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Short communication

An algorithm to correct for camera vibrations in optical motion tracking systems

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ABSTRACT

Recording and reconstruction of 3D motion capturing data relies on fixed, static camera positions with given inter-camera distances in a laboratory frame. To overcome this limitation, we present a correction algorithm that allows us to address camera movements in moving camera setups. Camera vibrations are identified by comparison of specialized target positions in dynamic measurements with their respective positions in static trials. This results in a 2D shift vector $\Delta\vec{w}$ with which the individual camera streams are corrected. The capabilities of this vibration reduction procedure are demonstrated in a test setup of four cameras that are (i) separately and (ii) simultaneously perturbed while capturing a static test object. In the former case, the correction algorithm is capable of reducing the reconstruction residuals to the order of the calibrations residual and enables reconstruction in the latter case, which is impossible without any correction. This approach extends the application of marker-based infrared motion tracking to moving and even accelerated camera setups.

1. Introduction

Optical systems form one group of human movement measuring devices and have been successfully used over the last three decades (Barris and Button, 2008). One subgroup of such systems uses reflective markers that are illuminated by infrared strobes and recorded by infrared cameras. The cameras are typically mounted and calibrated in a static setting, which is perfectly suited for many biomechanical applications. Recently, other approaches with comoving camera setups have been explored by Begon et al. (2009) and Kim and Martin (2010). While the former allowed to study walking at constant velocity over a distance of 40 m without a treadmill, the latter approach allowed to disentangle a person's (reaching) movements from the movement of a shaking environment.

By design infrared-based motion tracking systems discriminate visible marker regions against the remaining field-of-view, yielding either black-and-white or greyscale images. Numerous algorithms for the identification of motion in video sequences are available (Srinivasan et al., 1997), many of them are based on the characteristics of the optical flow field or corresponding points in images. However, determination of camera motion relies on image background information, which is suppressed in the aforementioned infrared-systems.

An ideal comoving camera setup has perfectly rigid camera mountings. In this work we present a procedure to identify and correct for artifacts that occur in non-ideal moving (including accelerated) camera setups, where rotations/vibrations do occur. Possible applications include studies of passengers in vehicles with attached cameras or extending rolling camera constructions moved alongside a performing athlete (Begon et al., 2009) to less-ideal situations.

2. Method

2.1. Projective geometry and homogeneous coordinates

Recording of images using a camera can be mathematically described using projective geometry (e.g., Hartley and Zisserman, 2004). A vector $\vec{x}$ in Euclidean space can be described using homogeneous coordinates:

$$(\vec{x}\ |\ 1)^T = (x_1\ x_2\ x_3\ |\ 1)^T, \tag{1}$$

where the last row of the vector always equals 1. A camera with focal length f and camera matrix $\mathbf{C}$ projects $\vec{x}$ to a vector $\vec{w}$ in the image plane,

$$\begin{pmatrix} \vec{w} \\ \hline 1 \end{pmatrix} = \begin{pmatrix} w_1 \\ w_2 \\ \hline 1 \end{pmatrix} = \sigma \mathbf{C} \begin{pmatrix} \vec{x} \\ \hline 1 \end{pmatrix} = \sigma \begin{pmatrix} x_1 \\ x_2 \\ \hline \frac{x_3}{f} \end{pmatrix} = \begin{pmatrix} f\,u_1 \\ f\,u_2 \\ \hline 1 \end{pmatrix} \tag{2}$$

with

$$\sigma = \frac{f}{x_3}, \quad \mathbf{C} = \left(\begin{array}{ccc|c} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \frac{1}{f} & 0 \end{array}\right) \quad \text{and} \quad u_{1,2} = \frac{x_{1,2}}{x_3},$$

where σ is chosen to ensure $\vec{w}$ is in homogeneous coordinates.

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