THE USE OF COMPUTER GRAPHIC AND PHOTOGRAMMETRIC METHODS IN THE STUDY OF TECHNIQUE SPORTS.

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Abstract

The feasibility of effectively using photogrammetric measurement and computer analysis in the study of technique sports has been investigated. The purpose of the work is to provide sports coaches with three-dimensional information about the movement of the body during the execution of a particular action. This type of information is particularly useful when attempting to improve performance by correcting faults in technique. Three-dimensional information, presented on a screen and able to be repeatedly viewed, is of great assistance in this corrective process.

The initial experimental work has involved the use of 3 movie cameras with each camera pointing toward the athlete in motion each from a different viewpoint. The analysis of the data has involved the digitisation of marks on the body and control points at particular instants in time. With this data input, software is being developed to present the information in a manner easily understandable by coaches and therefore of practical use to them in improving the level of performance of their athletes.

Introduction

In today's world, the attitude to sport is becoming very professional and the use of sophisticated training techniques is attracting widespread interest in the drive to achieve winning performances. The desire for gold is moving coaches into the world of computers.

One problem for the coach is to be able to record three dimensionally the performance of an athlete and then be able to analyse that performance, break it down into its component parts and consequently suggest ways in which the athlete may correct deficiencies and improve performance.

The recording on a permanent medium (film or video), photogrammetric measurement and computer analysis would seem to be a logical way to approach the problem.

The aim of this work has been to investigate the feasibility of this approach in the analysis of athletic performance, especially in technique events such as discus throwing, hurdling and the jumps.

The work is ongoing and various techniques and many problems are being addressed. The performance will be recorded and immediately analysed. The coach will then view the performance in a variety of ways (eg. slowed down, from particular viewpoints, etc.) and in such a form of presentation that can be readily understood. To be successful this research work must end up with a package and presentation which is acceptable by, and useful to, the coaching fraternity. After viewing the results the coach should be more readily able to understand technique deficiencies in the athlete's performance and suggest ways of remedying such deficiencies. For elite sportsmen small corrections and improvements mean the difference between winning and losing. It is the aim of this research to try to improve the chances of winning.

Experimental Work

The data set required for the analysis of the athletic motion is spatial co-ordinates of both control points and particular points on the moving human frame. Thus a control net or frame had to be established and particular points on the body had to be marked so that they would appear on the photographic images. To obtain spatial co-ordinates it was necessary to have more than one camera so that differences in parallax could be mathematically transformed into spatial co-ordinates. In this experiment three cameras were used (probably additional cameras would have been useful) to ensure that hidden points due to body movement and superposition were minimised. Because the target to be analysed is moving, conventional terrestrial metric cameras were inappropriate and high speed cameras were necessary.

When setting about the planning of the initial experiment there were very many possible ways to proceed. Our most limiting constraint was lack of funds such that the only equipment which could be used was that available within RMIT. We were not able to rent or buy more sophisticated equipment.

The choice of cameras was limited. Given that we had decided to use 2 or 3 cameras with generally horizontal axes, and that we had decided to obtain the maximum image resolution during data capture (thus precluding the use of video recording) we attempted to obtain three high-speed and synchronised cameras of 16mm format. These were not available and we had to accept the offer of three unsynchronised 8mm cameras.

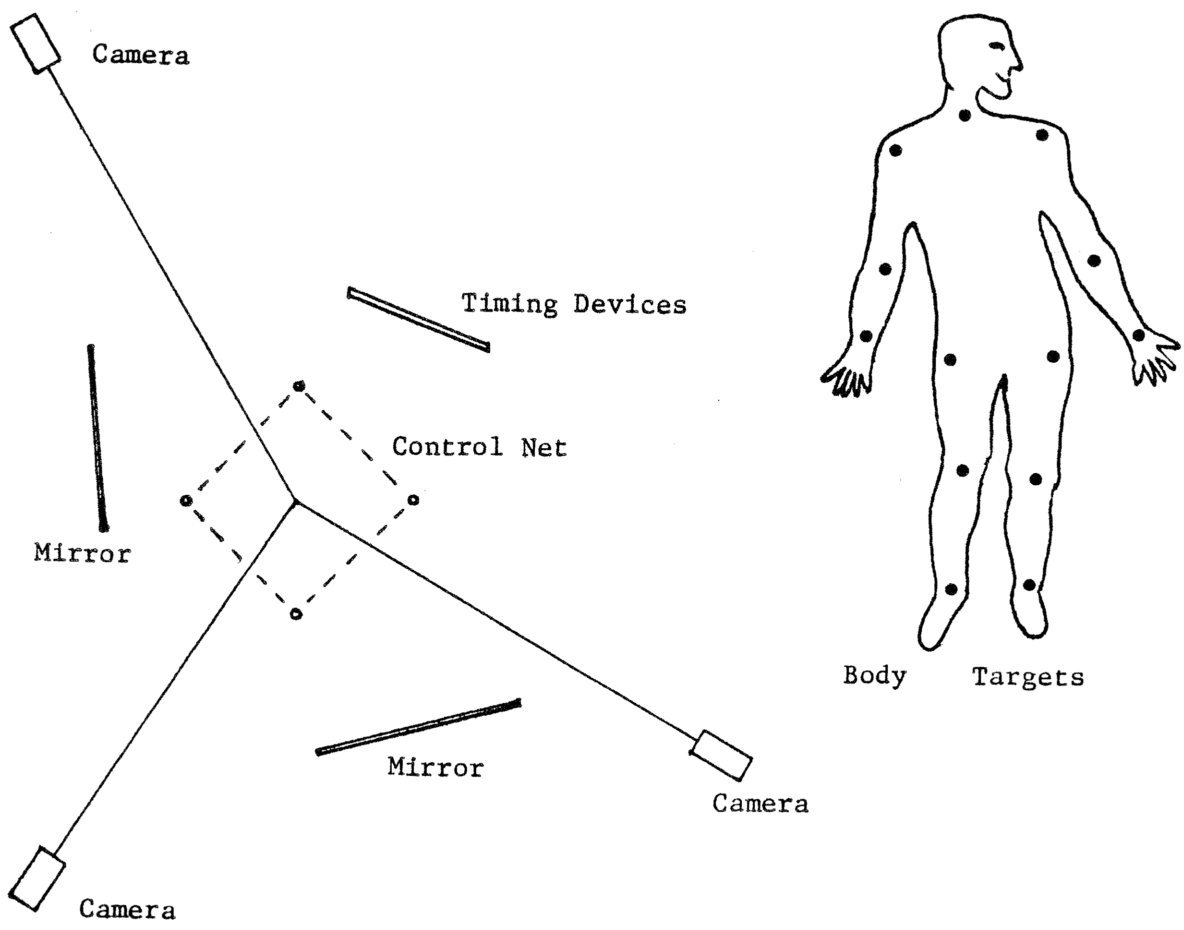
This initial work was carried out in a studio whereas an outdoor approach would have been more realistic. This was done because of power problems and difficulties in easily establishing a control net.

The choice of control points involved either the co-ordination of objects naturally occurring in the fields of view of the taking cameras, or the construction of a control framework. The studio filming session was decided upon, and the studio had overhead supports, so the control structure described below was adopted.

Masking tape marked with crosses and circles was placed on the body and served as targets for subsequent analysis.

The synchronisation of images from two or three cameras during the three-dimensional scene reconstruction was next considered. Ideally the three cameras used would be synchronised. We were unable to obtain such cameras and were then forced to resort to a timing system integrated into the individual scenes.

The initial filming session could have been of the control structure only, however it was decided to incorporate a moving body to possibly uncover deficiencies in the control network placement.



Plan View Of Experimental Layout

Description of the Experiment

A photographic studio was prepared and equipped with lighting suitable for filming with colour film.

A control framework was constructed, based on strings, weighted with plumbobs, suspended from convenient ceiling points. Control points were attached to these strings.

The cameras were next positioned each with an operator. The cameras were mounted on low tripods and gave three distinct views of the controlled area. One camera pointed directly at the mechanical timing devices, and mirrors were used to direct the timing information into the fields of view of the other two cameras.

When filming commenced, a countdown was initiated, the end of a filming period also being indicated by countdown. Initial filming was of the control network only. Later filming incorporated a person with body marks as targets moving in and through the controlled area.

The end result was three sets of 8mm film with a great many points per frame and a large number of frames, all of which needed to be digitised and then analysed.

Analysis of the Experiment

Control

Sixteen control points were provided to allow for camera calibration and to provide a basis for later computations of height and depth information in the scenes being photographed.

Control points consisted of four groups of four points, each point being a table tennis ball threaded on a string which in turn was weighted with a plumbob. The four strings were easily attached to overhead structures in the photographic studio used.

Alternative control point types were considered, however none of these alternatives were tested. Bearing in mind that portability is a major consideration in the choice of control points for the photographing of essentially outdoor activities, the following control point methods were considered:

- Field survey of existing objects.
- The construction of a rigid control framework.
- A tripod arrangement, constructed to support a series of suspended targets such as were used in the studio.

While sixteen control points were provided, the actual number required would not be known until an analysis of the scenes were made. The number provided is felt to be excessive, however the optimum control requirements have not been finalised.

Lighting

Photography was in a studio provided with a number of photographic floodlights suited to the film being used for this experiment.

It is obvious that in the outdoor filming of athletic activity lighting would not be a problem.

Film

Kodak Ektachrome Super 8 cartridge 160 ASA tungsten, no sound track was used.

Timing

Timing was needed in each frame recorded due to the lack of synchronisation of the three cameras being used.

Timing for a frame consisted of the imaging of a clock with sweep second hand as well as of a rapidly rotating arrow (painted black) spinning over a white background. An unmodified electric motor was used for the construction of the spinning arrow, and a calibrated strobe device was used to determine that its speed was 1000rpm. Subsequent computations will be directed towards bringing each frame onto a common time base, this base being related to the clock time and to the estimated position of the spinning arrow.

Mirrors were used to direct the images of the clock and arrow into each camera. The problem of mirror reversal of images will have to be resolved.

This timing method was not found to be satisfactory due to insufficient lighting on the clock and arrow as seen from all three camera stations, and due to image blur of the arrow caused by the relatively long shutter opening times (about one fiftieth of a second) and the lack of control of the arrow's speed of rotation (ie. it couldn't be set at a predetermined speed).

The solution to the problem of timing would partly be overcome by the use of synchronized cameras, thus eliminating the need to interpolate all scenes to a common time frame.

Camera Placement

Three cameras were used, each camera being mounted on a low tripod and operated manually. Each camera was positioned to attempt to include in a frame all sixteen control points, the subject and the timing devices.

A countdown was used to coordinate the three cameras in both starting and stopping, as a series of short scenes were recorded.

No attempt was made to control the alignment of the camera axes or the placement of cameras. Physical restrictions of the studio would have made this a difficult task had alignment been required.

Some control points were not imaged from one or more camera stations due once again to physical restrictions in the studio.

The alignment of mirrors to direct timing information to each camera was found to be difficult.

Body Targets

Adhesive targets were affixed to the subject's body at the points indicated on the diagram.

Placement of Control Points

Problems encountered included the obscuration of body targets during movements, the lack of coincidence of body targets with joint centres (this will be overcome computationally) and the obscuration of control points by the subject.

Other types of body targets to be considered may include point light sources or possibly high contrast reflectors, to be used in conjunction with special film types. The shape of the target could also be made to be conical rather than the flat types used initially.

Movement of the Subject

A variety of movements were undertaken.

Some frames were taken of the control points alone, to allow for the subsequent investigation of distortions.

Image blur was noticed in some activities involving throwing. The solution to this would be to look for faster cameras.

Frequency of Capture

Each camera operates at about 24 frames per second. With three cameras operating over about three minutes in total, the number of images to be processed is very great (about 12000 in all). Each image will require digitization and the storage of this digitized information on a computer.

Distortions

These are expected to be significant, being related to:
Film and camera combinations.
The transfer process from film to video tape.
The video tape to monitor combination.

Conclusion

After considering the work carried out so far it is thought that a careful look at the control requirements and camera calibration is the appropriate way to proceed.

Therefore the next experiment will be conducted outside, will have a more elaborate control network and will not be concerned with a moving human target.

This experiment will be conducted in an outdoor area using cameras whose format is compatible with available telecine equipment. This will allow conversion of film to video imagery and the use of video equipment for the later digitization process.

Initial work will be concerned with the control requirements and the camera calibration aspects related to the entire non metric chain of film and video to be used for the capture and digitization of athletic activity.

A portable control network will be constructed, being one that can be erected easily at a field location and one which may be added to if the number of control points provided is found to be insufficient. Conventional field survey methods will be used to provide coordinate information for the control points. Colour coding will be used to allow the identification of individual control points.

A group of three timing devices is to be constructed, consisting of three liquid crystal displays being driven by a central power source and timing device. These displays may then be included in the images of the two or three cameras used to record the athletic activity.

A telecine chain will be used to convert single 16 mm images to a PAL video image. This image will then be fed to a signal mixer which will allow the superimposition of a digitizing mark onto the single frame of athletic activity. The digitizing mark will be generated on the screen of a colour raster screen which will also have the ability to return the coordinates of the digitizing mark when requested. This digitizing mark will be freely moved using a joystick. The intention is to place a camera in front of the colour raster screen, to generate the freely movable digitizing mark and to mix the images of athletic activity and digitizing mark. A microcomputer will be interfaced to the colour raster screen to allow the collection of screen coordinates for the digitizing mark when requested. The microcomputer to be interfaced has twin disks giving a total of 2 Mb of disk storage. No more than 210 bytes will be required for each scene to be digitized, dependent on the number of control and body points to be located, and thus over 9000 individual scenes could be digitized and stored on the available microcomputer disk storage. Later processing related to image refinement and three dimensional computation and display will be performed on a minicomputer with large storage capacity.

In this work there are a number of perceived deficiencies which need to be looked at and overcome. The system to be successful must be of low cost, be portable, produce a result quickly and at a required accuracy and must be acceptable to the user.

The problems therefore are: how to keep the cost low but produce the required output?

How to produce a portable system when control is required and equipment is bulky?

How to produce rapid results, at low cost, when so many points and frames are involved in the digitisation, storage and analysis?

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