Camera Parameters Extraction Using Real-Time Video Analysis In Football Broadcasting

——Miguel Ramirez and Pereira Duarte. 2015

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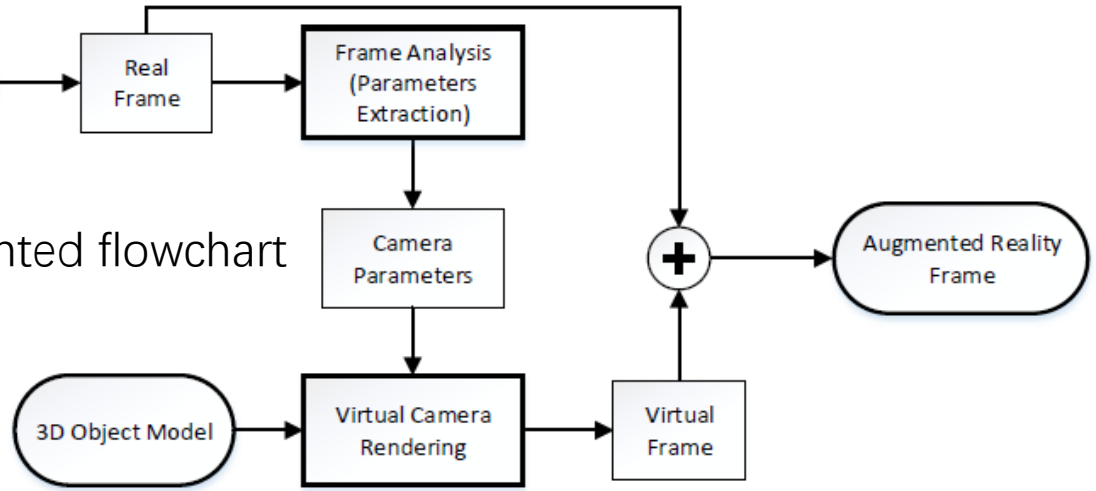
What it do

- Extract the camera’ s parameters using real-time video analysis in football broadcasting.

Parameters extraction

$$(f, \gamma, \beta, \alpha, X_{cam}, Y_{cam}, Z_{cam})$$

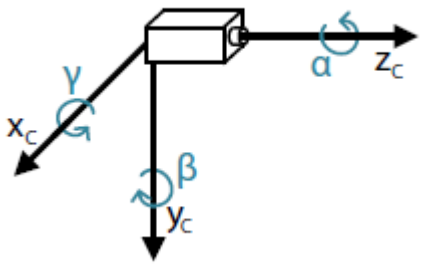
Video augmented flowchart



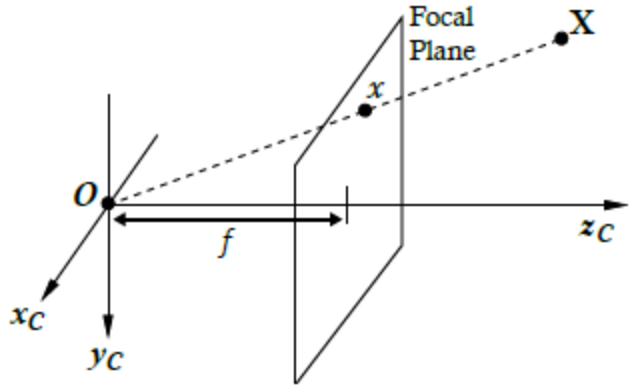
Camera Parameters

- 外参数R，T，C
- 内参数f
- 利用这些参数，可以将世界坐标系下的3D点投影到图像的对应位置，投影公式：

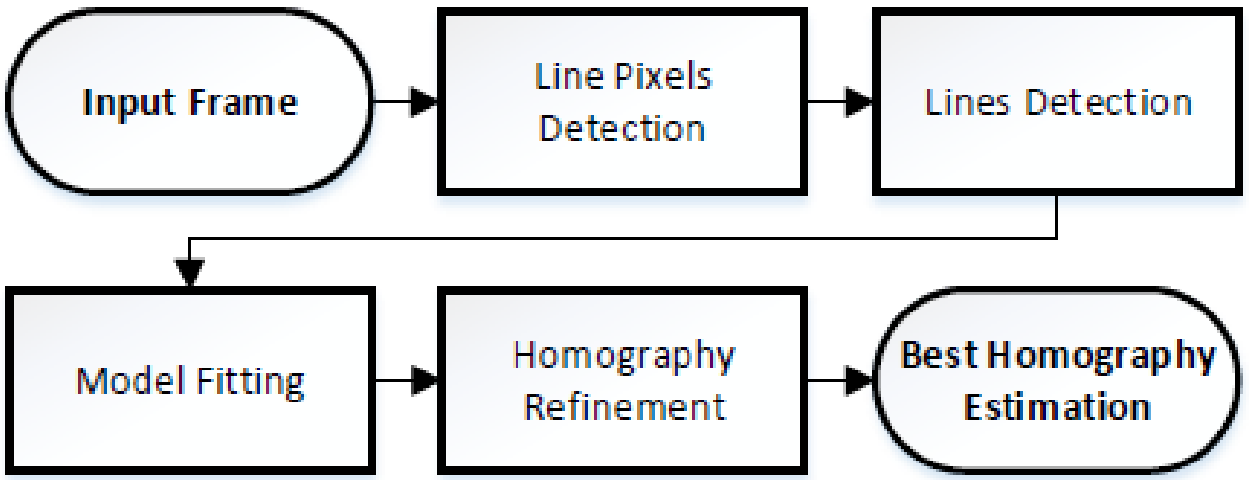
$$\mathbf{x} = \mathrm{K}\mathrm{R}[\mathrm{I} \mid -\widetilde{\mathbf{C}}]\mathbf{X}$$



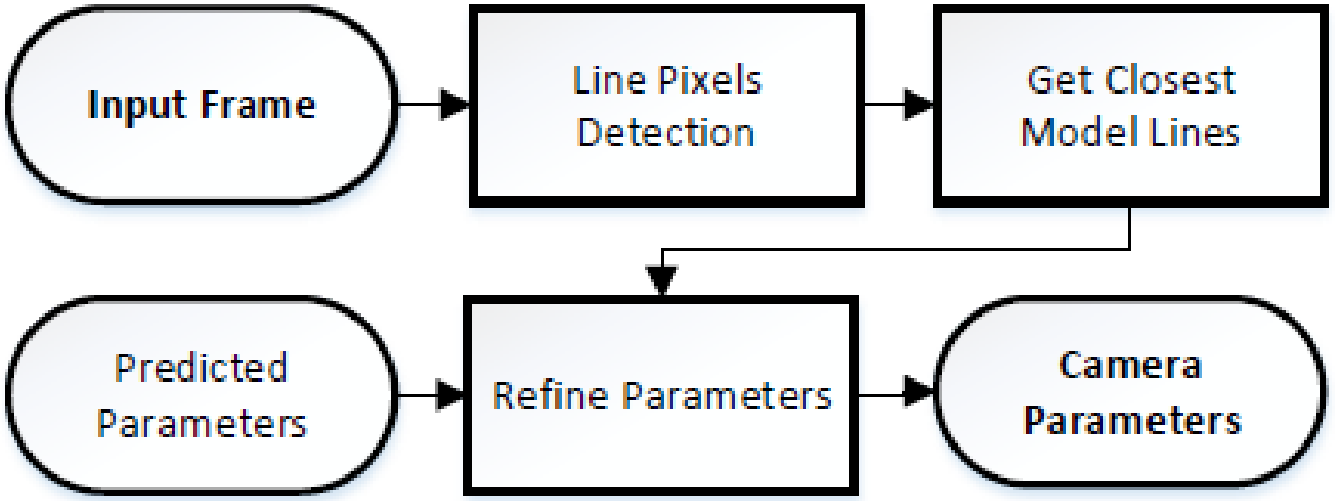
$$\boldsymbol{K} = \begin{bmatrix} f & 0 & c_x \\ 0 & f & c_y \\ 0 & 0 & 1 \end{bmatrix}$$



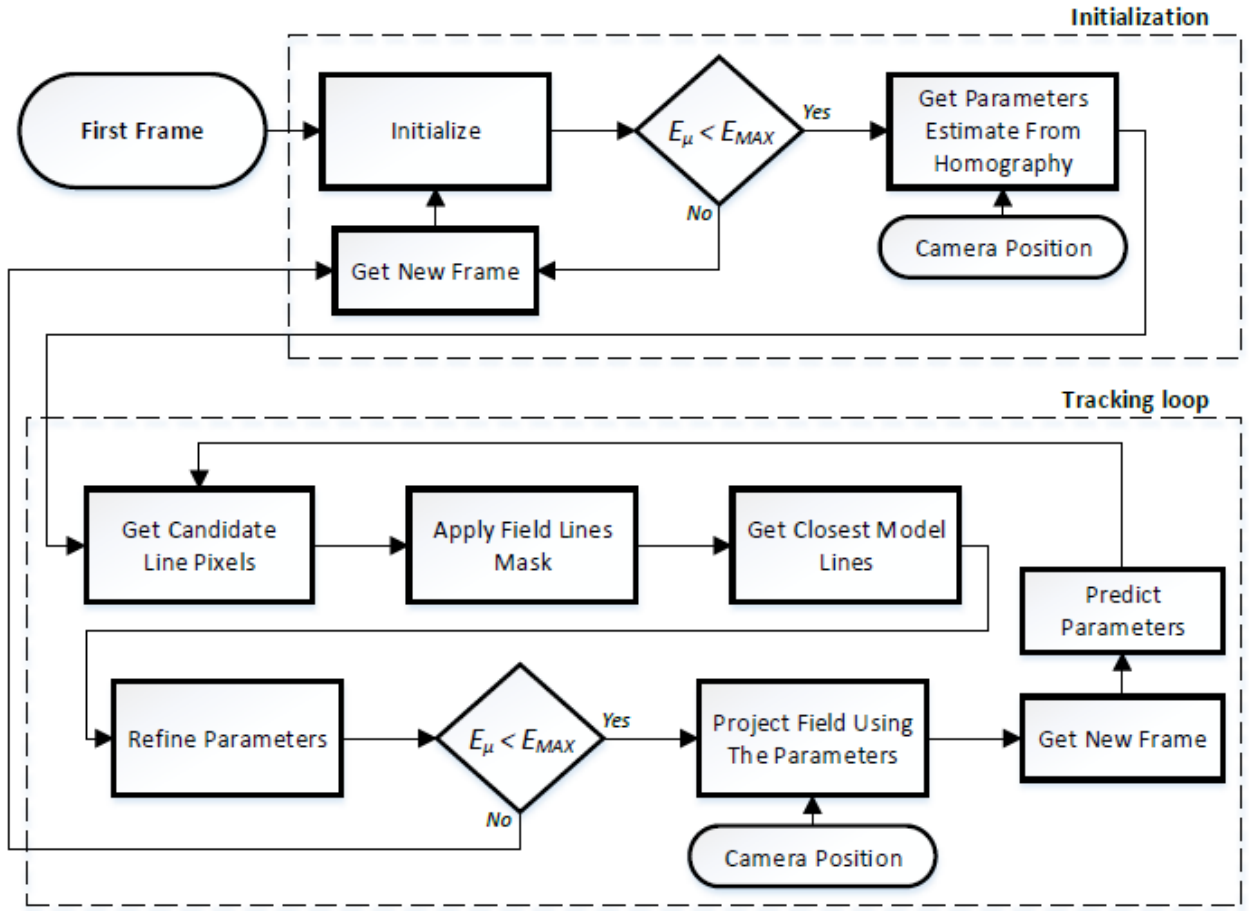
Flow Chart——initialization



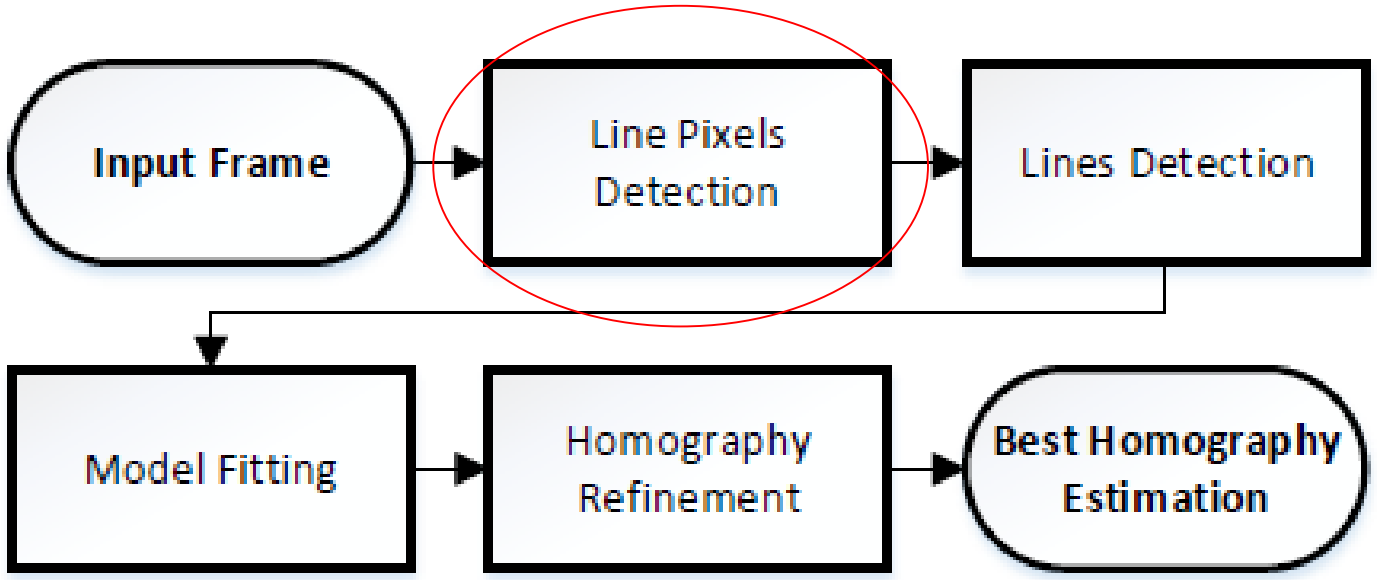
Flow Chart——tracking



Flow Chart

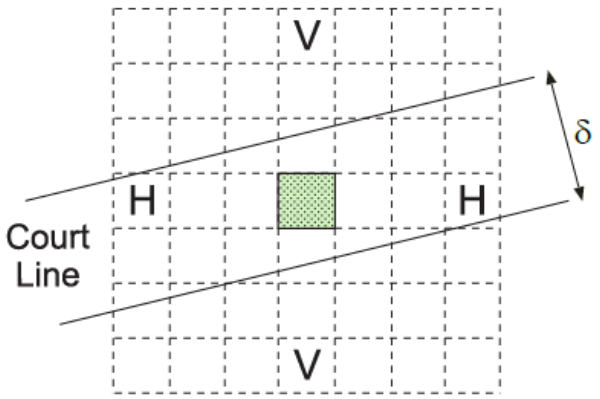

Initialization
First Frame
Initialize
$E_\mu < E_{MAX}$
Yes
No
Get Parameters Estimate From Homography
Camera Position
Get New Frame
Tracking loop
Get Candidate Line Pixels
Apply Field Lines Mask
Get Closest Model Lines
Predict Parameters
Refine Parameters
$E_\mu < E_{MAX}$
Yes
No
Project Field Using The Parameters
Get New Frame
Camera Position

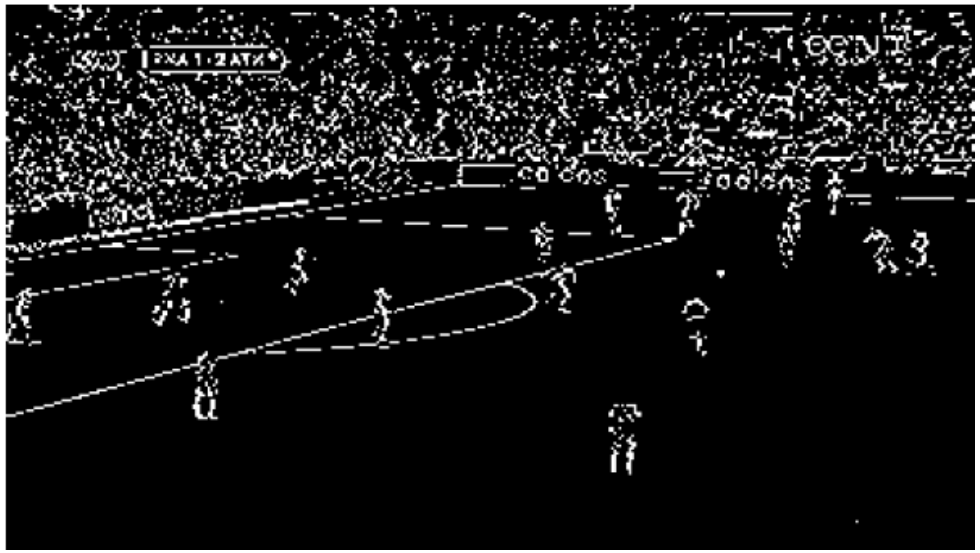
Flow Chart——initialization



Line Pixels Detection (1)

$$LW(x,y) = \begin{cases} 1, & \text{if } l(x,y) \geq \sigma_l \quad \wedge \quad l(x,y) - l(x-\delta,y) \geq \sigma_d \quad \wedge \quad l(x,y) - l(x+\delta,y) \geq \sigma_d \\ 1, & \text{if } l(x,y) \geq \sigma_l \quad \wedge \quad l(x,y) - l(x,y-\delta) \geq \sigma_d \quad \wedge \quad l(x,y) - l(x,y+\delta) \geq \sigma_d \\ 0, & \text{otherwise.} \end{cases}$$



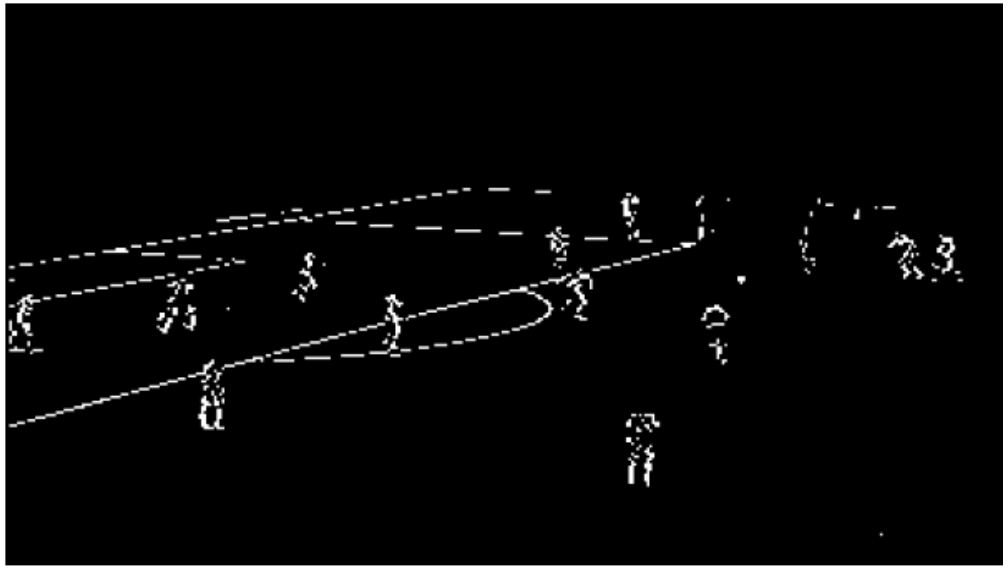


Line Pixels Detection (2)

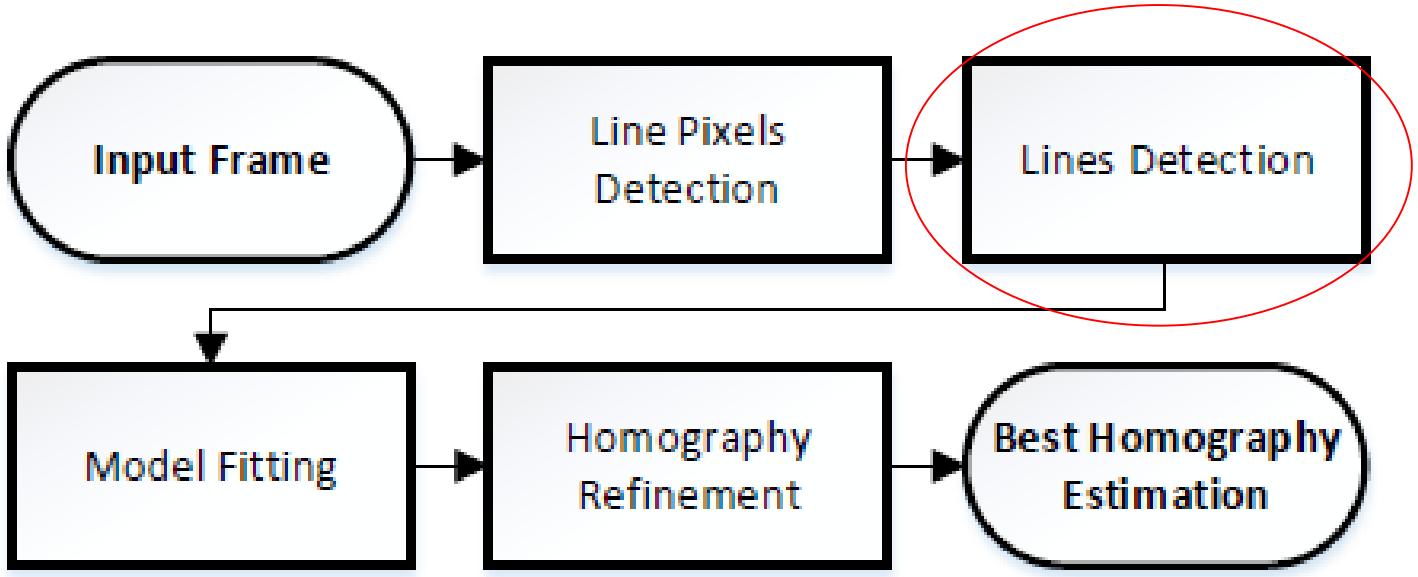
- Field mask (Hue Histogram)

$$\begin{cases} 1, & \text{if } H_{low} \leq h(x,y) \leq H_{high} \\ 0, & \text{otherwise.} \end{cases}$$

Line Pixels Detection (3)

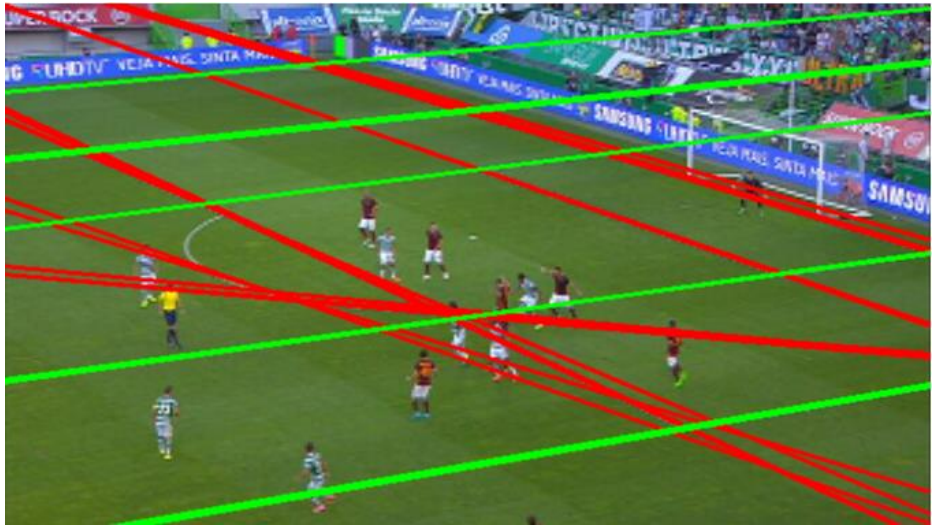


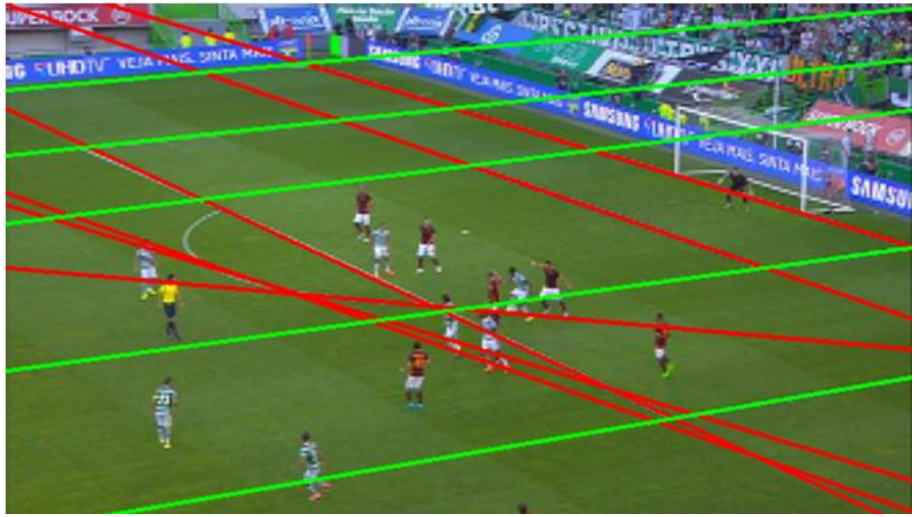
Flow Chart——initialization



Line Detection

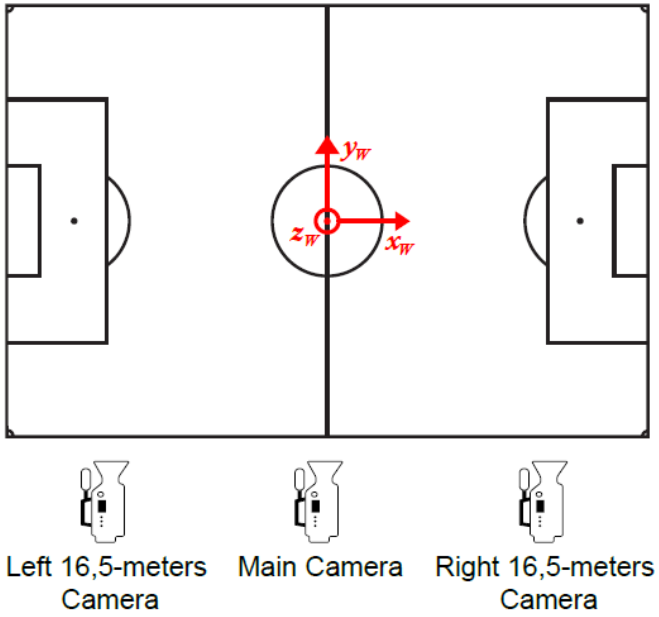
- Hough+Deduplication





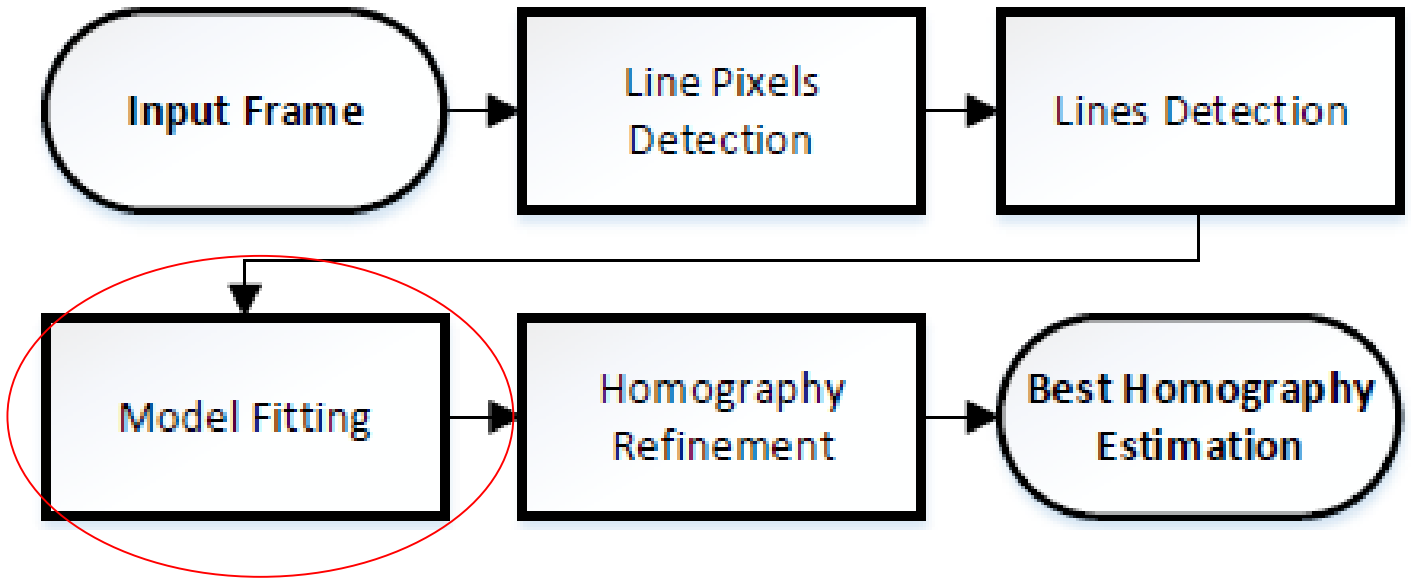
Line Detection

- Classification+Sort



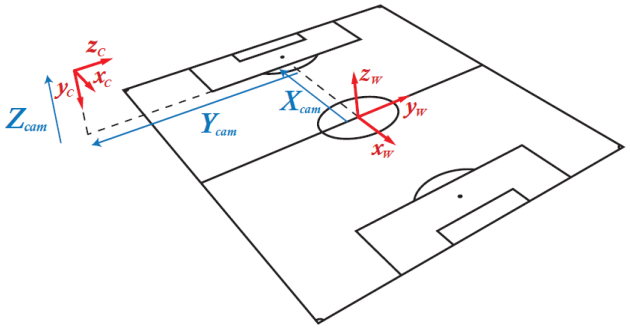
	Vertical $\theta[^\circ]$	Horizontal $\theta[^\circ]$
Left cam.	$]-85, 70[$	$[-90, -85] \cup [70, 89]$
Main cam.	$]-73, 73[$	$[-90, -73] \cup [73, 89]$
Right cam.	$]-70, 85[$	$[-90, -70] \cup [85, 89]$

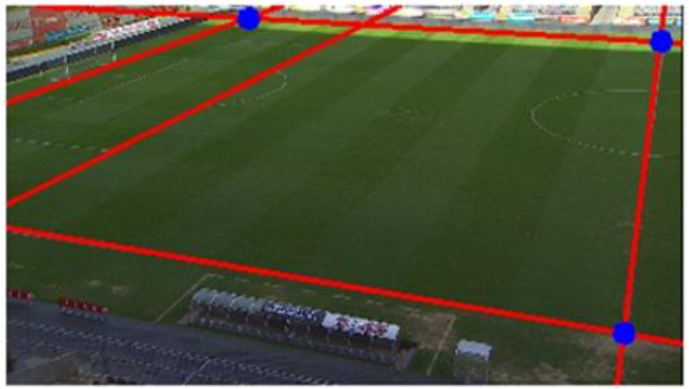
Flow Chart——initialization

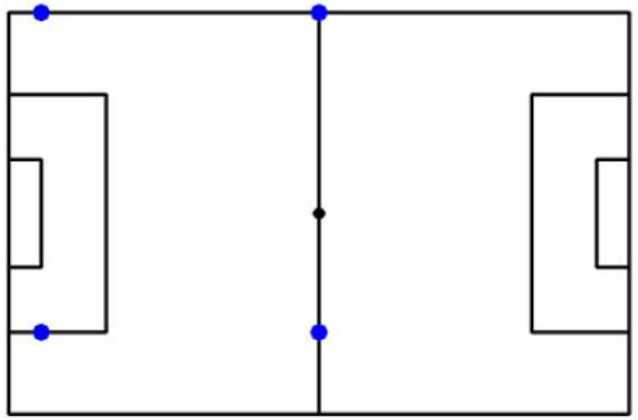


Model Fitting

- Solve the homography (8 degree of freedom)



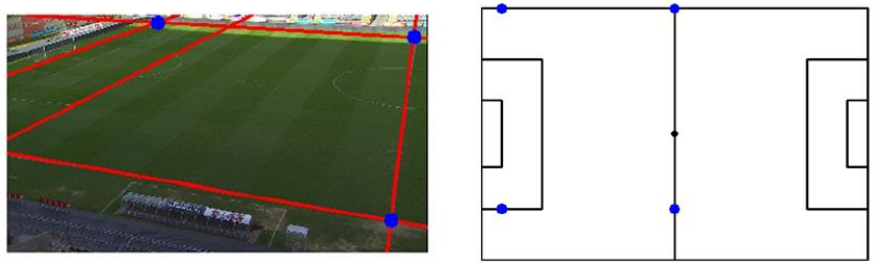




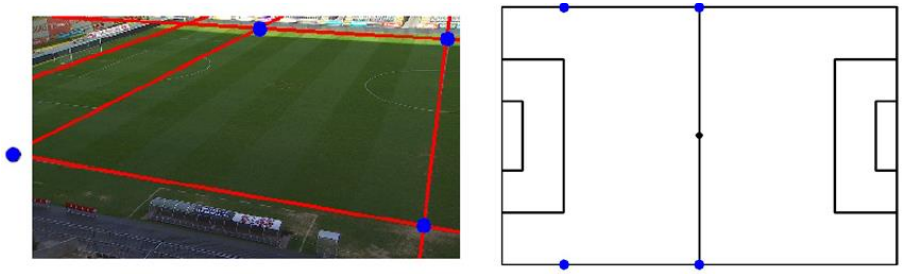
Model Fitting

- Conditional filter

Right match



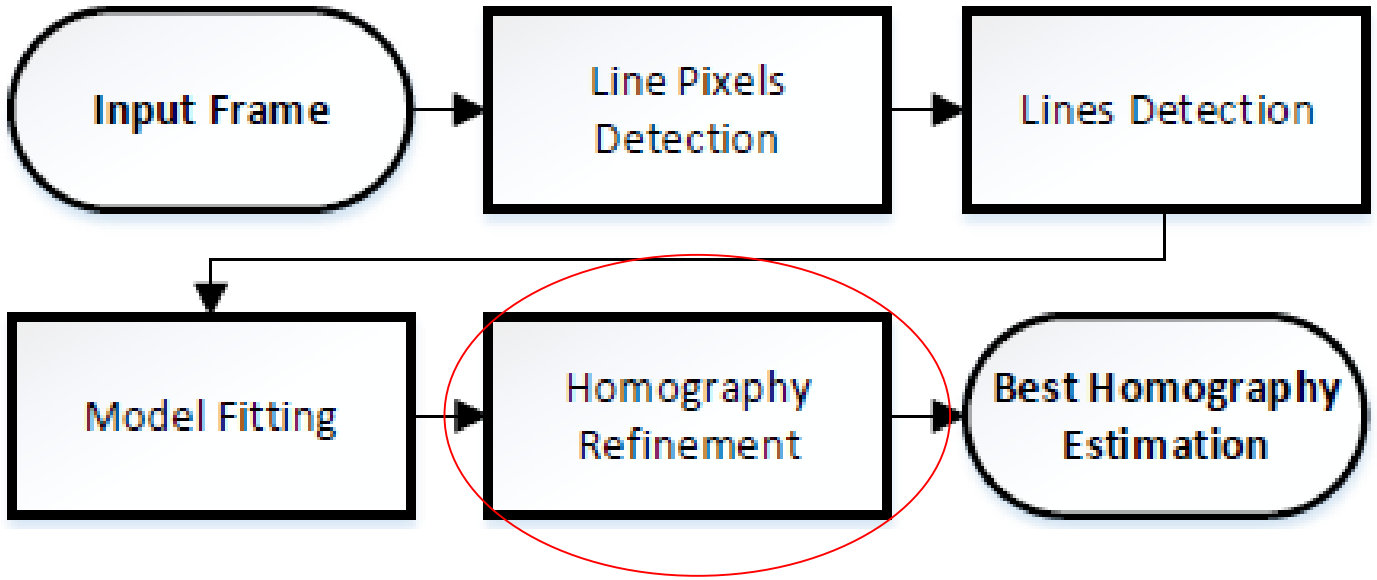
Wrong match



Score Homography

- Score: 1*cover pixel-0.2*no cover pixel

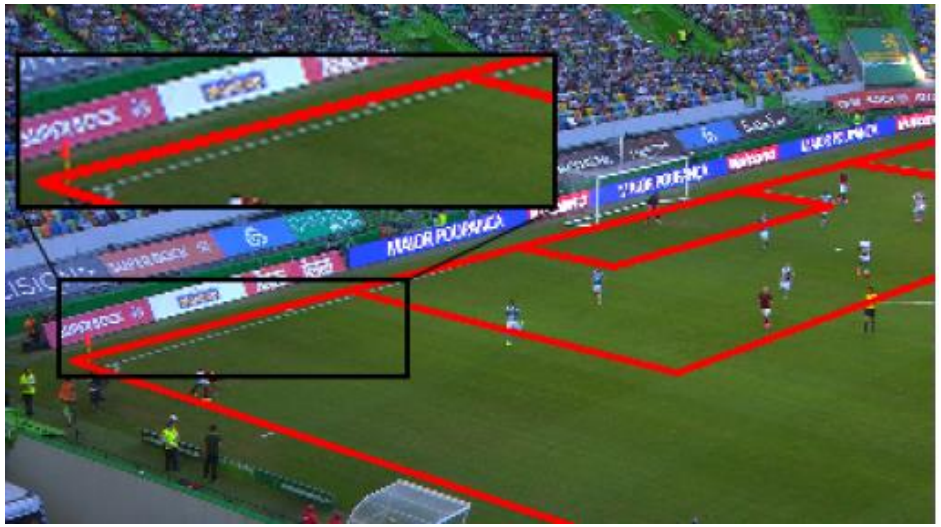
Flow Chart——initialization

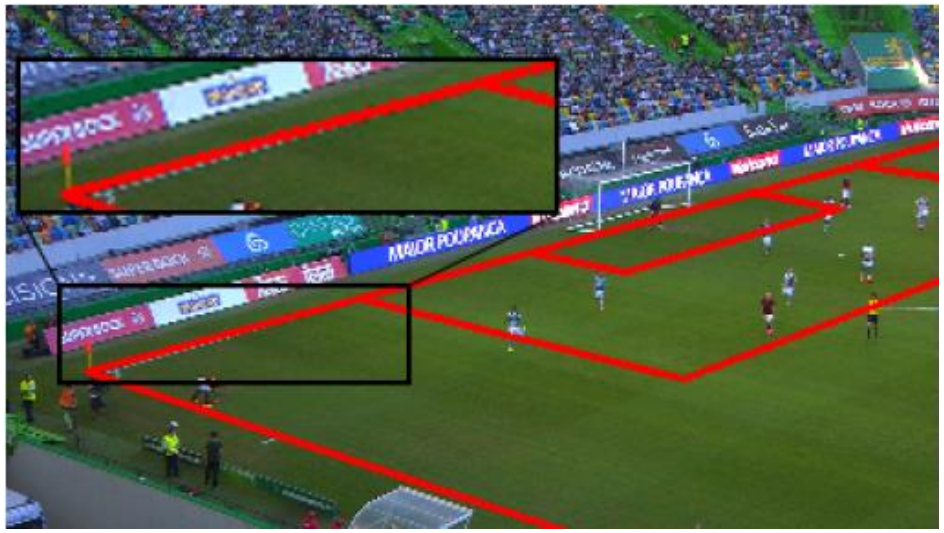


Homography and Refine

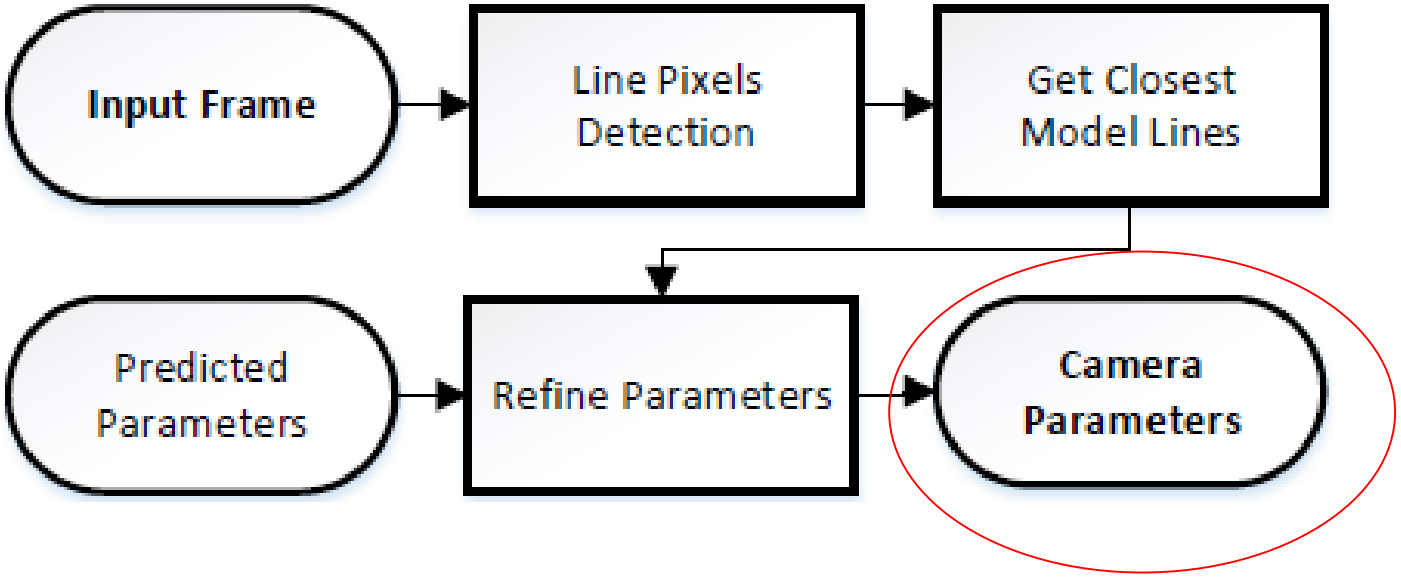
- Back project (project image to field model)

$$E_T = \sum_{i}^{\#points} \left[l_i{}^T \mathcal{L}\{\boldsymbol{H}^{-1}\boldsymbol{p_i}\} \right]^2 . \qquad E_\mu = \text{Et / N\_points}$$





Flow Chart——tracking

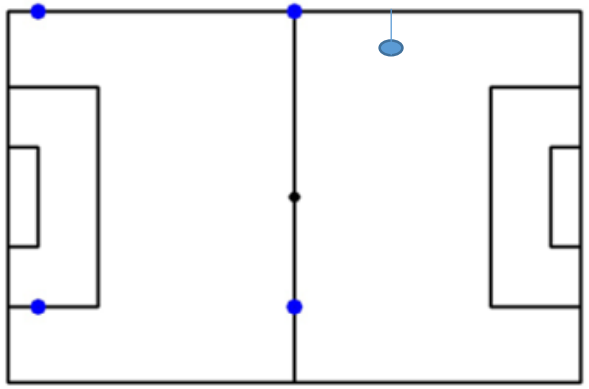


Extract Camera Parameters

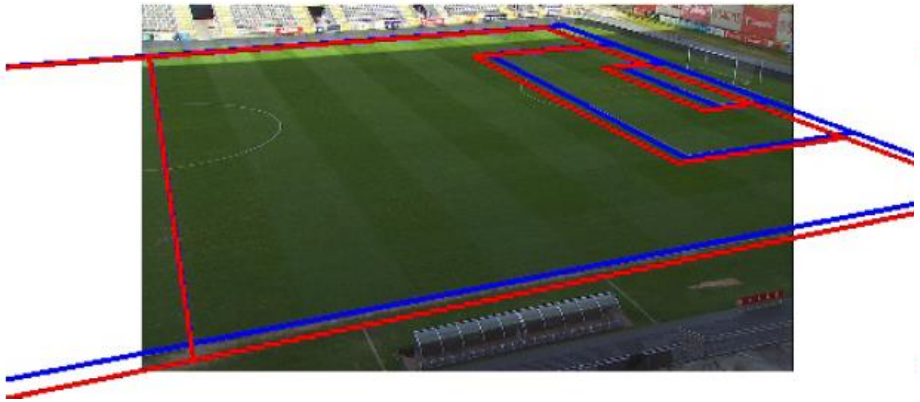
$$E_h = \sum_{i=1}^{3}\sum_{j=1}^{3}[h_{ij} - h_{ij}(\Psi)]^2$$

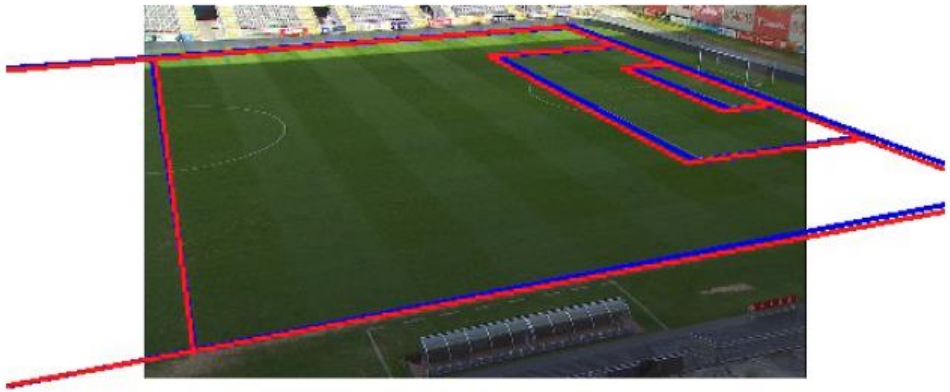
Solve: $(f, \gamma, \beta, \alpha, X_{cam}, Y_{cam}, Z_{cam})$

Refine Camera Parameters

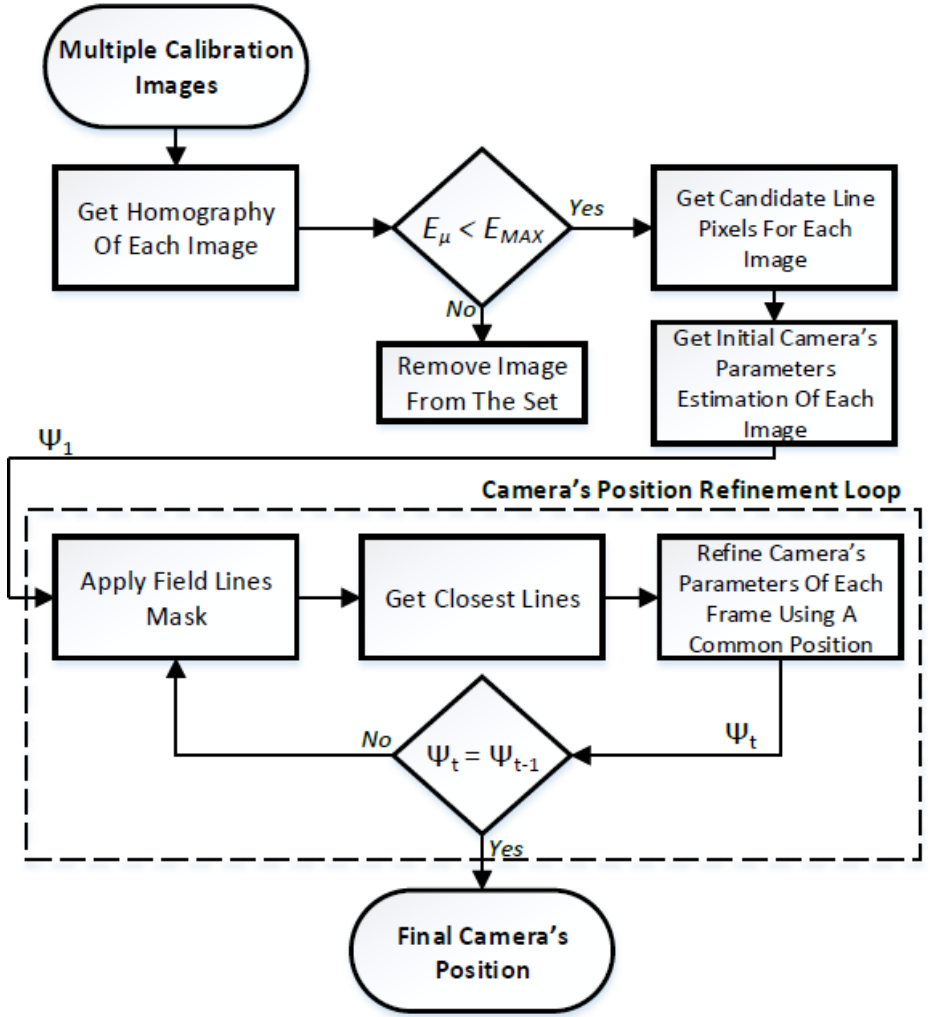


$$E_T = \sum_{i}^{\#points} \left[{l_i}^T \mathcal{L}\{\mathcal{H}^{-1}(\Psi) p_i\} \right]^2 .$$





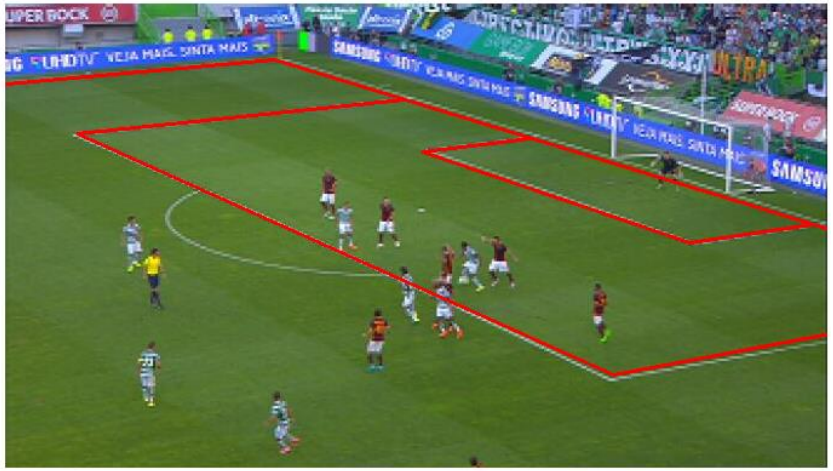
Refine Position



Experiment

Image Resolution:384 x 215, CPU

	Average time
line pixels detection	1,97 ms
Field area mask	2,85 ms
Lines detection	1,56 ms
Lines classification	1,77 ms
Extra lines removal	0,47 ms
Field side	2,03 μs
Image's lines intersection	8,77 μs
Rejection test #1	0,94 μs
Homography computation	21,40 μs
Rejection tests #2 and #3	3,55 μ
Homography score	0,53 ms
Homography refinement	12,80 ms



Advantage

- 1, For the sport field, automatic calibration camera.
- 2, High precision.
- 3, Fast.

Disadvantage

- 1, Some inconvenience on part of line detection.
- 2, Need two pairs of parallel white lines at least.
- 3, Chose initial value for part of refine parameters.

Improve

- 1, Combine other knowledge to be robust .

Thank you