BIOMECHANICAL SPORT ANALYSIS THROUGH DATA INTEGRATION

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This project consisted of the utilisation of a synchronised time base data software program (Ariel APASview), capable of dynamically integrating video, kinematic, kinetic, EMG, and force plate data for the analysis of selected sports under different competitive conditions (practice, Olympic and collegiate competitions). Biomechanical analysis through data integration was performed on discus throwing, basketball free throw shooting, and high jumping. Visual records from multiple perspectives and quantitative feedback were provided to the coaches and athletes for effective evaluation of their sport performance.

KEYWORDS: biomechanical data integration, multimedia, sport analysis

INTRODUCTION: The field of biomechanics, which examines the role of muscular function on effective movement patterns may be traced back as early as the times of Antiquity (131-201 A.D.). In the 17th century, Leonardo da Vinci combined modern dissection techniques for anatomical analysis with the application of mechanical principles to analyse human movement (from Keele, 1983, p.99).
These analysis procedures were followed by developments in the field of mechanics during the scientific revolution by scholars such as Newton, and Galileo, where Galileo's projects included analyses of human jumping and equine gait. The application of mechanical principles to analyse human movement was published in Borelli's book (1680) on the DeAnimalian Motibus (The Movement of Animals). His biomechanical analyses of jumping, swimming, and gait earned him the title of the 'father of biomechanics'.
In 1889, Marey developed the cinecamera permitting the sequential recording of human locomotion using frame by frame analysis and it was correlated with pneumatically recorded ground reaction forces. These simultaneous measurements of force and displacement were the first attempt of utilising multiple data sources to analyse jumping performance and the methods were re-published in the Movement text (1972).
Braune and Fischer conducted in 1891, the first 3-dimensional analysis of human gait. The mathematical/mechanical analysis of gait involving photographs required years to complete the hand calculations for kinematic and kinetic measurements attributed to the biomechanics of gait (1987).
As the development of modern computers occurred in 1950's, Plagenhoef was the first investigator to utilise high-speed computers for performing the calculations necessary for the analysis of human motion. In 1968, computerised analysis was performed on cinematographic records collected at the Olympic Games at Mexico City of Beamon's world record long jump. Plagenhoef in 1968 described his computerised process of calculating kinetic data from cinematographic records. Further developments accelerated the computer procedures incorporating graphic digitisers, and the digitising of separate but multiple camera views that are transformed from the video coordinates to the real coordinate measures and the simulation of the original movement pattern. Recently at the 1996 Atlanta Olympic Games, digital video records of the Track and Field performances were collected at the competition and immediately uploaded on the Internet for the world wide biomechanical analysis (Ariel, Finch and Penny, 1997; Finch, Ariel, & Penny, 1998).
Computerization of electromyographic (EMG) instrumentation, ground reaction force collection, now rapidly provide data concerning the causative factors of human movement and sport performance. Technological developments in video analysis permit biomechanists to digitise up to nine camera views, four of which may be viewed and digitised simultaneously using automatic digitising methods while performing real-time transformations, kinematic and kinetic analyses accompanied by computer simulated models. Typically, biomechanical analyses utilising the EMG, force plate, and video data

were conducted "off-line" and then the investigator performed the time consuming task of manually synchronising the individual analyses.

METHODS: The purpose of this project was to develop a system that could integrate video, EMG, kinematic and kinetic output data from various human movement applications. By providing time synchronisation the investigator could observe the kinematic, kinetic, EMG, and force plate output into a dynamic output locally and on the Internet worldwide. This "on-line" simultaneous integration of the multiple data sources would be beneficial in performing quantitative and qualitative analysis of sport performance factors.

Integrated biomechanical analysis techniques were used during various athletic conditions such as: Olympic competition, collegiate competition, and elite collegiate practice. Video records were collected from multiple views of the Men's discus preliminary and final competitions at the 1996 Atlanta Olympic Games. The collegiate competition application consisted of videographic analysis of the Indiana State University's Women's Basketball team shooting free throws during a conference competition. While the elite collegiate practice condition involved performing a videographic analysis of high jumping during a practice track meet.

RESULTS AND DISCUSSION: The best (65.4 m) and worst (61.3 m) discus attempts at the Atlanta Olympic Games thrown by the 4th place competitor, A. Washington (U.S.A.) were selected for analysis purposes. Twenty-one data points were selected, digitised, and entered into the 3D DLT module and converted to real displacements using field calibration information. Critical performance variables of resultant discus velocity, and angular velocity of the throwing shoulder were calculated and integrated synchronisation was performed on the video records, kinematic data, and the reconstructed 3D images of the throwing movement were performed for quantitative and qualitative of the throwers' performances (See Figure 1).

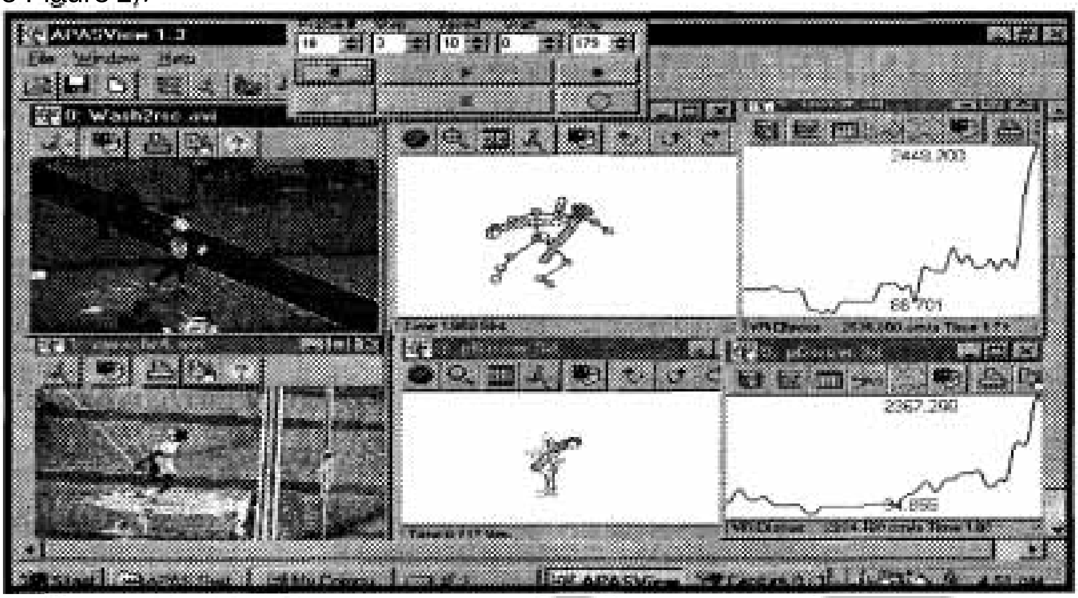

Figure 1 - Integrated Olympic discus analysis

The integrated results of biomechanical analysis found that the best attempt was thrown at 2498 $cm.sec^{-1}$ at a projection angle of 0.52 rad. and the worst throw was projected at 2439 $cm.sec^{-1}$ at 1.1 rad. Some of the technique errors in the poor attempt included a projection angle that was too steep and the elapsed time across the circle was so quick that there was too little time for the return of the elastic energy stored in the throwing arm. The discus should been thrown at an angle projected closer to 0.59 rad (Altmeyer, Bartonietz & Krieger, 1994) and if the movement across the circle was slower, then adequate time would have been permitted for the elastic energy return. These findings of the analysis were presented and discussed with the Olympic athlete and coach and suggestions for improvement were made.

The utilization of the integrated biomechanical procedures for the collegiate competition involved collecting video records of the Indiana State University's Women's Basketball team shooting free-throws during a conference competition. A successful and unsuccessful attempt by a starting player was selected for comparison. Selected data points from the video records from a sagittal and frontal view were digitized and transformed using a 3D DLT and digitally smoothed at a 10 Hz frequency cut-off. The athlete's shoulder and elbow velocities along the sagittal plane were calculated for each trial and a side by side comparison was performed using the Ariel APASview software module (See Figure 2). Also, the free-throws' projection velocity and projection angles were determined for the made and missed shooting trials (See Figure 3). The successful attempt was shot at a resultant velocity of 399 $cm.sec^{-1}$ at at 1.1 radians above the horizontal and the missed attempt shot travelled at 489 $cm.sec^{-1}$ at an .9 radian angle. Also, the successful free-throw's shoulder and elbow angular velocities were 8.8 and 15.2 $rad.sec^{-1}$, while the missed shot's angular velocities were 11.1 and 29.2 $rad.sec^{-1}$ respectively. The video records and kinematic data were synchronized to the nearest .0167 s, representing the camera's video field transport rate. The technique errors of the errant shooting performance consisting of a flat trajectory, excessive elbow extension, high ball velocity, and incomplete follow-through, were presented to the coaching staff and the athlete for skill modification in practice at a later time. The video records were synchronised with the stick figures and the data graphs provided clear visual feedback for the athlete and coach to correct the improper shooting technique.

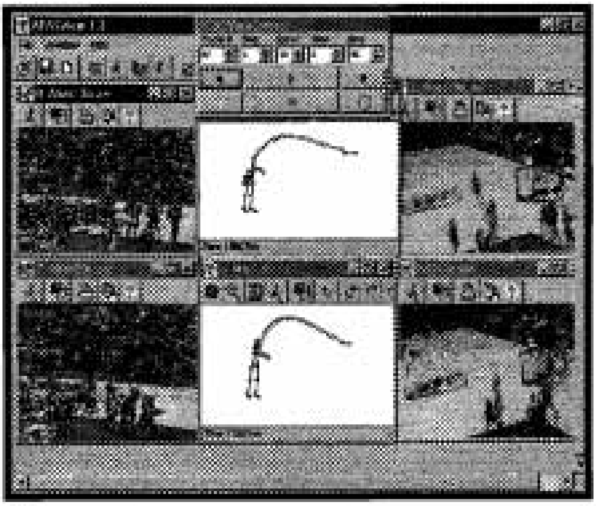

Figure 2 - Integrated free throw **analysis**

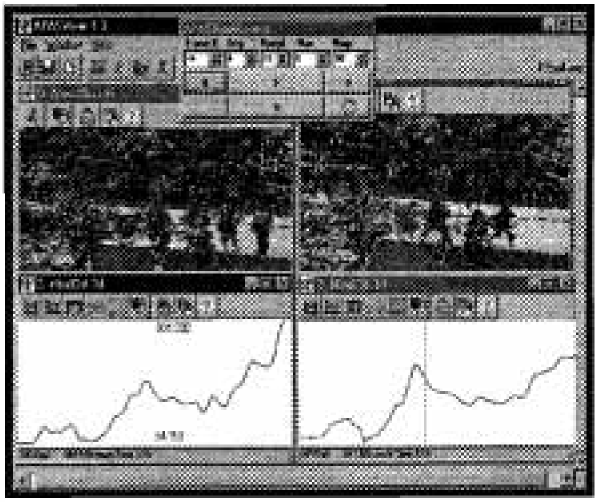

Figure 3 - Integrated free throw **projection velocities**

The application of videographic analysis during a practice situation provides the greatest opportunity for techique analysis and immediate technique modification. This phase of the project required video recording with two cameras of practice trials of elite collegiate high jumpers, who had qualified for the United States Olympic Trials. The height of the high jump attempt selected for analysis was 4.32 m. Sixteen body data points and four points defining the jumping bar were digitised, transformed the 3D DLT, and smoothed. Simultaneous integration of the jumper's video records, 3D computerised stick figure, CM vertical displacements and velocity .calculations were performed. The university coaching staff reviewed the jumper's technique and recommended adjustments in the high jumper's technique (Figure 4).

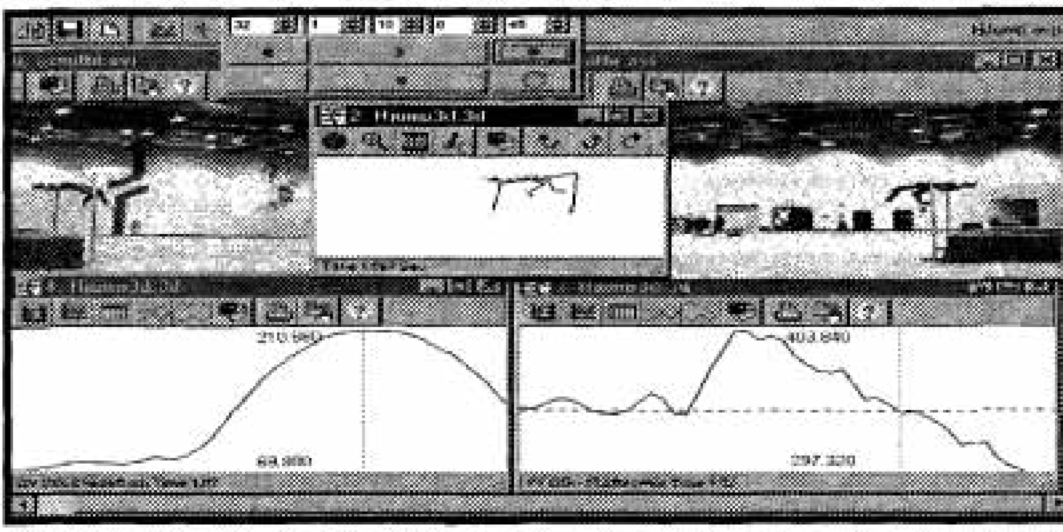

Figure 4 - Integrated analysis for high jump practice trial

CONCLUSIONS: Advances in software and hardware allowing the use of video capture boards, automatic digitising, real-time transformation, and filtering software provided simultaneously displayed kinematic and kinetic outputs. These dynamic outputs were synchronised on a time base such such that a researcher, coach, and athlete could effectively evaluate athletic performance from numerous perspectives simultaneously while under various competitive conditions and then make necessary skill adjustments.

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