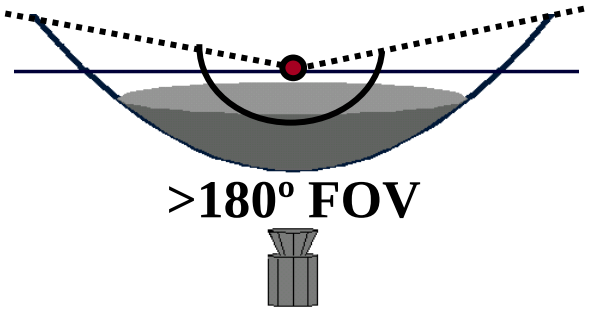
Omnidirectional Camera | definition

- An omnidirectional camera is camera characterized by a very large field of view (ultimately, a spherical field of view)

~180º FOV

Wide FOV dioptric cameras (e.g. fisheye)

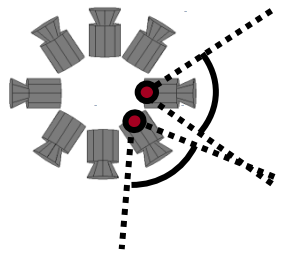
Dioptric



Catadioptric cameras (e.g. cameras and mirror systems)

Catadioptric

~360º FOV



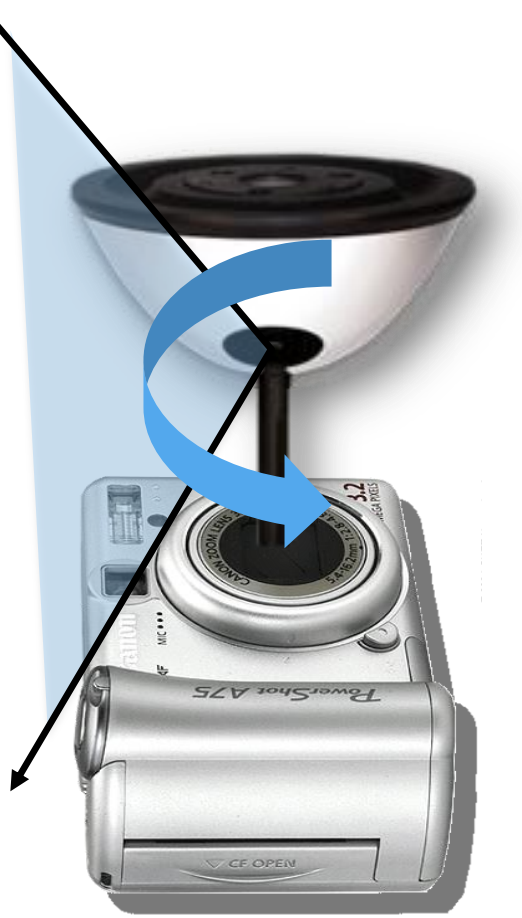
Polydioptric cameras (e.g. multiple overlapping cameras)

Polydioptric

Image courtesy of T. Pajdla

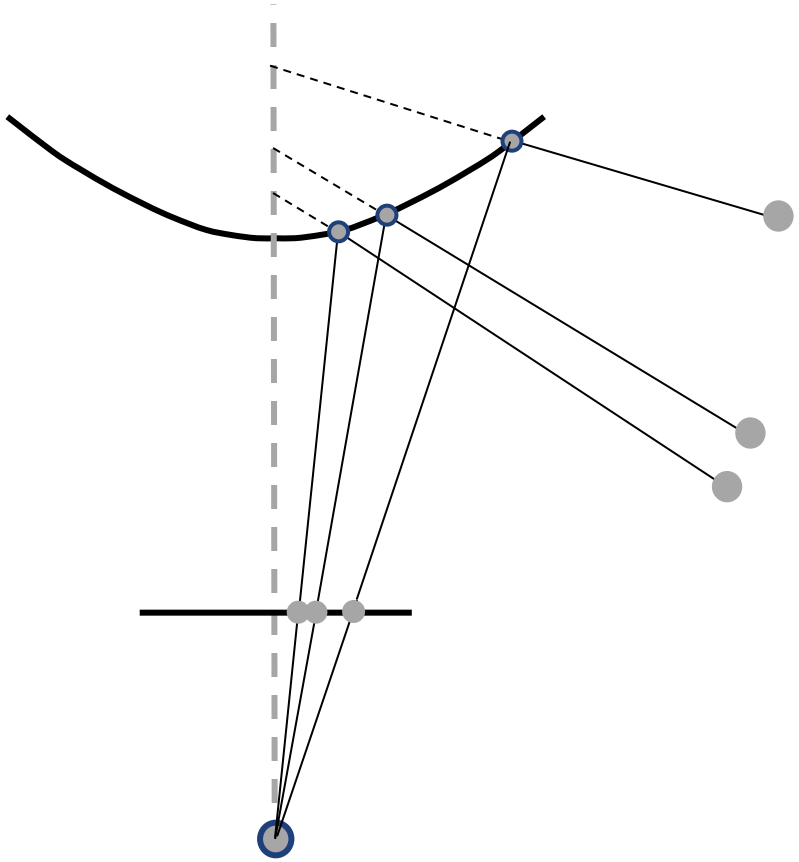
Omnidirectional Camera | catadioptric camera

- Vertical field of view larger than 100 degrees
- Horizontal field of view 360 degrees



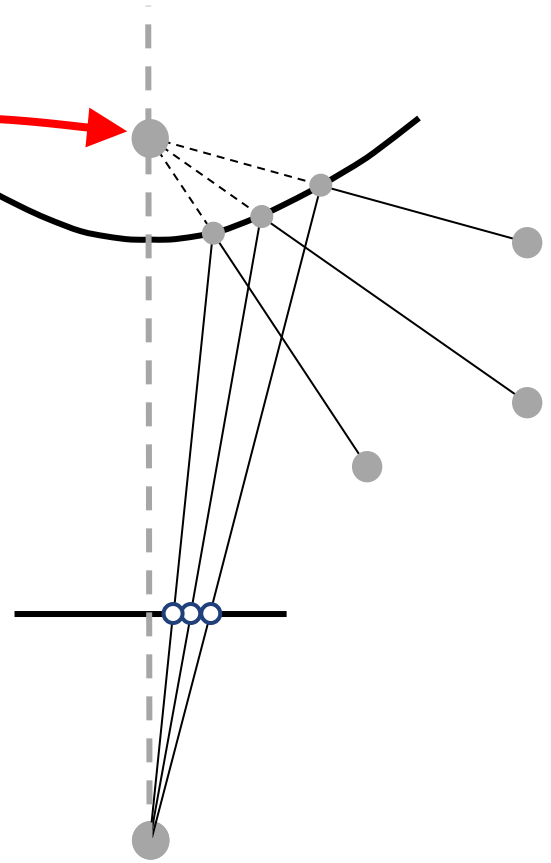
Omnidirectional Camera | catadioptric camera

- Mirror + perspective camera



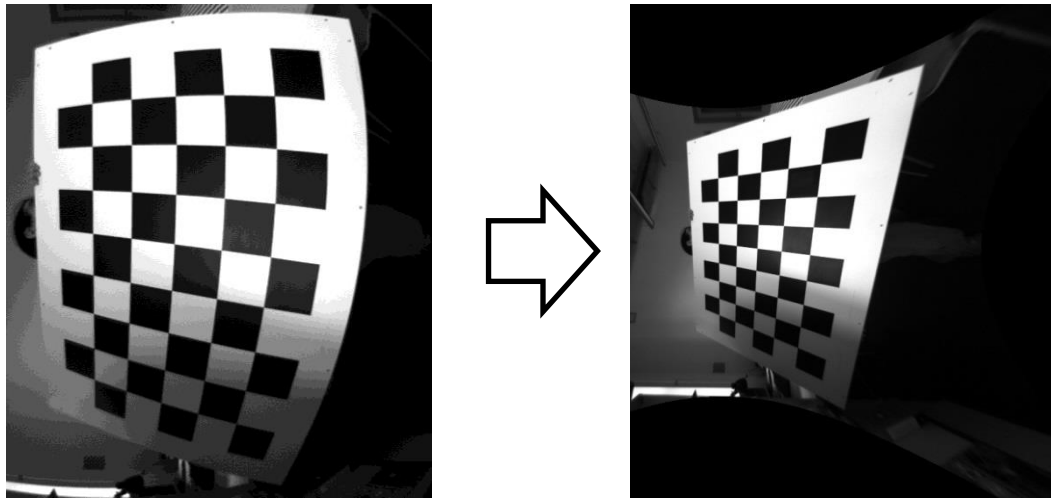
Omnidirectional Camera | central catadioptric camera

- **Central** catadioprtic camera
  - Mirror is surface of revolution of a conic
    - single effective viewpoint



Omnidirectional C| central catadioptric camera

- Why is a central camera preferable?
  - We can unwrap parts or all omnidirectional image into a perspective one
  - We can transform image points into spherical vectors
  - We can apply standard algorithms valid for perspective geometry



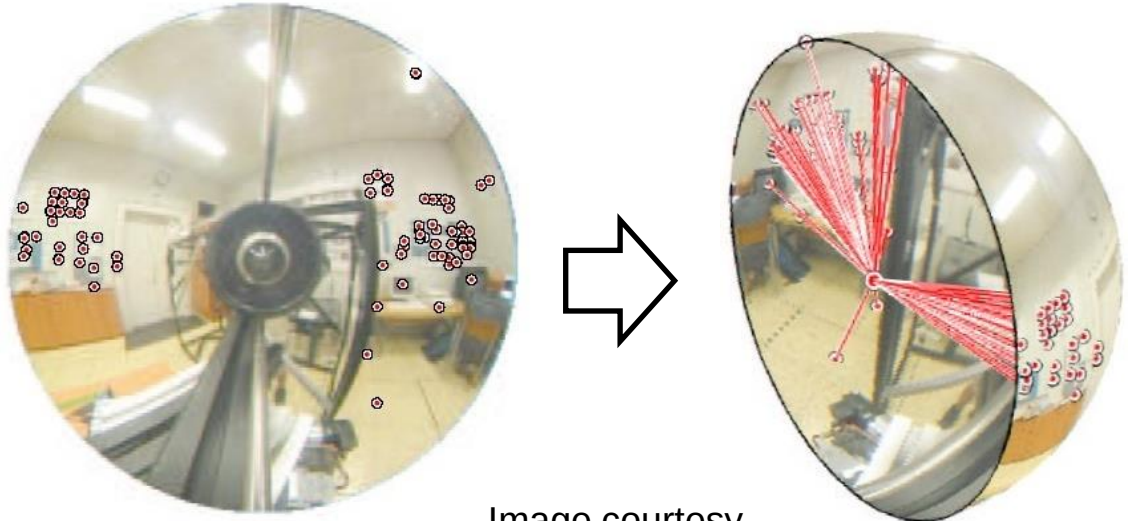
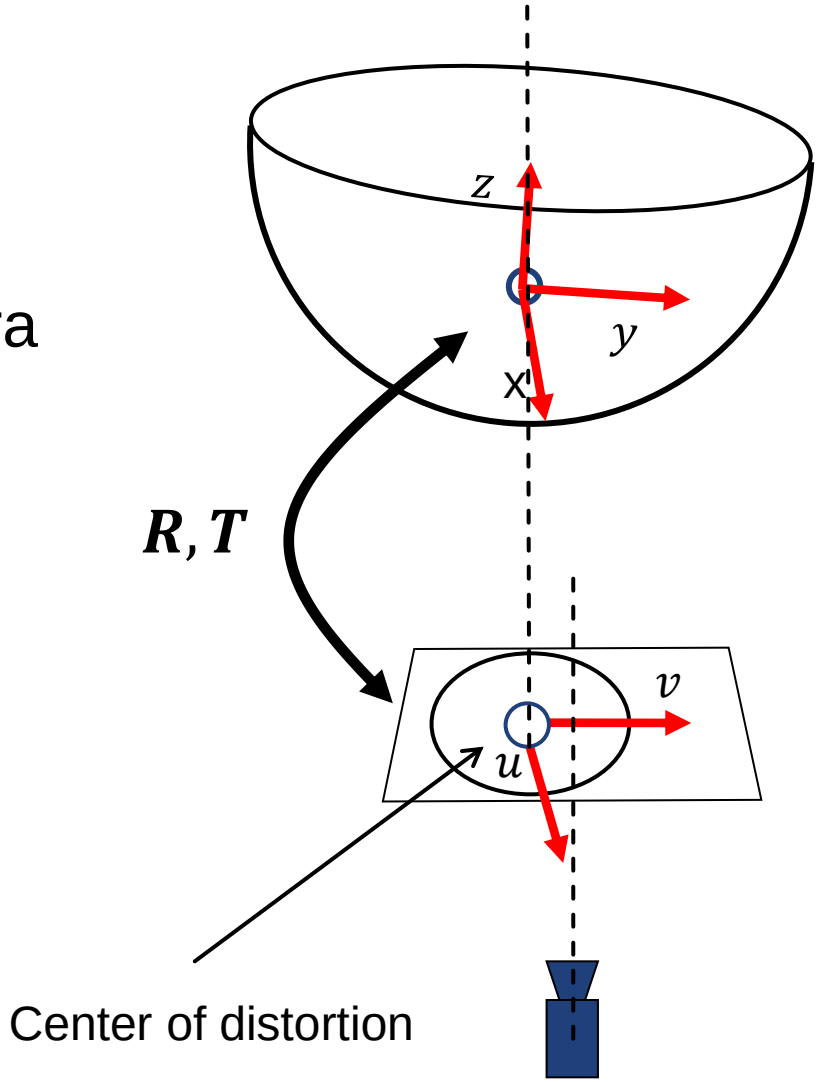


Image courtesy of T. Pajdla

Omnidirectional Camera | projection model

What are the intrinsic parameters?

- Center of distortion
- Intrinsic parameters of the perspective camera
- Relative orientation and position between camera & mirror (for catadioptric cameras)
- Distortion model
  - Mathematical model of the mirror
  - Distortion of the fisheye lens
- All these parameters define the intrinsic parameters of an omnidirectional camera

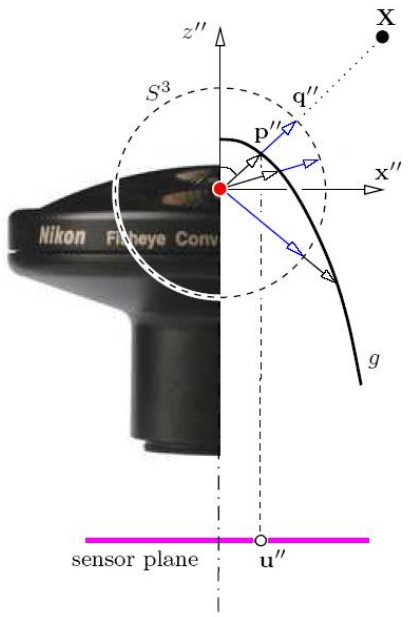


Omnidirectional Camera | distortion model

- We can model the distortion through an n^{th}-order polynomial

$$f(u,v) = a_0 + a_1\rho + \ldots + a_N\rho^N$$

- $n = 4$ describes accurately most catadioptric and fisheye cameras



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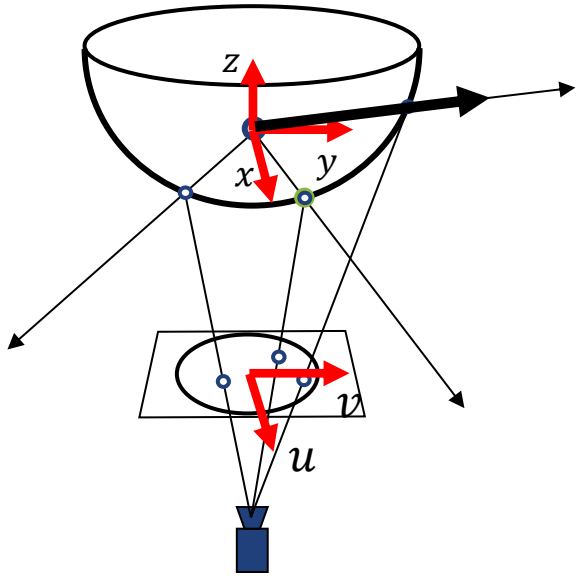
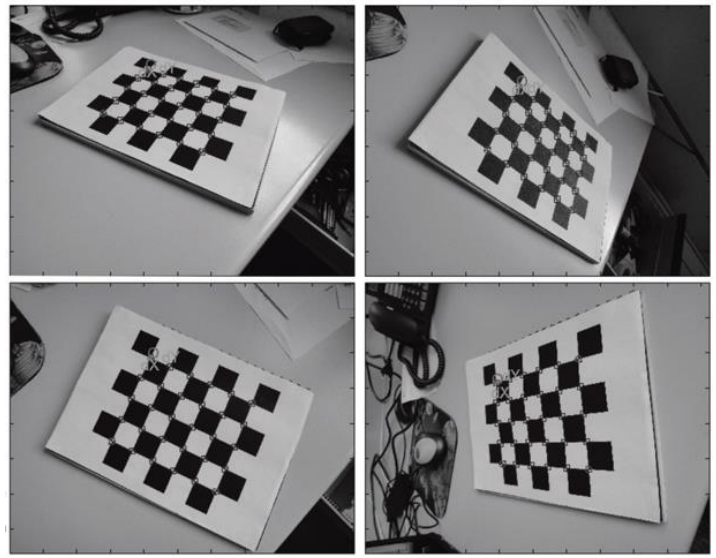


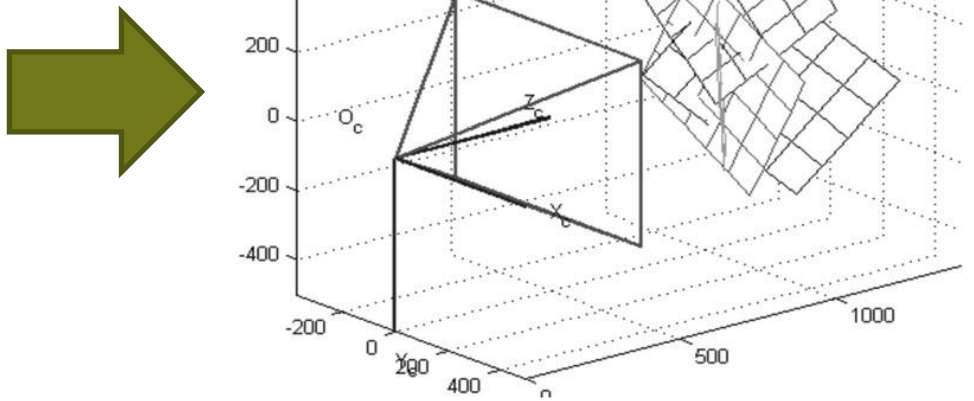
$$\mathbf{p} = \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} u \\ v \\ f(u,v) \end{bmatrix}$$

$$\|\mathbf{p}\| = 1$$

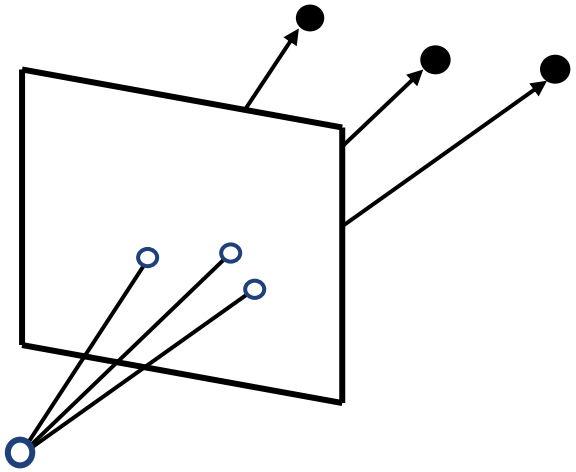
Camera Calibration

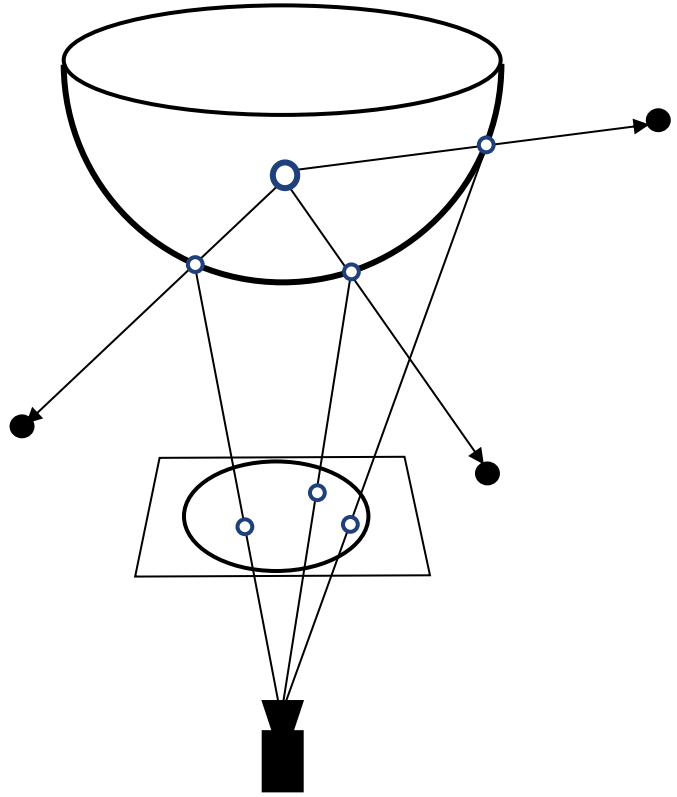
- Goal: to determine the intrinsic parameters of the camera model
- The standard method consists of measuring the 3D positions of n control points on a calibration object and the 2D coordinates of their image projections
  - $n \geq 6$ non-coplanar control points on a three-dimensional calibration target
  - $n \geq 4$ non-collinear control points on a planar pattern



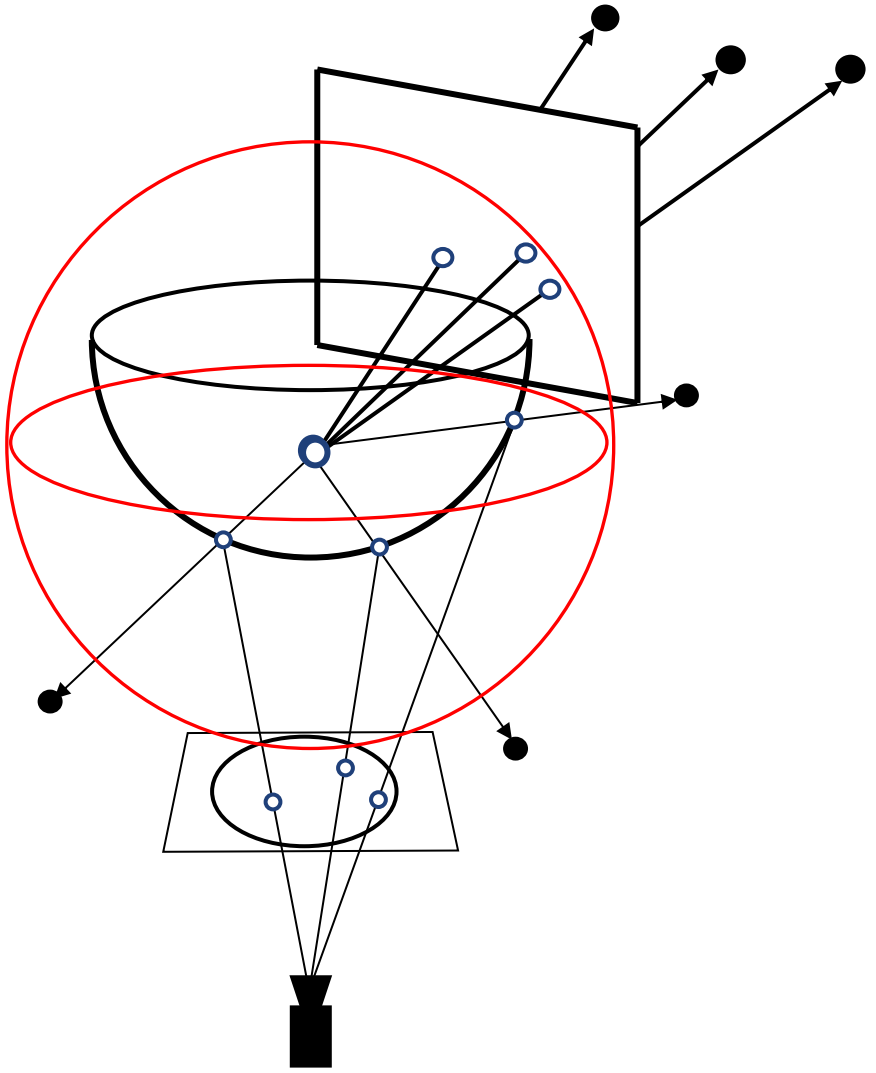


Unified Spherical Representation

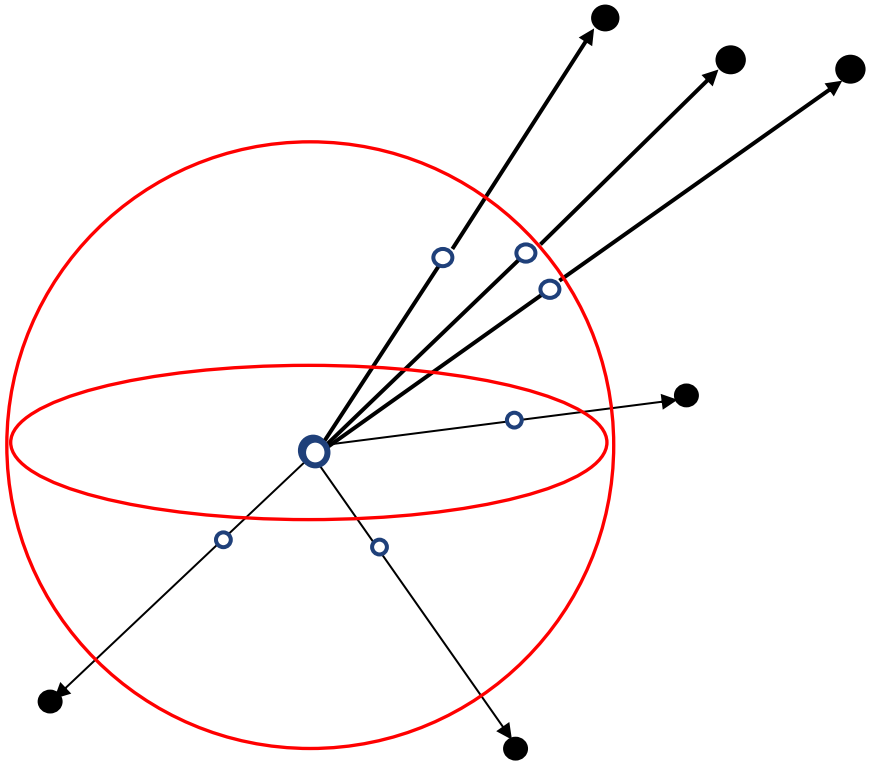




Unified Spherical Representation



Unified Spherical Representation



- Points from a perspective or central omnidirectional cameras can always be represented on the unit sphere (always possible when the camera is calibrated)