A Computer-Vision Based Apparatus For The Measurement of Planar Movement : An Application in physiotherapy.

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Abstract

The purpose of this paper is to present a computer vision-based apparatus designed for gait analysis of subjects. Under control of a host computer, the system digitizes a standard video signal and extracts the center of gravity of several markers placed on the subject's lower limbs (leg, knee, ankle, foot). It computes the distance between markers in "world coordinates" for all sampled image frames. The markers' space coordinate vs time data are useful to the physiotherapist who can use them to compute various motion parameters of the subject's limbs such as displacement, speed and acceleration. The error made on the measurements is less than 5 % for displacements of 5 cm with the camera 4 meters away from the patient. The main contribution of this work is to provide a low-cost yet easy to use and flexible motion data acquisition apparatus for clinical research in physiotherapy. Furthermore, the architecture of the system permits easy interfacing with various host personal computers.

Résumé

Ce travail présente un appareil de vision par ordinateur conçu pour faciliter l'étude du mouvement de patients en physiothérapie. L'appareil, sous la commande d'un ordinateur hôte, numérise le signal provenant d'une caméra vidéo et calcule le centre de gravité de marqueurs réfléchissants placés sur les membres inférieurs (jambe, genou, cheville, pied) du sujet. Les coordonnées des marqueurs dans l'espace tridimensionnel en fonction du temps sont ensuite calculées en utilisant les centres de gravité trouvés précédemment et en se basant sur la géométrie du système. La connaissance de l'évolution temporelle de ces coordonnées spatiales est utile au physiothérapeute qui peut calculer des paramètres objectifs d'analyse du mouvement tels le déplacement, la vitesse et l'accélération des parties de membre associées au marqueurs. Les coordonnées spatiales calculées par l'appareil montrent une précision de 5% sur des déplacements de 5 cm lorsque les marqueurs réfléchissants sont placés à une distance de travail de 4 m. Le principal apport de ce travail est qu'il fournit au physiothérapeute un outil flexible, peu coûteux et simple d'usage pour la recherche clinique. De plus, l'appareil dont il est question peut être interfacé facilement à plusieurs types d'ordinateurs personnels à un coût très raisonnable et sans subir de modifications majeures.

Keywords

Hardware implementation, motion analysis, biomedical application, moving light displays, vision in physiotherapy.

I- Introduction

Gait analysis is a wide research area in physiotherapy. A major problem in this field is the extraction of motion parameters such as the position of a patient's lower limbs during walk. The principal objectives of this project were to design a low-cost yet easy-to-use and flexible gait analysis system based on video information that could be interfaced to a standard microcomputer. A premium requirement was that the system should not interfere with other sensors already interfaced to the microcomputer (force plate, electrodes, etc).

The physiotherapy literature reveals that goniometers [1-5] (which give angles between segments), force plates (measuring force applied to the ground) and electromyographic signals (monitoring muscular electrical activity) are commonly used in such analysis. However, the problem with these devices is that they give no explicit information on the position of the subject in space and time. A cine-camera [7-11] can be used to obtain spatio-temporal information on the subject but the extraction of meaningful parameters from the film and their combination with data from other sources is time consuming and prone to error since it is often done manually. More recent systems rely on a tv-camera and on video processing hardware [12-13] to extract the motion parameters in real-time. The camera looks at reflective markers placed on the subject's limbs. Some systems, dedicated to the motion analysis of athletes, use sophisticated and expensive hardware while others use an approach that requires a large video buffer memory and important video post-processing.

The computer vision literature proposes a wide range of approaches for motion analysis such as optical flow techniques [14-15] and range from stereo [16]. For an overview of several techniques for range acquisition, see [17]. The extraction of range from texture [18] and motion from texture changes vs time is also of interest. Despite their wide use in general computer vision problems, these approaches require, in most cases, a large amount of processing time and powerful computer resources (see [16] for stereo vision and [19]-[21] for texture analysis). For these reasons, they are not suitable for the present clinical application in physiotherapy.

A paper by Roach *et al.* [22] addresses the problem of determining the general 3D movement (translation and rotation) of an object from a sequence of images. However, the assumption is made that the images are pre-segmented and that the same set of feature points on the object is available in each image of the sequence.

The work of Raschid [23] on moving light displays (MLD) presents the perceptual aspects of the interpretation of motion by humans when the subjects are shown a set of moving light markers of objects against a stationary background. The problem of MLD interpretation is decomposed into three principal tasks: *i)* the search for correspondence between light