



# To see or not to see

Perception Challenges in MSL

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28 November 2016



- Line detection
- Ball detection
- Obstacle detection

# Line Detection

# Line Detection

Color segmentation is the most common method for feature extraction in MSL



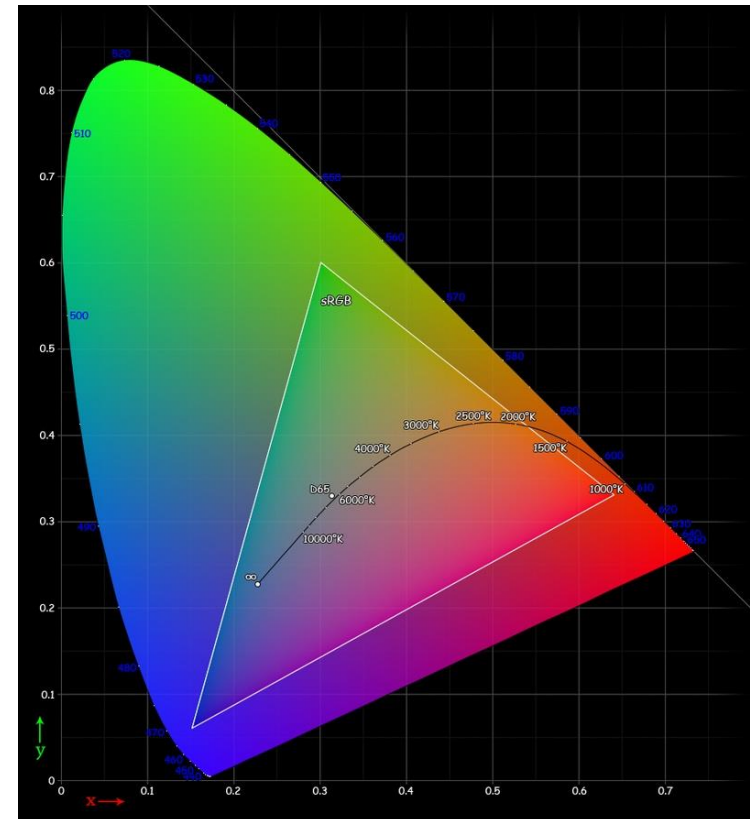
Automated techniques typically use Yuv or RGB color spaces



Assisted offline techniques typically use HSV, HSL or HSI color spaces



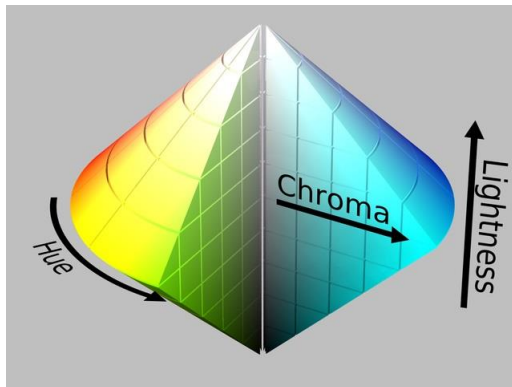
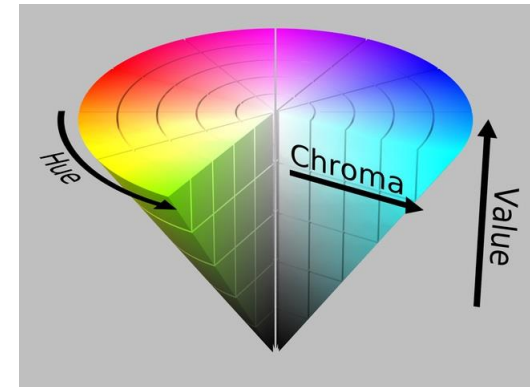
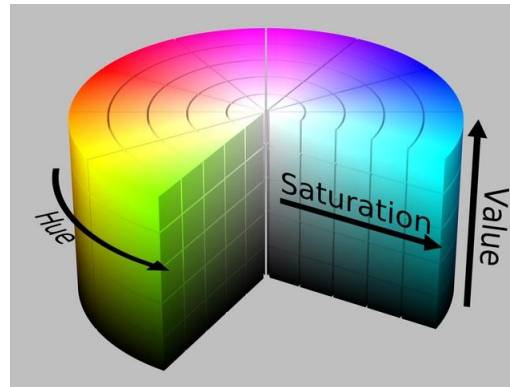
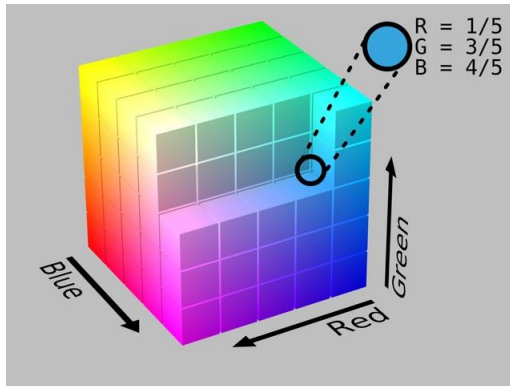
These can be performed offline to generate LUTs for time efficient segmentation



CIE 1931 with delimited sRGB space

# Line Detection

## Examples of well know color spaces



**Hue:** Spectrum related color value relative to CIE

**Lightness, value:** "Brightness relative to the brightness of a similarly illuminated white".

**Chroma:** Colorfulness relative to the brightness of a similarly illuminated white".

**Saturation:** Colorfulness of a stimulus relative to its own brightness.

Pictures by HSL\_color\_solid\_cylinder.png: SharkDderivative work: SharkD Talk - HSL\_color\_solid\_cylinder.png, CC BY-SA 3.0, <https://commons.wikimedia.org/w/index.php?curid=9801661>

## CAMBADA segmentation strategy

Assisted offline segmentation



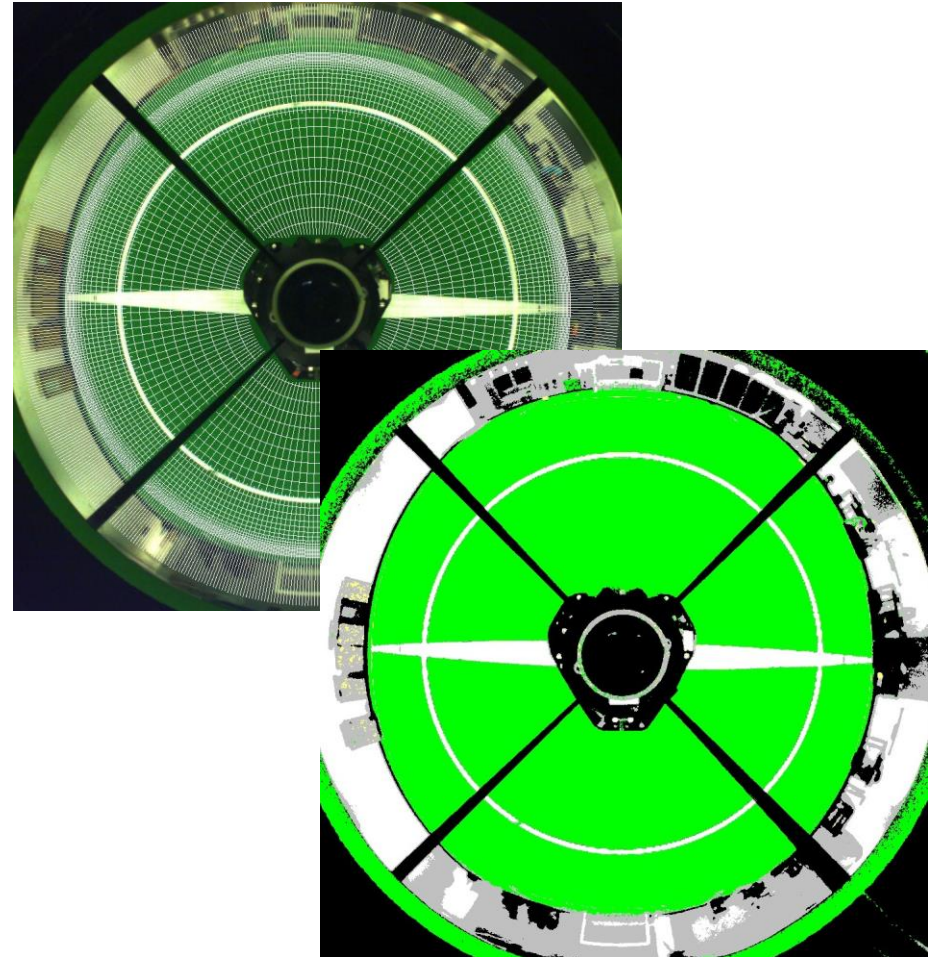
Color space is HCY' where  
 $Y' = 0.21R + 0.72G + 0.07B$



Feature extraction uses radial and  
circular sensors over the segmented  
image



Segmented pixel has 1 byte with flags  
for 8 different colors



## CAMBADA segmentation strategy

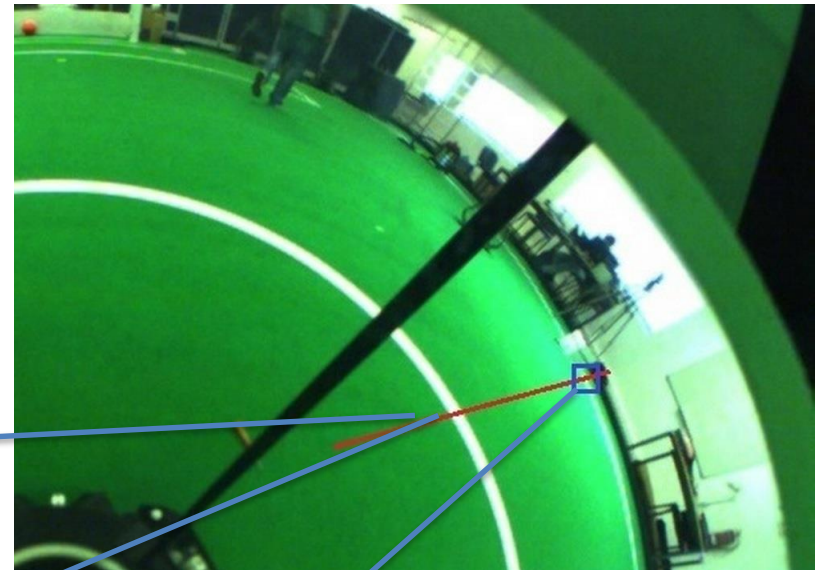
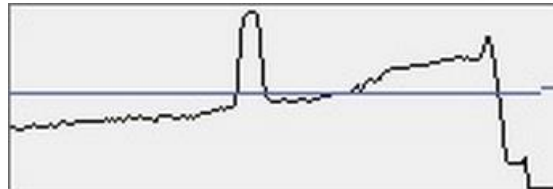
Use of  $Y'$  has advantages over  $V$ :  
over exposed areas;  
blooming and Bayer pattern effects;



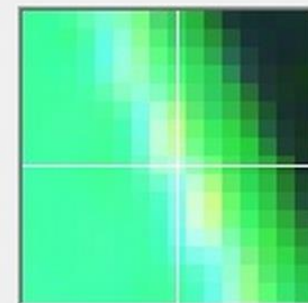
Using  $V$



Using  $Y'$



ZOOM

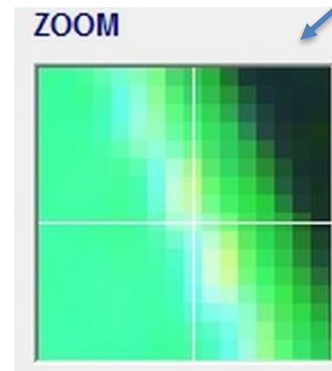
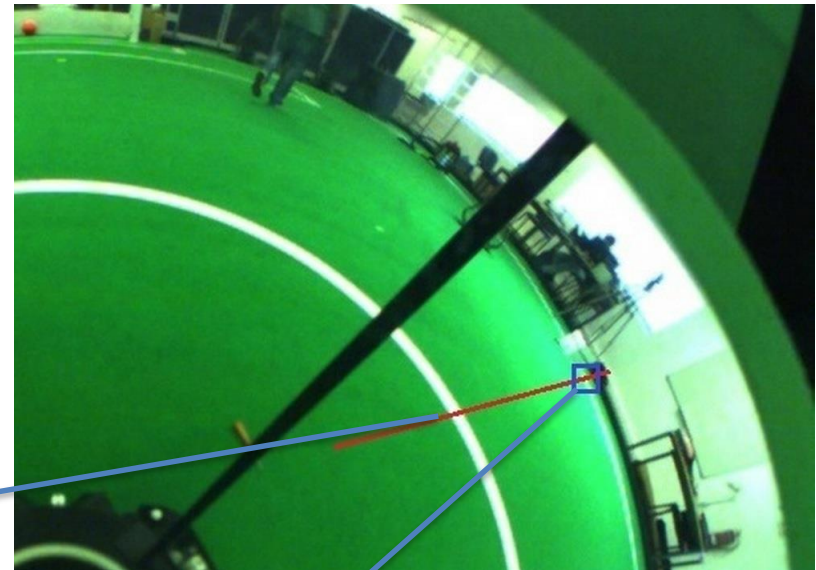
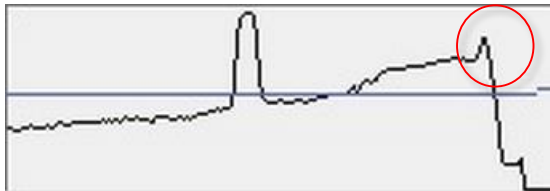


White line at 6m



## CAMBADA line segmentation strategy

Looking at  $Y'$ :  
Combination of Color Segmentation  
and  $Y'$  analysis can be used to  
improve line detection



White line at 6m



CAMBADA line  
segmentation strategy



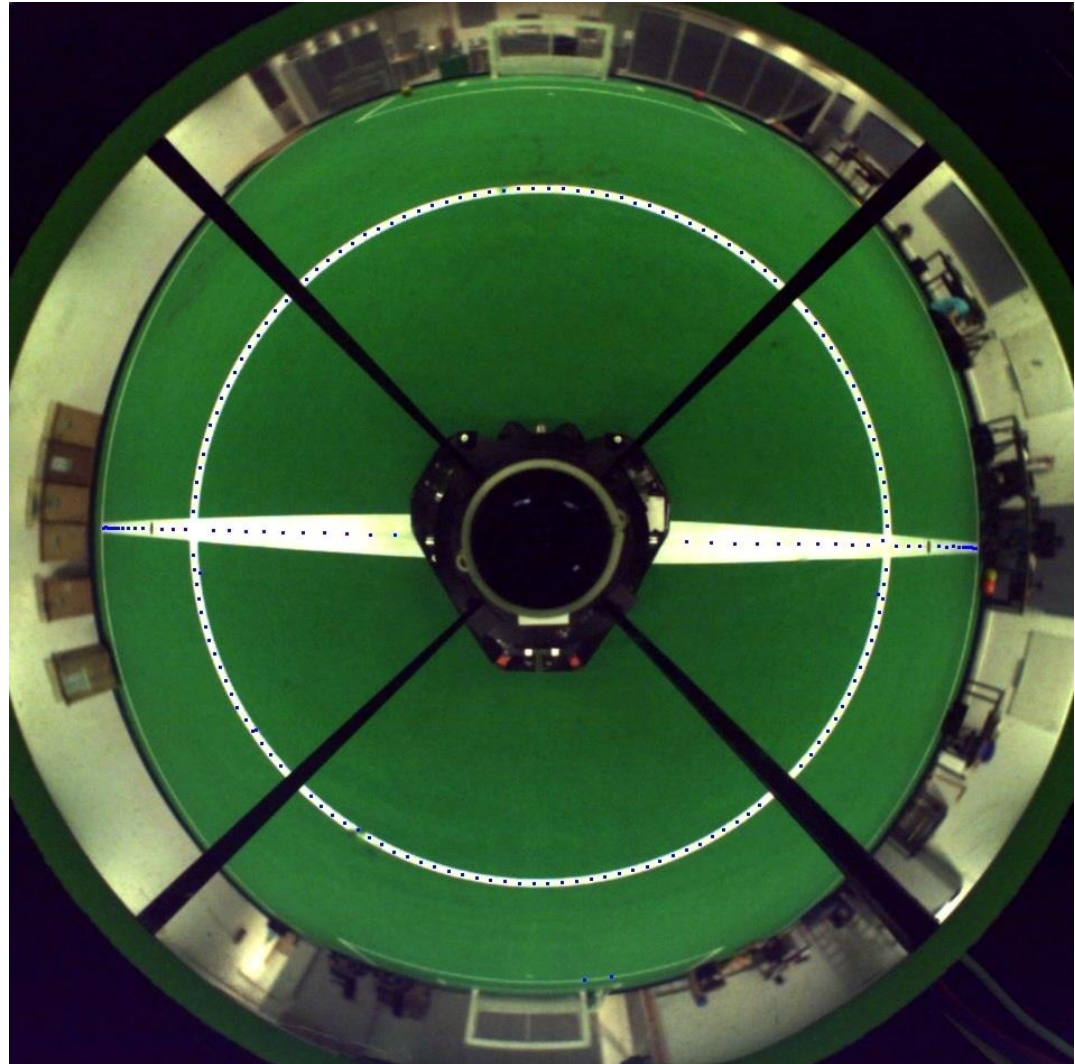
RLE of color sensors



Simple validation  
algorithms can produce  
white spot candidates



Blue spots on image



CAMBADA line  
segmentation strategy



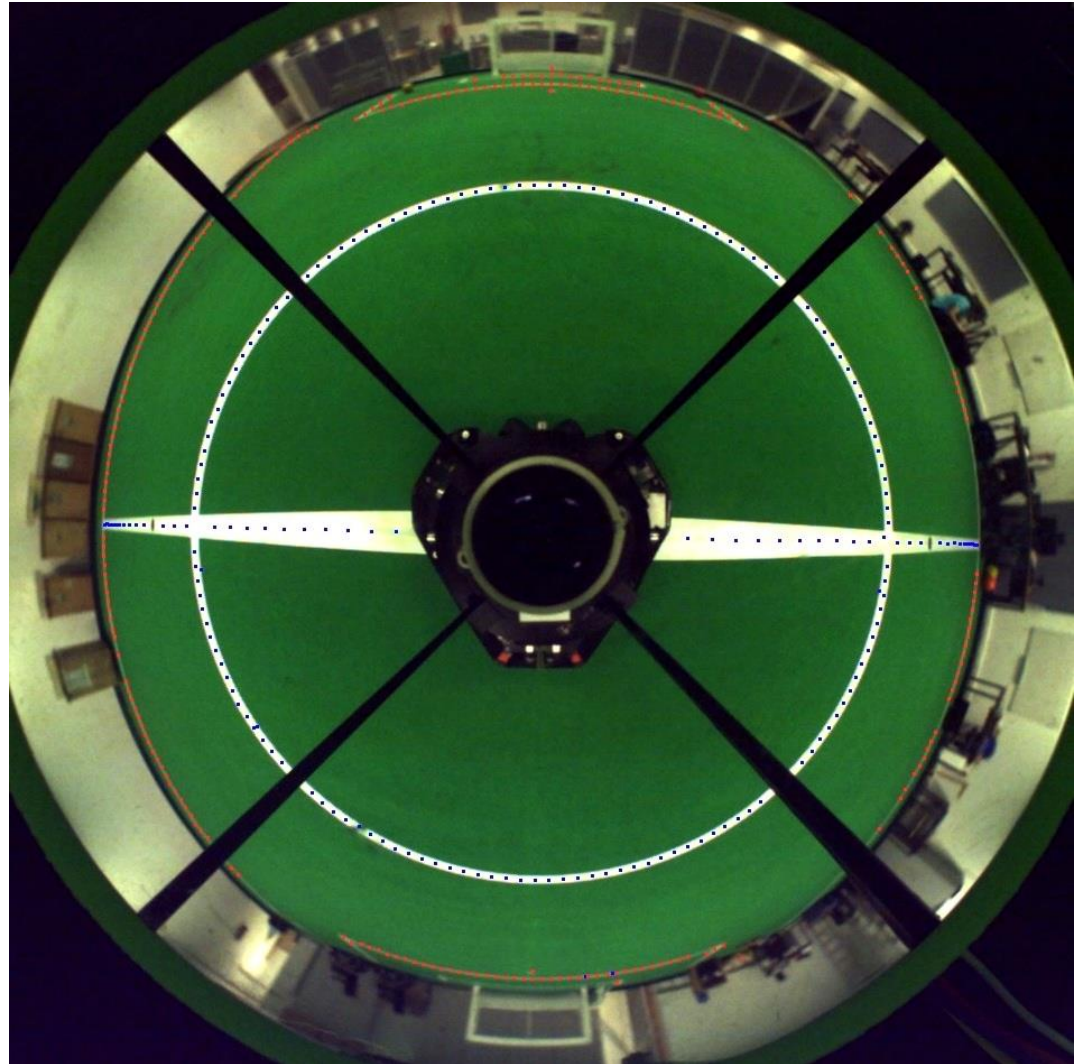
Derivative analysis on  $Y'$



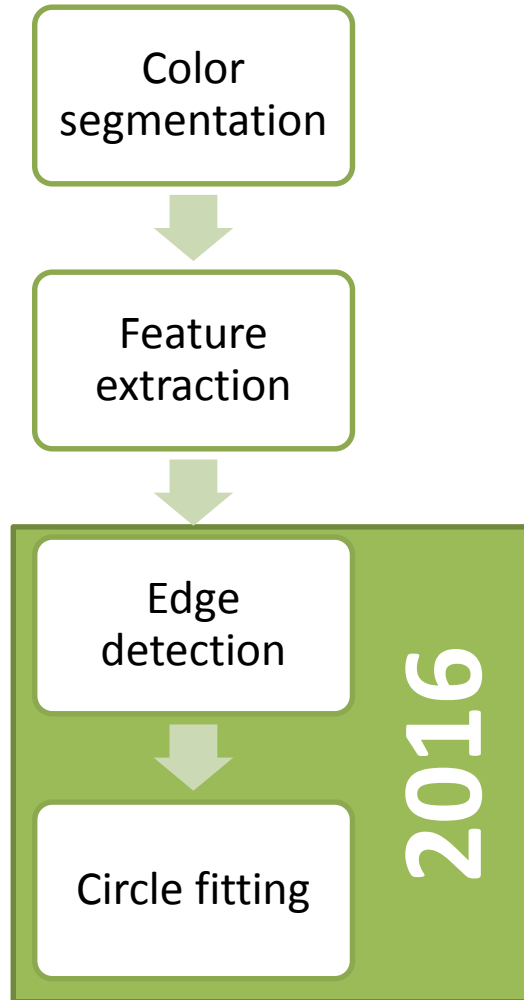
Q factor of far lines +  
Color boundaries



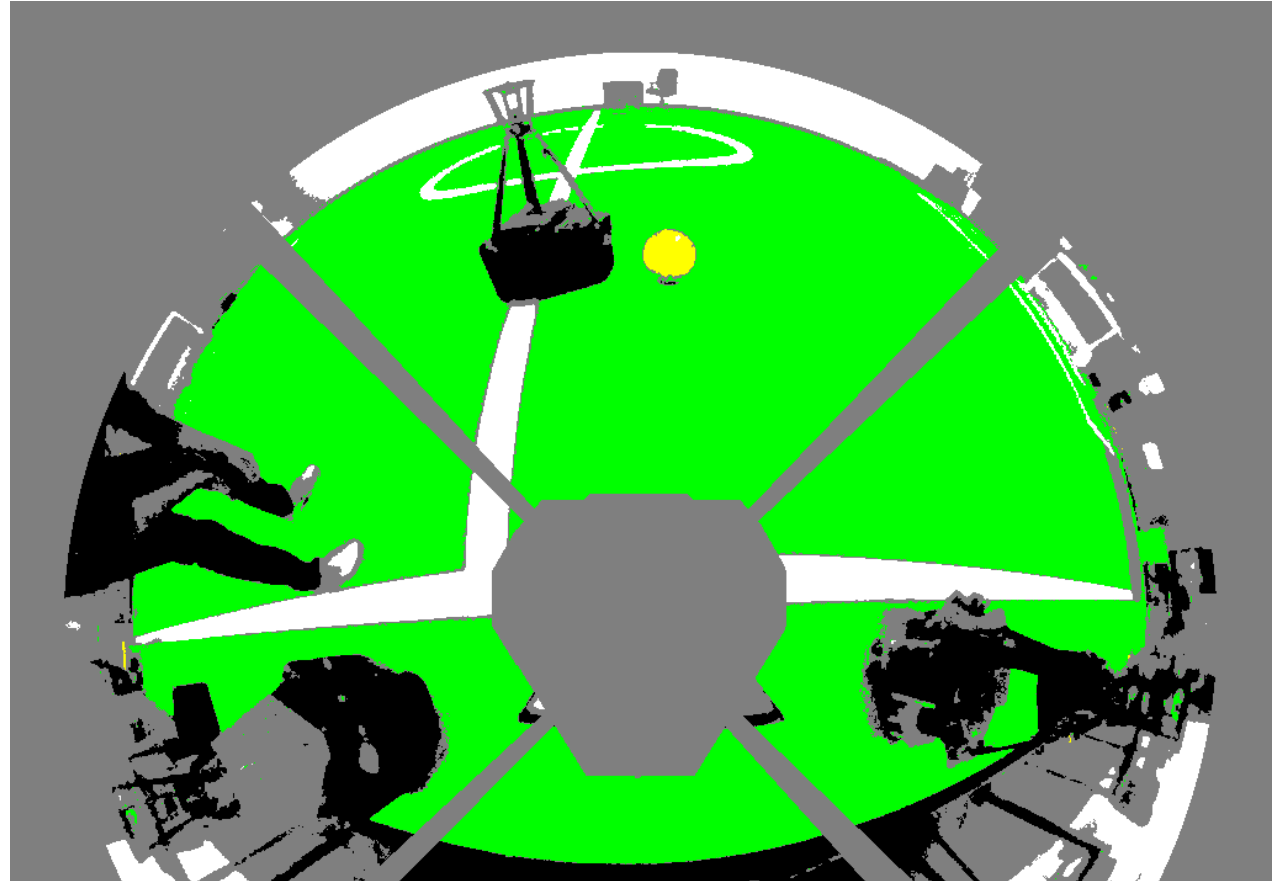
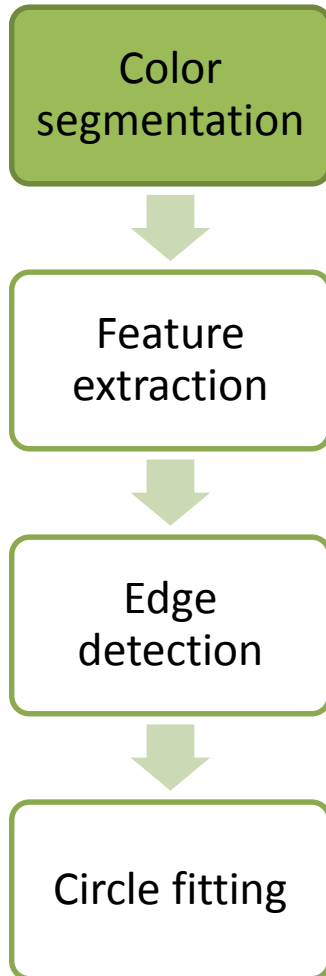
Red spots on image



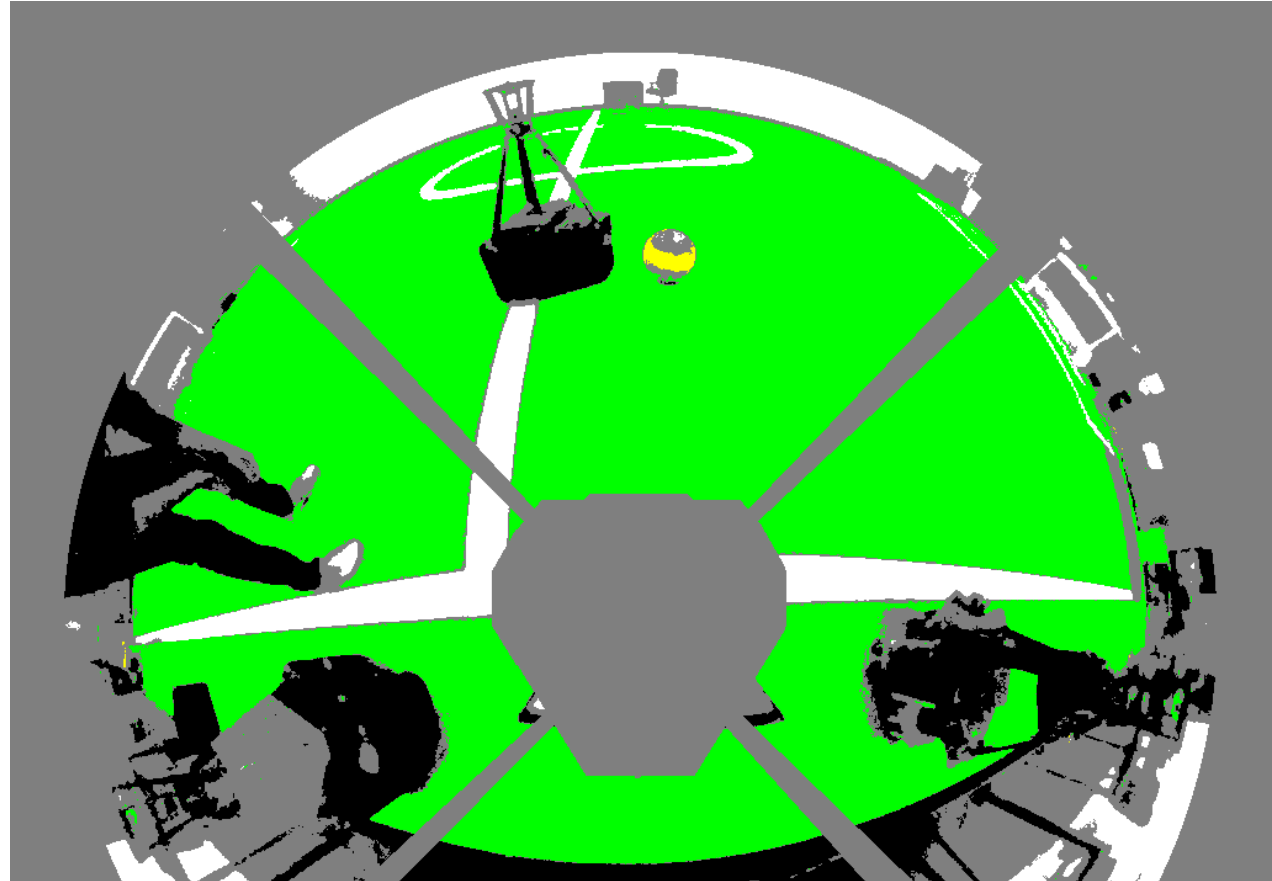
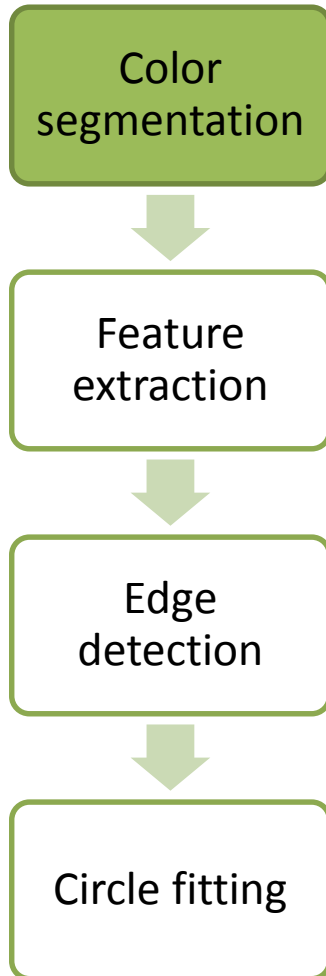
# Ball Detection



- Hue/Saturation/Value ranges

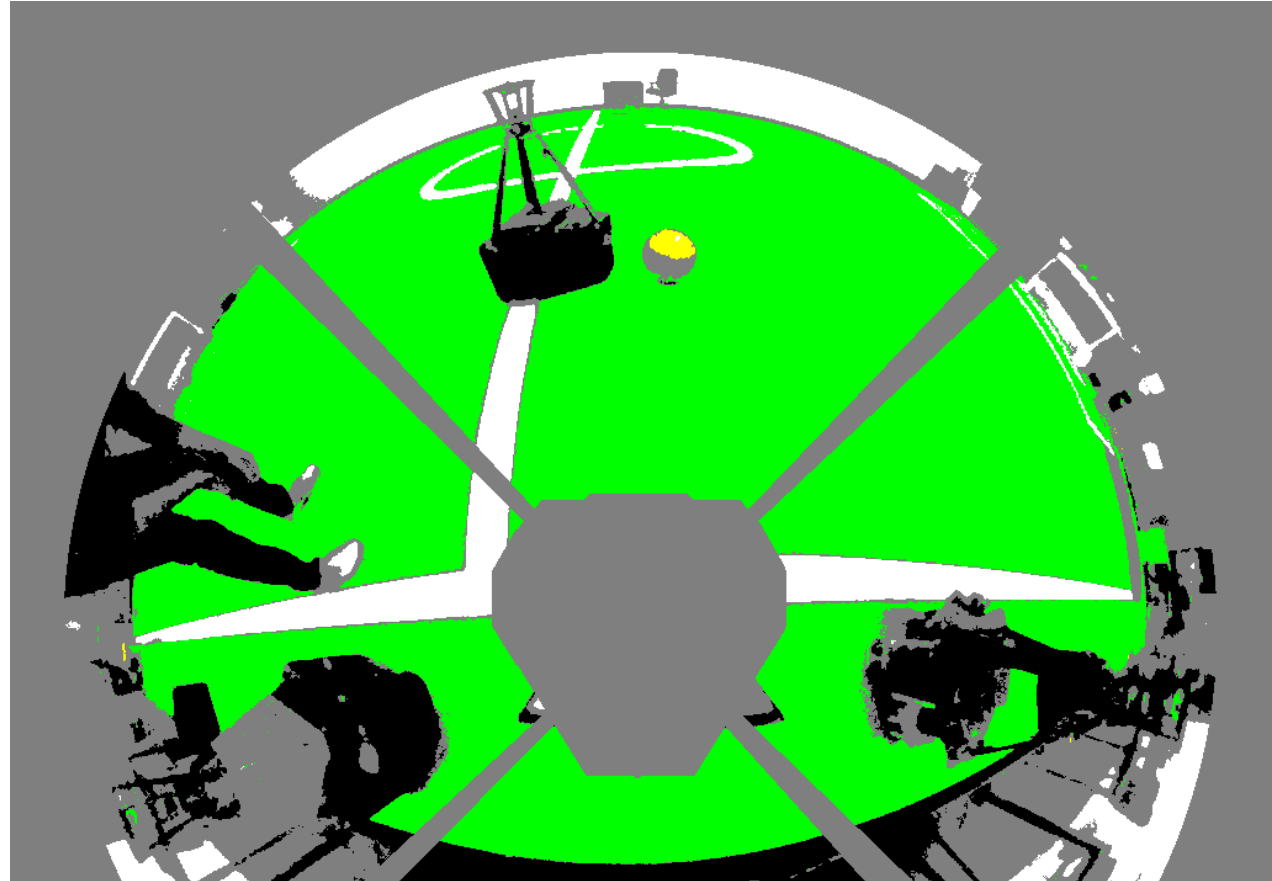
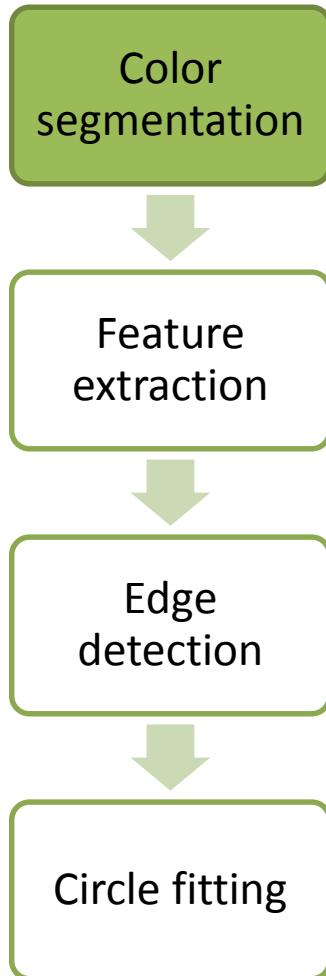


- Hue/Saturation/Value ranges

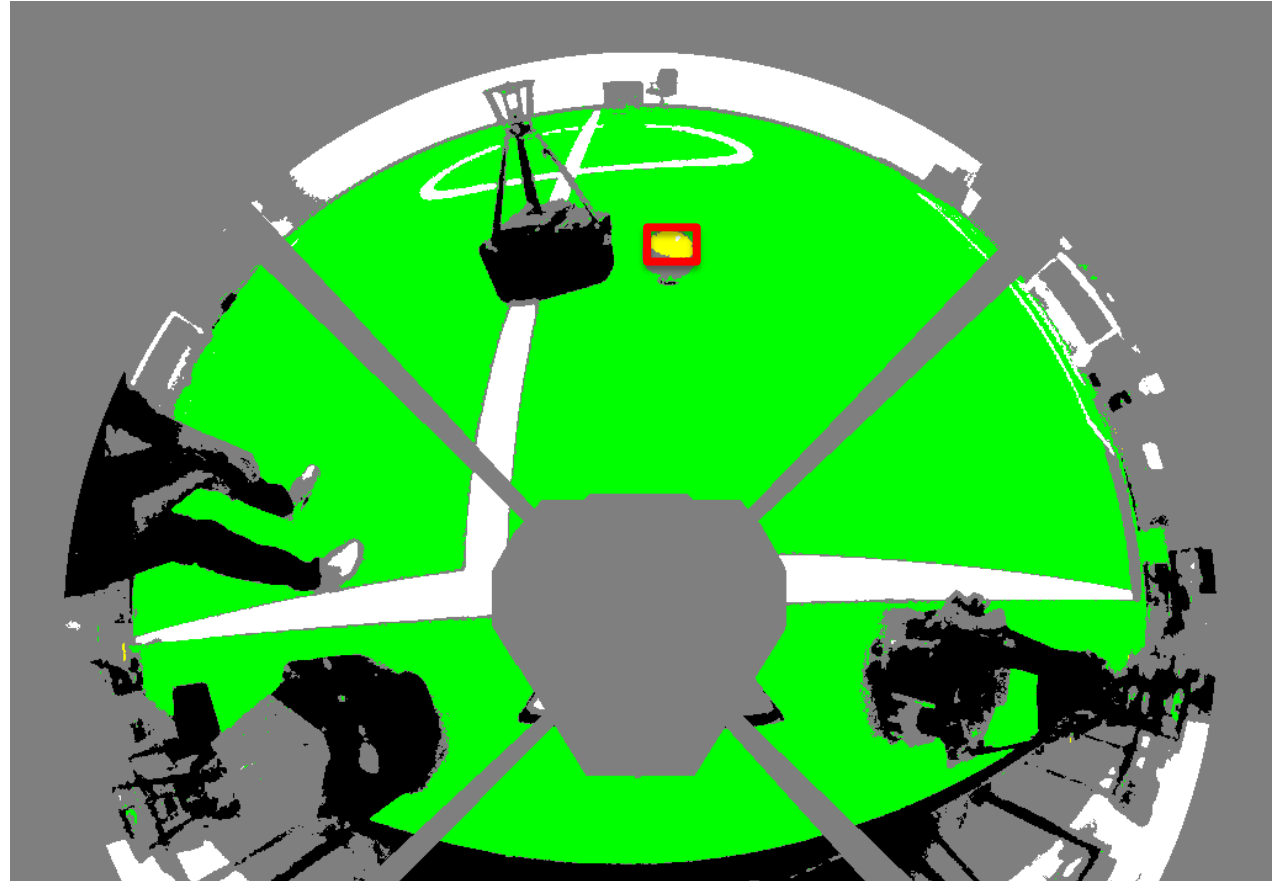
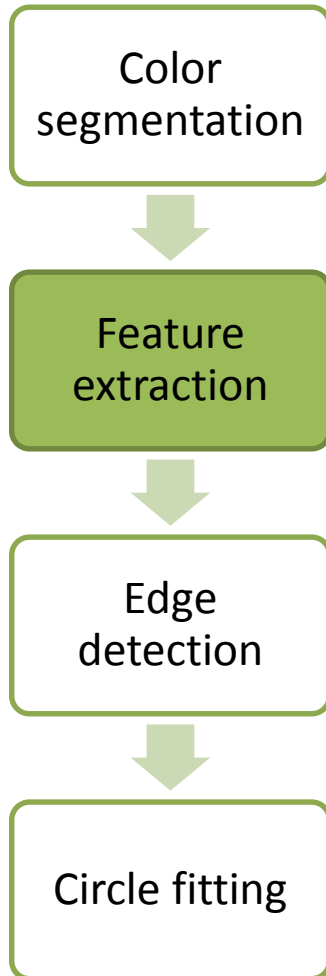




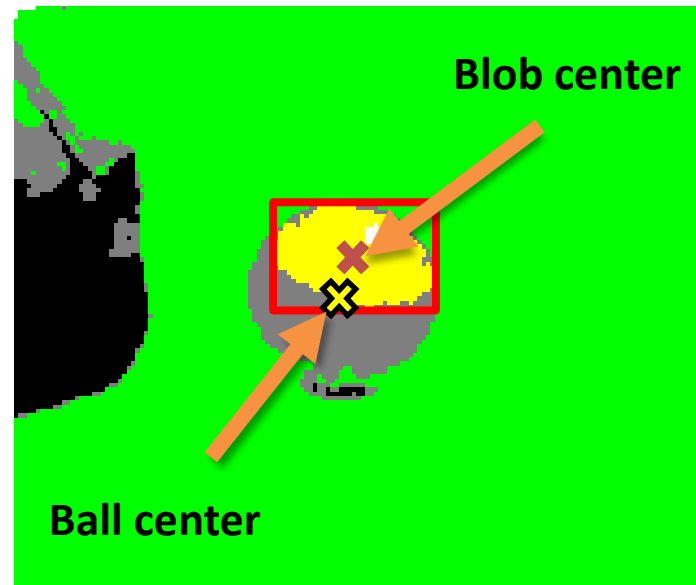
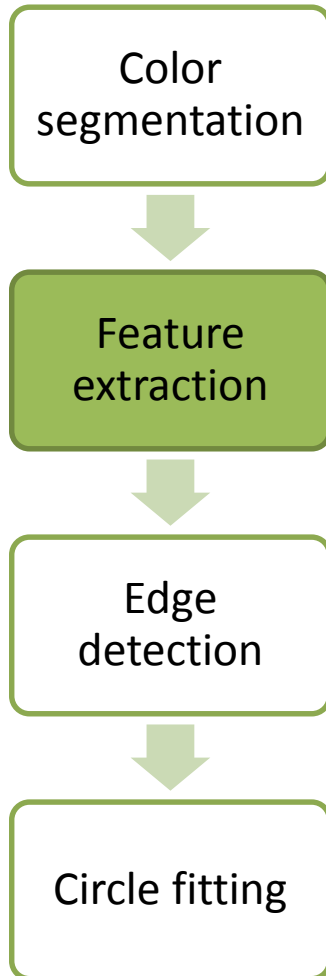
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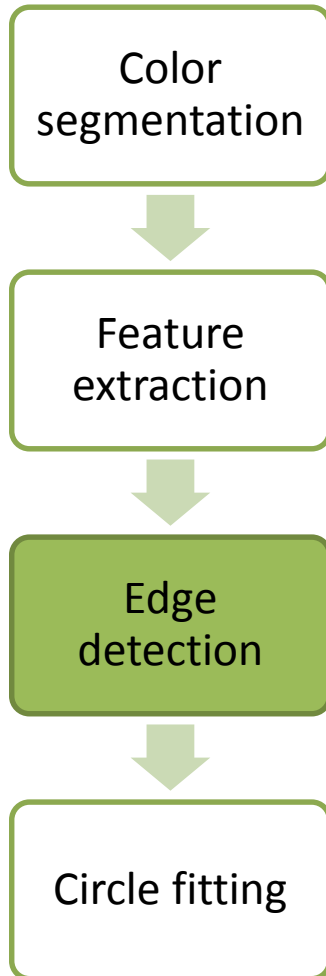


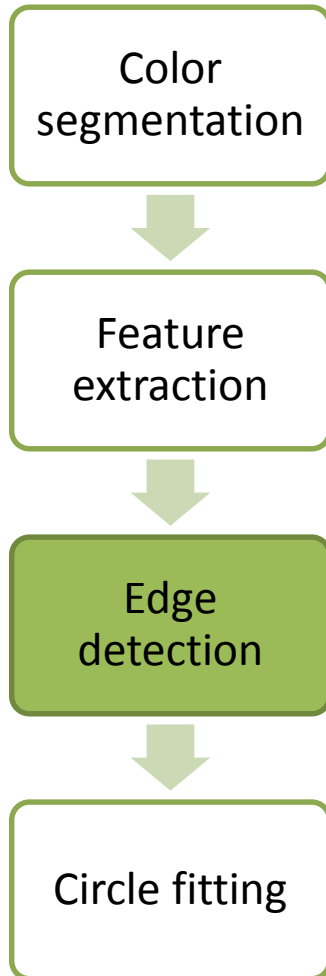
- Blobs of “ball color” (e.g. yellow)

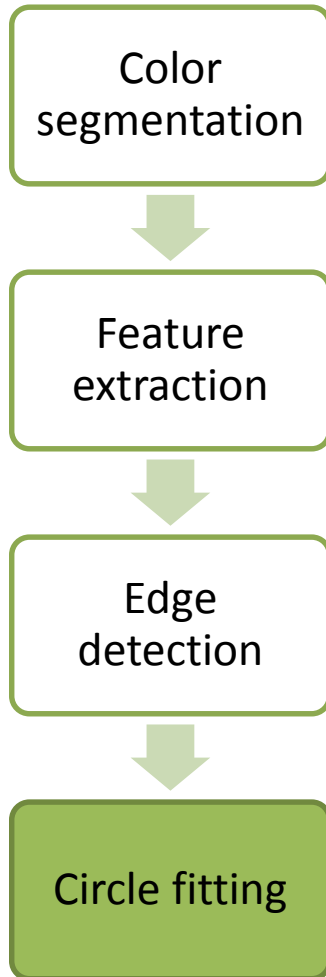


- Blobs of “ball color” (e.g. yellow)

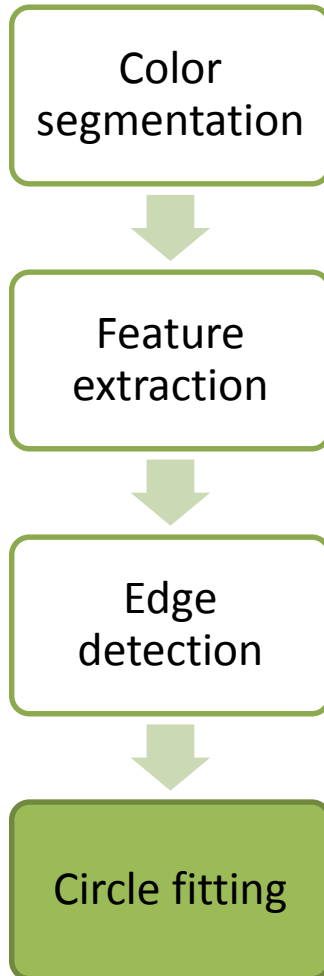






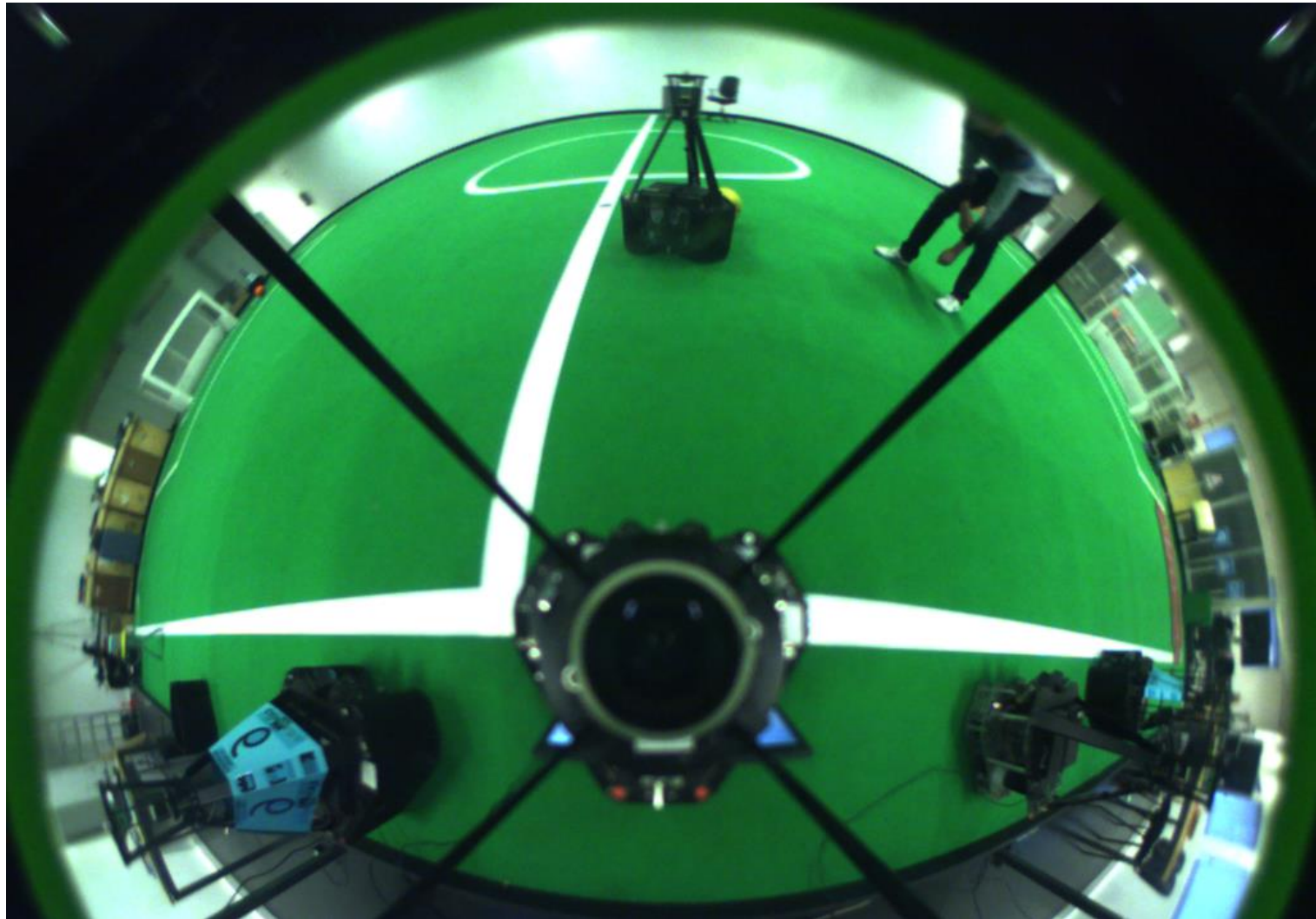






- RANSAC Circle Fit
  - 80 iterations
    - Sample 3 points
    - Fit a circle
    - Measure the “error”/score
  - Weighted average

# Ball Detection



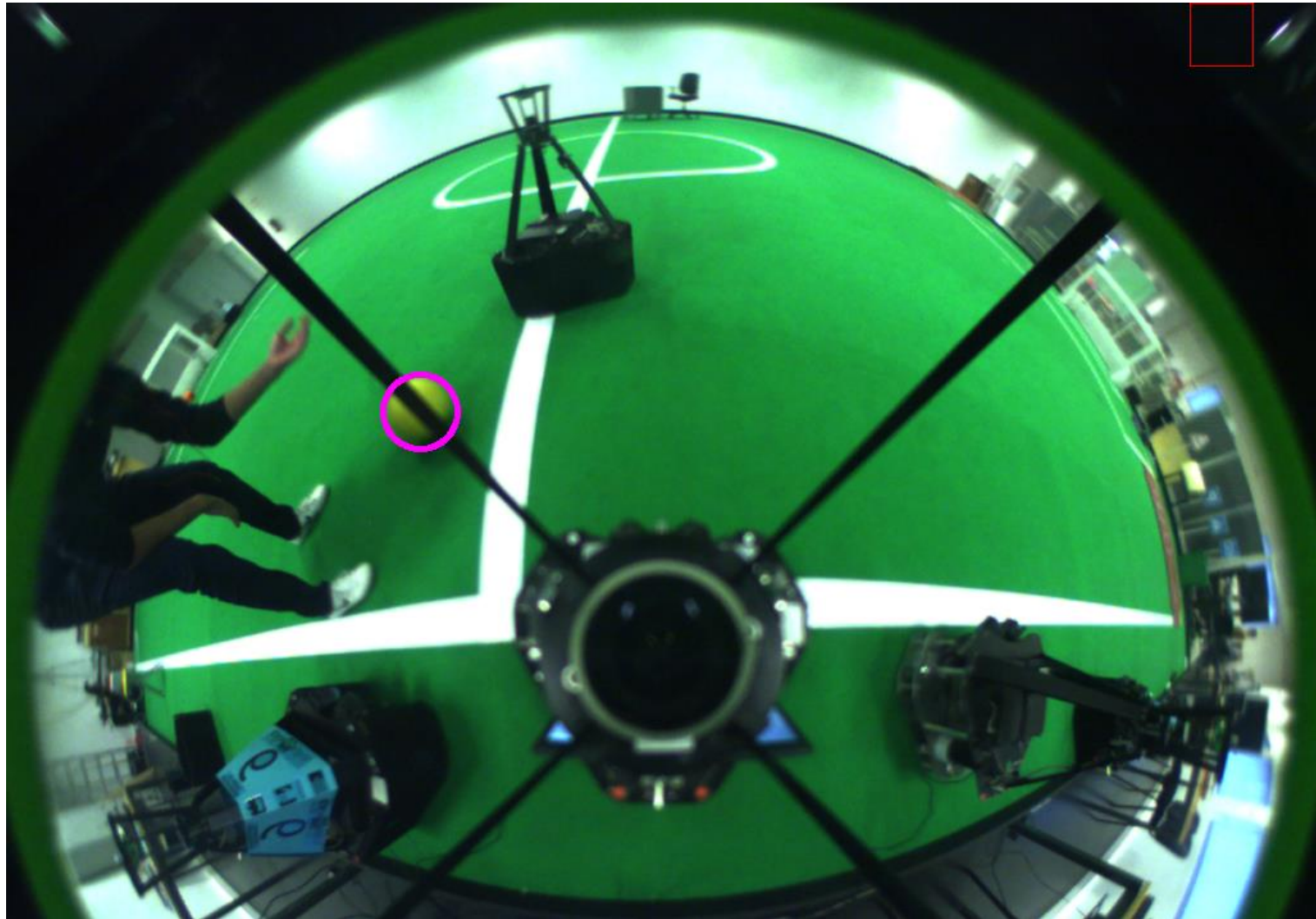
# Ball Detection





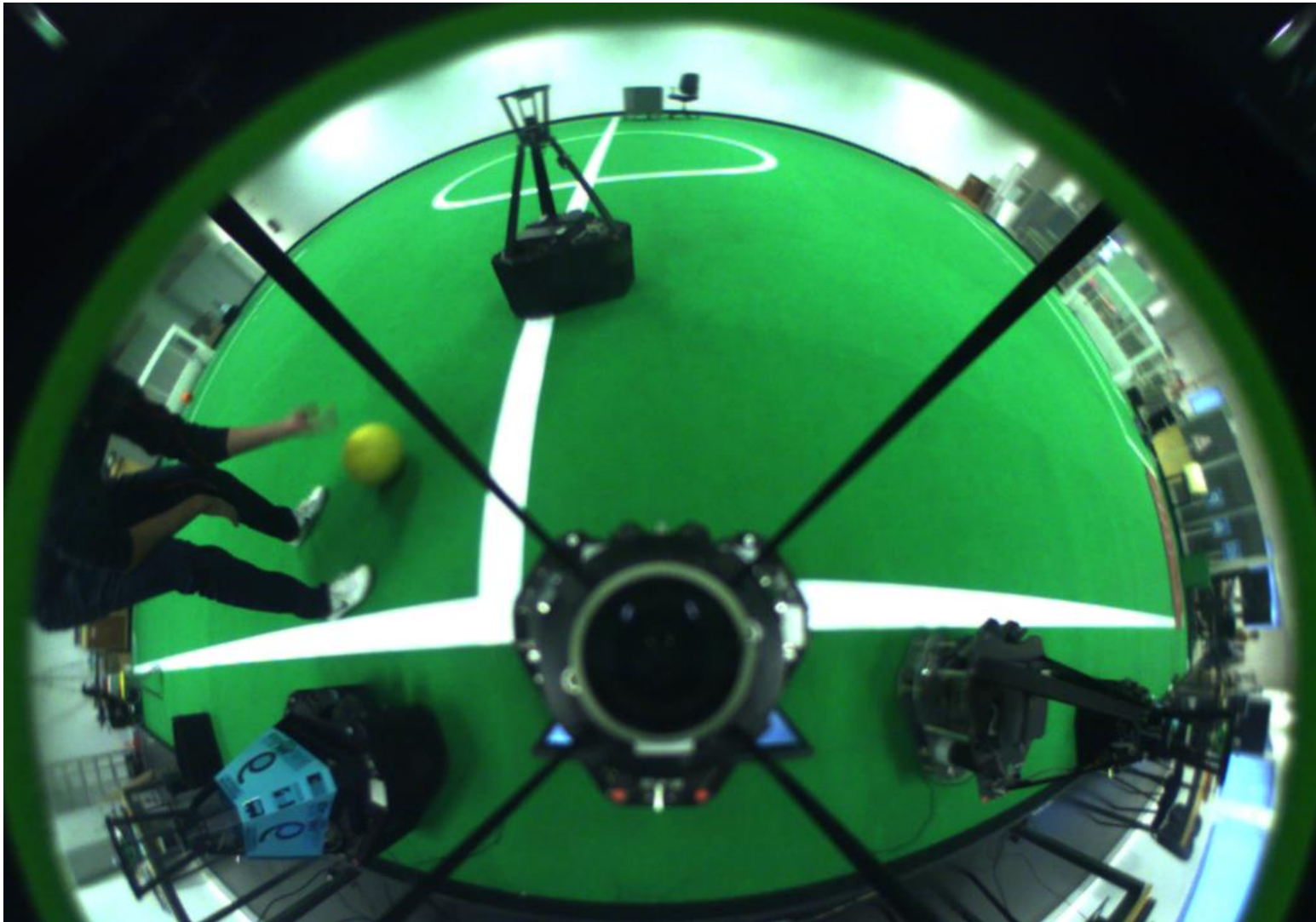


# Ball Detection

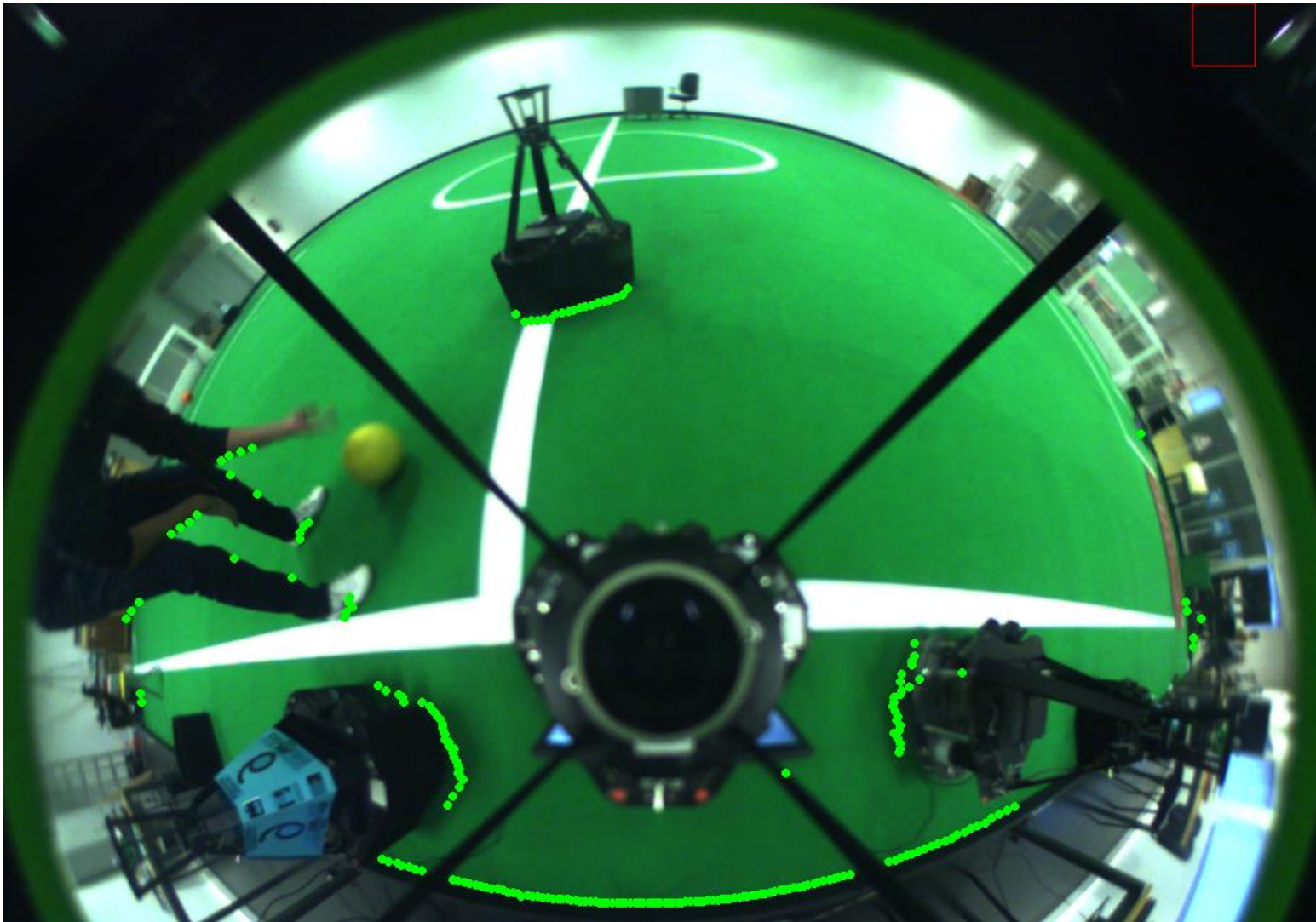




# Obstacle Detection

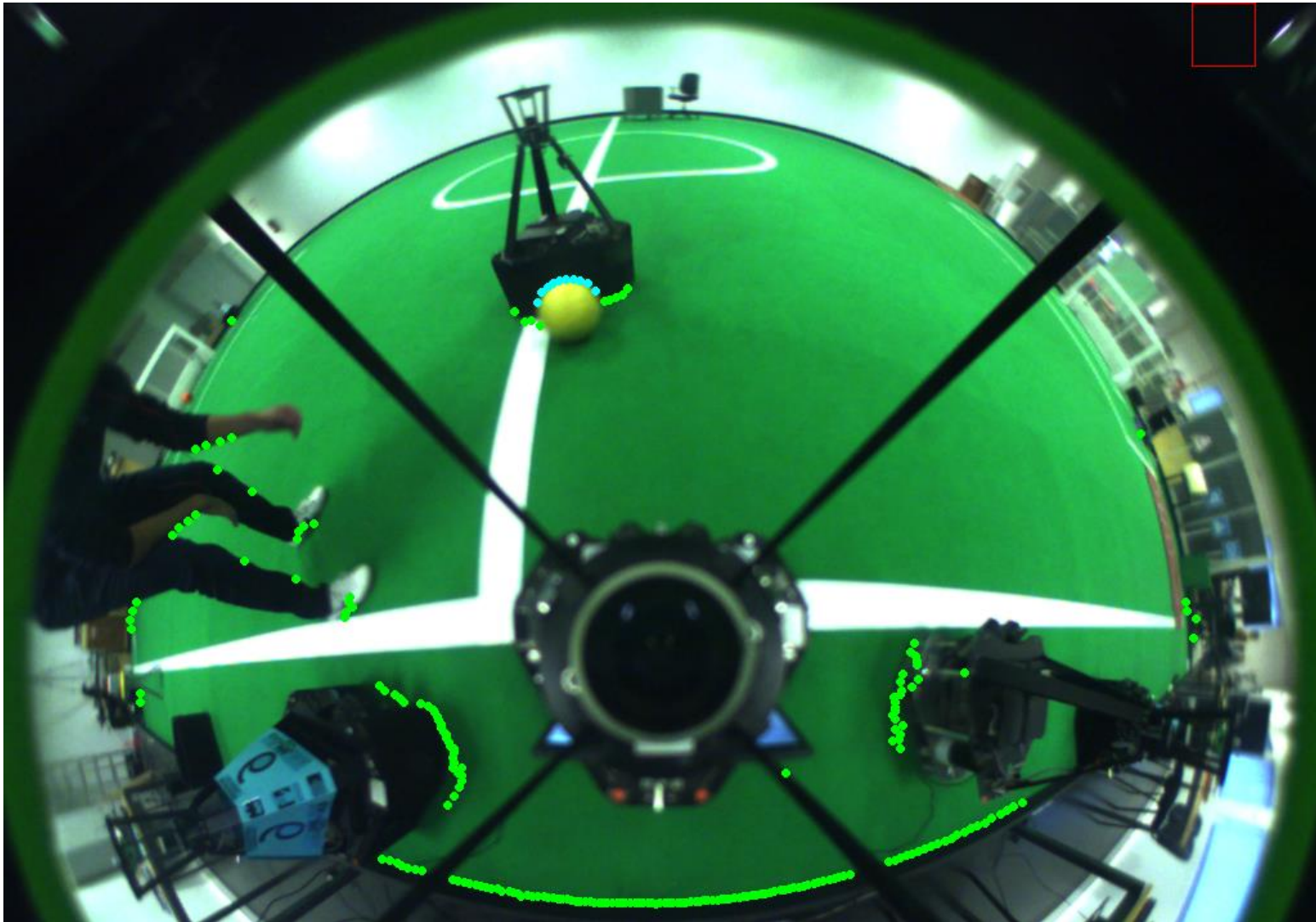


# Obstacle Detection





# Obstacle Detection



# Obstacle Detection



File Field Debug Points Obstacles Info RefereeBox Video Player

CAMBADA 0 : 0 OTHER

11:40

Coach Comm Logger

CAMBADA

Ref. Box

Cmd	Ref Cmd	Log	Maps
Kick Off	Play On	Kick Off	
Free Kick	Stop	Free Kick	
Goal Kick	Halt	Goal Kick	
Throwin	Dropped Ball	Throwin	
Corner	Parking	Corner	
Penalty		Penalty	

State: **SKstop**

Team

All Run All Stop

Blue Magenta

Auto

Manual Formation

Attack

Robot 1

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 2

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 3

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 4

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 5

SB Run M

Blue Magenta

Stop bStopRobot

0.0 0 21 82

None None

3 secs

Auto Reloc

Robot 6

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

# Obstacle Detection



File Field Debug Points Obstacles Info RefereeBox Video Player

CAMBADA 0 : 0 OTHER

12:44

Coach Comm Logger

CAMBADA

Ref. Box

Cmd	Ref Cmd	Log	Maps
Kick Off	Play On	Kick Off	
Free Kick	Stop	Free Kick	
Goal Kick	Halt	Goal Kick	
Throwin	Dropped Ball	Throwin	
Corner	Parking	Corner	
Penalty		Penalty	

State: **SKstop**

Team

All Run All Stop

Blue Magenta

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Manual Formation

Attack

Robot 1

KO Run M

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No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 2

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 3

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 4

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

Robot 5

SB Run M

Blue Magenta

Stop bStopRobot

0.0 0 21 82

None None

3 secs

Auto Reloc

Robot 6

KO Run M

Blue Magenta

No Role bNoBehaviour

0.0 0 0 -1

None None

Auto Reloc

# Conclusions



- Improve line detection at further distances
- Improve ball detection accuracy while dealing with occlusions
- Obstacle detection that accounts for partial occlusion by the ball

**Without significantly increasing computational cost**



# Thanks for your attention!

 /cambadamsl  /cambadamsl [robotica.ua.pt](http://robotica.ua.pt)



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