

Paper Title*

Davide Lusuardi

Department of information engineering and computer science

University of Trento

Trento, Italy

davide.lusuardi@studenti.unitn.it

Abstract—In this document, we discuss some methods to accomplish free-viewpoint video visualisation for soccer scenes. These methods generate novel views of actions from any angle and allow viewers to virtually fly through real soccer scenes.

I. INTRODUCTION

Nowadays, sport broadcasting plays a large role in current society. Therefore, it is important to provide a high quality and visually pleasing reporting of sports events. As we know, incidents in sport tend to be over very quickly. Slow-motion replays can be used to illustrate these incidents as clearly as possible for the viewer.

Although time is stretched in these replays, there is no exploration of the spatial scene information, which is usually important for understanding the event. A system that allows a replay from any angle adds a lot of value to the viewer experience.

Free-viewpoint video (FVV) is one of the new trends in the development of advanced visual media type that provides an immersive user experience and interactivity when viewing visual media. Compared with traditional fixed-viewpoint video, it allows users to select a viewpoint interactively and is capable of rendering a new view from a novel viewpoint. FVV has been a research topic in the field of computer vision since the virtualized reality system [4] was developed, ranging from static models for studio applications with a fixed capture volume, controlled illumination and backgrounds [5] to dynamic object models for sports scenes [6]–[8]. Live outdoor sports such as soccer involve a number of additional challenges for both acquisition and processing phases. The action take place over an entire pitch and video acquisition should be done at sufficient resolution in order to do analysis and production of desired virtual camera views.

In this paper we briefly present and compare some methods to accomplish free-viewpoint video visualisation for soccer scenes...

II. OVERVIEW

In the field of computer vision, the techniques for synthesizing virtual view images from a number of real camera images have been studied since the 1990s [1]–[3]. Free-viewpoint video in sports TV broadcast production is a challenging problem involving the conflicting requirements of broadcast picture quality with video-rate generation. FVV techniques for generating novel viewpoints using a multiview camera setup can be categorized into two classes: 3D reconstruction and

image-based rendering. Using 3D reconstruction, it is possible to construct 3D models of objects to generate the desired view from an arbitrary viewpoint. The quality of the virtual view image generated by these methods depends on the accuracy of the 3D model. In order to produce an accurate model, a large number of video cameras surrounding the object are used. Moreover, ... TODO:01

It is not practical to apply these methods to a scene that contains multiple objects with complicated movements such as a sporting match. TODO

III. THE IVIEW SYSTEM

In this section we present the DTI-funded collaborative project *iview* [9], a free-viewpoint video system which enables the production of novel desirable camera views such as the goal keeper view, the referee view or even the ball camera. This system exploits the already placed live TV broadcast cameras as the primary source of multiple view video. Usually football matches are covered by 12-20 high-definition cameras placed all over in the stadium providing wide-baseline views. Match cameras are manually controlled to follow the game play zooming in on events when occurs. However, only a fraction of these are focused on specific events of interest and can be used for production of free-viewpoint renders, the remaining cameras cover the pitch, crowd and coaches.

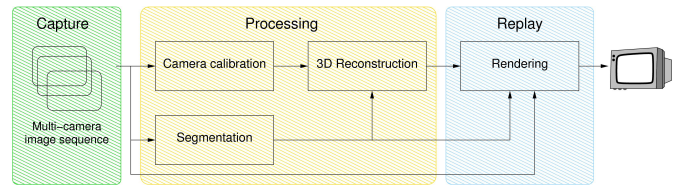


Fig. 1. Overview of the free-viewpoint system. [TODO: cite 02.1]

The *iview* system is composed of three main modules as shown in Figure 1: capture, processing, and replay module.

Capture is performed using time synchronised acquisition from both auxiliary and match cameras. The minimal number of cameras is about four, but for good quality results a higher number is required. Camera synchronisation is achieved using standard genlock process.

The processing module computes a 3D model of the scene. This is done using segmentation of objects from the background and 3D reconstruction [10].

In order to allow the use of footage from match cameras and to avoid the need for prior calibration, automatic calibration of all cameras is performed using a line-based approach against the pitch lines of the captured footage, achieving a root-mean-square error of 1-2 pixels for moving cameras. The calibration is very fast and robust, capable of real-time operation for use during live match footage. Calibration estimates the extrinsic and intrinsic parameters of each camera including lens distortion.

The segmentation is needed to separate the foreground, i.e. the players from the background. Matting of players from the green pitch is performed using chroma-keying matting. The authors developed and tested a k-nearest neighbour approach for chroma-keying and evaluated two other known techniques, *Fast green subtraction* in RGB colour space and keying in HSV colour space. The k-nearest neighbour classifier is controlled by a GUI where the user has to click on position in the image that correspond to background. The process is repeated until the resulting segmentation is satisfying. A deeper explanation is present in the paper [10] where the authors present and evaluate also *Fast green subtraction* and keying in HSV.

The accumulation of errors from calibration and matting can cause large errors in the reconstruction of the scene such as loss of limbs. Therefore, robust algorithms have been developed for scene reconstruction. One possible technique is called visual-hull (VH) and represents the maximum volume occupied by an object given a set of silhouettes from multiple views [2.2:8]. The visual-hull is a single global representation integrating silhouette information from all views. A polygonal mesh surface is typically extracted and texture mapped by resampling the captured multiple view video for rendering [2.2]. Due to accumulating errors in camera calibration and segmentation, visual-hull accuracy is reduced. A refinement of the view-dependent visual hull (VDVH) [2.1:12] using stereo correspondence to interpolate between captured views can be used to overcome these issues achieving the best alignment between adjacent views and hence improve visual quality. More information about *iview* 3D reconstruction can be found in [2.2.1,2.2].

Finally, the replay module renders the novel view of the scene using the computed 3D model together with the original camera images. Cameras closer to the virtual viewpoint are chosen to generate the novel viewpoint.

IV. IMAGE-BASED RENDERING

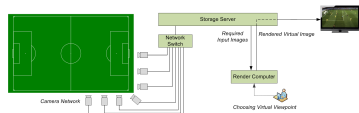


Fig. 2. Overview of the free-viewpoint system. [TODO: cite 02.1]

In this section we present a different approach to FVV. Instead of performing 3D reconstruction, image-based methods generate directly the image of the novel viewpoint. When

multiple cameras are present, plane sweeping can be used [05:Yang et al., 2004] for both small and wide baseline setups. Plane sweeping has already been used for novel view point in soccer scenes. Goorts et al. [05:Goorts et al., 2012a; Goorts et al., 2013a] present a method with two plane sweeps and a depth filtering step suitable for smaller baseline setups of about 1 meter. Moreover, this method has some problems like disappearing players if they overlap in the image.

ACKNOWLEDGMENT

The preferred spelling of the word “acknowledgment” in America is without an “e” after the “g”. Avoid the stilted expression “one of us (R. B. G.) thanks ...”. Instead, try “R. B. G. thanks...”. Put sponsor acknowledgments in the unnumbered footnote on the first page.

REFERENCES

Please number citations consecutively within brackets [1]. The sentence punctuation follows the bracket [2]. Refer simply to the reference number, as in [3]—do not use “Ref. [3]” or “reference [3]” except at the beginning of a sentence: “Reference [3] was the first ...”

Number footnotes separately in superscripts. Place the actual footnote at the bottom of the column in which it was cited. Do not put footnotes in the abstract or reference list. Use letters for table footnotes.

Unless there are six authors or more give all authors’ names; do not use “et al.”. Papers that have not been published, even if they have been submitted for publication, should be cited as “unpublished” [4]. Papers that have been accepted for publication should be cited as “in press” [5]. Capitalize only the first word in a paper title, except for proper nouns and element symbols.

For papers published in translation journals, please give the English citation first, followed by the original foreign-language citation [6].

REFERENCES

- [1] S. Pollard, M. Pilu, S. Hayes, and A. Lorusso, View synthesis by trinocular edge matching and transfer, *Image Vis. Comput.*, vol. 18, pp. 749757, 2000.
- [2] H. Saito, S. Baba, and T. Kanade, Appearance-based virtual view generation from multicamera videos captured in the 3-D room, *IEEE Trans. Multimedia*, vol. 5, no. 3, pp. 303316, Sep. 2003.
- [3] S. M. Seitz and C. R. Dyer, Photorealistic scene reconstruction by voxel coloring, in *Proc. Computer Vision and Pattern Recognition (CVPR1997)*, 1997, pp. 10671073.
- [4] Takeo Kanade, Peter Rander, and PJ Narayanan, Virtualized reality: Constructing virtual worlds from real scenes, *IEEE multimedia*, vol. 4, no. 1, pp. 3447, 1997.
- [5] Takashi Matsuyama and Takeshi Takai, Generation, visualization, and editing of 3d video, in *null*. IEEE, 2002, p. 234.
- [6] Jean-Yves Guillemaut and Adrian Hilton, Joint multi-layer segmentation and reconstruction for free-viewpoint video applications, *International journal of computer vision*, vol. 93, no. 1, pp. 73100, 2011.
- [7] Marcel Germann, Tiberiu Popa, Richard Keiser, Remo Ziegler, and Markus Gross, Novel-view synthesis of outdoor sport events using an adaptive view-dependent geometry, in *Computer Graphics Forum*. Wiley Online Library, 2012, vol. 31, pp. 325333.
- [8] Keisuke Nonaka, Ryosuke Watanabe, Jun Chen, Houari Sabirin, and Sei Naito, Fast plane-based free-viewpoint synthesis for real-time live streaming, in *IEEE International Conference on Visual Communications and Image Processing*. IEEE, 2018.

- [9] The iview project, <http://www.bbc.co.uk/rd/projects/iview>
- [10] Grau, Oliver and Thomas, Graham and Hilton, Adrian and Kilner, J. and Starck, Jonathan. (2007). A Robust Free-Viewpoint Video System for Sport Scenes. 1 - 4. 10.1109/3DTV.2007.4379384.