

## Specialized depth extraction for live soccer

***Citation for published version (APA):***

Vosters, L. P. J., Haan, de, G., & Peset, R. (2010). Specialized depth extraction for live soccer. In *Proceedings of 21st ProRISC Workshop of the STW.ICT Conference, 18-19 November 2010, Veldhoven, The Netherlands* (pp. 1-31). STW Technology Foundation.

***Document status and date:***

Published: 01/01/2010

***Document Version:***

Publisher's PDF, also known as Version of Record (includes final page, issue and volume numbers)

***Please check the document version of this publication:***

- A submitted manuscript is the version of the article upon submission and before peer-review. There can be important differences between the submitted version and the official published version of record. People interested in the research are advised to contact the author for the final version of the publication, or visit the DOI to the publisher's website.
- The final author version and the galley proof are versions of the publication after peer review.
- The final published version features the final layout of the paper including the volume, issue and page numbers.

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# Specialized Depth Extraction for Live Soccer Video

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November 18, 2010



Introduction

Related Work

Proposed Approach

Results

Conclusion

Questions



## 2D-To-3D Conversion

## 3D

## ▶ 3D Cinema.



## ▶ 3D TV sets.



## ▶ 3D broadcast.



sky 3D

## ▶ 3D Live Events.



# 3D Productions

- ▶ 3D cameras.



- ▶ 2D-to-3D conversion.
  - ▶ Offline (semi-) automatic.
  - ▶ Real-time.





# 3D Productions

- ▶ 3D cameras.



- ▶ 2D-to-3D conversion.
  - ▶ Offline (semi-) automatic.
  - ▶ **Real-time.**





# Why 2D-To-3D conversion?

## 2D-to-3D Conversion



- ▶ 10,000\$
- ▶ Widely available.
- ▶ No camera rig.
- ▶ No stereographer.

## 3D Recording

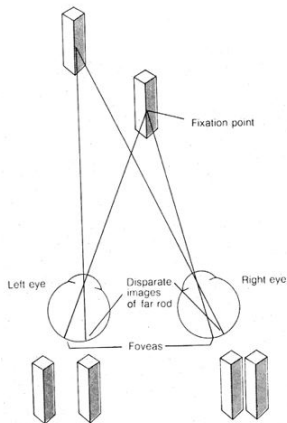


- ▶ 80,000\$
- ▶ Investment.



## Stereoscopic 3D

# Binocular Disparity

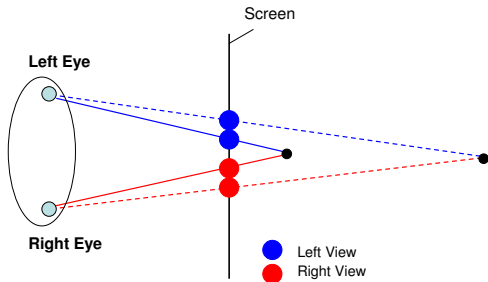






# From Depth to Stereo 3D

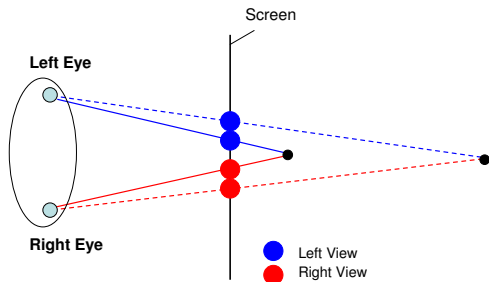
- ▶ Depth  $\leftrightarrow$  disparity.
- ▶ 2D-To-3D:
  1. Extract depth.
  2. Calculate disparity.
  3. Render Left/Right image.
- ▶ Occlusion handling.





# From Depth to Stereo 3D

- ▶ Depth  $\leftrightarrow$  disparity.
- ▶ 2D-To-3D:
  1. Extract depth.
  2. Calculate disparity.
  3. Render Left/Right image.
- ▶ Occlusion handling.





## 2D-To-3D Conversion of Live Soccer Video

## Long Shot Images in Live Soccer.



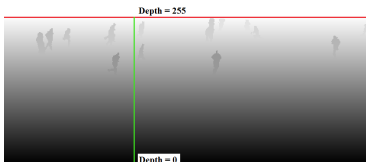
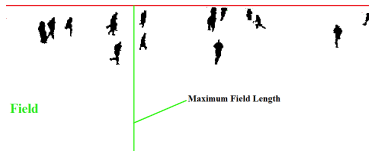


Jung et al.

# Jung et al. [1]



Audience





# Jung et al. cont.

## Advantages

- ▶ No occlusions.
- ▶ Few computations.

## Disadvantages

- ▶ Pan, tilt, zoom not modeled.
- ▶ Audience depth constant.
- ▶ No depth offset.

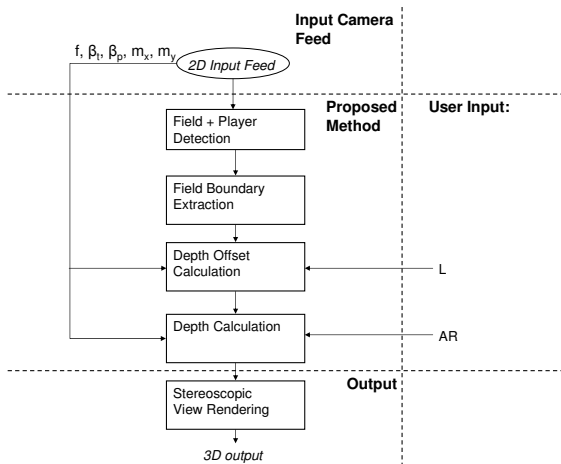


# Proposed Approach

- ▶ Field and audience depth model.
- ▶ Exploit *Camera* + *Scene* information.
  - ▶ Focal length
  - ▶ Tilt/Pan angle
  - ▶ Image sensor size
  - ▶ Average player length



## Image Model



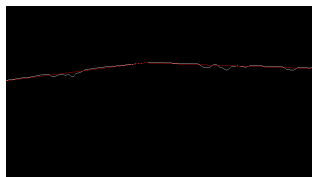
## Field Detector (Seo et al. [2])

- ▶ Train Hue, Sat, Val histograms.
- ▶ Extract *PeakValueIndex*, *SaturationMean*.

$$Field, \text{ if } \begin{cases} G > 0.95 \cdot R \\ R > 0.95 \cdot B \\ V < 1.25 \cdot \textit{PeakValueIndex} \\ S > 0.8 \cdot \textit{SaturationMean} \end{cases} \quad (1)$$



# Field Boundary Extraction



- ▶ Piecewise linear curve fit. (Cantoni [3]).
  - ▶ Specify start, end and line intersection.

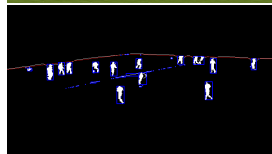


# Player Detection

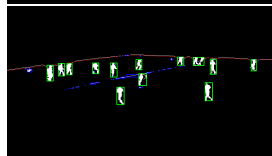
Input image



Connected Components



$$Player \quad if \quad \left\{ \begin{array}{l} 0.4 < AspectRatio < 3 \\ \frac{\#Pixels}{BBwidth \cdot BBheight} > 0.05MN \\ \frac{BBwidth \cdot BBheight}{\#Pixels} > 0.25 \end{array} \right.$$



# Player Detection Cont.

- ▶ Field Boundary Extraction aides Player Segmentation.

Input



Jung et al. [1]



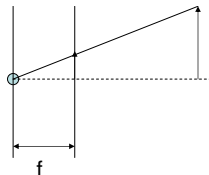
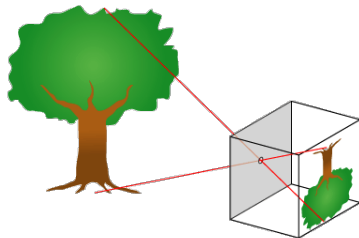
Proposed





# Camera depth model

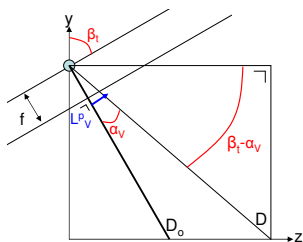
- ▶ Long shot camera
  - ▶ Small lens aperture.
  - ▶ High depth of field.
- ▶ Pin-hole camera.





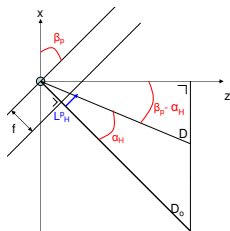
# Field Depth

Depth in YZ-plane:



$$D = D_o \frac{\sin |\beta_t|}{\sin (|\beta_t| - \alpha_v)}$$

Depth in XZ-plane:



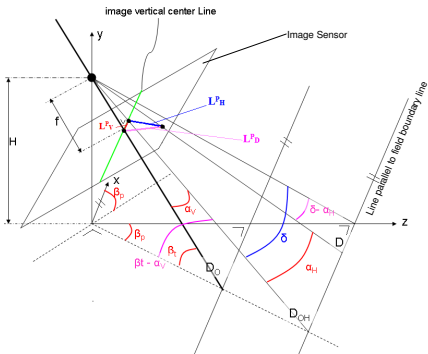
$$D = D_o \frac{\cos |\beta_p|}{\cos (|\beta_p| - \alpha_H)}$$



## Camera Depth Model

## Field Depth cont.

## Depth in XYZ-Plane.



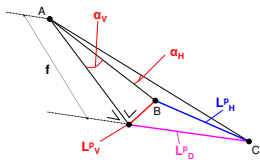
$$D_{field}(\alpha_V, \alpha_H) =$$

$$D_o \frac{\sin |\beta_t|}{\sin(|\beta_t| - \alpha_V)} \frac{\cos |\beta_p|}{\cos(|\beta_p| - \alpha_H)}$$



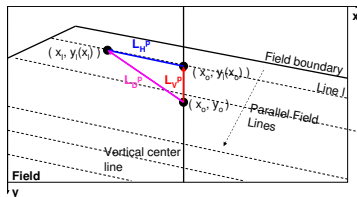
## Camera Depth Model

## Field Depth Calculation



$$\alpha_V = \arctan\left(\frac{L_V^P}{f}\right)$$

$$\alpha_H = \arccos\left(\frac{2f^2 + L_V^{P2} + L_D^{P2} - L_H^{P2}}{2\sqrt{(f^2 + L_V^{P2})(f^2 + L_D^{P2})}}\right)$$

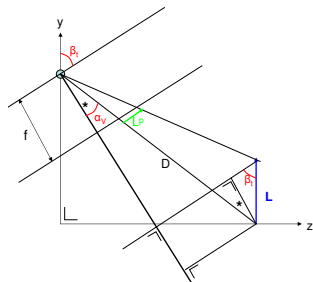


- ▶ Depth offset unknown.



# Depth Offset

- ▶ Player length  $\approx 1.80m$
- ▶  $L^P \leftrightarrow$  Tilt,  $f$ , Depth,  $L$ .
- ▶  $D_{o,i}$  depth offset player  $i$ .
- ▶  $D_o = \text{median}\{D_{o,i} | \forall i\}$



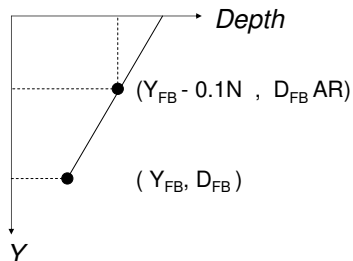
$$D = L \cdot \frac{\sin \beta_t [L^P \cdot m_y + f \tan \alpha_v] + f \cos \beta_t}{\cos \alpha_v [L^P \cdot m_y + f \tan \alpha_v] - f \sin \alpha_v}$$





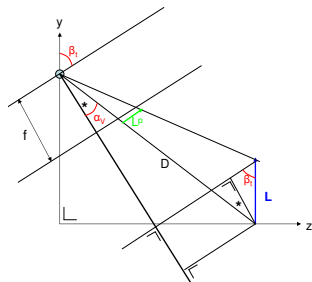
# Audience Depth

$$D_{aud}(y) = \frac{D_{FB} \cdot AR}{0.1N} (y - y_{FB}) + D_{FB} ,$$





# Player Depth



- ▶ Player approximately constant.
- ▶  $D_{player} = D_{field}(x_i, y_i)$ .

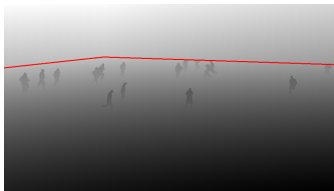


# Complete Camera Depth Model

- ▶ Depth Map Quantization.

$$DEPTH(x, y) = 255 \cdot \left( \frac{D(x, y) - D_{min}}{D_{max} - D_{min}} \right)$$

- ▶ Clip outside  $[D_{min}, D_{max}]$ .



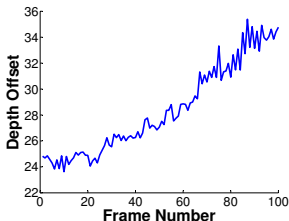


# Depth Offset Calculation

## ► Zooming



## ► Keep focal length constant in depth offset calculation.





# Qualitative Comparison

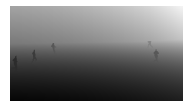
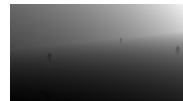
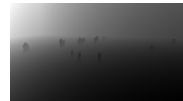
Input



Jung et al. [1]



Proposed








# Conclusion

- ▶ Jung et al. [1] proposed specialized 2D-3D conversion of long shot images.
- ▶ We propose more advanced model:
  1. *zooming, panning* and *tilting* modeled.
  2. Calculates depth offset from player length.
  3. Improved player segmentation by field boundary extraction.
- ▶ Few computations.
- ▶ Hardware attractive.
- ▶ Future work: perceptual tests.



# Questions

Thanks for your attention.

-  Y. J. Jung, C. Kim, D. Park, Y. Kim, and J. Ko, “Method, medium, and system for generating depth map of a video image,” U.S. Patent US20 090 196 492, August 6, 2009.
-  K. Seo, J. Ko, I. Ahn, and C. Kim, “An intelligent display scheme of soccer video on mobile devices,” *IEEE Transactions on Circuits and Systems for Video Technology*, vol. 17, no. 10, pp. 1395–1401, October 2007.
-  A. Cantoni, “Optimal curve fitting with piecewise linear functions,” *IEEE Transactions on Computers*, vol. C-20, no. 1, pp. 59–67, Januari 1971.