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Review

Human movement analysis using stereophotogrammetry Part 3. Soft tissue artifact assessment and compensation

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Abstract

When using optoelectronic stereophotogrammetry, skin deformation and displacement causes marker movement with respect to the underlying bone. This movement represents an artifact, which affects the estimation of the skeletal system kinematics, and is regarded as the most critical source of error in human movement analysis. A comprehensive review of the state-of-the-art for assessment, minimization and compensation of the soft tissue artifact (STA) is provided. It has been shown that STA is greater than the instrumental error associated with stereophotogrammetry, has a frequency content similar to the actual bone movement, is task dependent and not reproducible among subjects and, of lower limb segments, is greatest at the thigh. It has been shown that in in vivo experiments only motion about the flexion/extension axis of the hip, knees and ankles can be determined reliably. Motion about other axes at those joints should be regarded with much more caution as this artifact produces spurious effects with magnitudes comparable to the amount of motion actually occurring in those joints. Techniques designed to minimize the contribution of and compensate for the effects of this artifact can be divided up into those which model the skin surface and those which include joint motion constraints. Despite the numerous solutions proposed, the objective of reliable estimation of 3D skeletal system kinematics using skin markers has not yet been satisfactorily achieved and greatly limits the contribution of human movement analysis to clinical practice and biomechanical research. For STA to be compensated for effectively, it is here suggested that either its subject-specific pattern is assessed by ad hoc exercises or it is characterized from a large series of measurements on different subject populations. Alternatively, inclusion of joint constraints into a more general STA minimization approach may provide an acceptable solution.

Keywords: Human movement analysis; Experiments; Soft tissue artifacts; Minimization; Compensation

1. Introduction

The fundamental role of human movement analysis in the advancement of the understanding of musculo-skeletal system physiopathology is well established [1], and the utilization of this technique continues to flourish. However, there are limitations due to limited awareness of the methodological fundamentals and experimental inaccuracies associated with the instrumentation examining a biological system. The present paper is the third in a series of articles addressing the major issues concerning the reconstruction of human skeletal system 3D kinematics when analyzed using optoelectronic stereophotogrammetry, by far the most widespread technique used. The series is aimed at enhancing the comprehension of the fundamentals of human movement analysis techniques and its concomitant problems.

The first article in this series [2] provided the necessary theoretical bases for the description of human movement, and suggestions for appropriate terminology. The second [3] reported on the instrumental errors associated with any stereophotogrammetric system and on the analytical and technical procedures necessary to cope with this source of inaccuracy. In this article, where rigidity of the body

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