Line Detection and Tracking in Video Recordings of Rugby Games

A thesis presented in partial fulfilment of the requirements for the degree of

Master of Science

in

Computer Science

at Massey University, Palmerston North, New Zealand

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2004

Errata Sheet

P.7, third paragraph, change "no-glass-coloured" to "no-grass-coloured"

P.10, move last line (sub-heading) to P.11

P.14, change equation at the top of the page from

$$G_{Ori} = \arctan(G_y / G_x) - 3\pi/4$$

to

$$G_{Ori} = \arctan(G_y / G_x) + \pi/4$$

P.19, line11, change "b is the intercept" to "b is the y intercept"

P.53, line 3, change "In frame 109" to "In frame 139"

Abstract

Video analysis has long been used in sports analysis. More and more coaches and instructors choose to use computer-based video analysis systems in decision-making and player training, which makes computer-aided sports analysis a fast growing industry. AnalySports Ltd is a New Zealand based sports analysis company providing performance analysis for sports, especially for team games such as rugby. Currently AnalySports uses human coders to manually track the activities and position of the ball carrier.

This thesis is part of a player-tracking project. The overall aim of the wider project is to build a cost-effective system to semi-automatically track individual players' positions in video recordings of team sport games. To obtain the information on movement and tactics of the team as a whole, it is necessary to identify the position of each player on the field at every point of time during the game. To perform the tracking, wide-angle video recordings from rugby games are used as input data. As the camera is moving, it is necessary to find the mapping between the pixels in the image and positions in the rugby field for every video frame. To make the size of the task realistic for a one-year masters project, the work presented in this thesis focuses on finding formulae and parameters for this conversion. Analysis of the position data for player performance and game tactics is outside the scope of this thesis.

The conversion between image coordinates and field positions can be established by identifying the field characteristics. The positions of the players in the field then can be calculated using this conversion once they are identified on the video frame. Based on single video frames, algorithms have been developed to detect and identify field characteristics (lines) in the frames of the video recordings. Using the identified field characteristics as reference, a transform matrix was calculated to convert pixels in the image to positions in the rugby field. For a sequence of video frames, algorithms have been developed to track the identified reference lines in order to save time and human power. These tasks were complicated by the zooming, tilting, and panning movements of the camera and therefore a potential of loss of reference lines, the noise in the data caused by field properties such as advertisement, the varying light conditions, the movements of the sun, or the shadows of the stadium roof. An application was developed to perform the developed algorithms. The testing shows that for about seventy percent of the video clips investigated, lines can be recognised and tracked. That means the application can be used to find the conversion for the majority of the video clips. Based on the testing performed,

further development based on this project could be a refinement of the image recognition parameters, efficiency improvements and the development of the actual player recognition.

This project was supported in part by a grant from the (New Zealand) Foundation for Research, Science, and Technology (FRST) and the Technology for Industry Fellowships (TIF) programme (contract number: ANLY0201).

Acknowledgements

First of all, I would like to thank Dr Eva Heinrich, my project supervisor, for her support throughout the project. Without the advice, comments and helpful guidance from her, this thesis would not have been possible. I thank her especially for her great patience and her professional, unconditional, dedicated encouragement and support.

I would like to express my gratitude to Dr George Serrallach of AnalySports Ltd, for his valuable advice and guidance in this project. Thanks must go to AnalySports Ltd, for providing video files and a laptop for this research.

Many thanks to Foundation for Research, Science, and Technology (FRST) for granting the financial support for this project.

Acknowledgement is also due Dr Donald Bailey for his advice on image and video processing techniques.

Finally, I would like to thank my family for their infinite love and support throughout my life.

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1 Introduction

Computer systems are being used in modern coaching and training, especially in sport analysis, to improve the sport performance of the athletes. Video recordings of sports are often transferred to the computer systems to perform accurate measurements on the performance of the athletes, which are essential to sport analysis. In order to improve the accuracy of the measurement, image-processing techniques can be used in computer aided sport analysis systems.

Section 1.1 of this chapter will give a brief introduction to computer aided sport analysis systems. In Section 1.2, some basic image processing techniques will be briefly reviewed. Section 1.3 will discuss the goal of this project. In Section 1.4, the structure of this thesis will be introduced.

1.1 Computer Based Sport Analysis

Computer systems have become more and more popular in sport coaching and training. Video recordings of sports are important input for those computer systems. Two kinds of computer systems will be introduced below: computer systems developed for training and computer systems developed for performance analysis.

In computer systems developed for athletes training, athletes' motions are captured and transferred to the computer. The video recordings in such a computer system are usually taken in a controlled environment, such as a controlled background or a controlled camera movement. Compared to video recordings played in VCRs, video recordings in computer systems are much easier to control; for example, the user can examine any frame of the video easily. The computer systems also provide accessorial tools, such as drawing tools and video editing tools to facilitate the analysis. Developed by Seaside Software, the SportsCAD GOLD system (SportsCAD GOLD, 2002) is an example of this kind of computer application. SportsCAD GOLD is an advanced video motion analysis program, which combines the power of video instruction and the graphic capabilities of the computer. It is used to support the training of athletes in sports like baseball, golf, and bowling. The drawing tools in SportsCAD GOLD allow users to draw shapes directly on the videos. Drawings can be saved as drawing macros and be called up and displayed over any video. The drawing tools also provide calibration for lines and can calculate angles. The path tracking function allows the user to mark interesting objects on the video

and track their trajectory using the mouse. The video editing tools in SportsCAD GOLD allow the user to display or align the videos in different modes. The user can play different videos on one screen, or show multiple frames of one video on the screen. Further more, two videos can be placed transparently for comparison. In such computer aided training systems, athletes' performances can be measured using accessorial tools provided by the computer application; for example, distance can be measured by measuring distance for lines in the image.

In computer systems developed for performance analysis, the video recordings used are usually taken in uncontrolled environments. Thus measurements (quantitative data) or observations (qualitative data) of the athletes' performances are usually entered to the system by the human investigator through observing the video recordings of sports. The computer applications then analyse the data prepared by human investigator and generates statistics and reports automatically. StadeXpert (StadeXpert, 2003) is an example of this kind of tool. Developed by REM Informatique, StadeXpert is a powerful game analysis system. For example, the StadeXpert application developed for rugby analysis allows the users to group the players' activities into different classes, such as 'tackle' and 'lineout'. Then it provides interfaces (Figure 1-1) to analyse the sequences of the rugby game to find out plays in the video clips, and qualify how successful the plays are. The computer system can generate reports and statistics of the rugby game.

There are difficulties in providing accurate measurements in video recordings taken in an uncontrolled environment. The biggest barrier comes from the fact that the camera's parameters (such as focal length, position and movement) are unknown, which makes traditional movement detection and analysis techniques not feasible. One possible solution is to use human investigators to take the measurement manually, which is time consuming and requires lots of human resources. The research project presented in this thesis focuses on providing accurate measurement data semi-automatically using image-processing techniques for video recordings taken in uncontrolled environments. Supported by Foundation for Research, Science and Technology (FRST) New Zealand, this research project was undertaken in collaboration with AnalySports Ltd. AnalySports Ltd is a New Zealand based sport analysis company providing performance analysis for sports, especially for team games such as rugby and soccer. Like other sports analysis companies, AnalySports currently uses human coders to manually track the activities and position of the ball carrier. The overall aim of this project is to develop a system that could track the players' positions in the field semi-automatically and thus provide accurate position information of the players in video recordings taken in an uncontrolled

environment. The final system would provide the coach with positions of players in the field at anytime, so that can be used in development and analysis of game tactics.

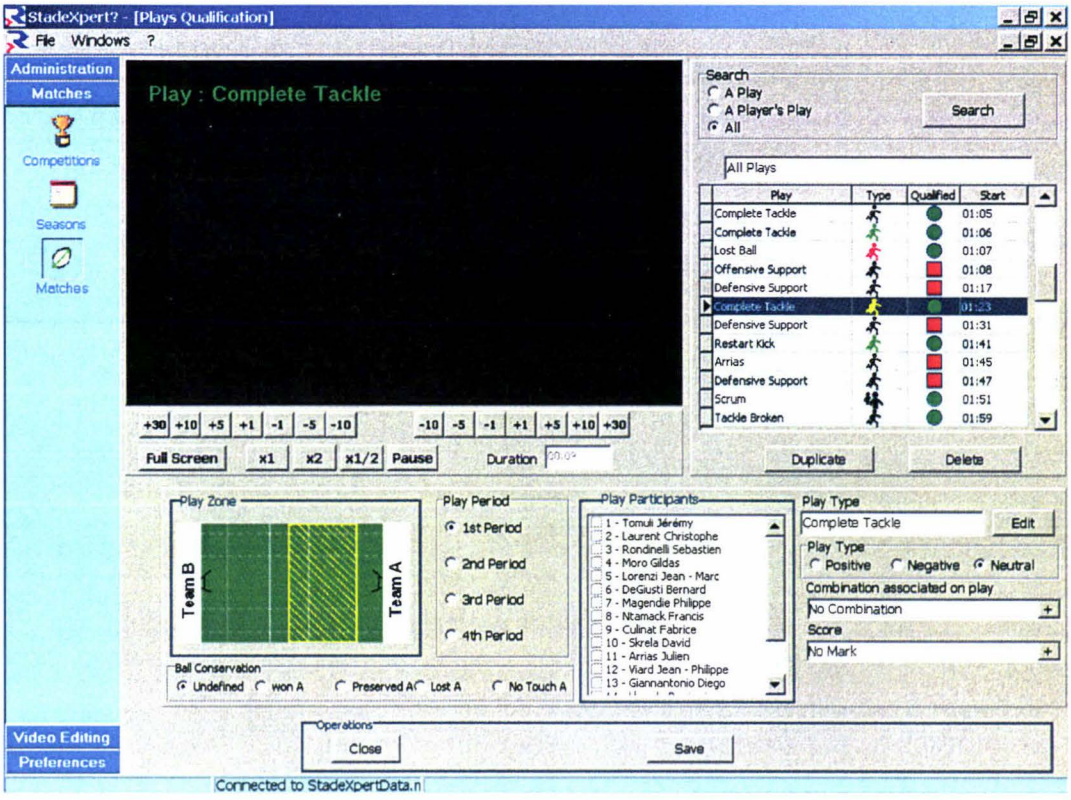

Figure 1-1 Video analysing interface of StadeXpert

1.2 Digital Image Processing Techniques

Digital image processing techniques have been used in a wide range of applications such as biological research, medical diagnostic imaging, video/film special effects, and remote sensing. Baxes (1994, p.1) gives a definition of image processing:

> Image Processing, in general terms, refers to the manipulation and analysis of pictorial information. In this case, pictorial information means a two-dimensional visual image. Any operation that acts to improve, correct, analyze, or in some way change an image is called image processing.

According to Baxes (1994), there are five classes of digital image processing operations – enhancement, restoration, analysis, compression, and synthesis. Of these techniques, digital image-analysis techniques are most commonly used in computer aided sport analysis systems. Image segmentation techniques are used to extract players from

backgrounds (fields) in video frames. Motion detection and tracking techniques are used to detect and track players' activities in video recordings. In Chapter 2 of this thesis, important fundamental image analysis techniques are reviewed.

1.3 Project Goal

The overall goal of the wider project was to develop a cost-effective system for the semi-automated tracking of individual players in video recordings of team sports like rugby and soccer. Such a system can be used to help the coach analyse the performance of players and develop game tactics.

The original plan for this one-year research was to use controlled test conditions, that is, one fixed camera to capture the whole rugby field and to initially place only one player on the field. With a static camera position, motion detection techniques could have been used to detect moving objects in the field, that is, the players and the referees. The conversion from pixels in the image to the position in the field would have required only one formula for the entire video recording. In sport fields, field characteristics like lines usually have known positions. For example, the rugby field is normally 100 meters by 70 meters, which means the distance between two goal lines is 100 meters and the distance between two touchlines is 70 meters. These characteristics make it possible to calculate the conversion formula by detecting and identifying lines. In order to find the formula for a video recording taken by a fixed camera, field characteristics (lines) would only have to be recognised once for the whole video recording, which could be done at the beginning of the video recording by a human operator. Thus a player's position as identified in the video recording could have been transformed to coordinates in the rugby field. A human operator was to manually mark the position of the player at the beginning of the video recording and the application would automatically track the player with image recognition techniques.

From the analysis of the geometric model, it was found that in order to capture the whole rugby field on one MPEG1-format video frame, the camera's position must be very high and far from the rugby field. A fixed camera position and angle is not feasible because the camera cannot be put that far back, further more, in such a situation, the number of pixels per player will become insufficient for recognition. One possible solution to this is to use multiple fixed cameras, which each capturing part of the rugby field. The retrieved video recordings can then be processed individually and the information from different video recordings can be combined to generate the final result. The problem with this approach

is that it requires extra costs for hardware and might consume more time in processing because of the increase in the number of video recordings. Another possible solution is to use only one camera to capture part of the rugby field. In this case, the camera has to swing or zoom to follow the players on the field, so that the camera captures the most important part of the rugby field where most activities of the player take place. As this approach reduces the cost in hardware, and simplifies the processing, it is selected as the direction of the research in this project. Thus, there is no point in making specific video recordings; video recordings from televised rugby games are suitable for the research. This change in the project from fixed to moving camera raised the complexity because with a moving camera, a conversion must be made for every video frame, that is, reference points need to be calculated for every frame.

With this change from a static to a moving camera, the change of a player's position between two sequential video frames can result both from the movement of the camera and the movement of the player. This means that player tracking has three components: detect a player in the video image; refer the location of the player in the video image to reference points on the rugby field to be able to find out the player's position on the rugby field; recognise the identity of the player by tracking. It is therefore essential to have reference points. Field characteristics, lines, have to be recognised for each video frame to achieve correct conversion between image coordinates and rugby field coordinates. Line tracking needs to be performed to avoid asking the human operator to identify lines for every frame.

With the change in requirements from fixed to moving camera, the focus of the project had changed to semi-automated tracking of field characteristics in video recordings of rugby games. A line tracking system needed to be conceptualised, built and tested.

1.4 Structure of the thesis

This thesis consists of six chapters. In Chapter 2, related research is discussed and relevant background knowledge is introduced. Chapter 3 of this thesis presents the conceptual design of the line tracking system. Chapter 4 discusses the implementation issues of the system. In Chapter 5, testing of the developed line tracking system is introduced and analysed. Finally, Chapter 6 concludes the thesis and discusses the potential for future work.