

NUMERICAL APPROACH TO SKIN ARTIFACTS CORRECTION IN STEREOPHOTOGRAMMETRY

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INTRODUCTION

Stereophotogrammetry represents one of the most useful tools for reconstruction of human movement body kinematics in several areas including rehabilitation, mobility assessment sport performance analysis and computer animation. However estimation of bone segment movement is corrupted by experimental errors that have been studied by many authors [Cappozzo 1996, Fuller 1997, Sati 1996]. They are mainly due to: i) marker position reconstruction, ii) calibration errors and iii) skin artifacts due to relative movement of skin markers and bone. This last factor is relatively more important than the two others which are also more repeatable and subject invariant. The present work deals with the correction of skin artifact in the acquisition of thigh kinematics i.e. location in space of femoral segment. The analyzed movement is a hip flexion-extension. The knee is held fully extended in order to permit the use of articular skin marker as reference. A numerical simulation through Finite Elements method is used to identify more promising regions for markers placement in the thigh. Numerical algorithms and in particular a Kalman smoothing filter are employed to improve measurement precision and accuracy.

METHODS

We have first identified the best region on the thigh for skin markers positioning (i.e. minimal skin stretching during hip joint

movements) by FEM numerical simulation. Bony parts are assumed to be rigid while thigh soft tissue nonlinear elastic. The subject previously acquired kinematics is used as dynamic load applied in the simulation to bony segments, obtaining as output the deformation of thigh soft tissue. This allowed the identification of a region in the central part of the thigh in which skin stretching is minimal during flexion-extension movement of hip joint. Once acquisition protocol and marker position on the thigh (firstly, a grid of 8 markers, then reduced to 4) are defined, several motor acts are acquired on three different subjects. The hip joint center is identified with functional method [Stagni 2000, Leardini 1999, Camomilla 2002]. The acquisition of femur movement using articular skin markers (anatomical landmarks are lateral and medial epicondyles) can be considered as reference movement because the knee is maintained fully extended during motor act. The movement of femoral segment obtained from grid markers placed on the thigh skin is compared with the reference frame. Once the former is properly corrected to adhere with the latter, it can be used also for more general movement because perturbations on markers grid on the thigh due to knee flexion is negligible. Correction algorithms utilize geometric constraints to make the movement of grid markers frame the more similar to the reference one. Adopted constraints are the mutual distance of the markers from each other and the distance of them from the hip joint center (HJC) previously identified. The

optimal corrected position of the grid markers in relation to experimentally acquired data is found by minimizing a cost function. Once the optimal position of the 4 grid markers is identified, it is used to estimate useful reference point on the femur (e.g. LE-ME intermediate point). The point trajectory is finally reconstructed by employing a Kalman smoothing filter [Kitagawa 1985] containing unknown parameters that are estimated via a maximum likelihood strategy.

RESULTS AND DISCUSSION

The efficacy of skin artifact correction algorithm goes from about 45% reduction in the vertical direction to only about 5% in the mediolateral direction (pelvic bone-embedded anatomical frame is used). The most important consequence of the use of this protocol is that errors will remain of the same magnitude once the movement start varying, e.g. during gait analysis, because knee flexion doesn't affect thigh markers data as occurs for articular markers.

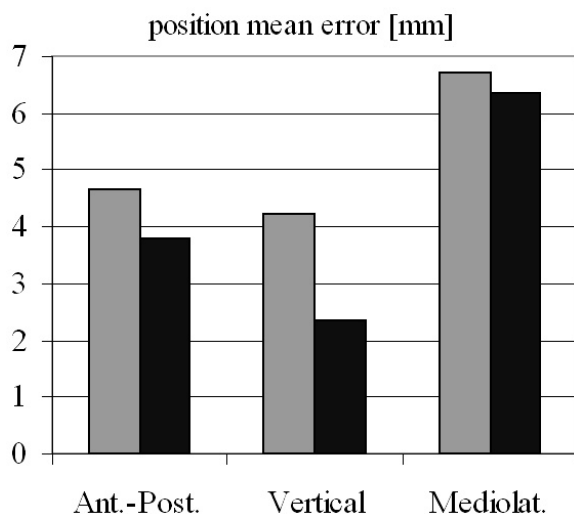


Figure 1: Mean position error for the 4 markers of the grid before (gray) and after (black) the use of correction algorithm.

The smoothing algorithm gives a further improvement of trajectory data quality and estimates the measurement standard deviation through maximum likelihood algorithm.

SUMMARY

A new approach for correction of thigh skin artifacts has been proposed, based on numerical methods that involve both geometrical constraints and statistical approaches. An acquisition protocol is formulated that guarantees smaller artifact errors. Moreover these errors are much less correlated with lower limb joints angles.

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ACKNOWLEDGEMENTS

Authors want to thank Prof. Aurelio Cappozzo for the precious help and eMotion company for supporting the research.