Cone-pixel camera model using CGA for linear and variant scale sensors

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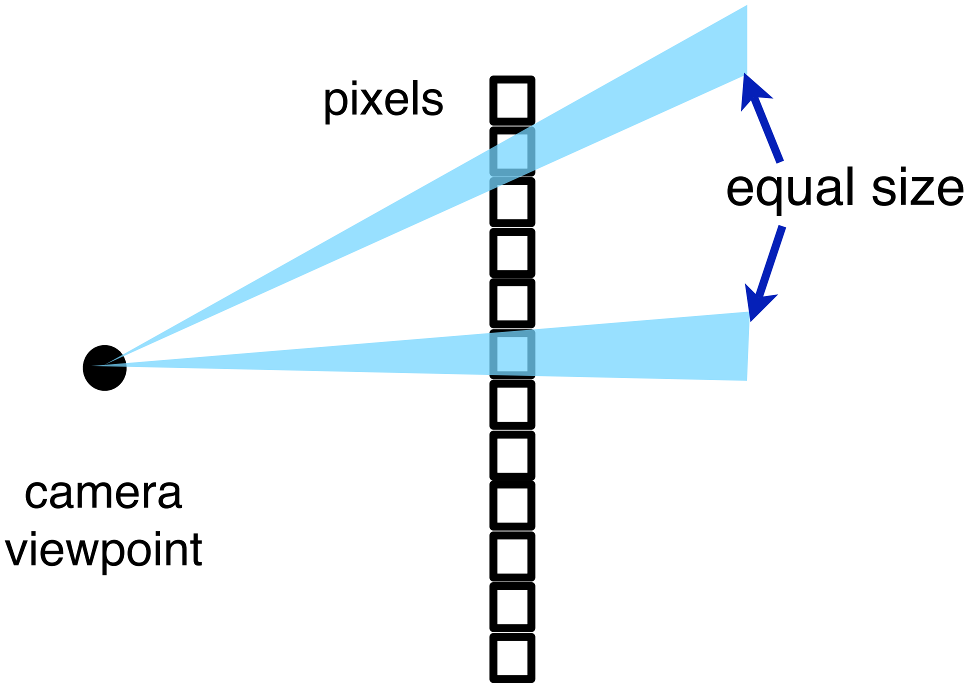
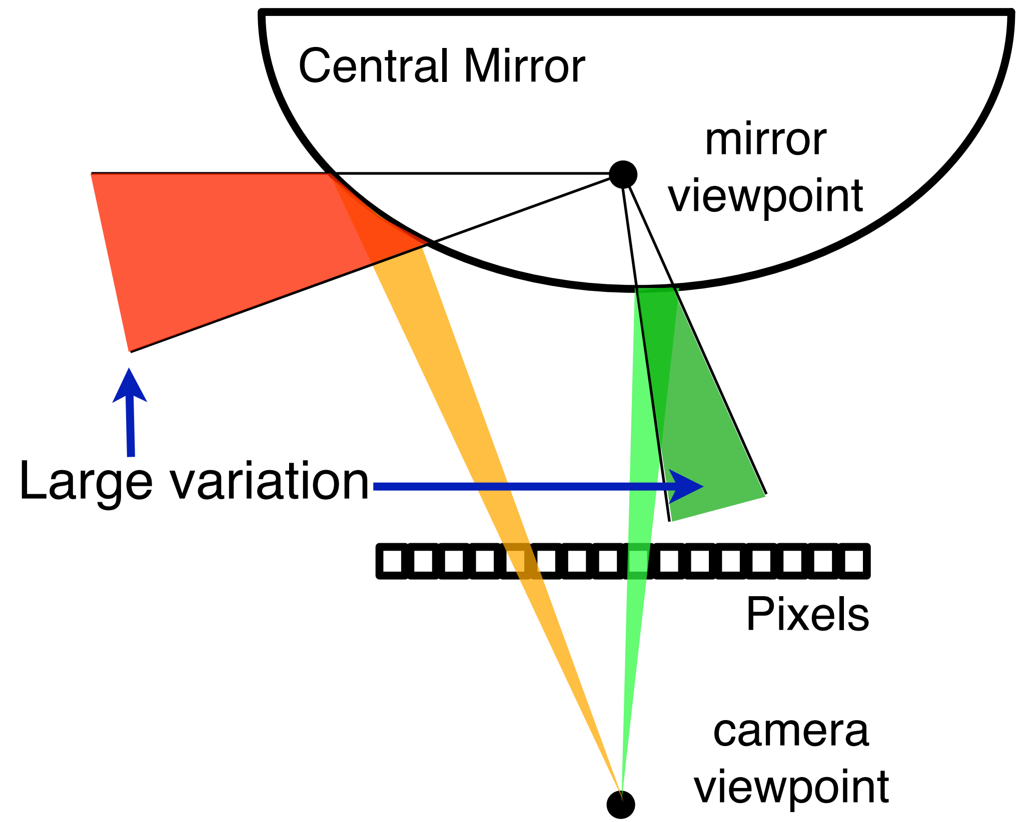
Problem 1
Pixel definition - Aperture problem

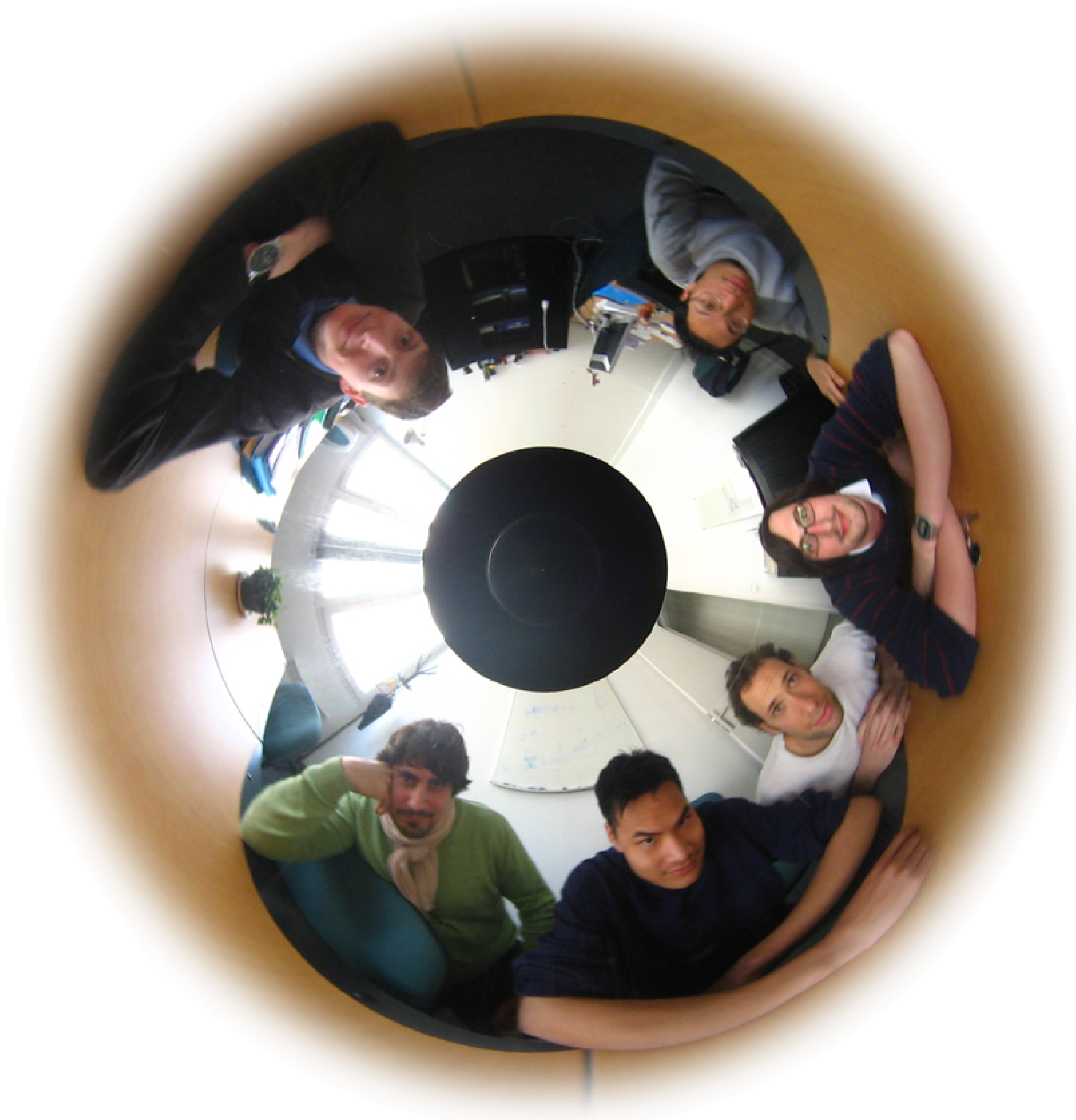
Perspective camera



Catadioptric camera

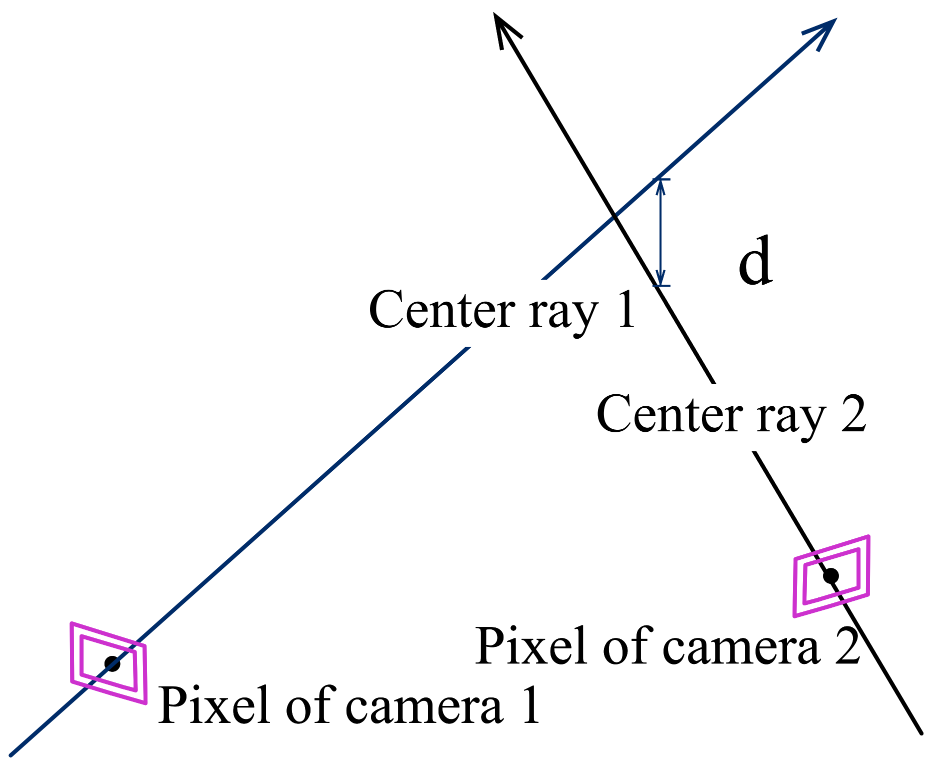


Panoramic image example

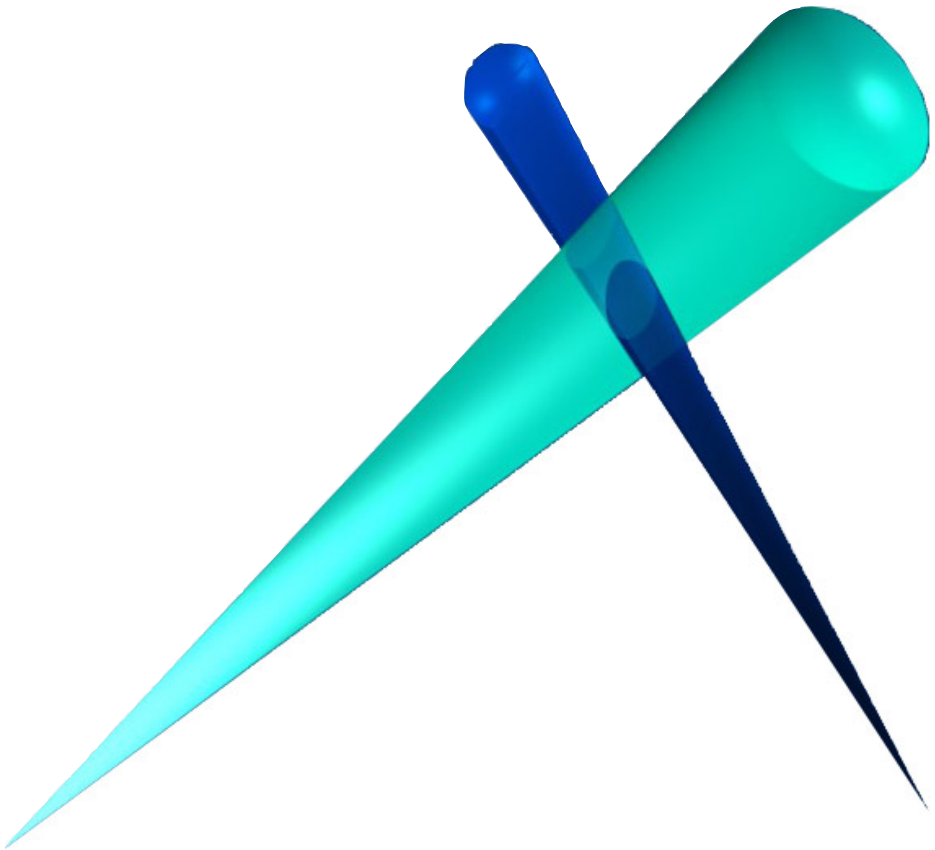


Problem 2
Pixel correspondences

Classic ray/pixel approach



Cone/pixel approach



Volume intersection when rays are not coplanar

State of the Art

Bundle Adjustment: [Triggs99]

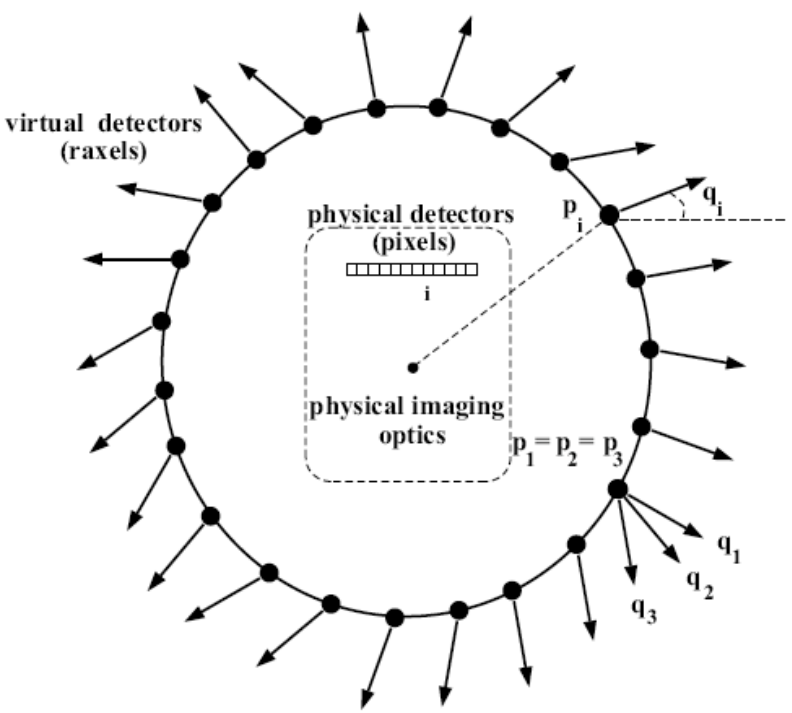
-Minimization method

-Compel the rays for better intersections

Triggs, B., McLauchlan, P., Hartley, R., Fitzgibbon, A.: Bundle adjustment – A modern synthesis. (2000) 298–375

Raxel: [Grossberg01]: Association of a pixel and a 3D direction

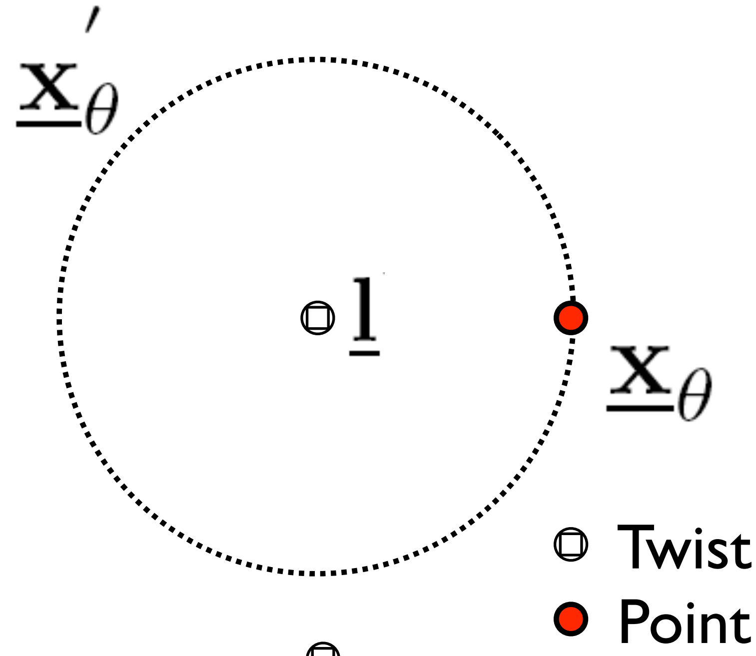
Grossberg, M.D., Nayar, S.K.: A general imaging model and a method for finding its parameters. ICCV (2001) 108–115



Generating shapes with twists

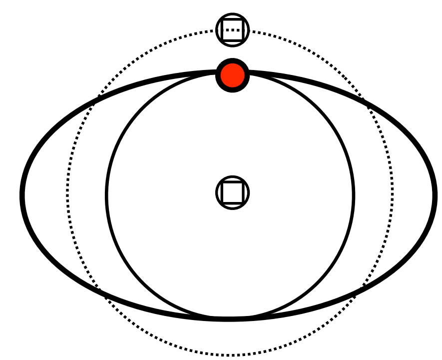
$$\underline{\mathbf{x}}_\theta' = \mathcal{M}(\theta,\underline{\mathbf{l}})\,\underline{\mathbf{x}}_\theta\,\tilde{\mathcal{M}}(\theta,\underline{\mathbf{l}})$$

$$\mathcal{M}(\theta,\underline{\mathbf{l}}) = exp(-\frac{\theta}{2}\underline{\mathbf{l}})$$



It is possible to generate other shapes and especially ellipsis which fit better rectangular surfaces.

T2



$\lambda_1 = -2$ and $\lambda_2 = 1$

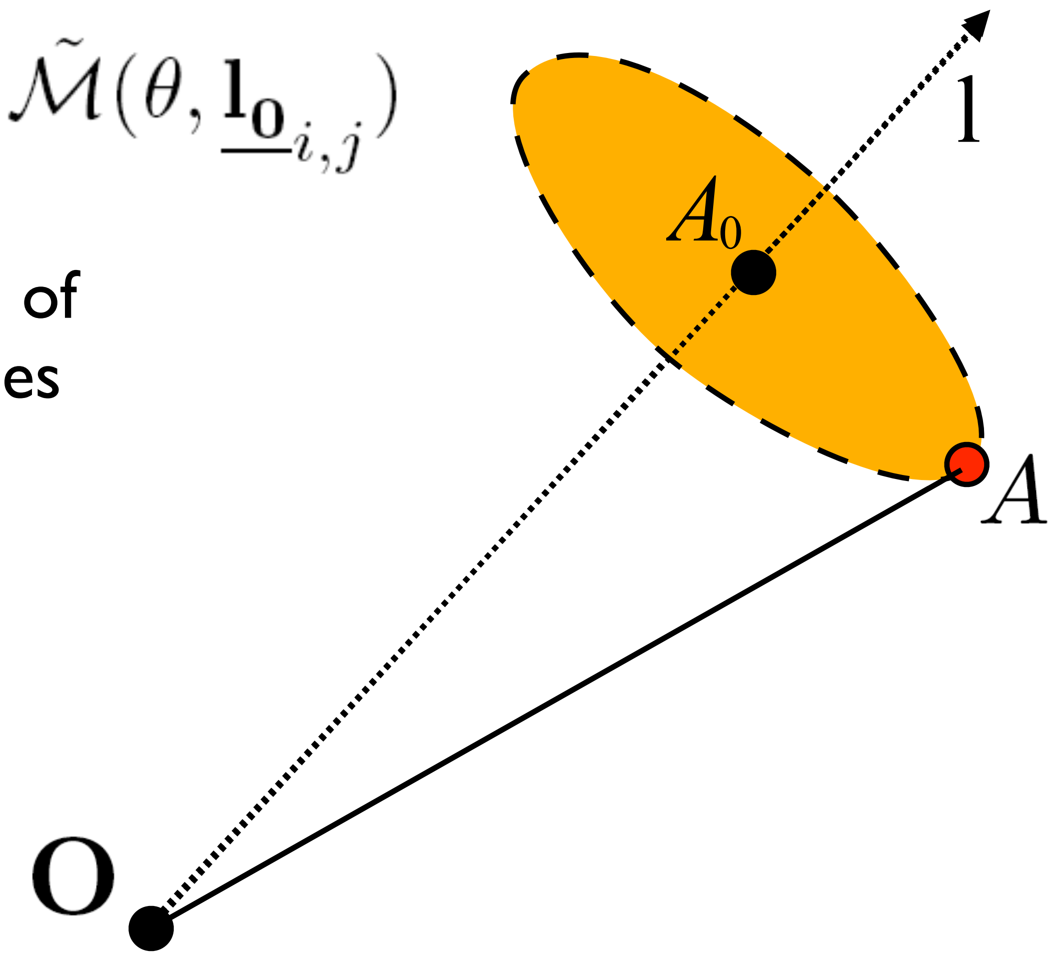
$$\underline{\mathbf{x}}_\theta = \mathcal{M}^2(\lambda_2\theta,\underline{\mathbf{l_2}})\mathcal{M}^1(\lambda_1\theta,\underline{\mathbf{l_1}})\underline{\mathbf{x}}_0\tilde{\mathcal{M}}^1(\lambda_1\theta,\underline{\mathbf{l_1}})\tilde{\mathcal{M}}^2(\lambda_2\theta,\underline{\mathbf{l_2}})$$

Generating a Cone with CGA

$$\underline{\mathbf{l_0^*}}_{i,j} = e \wedge \underline{\mathbf{O}} \wedge \underline{\mathbf{A}}_0$$

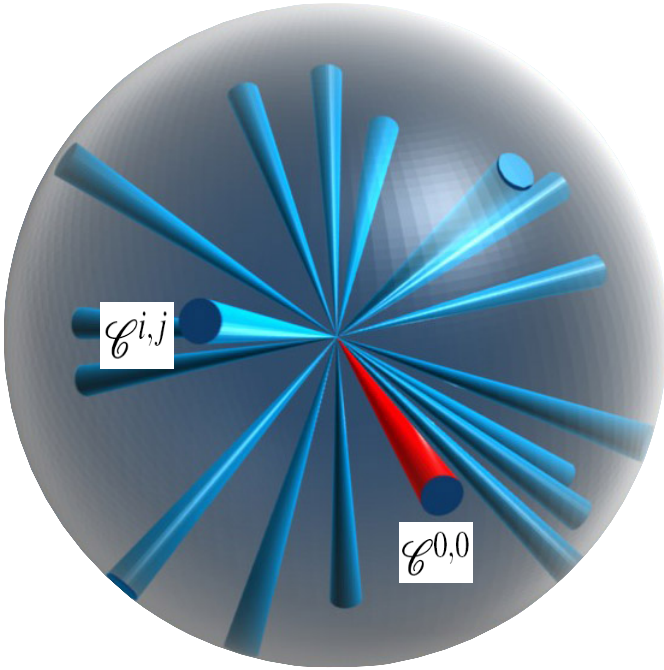
$$\mathcal{C}^{i,j}(\theta) = \mathcal{M}(\theta, \underline{\mathbf{l_0}}_{i,j})\underline{\mathbf{l_{OA}}}^{i,j}\tilde{\mathcal{M}}(\theta, \underline{\mathbf{l_0}}_{i,j})$$

$\mathcal{M}(\theta, \underline{\mathbf{l_0}}_{i,j})$ can be a combination of motors to generate complex shapes

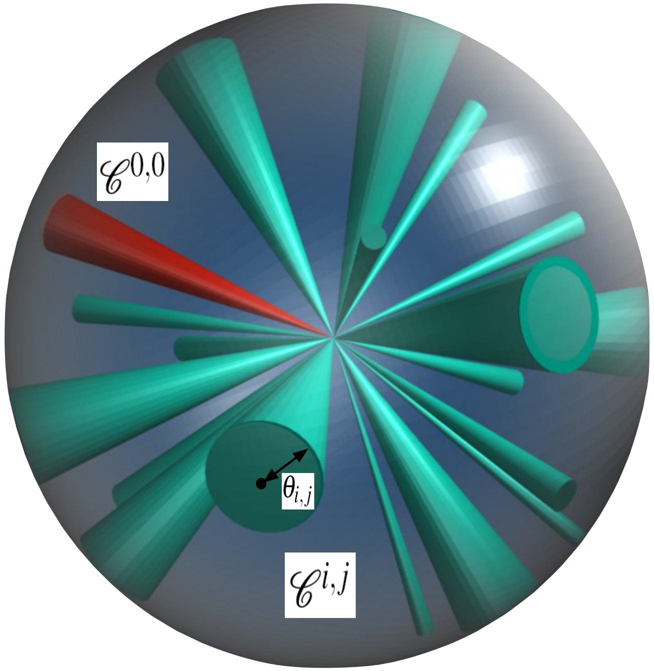


General model of a pixel cone camera

A bundle of pixel-cones of a central linear sensor.



A bundle of pixel-cones of a central variant linear sensor



$$\mathcal{C}^{i,j}_{\phi,\psi}(\theta) = \mathcal{M}^2(\psi, \mathbf{e_{23}})\mathcal{M}^1(\phi, \mathbf{e_{13}})\mathcal{C}^{0,0}_{0,0}(\theta)\tilde{\mathcal{M}}^1(\phi, \mathbf{e_{13}})\tilde{\mathcal{M}}^2(\psi, \mathbf{e_{23}})$$

Cone intersection in GA

Cone

$$P_{p,q} = \{\mathcal{C}_1^p \vee \mathcal{C}_1^q\}$$

Coordinate Frame

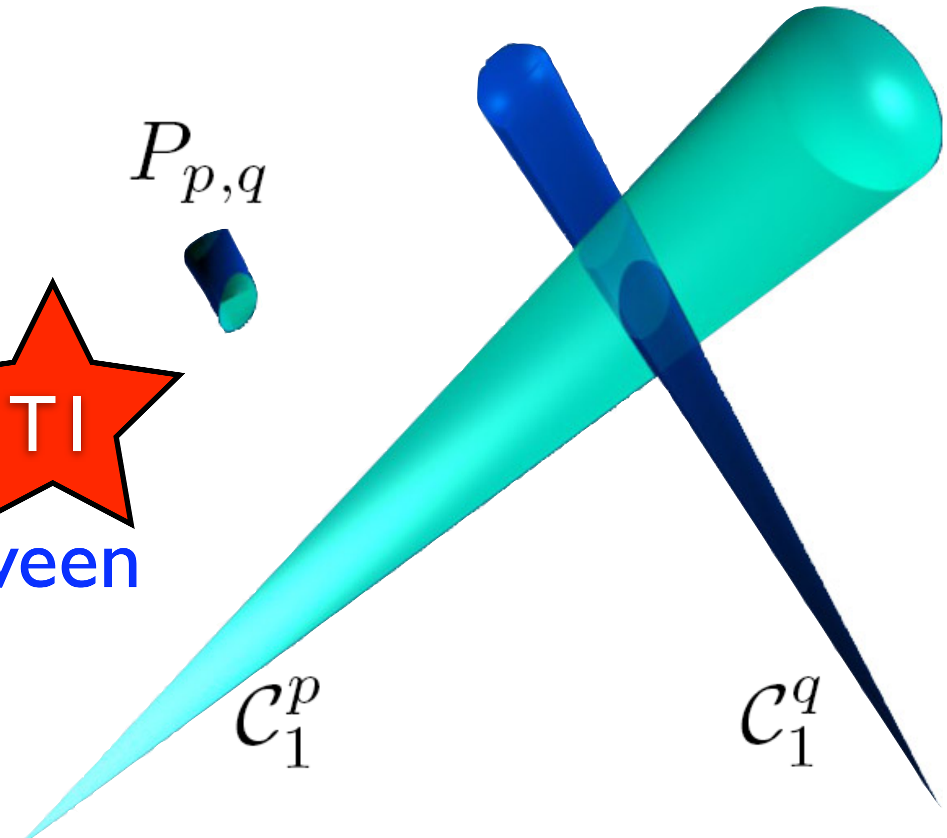
$$= \{\mathcal{C}_1^p \vee \mathbf{M}\mathcal{C}_2^q\tilde{\mathbf{M}}\}$$

T1

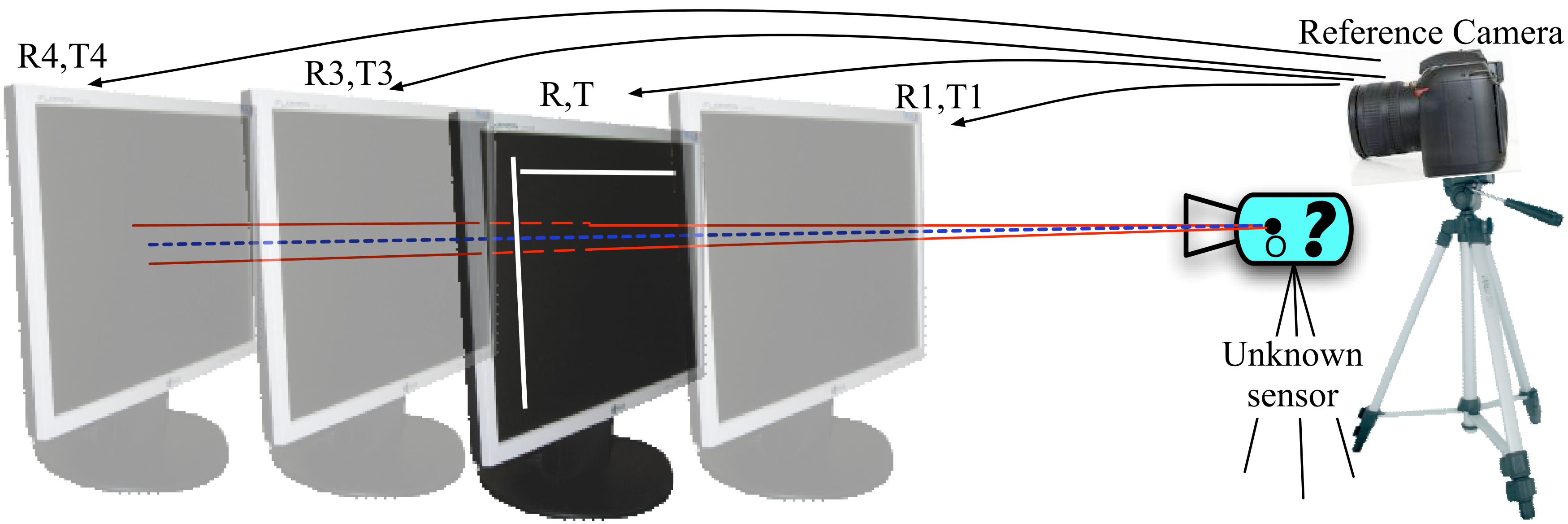
Discrete Motion (R,T) between Frame 1 and 2

$$(\mathcal{C}_1^p \wedge \mathbf{M}\mathcal{C}_2^q\tilde{\mathbf{M}})I^{-1} = 0$$

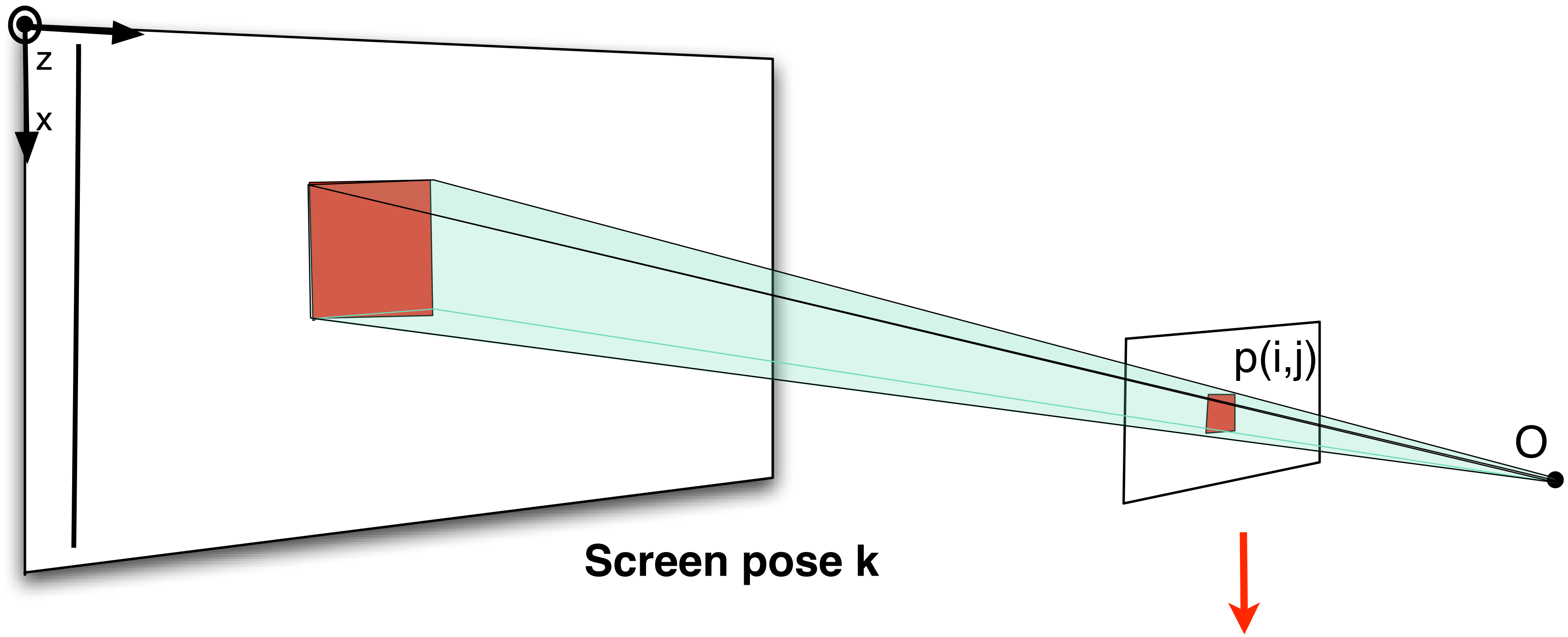
Classic Pseudo-Scalar



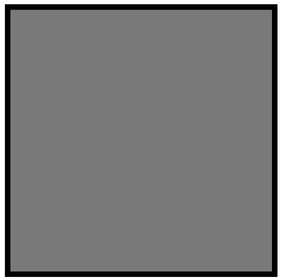
Experimental Protocol Overview



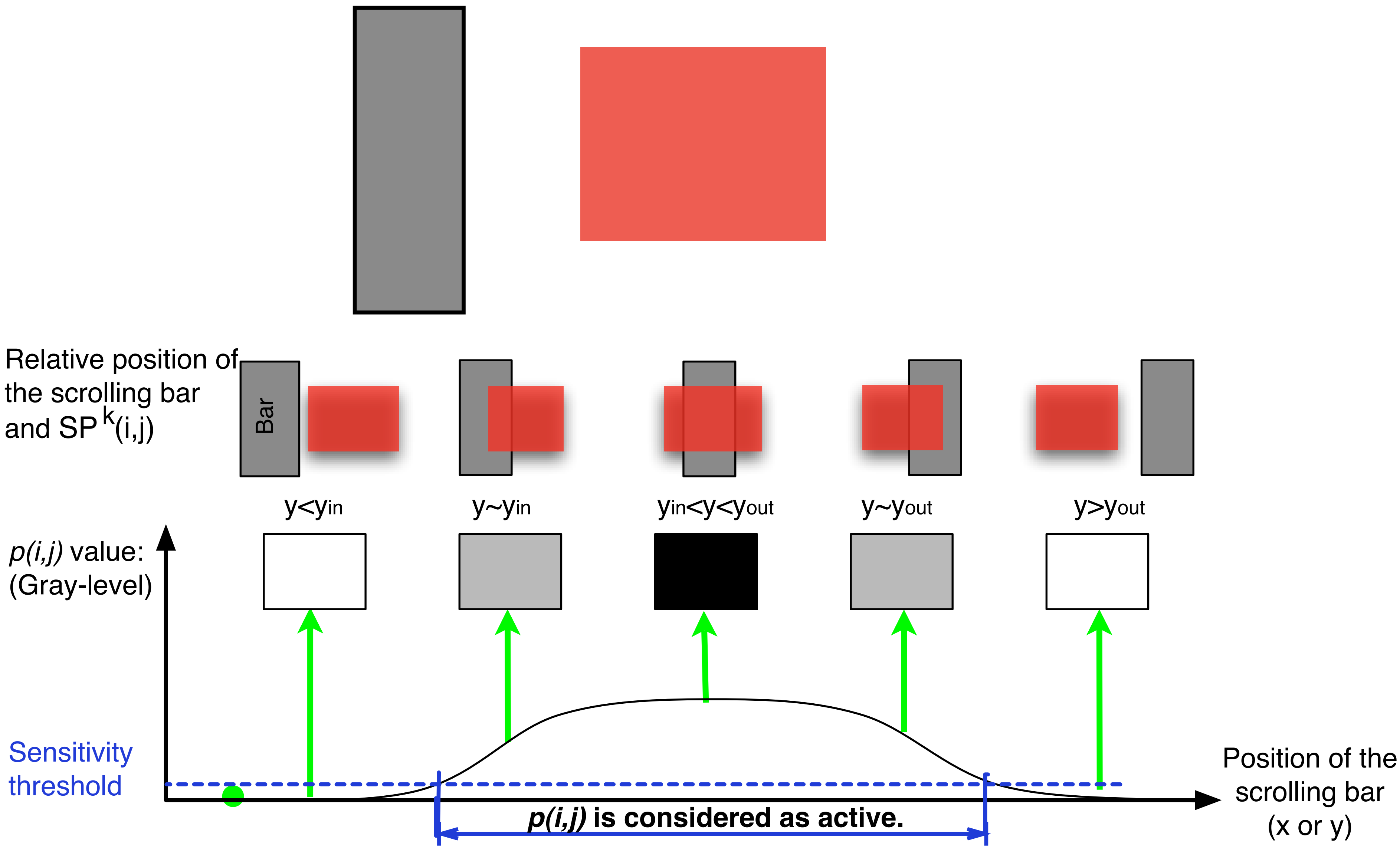
Experimental Protocol
Pixel-activity



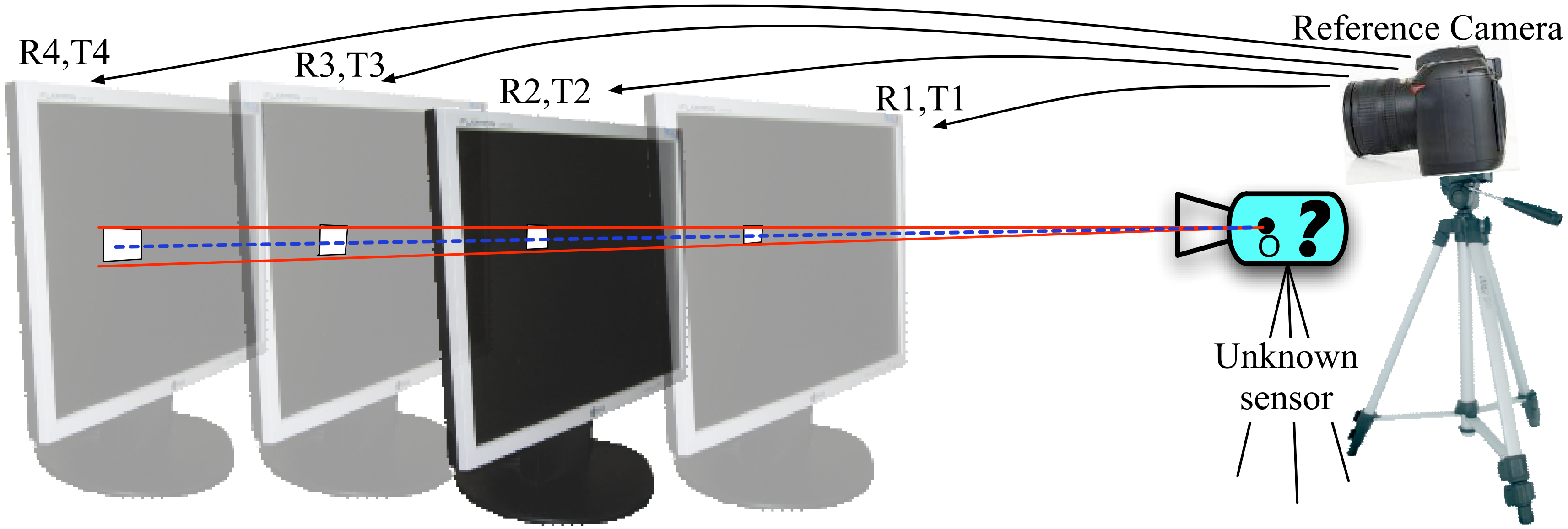
Pixel activity



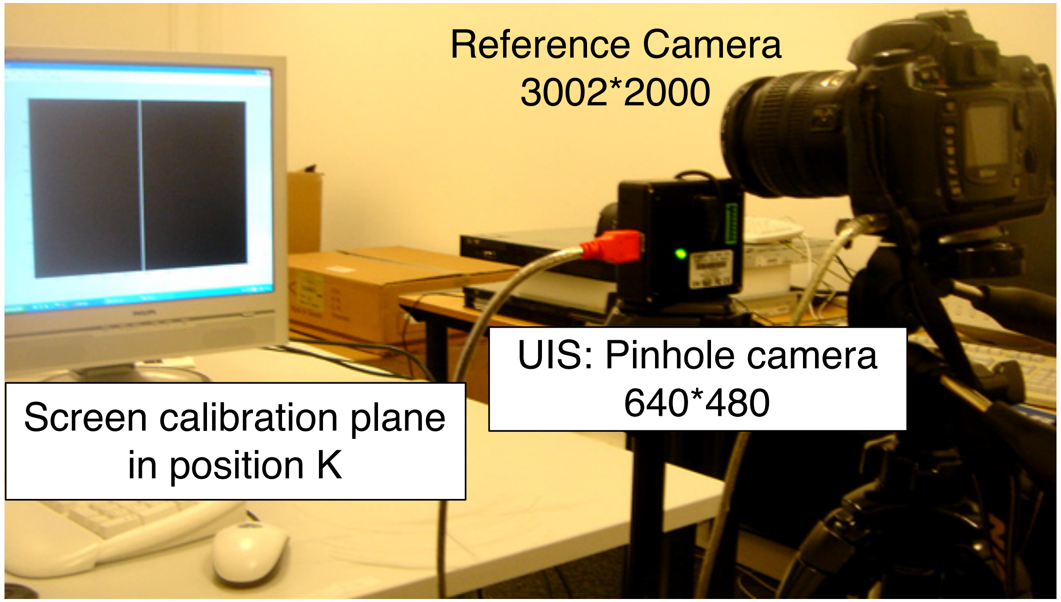
Experimental Protocol
On/Off decision

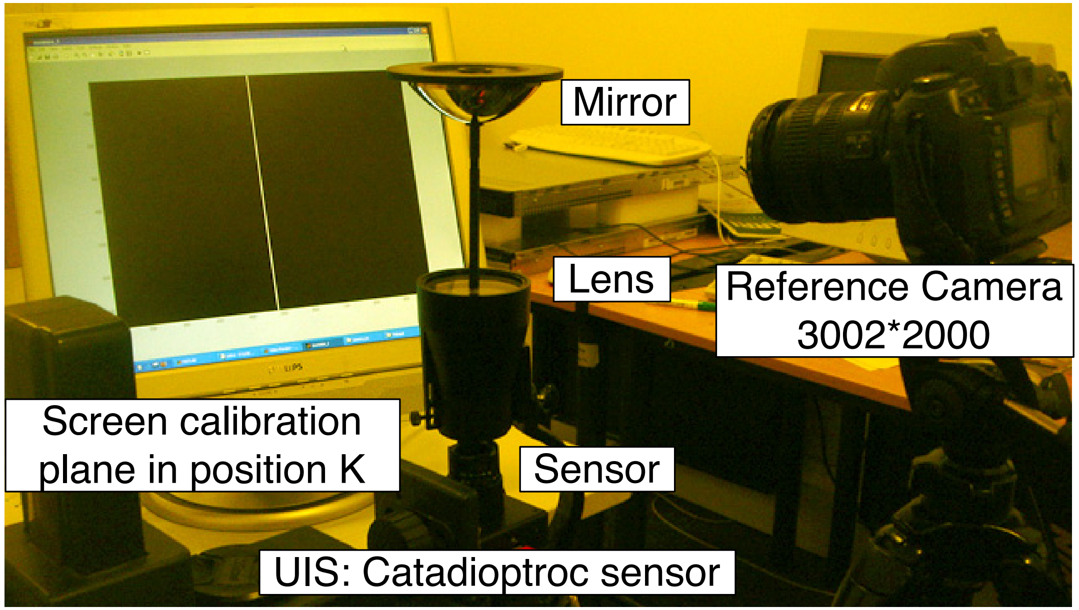


Experimental Protocol
Cone of view Estimation



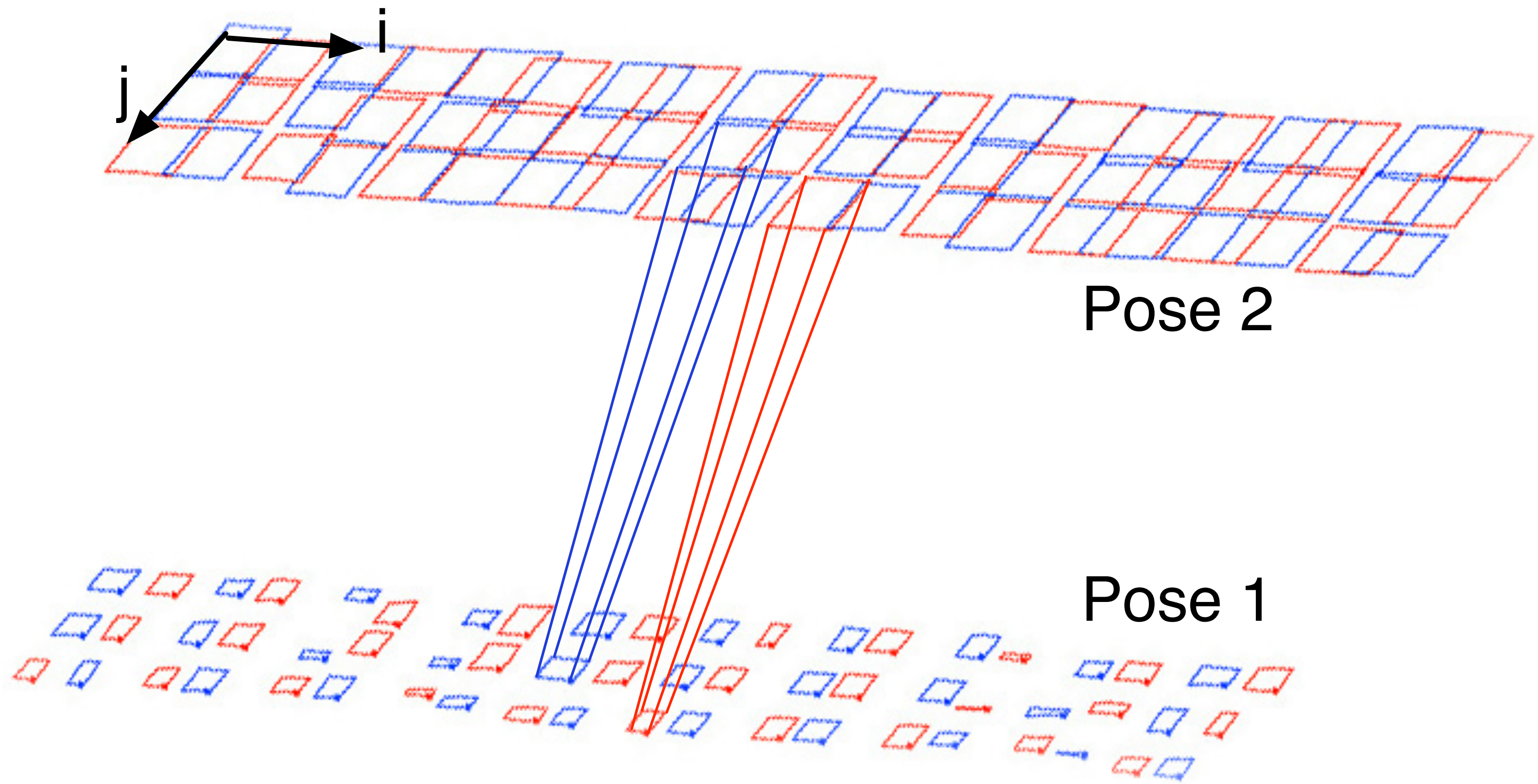
Experimental Device





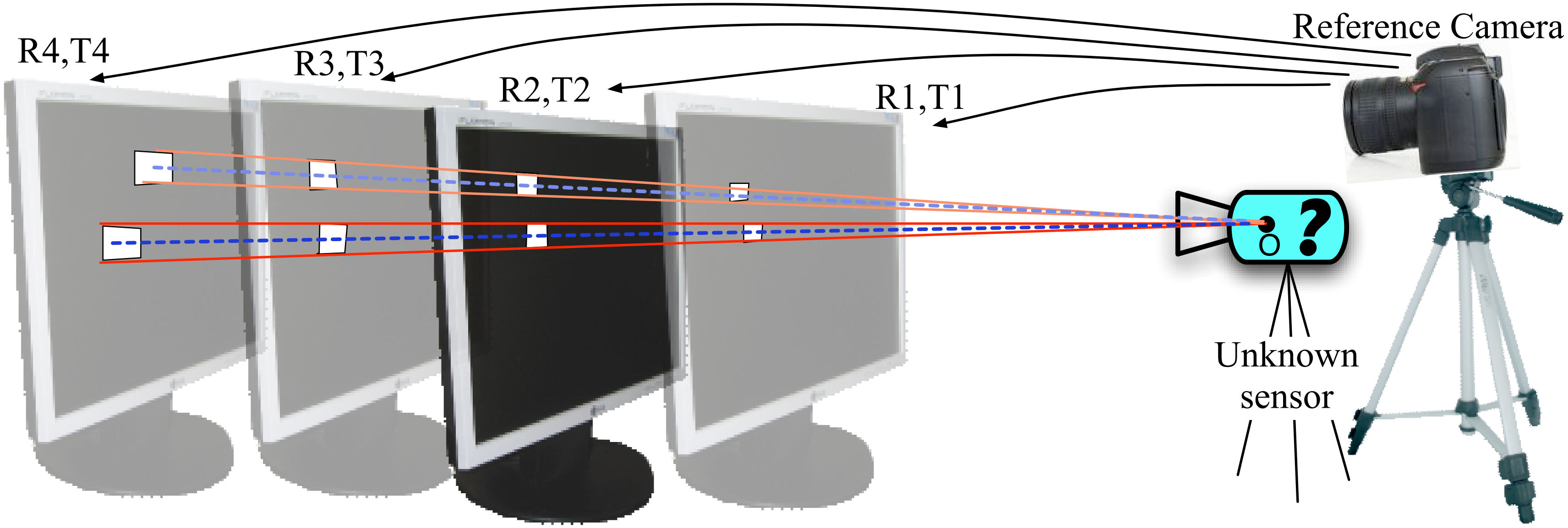
Experimental Results

Cone reconstruction: example for a pinhole camera



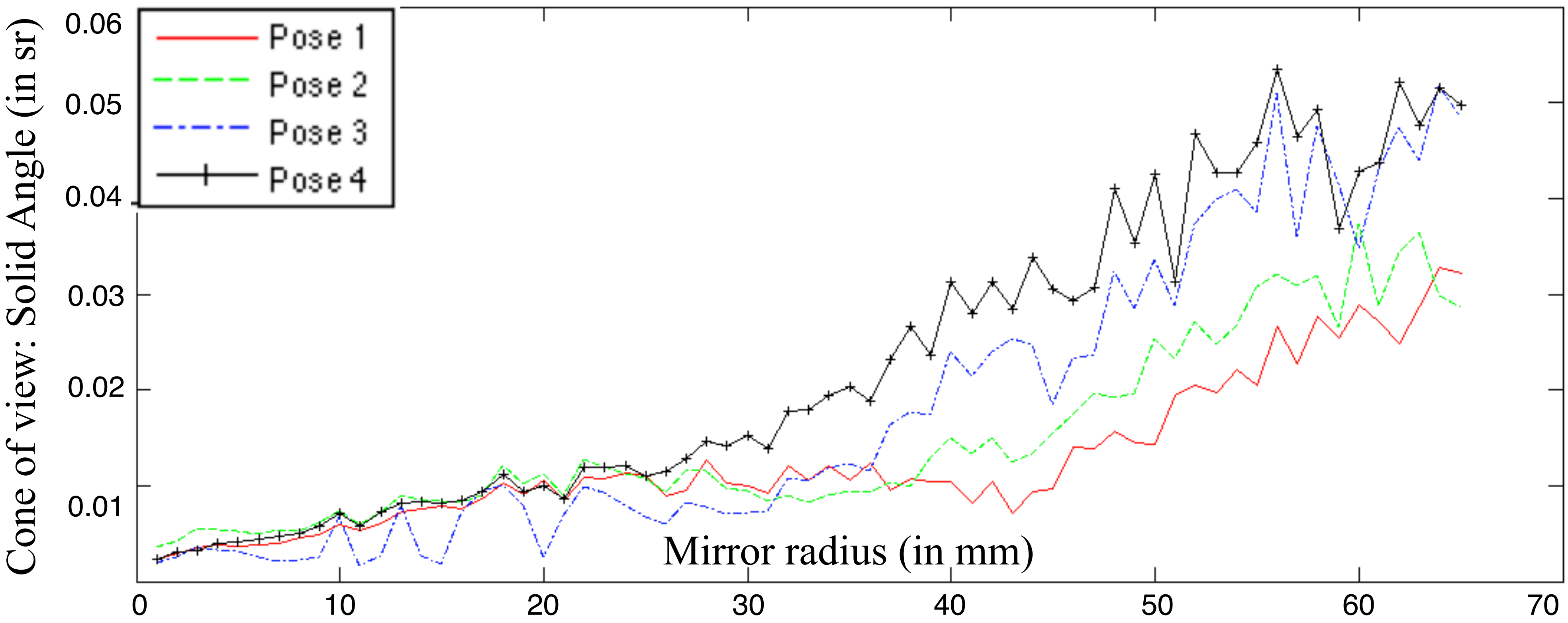
Experimental Results

Central projection point coordinates estimation:



mm	Ground Truth	First Estimation	Second Estimation
x	-78,33		
y	45,36		
z	45,74		

Experimental Results



Conclusion & Oppenings

-General model of central image sensor

-It holds the classic models (Raxel, epipolar geometry) and fits to the physical reality.

-CGA enabled us to write it and provides simple geometric entities which can be easily manipulated

-Experimental results prove the reliability of the model