

Tracking of Markers for 2D and 3D Gait Analysis Using Home Video Cameras

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ABSTRACT

This work presents the development of an affordable optical motion-capture system which uses home video cameras for 2D and 3D gait analysis. The 2D gait analyzer system consists of one camcorder and one PC while the 3D gait analyzer system uses two camcorders, a flash and two PCs. Both systems make use of 25 fps camcorder, LED markers and technical computing software to track motions of markers attached to human body during walking. In the experiment for 3D gait analyzer system, the two cameras are synchronized by using flash. The recorded videos for both systems are extracted into frames and then converted into binary images, and bridge morphological operation is applied for unconnected pixel to facilitate marker detection process. Least distance method is then employed to track the markers motions, and 3D Direct Linear Transformation is used to reconstruct 3D markers positions. The correlation between length in pixel and in the real world resulted from calibration process is used to reconstruct 2D markers positions. To evaluate the reliability of the 2D and 3D optical motion-capture system developed in the present work, spatio-temporal and kinematics parameters calculated from the obtained markers positions are qualitatively compared with the ones from literature, and the results show good compatibility.

Keywords: *2D Gait Analysis, 3D Direct Linear Transformation, 3D Gait Analysis, Camera Synchronization, Home Video Camera, Image Processing, Least Distance Method*

INTRODUCTION

Human gait analysis has been widely employed in many areas of application such as in sport, medical rehabilitation, and even in product design (Whittle, 2007; Winter, 2009; Perry, 1992; Medved, 2001; Huston, 2009). In the field of human motion study, optical-based motion analyzer systems have been widely used, most notably in gait analysis for medical rehabilitation purposes (Medved, 2001) where it can be used to monitor a patient's response during medical rehabilitation. Gait parameters, such as step length, cadence, cycle time, stance time, speed), of a patient could be observed and analyzed to indicate whether improvement or deterioration has taken place. These parameters could also be compared against sex- and age-matched normal population distributions to determine whether the patient is approaching normal performance (Bohannon, 1988; Himann, et al., 1988; Ostrosky, et al., 1994). It is also reported that a knowledge of the expected changes in joint angle allow therapists to better understand a patient's gait pathology (Stanic, et al. 1977; Rancho Los Amigos Research Centre, 1989; Brandstater, et al., 1983; Olney, et al., 1991; Steadman, et al., 1997).

In general, human gait could be measured by direct measurement techniques and also imaging (optical) measurement techniques. Examples of direct measurement techniques include goniometry, accelerometers, foot-switches and others. However, direct measurement techniques are sometimes inaccurate and do not provide information with adequate details. The main problem in direct measurement techniques is subject has to carry many cables or other components that could affects walking motion (Winter, 2009). Most of the problems encountered by direct measurement techniques could be overcome by imaging (optical) measurement techniques. A variety of automatic visual measurement technique have been developed using special purpose hardware. This involves placing active and passive markers on different joints of the subject under consideration (Orr, 1997). The only

system that can capture all the motion data is an imaging system due to complexity of most walking movements (Winter, 2009).

At present, many commercial camera-based motions capture for both *2D* and *3D* gait analyzer systems are available. In such systems, the cameras send out infrared light signals and detect the reflection from the markers attached on the body. The measurement is based on the angle and time delay between the original and reflected signal, which make triangulation of the marker in space is possible. The sampling rates of such systems can be as high as 1000 Hz, although typically most systems operate in the range of 60–250 Hz. These systems are highly accurate, and often locating a marker to within 1 mm, having less than 1 mm of error (Richards, 1999). However such benefits come at a price and may not within the budget of most hospitals, especially in Indonesia.

As alternative to the above system, inexpensive quantitative methods based on video technology and personal computers are available such as ones reported in (Wall & Crosbie, 1997; Stillman & McMeeken, 1996). To overcome the lack of system availability in Indonesia, a series of research on the development of affordable *2D* and *3D* optical motion analyzer system has been conducted in Faculty of Mechanical and Aerospace Engineering, Institut Teknologi Bandung (FMAE-ITB), Indonesia.

Recently, the authors have developed an affordable system for *2D* kinematics and kinetic analyses of human gait (Mahyuddin, et al., 2010) by using a 25 *fps* home video recorder. The system is further improved to overcome the occlusion problem of markers (Juliyad, et al., 2010) and has been successfully used to determine *2D* gait parameters of Indonesian people as an effort to develop the first Indonesian gait database (Mahyuddin, et al., 2011; Maulido, 2011). However, information obtained from *2D* measurement, i.e. in sagittal plane, is not as much as information obtained from *3D* measurement. Although the sagittal plane is probably the most important one, where much of the movement parameters could be observed, there are certain gait pathologies where another

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