Computer Vision in Basketball

Jack Mahoney

University of Minnesota, Morris

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Overview

- Introduction
- Introductions To Papers
- Important Components
    - Camera
    - Other
- Equations
- Recap

Introduction

- Sports are a large industry
- Growing
- You are a fan or someone watching
- Fast paced
- Adds challenges
- Some way to help understanding

Figure: 1. Basketball Images

Introduction to Computer Vision

- Computer Vision
  - Extracts Useful Information
  - Processes Images
  - Basketball
  - Arena

Figure: 2. Basketball Images

3D Ball Localization From A Single Calibrated Image

- Equations to figure out the ball position
- Matrices involved in the equations

Deep Sport Radar

- Kaggle
  - Platform
  - Data Scientists
- Deep Sport Radar
- Competition
- Winner
- Data Set

Figure: 3. Logo

Important Components

- Camera
  - Type
  - Components
- Arena
- Coordinate
- Challenge
- Image Quality

Pinhole Camera

Pinhole camera

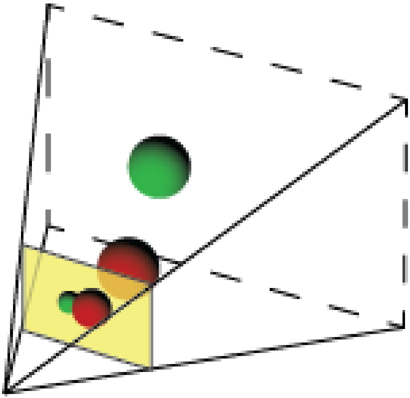

Figure: 4. Pinhole Camera

Lens Camera

Lens camera

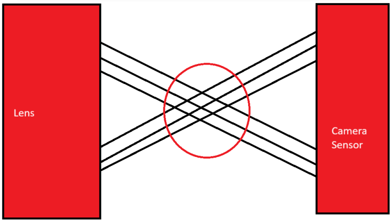

Figure: 5. Lens Camera

Focal Length

Focal length is the distance between the camera lens and optical sensor.

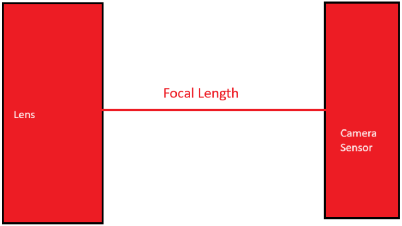

Figure: 5. Focal Length

Optical Center

- Optical Center
  - Lens
  - Camera sensor
  - Middle
  - Rays of light
  - Center of coordinate system

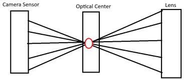

Figure: 6. Optical Center

Skewness

Figure: 7. Skewness Example 1

Figure: 8. Skewness Example 2

Distortion

- Handles curvature
- Different lenses

Distortion

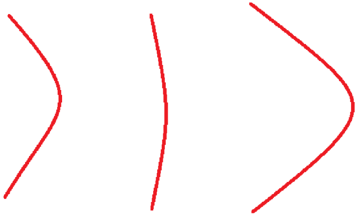

Figure: 9. Distortion

Camera Position

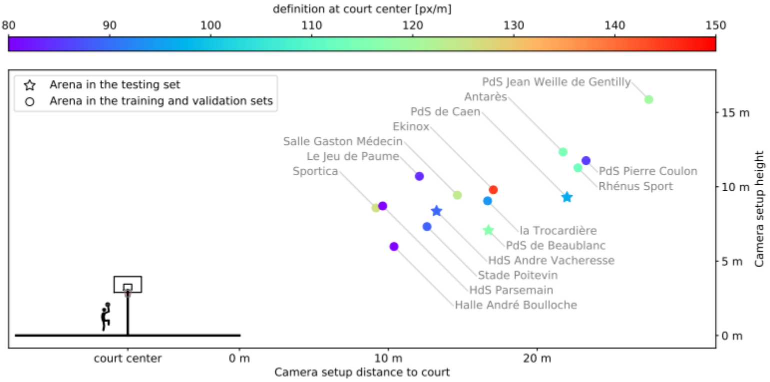

Figure: 10. Camera Locations

Arena 1

Figure: 11. Arena 1

Arena 2

Figure: 12. Arena 2

Image Quality

- Bad resolution
- Noise
- Other Players

Figure: 13. Bad Resolution

Image Quality

- Bad resolution
- Noise
- Other Players

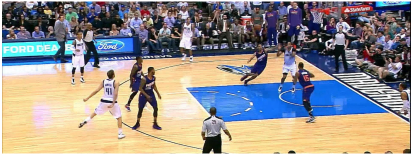

Figure: 14. Noise

Image Quality

- Bad resolution
- Noise
- Other Players

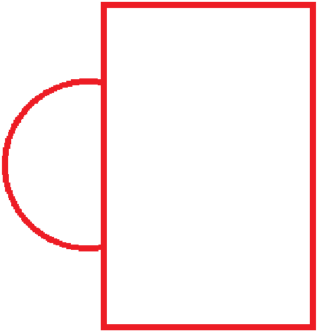

Figure: 15. Other Player

Data Set

- The data set involved details from Arenas
  - Camera Angles
  - Lighting Conditions
  - Court Layouts
  - Crowd
  - Resolution
  - Distance

Coordinate Systems

- Uses numbers (x,y,z)
- Position
- Three
  - Camera
  - Real
  - Homogeneous

Camera Coordinate

- Pixels
- The camera coordinates is what the camera sees

Real World

- Meters
- Inches
- The real world coordinates is what we see

Ray

- The a straight line of light from the camera

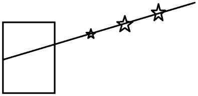

Figure: 16. Ray

Homogeneous

- $\begin{bmatrix} c_x \\ c_y \\ 1 \end{bmatrix}$

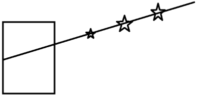

Figure: 17. Homogeneous Coordinates

Challenge in Deep Sport Radar

- Ball 3D localization in calibrated scenes
- Origin is middle of the court
- 3D Localization
  - Process of finding the precise position and orientation of an object
- Calibrated Scene
  - An environment in which the photo coordinates are precisely measured and then calibrated to the real world coordinates

Model

- $b^c = K^{-1} * \mathcal{R} \begin{bmatrix} b_x \\ b_y \\ 1 \end{bmatrix}$
- $b^o = R^T * \frac{\phi * b^c}{e^c_{+y} - e^c_{-y}} + c^o$

Camera Matrix Setup for Camera Position

$$k = \begin{bmatrix} \mathbf{f} * \mu_{\mathbf{x}} & \gamma & u_x \\ 0 & f * \mu_y & u_y \\ 0 & 0 & 1 \end{bmatrix}$$

- f is the focal length
- μ_x is the x scaling factor

Camera Matrix Setup for Camera Position

$$k = \begin{bmatrix} f * \mu_x & \gamma & u_x \\ 0 & f * \mu_y & u_y \\ 0 & 0 & 1 \end{bmatrix}$$

- γ is the skewness of the camera

Camera Matrix Setup for Camera Position

$$k = \begin{bmatrix} f * \mu_x & \gamma & \mathbf{u_x} \\ 0 & f * \mu_y & u_y \\ 0 & 0 & 1 \end{bmatrix}$$

- u_x is the x-coordinate where the optical axis intersect the image sensor

Camera Matrix Setup for Camera Position

$$k = \begin{bmatrix} f * \mu_x & \gamma & u_x \\ 0 & \mathbf{f} * \mu_{\mathbf{y}} & u_y \\ 0 & 0 & 1 \end{bmatrix}$$

- f is the focal length
- μ_y is the y scaling factor

Camera Matrix Setup for Camera Position

$$k = \begin{bmatrix} f * \mu_x & \gamma & u_x \\ 0 & f * \mu_y & \mathbf{u_y} \\ 0 & 0 & 1 \end{bmatrix}$$

- u_y is the y-coordinates where the optical axis intersect the image sensor

Camera Matrix Setup for Camera Position

$$k = \begin{bmatrix} f * \mu_x & \gamma & u_x \\ 0 & f * \mu_y & u_y \\ 0 & 0 & \mathbf{1} \end{bmatrix}$$

- Preserve the homogeneous coordinates
- Value helps to allow to show (x,y) as (x,y,1)
- Transformation

Ball Center

$$b^c = \mathbf{K^{-1}} * R \begin{bmatrix} b_x \\ b_y \\ 1 \end{bmatrix}$$

K^{-1} is the inverse of the camera matrix.

Ball Center

$$b^c = K^{-1} * \mathbf{R} \begin{bmatrix} b_x \\ b_y \\ 1 \end{bmatrix}$$

R is a function

Ball Center

$$b^c = K^{-1} * R \begin{bmatrix} \mathbf{b_x} \\ \mathbf{b_y} \\ \mathbf{1} \end{bmatrix}$$

The function takes three agruments to determine the balls center:

- The balls x cordinate represented by b_x
- The balls y cordinate represented by b_y
- The balls depth which is a constant represented by 1

The x and y of a Ball Size with out edges

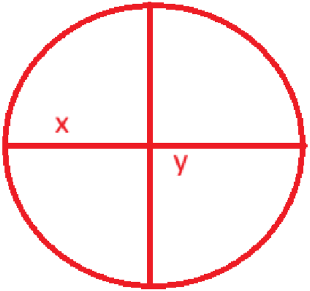

Figure: 18. Normal Ball with no split

Ball Edges

$$e^c_{\pm} = K^{-1} * R \begin{bmatrix} b_x \\ \mathbf{b_y} \pm \mathbf{\frac{d}{2}} \\ 1 \end{bmatrix}$$

The equation to figure out the diameter of the ball is similar to that of the one used to figure out the balls center. The difference is we need to consider the diameter d.

The x and y of a Ball Size with edges

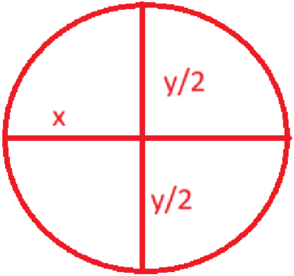

Figure: 19. Normal Ball with split

Ball Position

$$b^o = \mathbf{R^T} * \frac{\phi * b^c}{e^c_{+y} - e^c_{-y}} + c^o$$

R^T is the transposition of the function R

Ball Position

$$b^o = R^T * \frac{\phi * \mathbf{b^c}}{\mathbf{e^c_{+y}} - \mathbf{e^c_{-y}}} + c^o$$

- This fraction is calculates how big the ball is
- ϕ is the true ball diameter

Ball Position

$$b^o = R^T * \frac{\phi * b^c}{e^c_{+y} - e^c_{-y}} + \mathbf{c^o}$$

C^o is the position of the camera in the specific arena you are in

Real World Uses

- Sports betting
- Improves description of the game

Figure: 20. Sports

Recap

- Camera
- Arena
- Coordinate Systems
- Equations
- Matrices
- Real World Applications

Acknowledgments

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References

References

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Questions