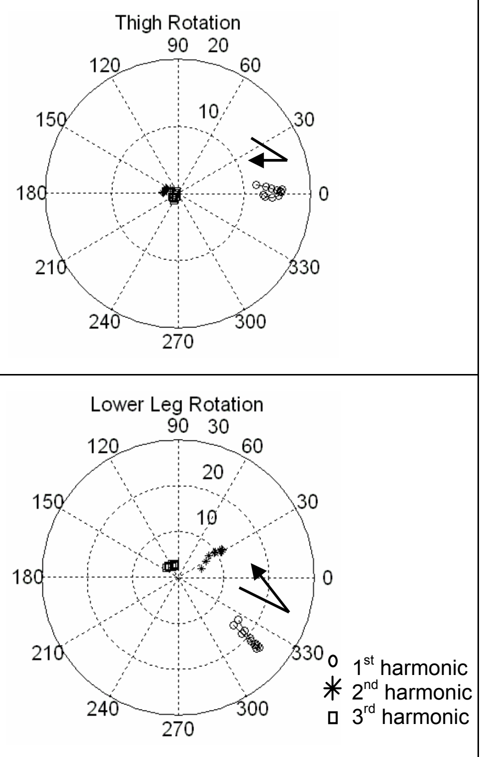


Figure (4): Phasor diagram for the phase and magnitude with trajectory angle ranging from -50° to 50°.

References

[1] Murray, M.P., *American J. of Phy. Med.* **46**, 290-332, 1967. [2] Alexander, R.M., *Phil. Trans. R. Soc. London.* **338**, 189-198, 1992. [3] Mochan, S. et al, *Math. BioSc.* **52**, 241-260, 1980. [4] Yam, C.-Y. et al, "Automated Markerless Analysis of Human Walking and Running by Computer Vision", *4th World Congress Biomechanics*, 2002. [5] Yam, C.-Y. et al, "Gait Recognition by Walking and Running: A Model-based Approach", *5th Asian Conference on Computer Vision*, pp 1-6, 2002.