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SINGLE-CAMERA MOTION CAPTURE SYSTEM FOR NETBALL TEAM STRATEGIC TOOL

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ABSTRACT

Team sports coaches are always looking for tools to help them in their coaching routines. They are more toward statistical analyses and quantitative judgements like never before. Decades have passed, manual counting of athletes' attempts and blocks are no more practical for today's fast-paced team sports. In recent years, various commercial motion capture systems have been developed with scaring price tag since considered as hi-tech and exclusive. This work is established to document the elementary procedures to perform a motion capture system and analysis as a team sports strategic tool. Netball is used as case study in order to describe the steps involved for clarification. To further simplify the raw to simulated data process, a set of magnetic-driven points on a scaled-down court is used to represent players' movements during a match. A single camera located at the top centre of the court was used throughout the motion capture process. The full area covered 60 fps digital video was then converted into three-dimensional matrix consist of RGB colour values via a matrix based programming platform. 'Players' from the competing teams were distinguished based on this colour differences. Interpolation methods were used to quantify players' movements from the pixel data before it was then interpreted as transient simulation, motion analyses, statistics and strategic implications. In this work, the data was represented as a tailed displacement of all players, velocity and acceleration of selected players together with sample analyses. This work is expected to give an overview on how a motion capture system is manipulated in team sports such as netball. The same principle can be implemented for other team sports with proper arrangements and modifications.

Keywords: motion capture, team sports, strategic tool.

INTRODUCTION

In any team sports, player's action and interaction is complex because they are influenced by various factors. Parameters such as short-term goal for individual player, team overall strategy, the sports rules, and game current context [1]. Coaches are always looking for tools to help them in providing the best strategy to win most matches. Prompt analysis on team's performance versus the opponent's feat is essential in order for them to decide on what to do next. Coaches nowadays are not depending on wild predictions anymore. Instead, their decisions are projections based on real time statistics of both teams' performance. This has long mentioned by Wayne Gretsky, legendary hockey player who once said,

> "A good hockey player plays where the puck is. A great hockey player plays where the puck will be".

The same trust was also shared by many other thinkers. More accurate and comprehensive analyses are normally interpreted as deeper view and clearer understanding on the development of the game during matches. Infact, the movement of players on the field reflects their interpretation, and perhaps their intentions, based on their role in the game, which we should utilize to interpret the state of the game [2].

In this work, netball was chosen as a case study in describing the procedures used to perform motion capture up to the analyses. Netball is a fast, exciting team sport that involves jumping, running, catching and throwing. In additional, players have to be fast, strong and agile since they always face pressure throughout matches. Netball is adapted from basketball that once known as "Women's Basketball" in early 1900s. In any match, everything happens too fast, and those who hesitate will lost. All teams should have a few basic strategies in place to take advantage of set-up time in any match. Instead of conventional way of observation by coaches during matches, real time motion capture analysis is now considered as the next big thing.

Netball strategies and techniques

Several netball strategies were emulated in this work to see whether the motion capture system is reliable or not. Netball as a team sport is very much dependent on good strategies to win. Strategies give structure, direction and satisfaction of working together as team to create success. Too many strategies in one game can cause confusion and deflect concentration for the core objectives of the game. Some play need signals from the centre and other can be set spontaneously between the goal attack and wing attack. It is up to the coach and style of players as to which strategies are used and how they will link in the possible goaler's system. Several basic strategies are available for the centre pass. Three commonly used strategies are Double-Clear Strategy, Forward to Forward Strategy and Overload Strategy.

In Forward to Forward Strategy for instance, WA and GA start up at the transverse line on their respective sides, accelerate forwards then transform their leads to a clearing move towards their respective sidelines, opening up the centre corridor. GD and WD present as dual

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primary targets. C has two options and chooses the best one. The next pass should connect to GS on top of goal arc. GD and WD are running full pace in the direction of the goal while WA and GA are on clearing leads at the sides of court [3]. This basic strategy is illustrated in Figure-1 below.

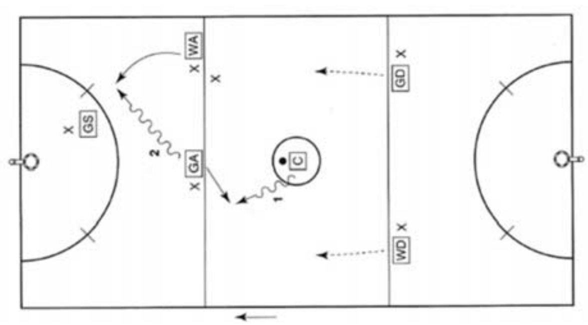

Figure-1. Forward to forward strategy in netball (JaneWoodlands, 2006).

Single-camera system as strategic tool

Nowadays, sports are more intense with whatever means to win. This situation has increased the need for scientific analysis for game strategies. In many situations, the strategies are studied and analysed manually that require a lot of time and effort. This sort of analysis is also less accurate, since it depends on human factors. Adopting the advancement of certain technologies such as image processing and motion analysis, athletes' motions are now captured and analysed almost without human interventions. These most commercially available technologies are employed as strategic tool for coaches in needs of high-precision motion capture and analysis. Furthermore, coaches' strategic judgements are now more reliable, not only based on experience and emotions but also based on athletes' motion simulation and emulation [4, 5, 6]. During the earlier development of this strategic tool technology, the information must be obtained first. Normally, researches often used video cutting technology or also called motion capture technology. This method was then replaced by active tracking method which recorded moving objects by tracking a set of reflective label affixed to the joint or non-contact video-based motion tracking [7, 8]. In this research, complex human behaviours were captured in representative sports contexts with a single camera. The work had proven that time-motion analysis procedures are feasible to be carried out using a single camera.

Single-camera motion capture system is very helpful for team sports like netball and basketball especially to replace conventional way of capturing and analyzing team players' individual and cumulative performance [9]. More accurate data and motion pattern of the player in the team sports such as netball could be analyzed statistically. The coaches are able to guide their athletes individually and the athletes will get the feedback of their motions in order to maximize the athlete's potential ability.

In additional, the coaches will have more accurate data and have more choices to give the best techniques and movement based on previously recorded data so that the player could perform well either during training or competition. Moreover, player can maximize quality time with only limited training exercises based on data taken. Player's level of ability and intelligence can be monitored based on data taken. This can improve player's potential and boost the performance itself from time to time.

Even though there exist numerous single-camera commercial motion capture system to chose from, this work's main objective is to describe the whole procedure of setting up an in-house single-camera motion capture system, collecting data and finally perform a mock-up analysis specifically for netball team sport. Through the procedures developed, motion pattern of a netball team can be interpreted and it allowed the coach to make decisions on the team's strategy [10]. Apart from that, the coach is also has the ability to analyze and compare their player's movement patterns via combined recorded analyses.

METHODOLOGY

The main objective of this work is to elaborate the procedures required for motion capture system analysis on netball team sport and does not involve the details of the sport itself. A lab-scaled court was built for the purpose. The player models were however created, located and moved on the scaled-down court based on the real positioning and movements during a match.

The first milestone of this work is to setup a single-camera motion capture system for team sports player's motion and behaviour. Figure-2 shows a setup for a scaled-down model of netball half-court. The players were modelled as red and blue points. These colours represent players from the two competing teams. The colour difference was also the basis of the developed algorithm to track and differentiate between players. The details are explained in the algorithm development section of this paper.

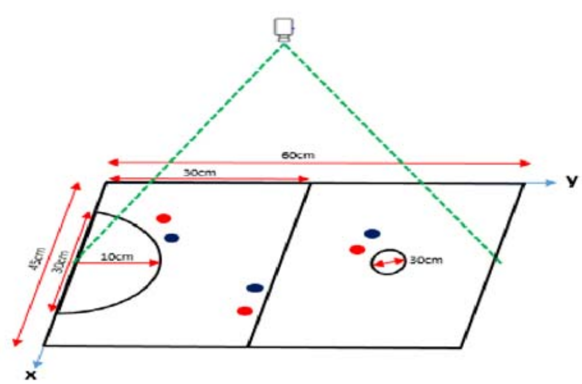

Figure-2. Netball half-court scaled-down model.

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Setup of motion capture system

In this work, a single camera is used in the study of three-on-three netball half court model player movements. A fixed digital camera was set in an elevated plane, 0.5 meters of height from the scaled-down court. In order to capture the movement of all players participating in each trial, the video camera height was placed so that the whole region of interest was covered as seen in Figure-3. Selection of camera resolution was also crucial for the process since the algorithm developed to process the raw captured pixels was meant for relatively fine quality data.

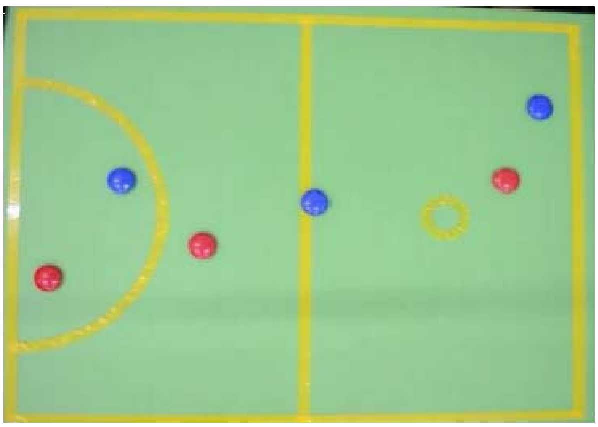

Figure-3. Camera view.

Generally, the number of cameras is not subject to any rule for 2D motion capture. However, the analysis of the collected data is slightly different by using number of cameras. In addition, the motion capture obtained from higher number of cameras is more accurate as compared to single camera video acquisition. Therefore, the more camera used, the more precisely the analysis can be performed. Taking into account the complexity of the setup, algorithm development and other issues pertaining the use of multi-camera system, this work was planned for single camera with suitable specification for the scaled-down court analyses. Table-1 shows the camera used and its specifications.

Table-1. Camera specifications.

Specification	Camera
Model	Nikon D3100
Camera format	SLR
Effective Megapixels	14.2
Video Resolution (Frame size in pixel to frame rate)	• 1920 x 1080 (24p): 24 fps (23.976 fps) • 1280 x 720 (30p): 30 fps (29.97 fps) • 1280 x 720 (25p): 25 fps • 1280 x 720 (24p): 24 fps (23.976 fps) • 640 x 424 (24p): 24 fps (23.976 fps)
Maximum frame per second	29

Algorithm development

The previous section described a relatively common video data acquisition used in many fields. In this section however, the focal strength of this work is explained in brief so that the same procedures can be reproduced with more variance. The coding platform used in this work is an open-source matrix based programming language. The platform was chosen for its simplicity and capability to handle pixels in the digital raw data as matrices.

The algorithm flow was started by converting the raw video file into a format readable by the platform. In this case, the raw video was converted into *.avi format. The converted video was the transformed into three-dimensional matrix consists of the video frame and the slices representing the number of frames for the whole duration of the raw video.

The next step was to extract colour profiles for each frame that we have transformed earlier. This was done by taking one frame at a time and extracts the RGB (Red-Green-Blue) components of the frame. This step would multiply each frame, presented as a two dimensional matrix into three dimensional matrix consists of red, green and blue intensity layers.

Based on the raw frames, players on each teams could be distinguished by the colours. The same principle was used to locate and distinguish players in each frame. In this work, a strong set of contrasting colour scheme was used on the model construction. This was purposely done to ensure the algorithm made was straightforward without complex procedure of noise filtering or data exaggeration.

Referring to an example frame in Figure-3, the calculation of players trajectories, velocities, accelerations and other related analyses were made by comparing the pixel number from each corner of the court appear in the first frame with the actual court size. The ratio between the two measurements was used to determine the actual motion parameters involved.

Once the frame data was converted into RGB values, it was easy to distinguish between players from both teams and the court itself. Players' positions having the same red colour were first established in this algorithm. This was done by retrieving the red intensity layer that has red intensity values in two dimensional matrix arrangements, representing the whole pixels on that particular frame.

Based on the red intensity values on each element of the matrix, the red players' position could be determined where the red intensity was relatively high. These pixels with high red intensity was then converted into full white colour, leaving the low red intensity converted into full black colour. This resulting black and white frame can be treated as it is for further analyses or converted into much smaller in size binary matrix for more efficient data processing.

Once these processes were done, the frame would be a black frame with three white spots located exactly at the previous red player positions. The coordinate of the red players were then determined by finding the centre

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points of the white spots and revert the pixel location into actual court-size positions.

The same procedures were then repeated for blue players. Once the positions of both red and blue players recorder, the whole process was repeated for the next frame accept for the pixel-distance ratio determination that was made only once in this case study. This ratio however needs to be determined for each frame if the camera was not positioned in static condition.

At this stage where all frames were already converted into positions of each player, all sorts of motion analyses can already be started. The most basic step was to simulate back the whole motion captured in the video into full size point-trajectory simulation. Players' velocities and accelerations could be calculated by determining the displacement of each simulated player from frame to frame and differentiate it with the time lapse between frames.

More specific analyses could also be made depending on the coach's requirements such as distance travelled by the players, area covered by the players, agility comparison between player or any analyses that can be used to improve the team's performance.

RESULTS AND DISCUSSIONS

The first analysis presented in this work is the players' tail movement as shown in Figure-4. This figure illustrates the final tail trajectories of all six players competing at the scaled-down half-court region from the start to the end of the short period of interest. The differences between all players are marked in different colour as tabulated in the figure legion. The red players are denoted as 1R, 2R and 3R while blue players are marked as 1B, 2B and 3B.

From the figure, it is clearly seen that the opposing players closest to the goal post (Player 1B and Player 1R) are more concentrated. Their movements are relatively compact as compared to the other four players. This is in contrast with the next two opposing players at the middle of the court (Player 2B and Player 2R). These players were the busiest amongst them where the tail trajectories show active movement around the court with Player 2R is tailing closely the opponent, Player 2B. Player 3B and Player 3R on the other hand are more passive with moderate movements and they move not so close as the positioning at this area is less critical.

From this nature of visualization, coaches could easily determine which players are doing the most movement and which players are more concentrated. With additional dynamic calculation of each players' velocity and acceleration, coaches could determine whether any players are lacking in pace and agility to challenge the opponent's players. Temporal finite difference methods are excellent selection that suits the purpose. Although this is just a scaled-down model of netball court and players, this simple motion analysis suggested that this sort of arrangement and studies are possible to be implemented in real team sports strategic analyses.

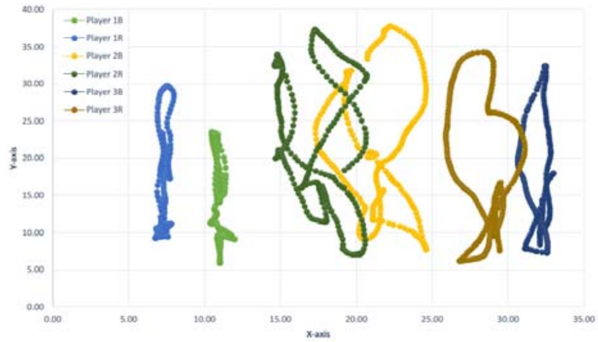

Figure-4. Tail trajectories of all players for the given period of time.

Another analysis presented in this work is velocity comparison for opposing players. The one shown in Figure-5 is a sample for two opposing players (3R and 3B). In general, both players have similar maximum velocity and movement pattern. If we look closer, Player 3B is less dynamic and sometimes observed to be at stationary condition while letting the Player 3R moves first before tailing the movement with higher velocity.

The figure also shows that Player 3R has higher agility as compared to Player 3B. This can be seen from the more fluctuating velocity of Player 3R throughout the period. This type of analysis could help coaches to decide on player selections and strategies to overcome the playing style of the other team.

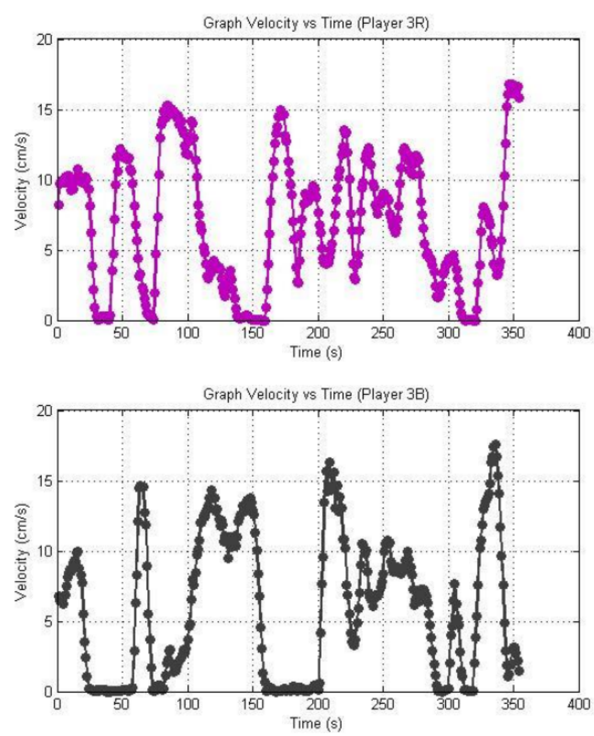

Figure-5. Sample velocity comparison for two opposing players (3R and 3B).

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CONCLUSIONS

The aim of this work which is to apply engineering knowledge of motion data acquisition, dynamics analysis of movement and algorithm development in team sports strategic analysis has successfully achieved. Netball as a case study has proven to be a good selection especially in terms of proper procedures during the motion capture process and clear analyses. The same concept can be used for other team strategic analyses with proper adjustment on the selection camera specifications, algorithm complexity and types of analyses based on the team sports selected. More filtering, data optimization and assumptions are expected when the same concept is applied to real sports matches.

ACKNOWLEDGEMENTS

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