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QUANTITATIVE ASSESSMENT OF HUMAN MOTION USING VIDEO MOTION ANALYSIS

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INTRODUCTION

In the study of the dynamics and kinematics of the human body a wide variety of technologies has been developed. Photogrammetric techniques are well documented and are known to provide reliable positional data from recorded images. Often these techniques are used in conjunction with cinematography and videography for analysis of planar motion, and to a lesser degree three-dimensional motion. Cinematography has been the most widely used medium for movement analysis. Excessive operating costs and the lag time required for film development, coupled with recent advances in video technology, have allowed video based motion analysis systems to emerge as a cost effective method of collecting and analyzing human movement. The Anthropometric and Biomechanics Lab at Johnson Space Center utilizes the video based Ariel Performance Analysis System to develop data on shirtsleeved and space-suited human performance in order to plan efficient on-orbit intravehicular and extravehicular activities.

VIDEO BASED MOTION ANALYSIS

The Ariel Performance Analysis System (APAS) is a fully integrated system of hardware and software for biomechanics and the analysis of human performance and generalized motion measurement. Major components of the complete system include the video system, the AT compatible computer, and the proprietary software.

VIDEO SUBSYSTEM

The video system consists of commercial quality 112-inch VHS format portable video cameras. They are used to record motion sequences for subsequent analysis. A minimum of two cameras are required for full three-dimensional analysis. A high quality VCR and monitor are used for the display and digitizing of videotaped sequences. The playback unit accommodates standard VHS videotapes recorded from any standard video source to allow high precision freeze-frame video imaging with accurate single frame advance and reverse as well as a variable speed search capability.

HARDWARE SUBSYSTEM

An AT compatible computer is the primary component of the analysis system. The computer uses a combination of a frame grabber and a VCR controller board to digitize from the playback unit. The APAS captures video images from video tape and imports them into the computer memory. The operator can then digitize the desired sequence by positioning a cross-hair cursor over the joint center of interest and recording the coordinates of this point by pressing a button on the mouse. Digitization of the joints on the first frame is performed completely by the operator. For subsequent frames, the point locations from previous frames are used to predict the positions of each point on the current frame. This significantly reduces the time required to digitize a sequence. Additionally, since the computer stores a digital image, the analysis frame can be contrasted, enhanced, or filtered for clarification.

SOFTWARE SUBSYSTEM

An extensive integrated software package makes up the third component of the APAS. For ease of operation, the software has been highly structured and modularized. Each module is designed to perform a particular function and is completely menu driven. A brief functional description of each module is listed below.

Performance analysis always begins with the *digitizing* module. This module allows video images to be converted to body joint location coordinates in the computer. These digitized locations are saved for subsequent conversion to true image space location.

The *transformation* module converts digitized video data into true two or three-dimensional image data using an algorithm called direct linear transformation (1). If a single camera view is used, the resulting image is two-dimensional. If two or more camera views have been used, the resulting image is three-dimensional.

The *smoothing* module removes small random digitizing errors from the computed image coordinates. At the same time, it computes body joint velocities and accelerations from the smoothed joint coordinates. The operator may choose any of three different smoothing functions: cubic spline, digital filter, and polynomial smoothing. The APAS utilizes, as the smoothing method of choice, a modified cubic spline smoothing algorithm formulated by Reinsch (2). In addition, the user may control the amount of smoothing applied to each joint to insure that smoothing does not distort the digitized data.

The *viewing* module is used to examine image data in "stick figure" format. Viewing options include single frame, multiple frame, and animated images. Three-dimensional images may be rotated to allow viewing from any chosen direction.

The *graphing* module is used to draw graphs of image motion. Displacement, velocity, and acceleration curves may be graphed for any number of individual body joints or segments. Joint motion may be presented in either linear coordinates or angular coordinates, while segment motion is presented in angular coordinates about a single segment endpoint. The data may be displayed on cartesian graphs or as full figure models.

Printed reports of the image motion data are produced by the *print* module. Data can be saved for future printing. Additionally, reports may be transferred to other systems such as spread sheets or data base programs.

The *analog* module includes a hardware interface and an analog sampling unit with program selectable gain for collection of up to 16 channels of analog input. Specialized features support the use of force plates and electromyography (EMG) measurement and analysis. Included are options for spike analysis, envelope processing, signal integration analysis, waveform analysis, and spectral analysis.

STUDIES IN PROGRESS

The Anthropometric and Biomechanics Lab (ABL) is currently involved in ongoing studies to enhance astronaut performance in a space environment. Depending on the study, all or part of the APAS may be used for data collection and analysis.

Initial investigations are in progress utilizing motion analysis, EMG, and an instrumented treadmill to measure and compare the shirtsleeved one-gravity relations between velocity, angle of inclination, skeletal muscle contraction patterns, and impact loading of the skeletal system to identical conditions in a zero-gravity environment.

An unrelated but similar investigation is in progress to determine the lower torso mobility of one of the Space Station prototype space suits in one gravity, in addition to simulated lunar and martian gravity, 1/6 and 1/3 Earth gravity respectively. The treadmill and EMG are also being incorporated into this study. The ABL is also investigating the possibility of using the APAS to determine reach envelopes of astronauts as a function of varying gravitational loads while wearing the Launch/Entry Suit (LES).

CONCLUSION

The video based motion analysis system being used by the ABL has proved to be a viable means for collecting and analyzing human motion. A great strength of video based systems is their flexibility. The system is used in the one-gravity lab environment, in neutral buoyancy at JSC's Weightless Environment Training Facility (WETF), and in zero gravity on board NASA's KC-135. The systems are versatile and allow the operator to analyze virtually any motion that can be sequentially imaged.

REFERENCES

1. Shapiro, R. "Direct Linear Transformation Method For Three-Dimensional Cinematography." *Research Quarterly*, 49:197-205, 1978.

2. Reinsch, C. H. "Smoothing By Spline Functions." *Numerische Mathematik*, 10:177-184, 1967.