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Markerless analysis of front crawl swimming

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ABSTRACT

Research on motion analysis of swimmers is commonly based on video recordings of the subject's motion, which are analyzed by manual digitization of feature points by an operator.

This procedure has two main drawbacks: it is time-consuming, and it is affected by low repeatability. Therefore, the application of video-based, automatic approaches to motion analysis was investigated. A video-based, markerless system for the analysis of arm movements during front crawl swimming was developed. The method proposed by Corazza et al. (2010) was modified in order to be used into water environment. Three dimensional coordinates of shoulder, elbow and wrist joints centers of 5 sprint swimmers performing front crawl swimming were determined. Wrist joint velocity was also calculated. Accuracy and reliability of the proposed technique were evaluated by means of comparison with traditional manual digitization (SIMI Reality Motion Systems GmbH). Root mean square distance (RMSD) values between trajectories estimated with the two techniques were determined. Results show good accuracy for wrist joint (RMSD < 56 mm), and reliability, evaluated on one subject, comparable to the inter-operator variability associated with the manual digitization procedure. The proposed technique is therefore very promising for quantitative, wide-scale studies on swimmers' motion.

1. Introduction

Analysis of swimmers' kinematics is a challenging problem in the field of sports biomechanics because of the difficult experimental conditions that affect the setup of motion capture devices.

The presence of water and the limited space available in swimming pools are some of the factors that hinder the use of electronic devices. For example, commercial stereophotogrammetric systems that employ reflective markers cannot be adopted. Hence, research on motion analysis of swimmers is commonly based on video recordings of the subject's motion. 2D analyses require a single camera; points of interest are digitized on each video and analysis of movement on the sagittal plane is performed (Holthe and McLean, 2001). Since the motion in front-crawl swimming occurs on different planes (Schleihauf et al., 1983), for a descriptive analysis of three-dimensional (3D) motion a multi-camera setup is needed, which requires not only calibration, but also synchronization of the cameras. These procedures are hindered by the underwater experimental environment (Gourgoulis et al., 2008): refraction of light rays causes image deformations, yielding to lower accuracy, and the equipment must comply with safety regulations. Furthermore, videos are analyzed by manual digitization of feature points on all images, which may correspond to either visual markers drawn on the subject or crucial points, such as joint centers, identified by the operator. This procedure has two main drawbacks: it is time-consuming and can easily lead to misidentification of features, especially when a large number of points are involved. Recently, the adoption of markers constituted of Light Emitting Diodes has been introduced (Slawson et al., 2010). These allow to automate the tracking process, but investigation so far has only regarded identification of areas instead of single points, and motion on the sagittal plane. Alternative approaches based on accelerometric sensing units have also been adopted (Ohgi, 2002; Slawson et al., 2008; Callaway et al., 2009). This technology is relatively cheap and provides higher sampling rates; however, processing and interpretation of measured data is not straight-forward. Furthermore, sensing units may encumber the subject, which hinders their application for analysis of swimmers' performances during competitions.

In this context, the application of video-based, markerless approaches to motion analysis were investigated (Sigal and Black,

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