Camera Calibration

What is it?

- Build a relationship between an image and the 3D world

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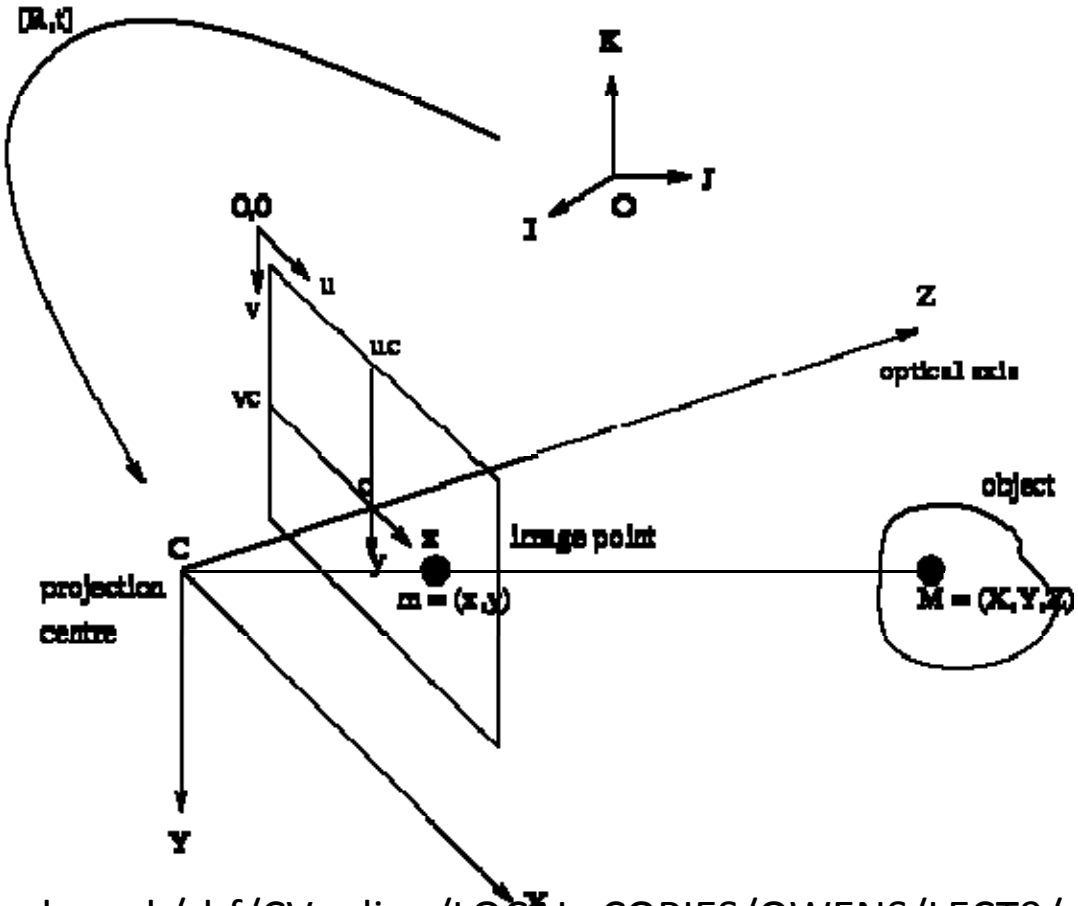
- Build a relationship between an image and the 3D world
- why bother?
  - Scale
  - Orientation
  - Lens distortion
  - etc

What is it?

- Build a relationship between an image and the 3D world



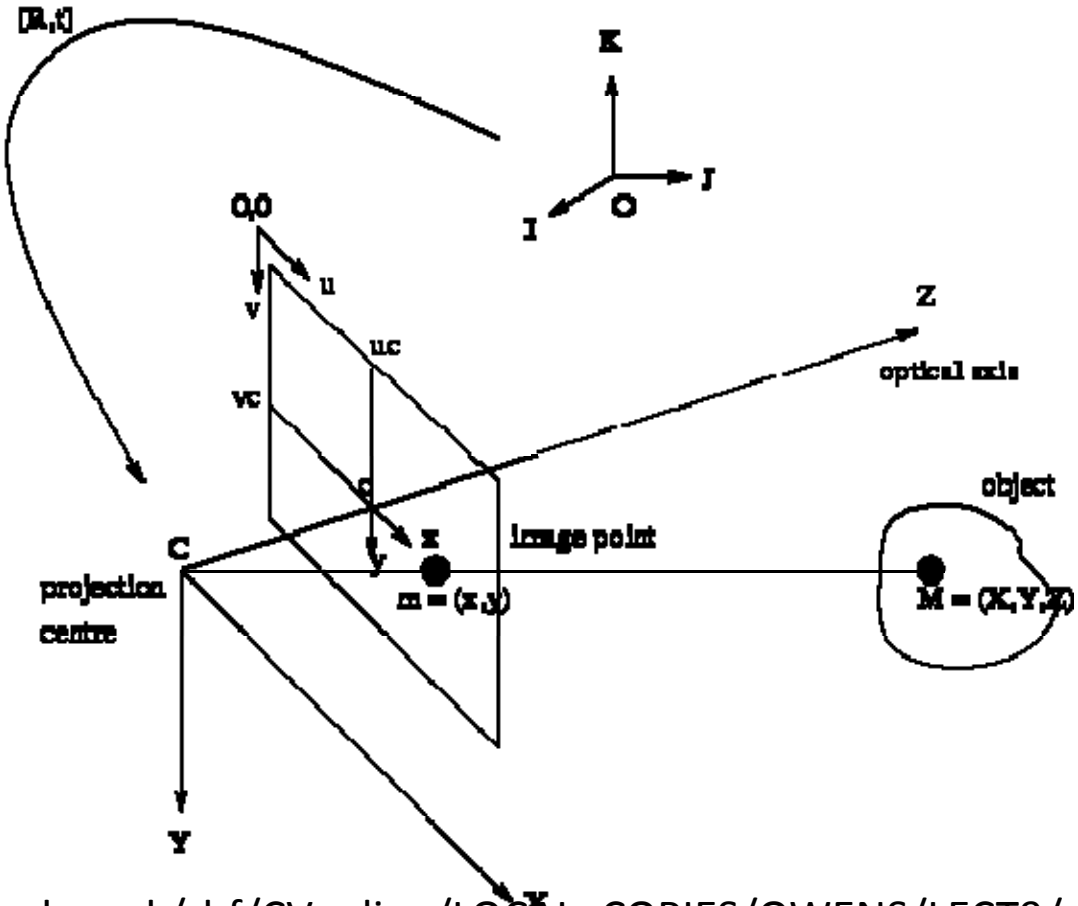
http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/OWENS/LECT9/node2.html

What is it?

- Build a relationship between an image and the 3D world

$$x = \frac{Xf}{Z}$$

$$y = \frac{Yf}{Z}$$



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$$x = \frac{Xf}{Z}$$

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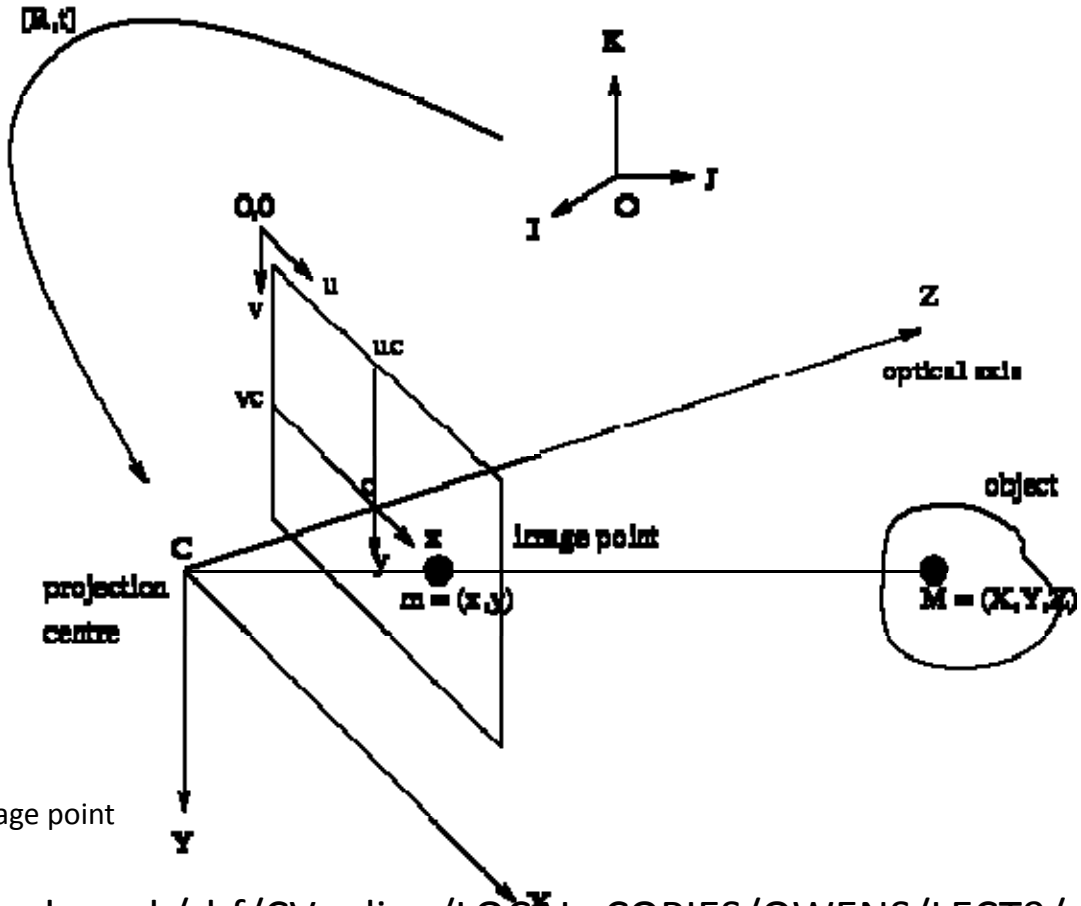
$$\begin{bmatrix} sx \\ sy \\ s \end{bmatrix} = \begin{bmatrix} f & 0 & 0 & 0 \\ 0 & f & 0 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Convert from 3D in camera space to image point



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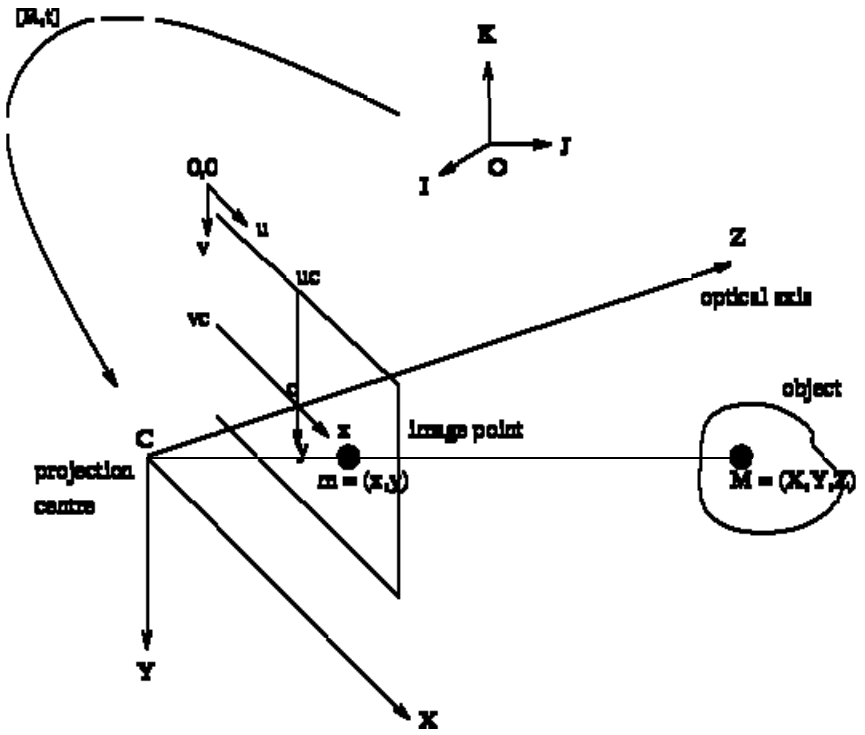
Calibration– more

- convert from x,y to u,v

$$u = u_c + \frac{x}{\text{pixel width}}, \quad v = v_c + \frac{y}{\text{pixel width}}$$



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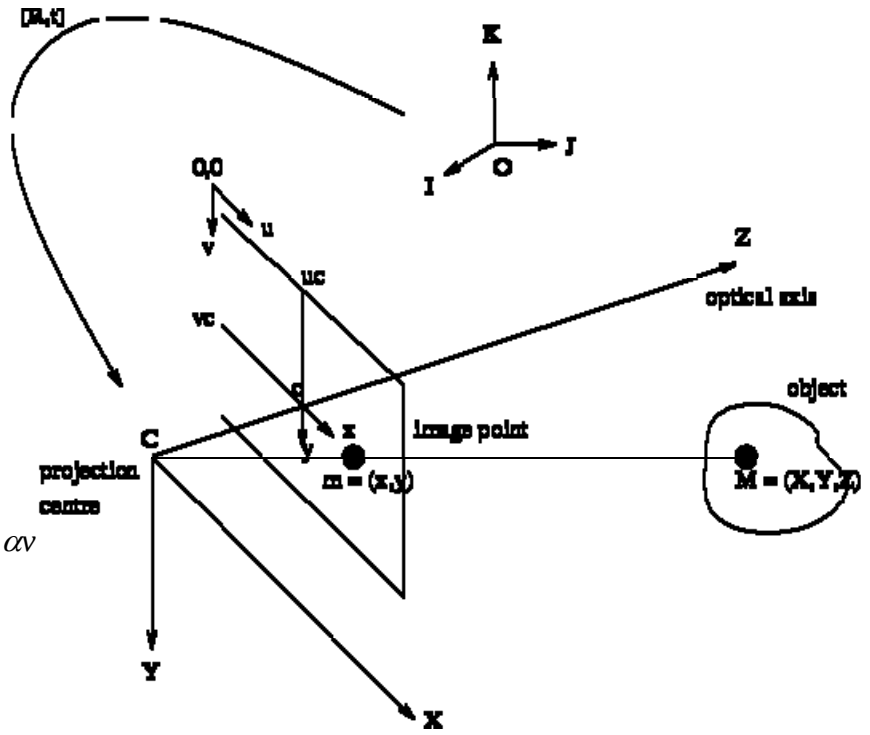
$f/\Delta u = \alpha u, \quad f/\Delta v = \alpha v$



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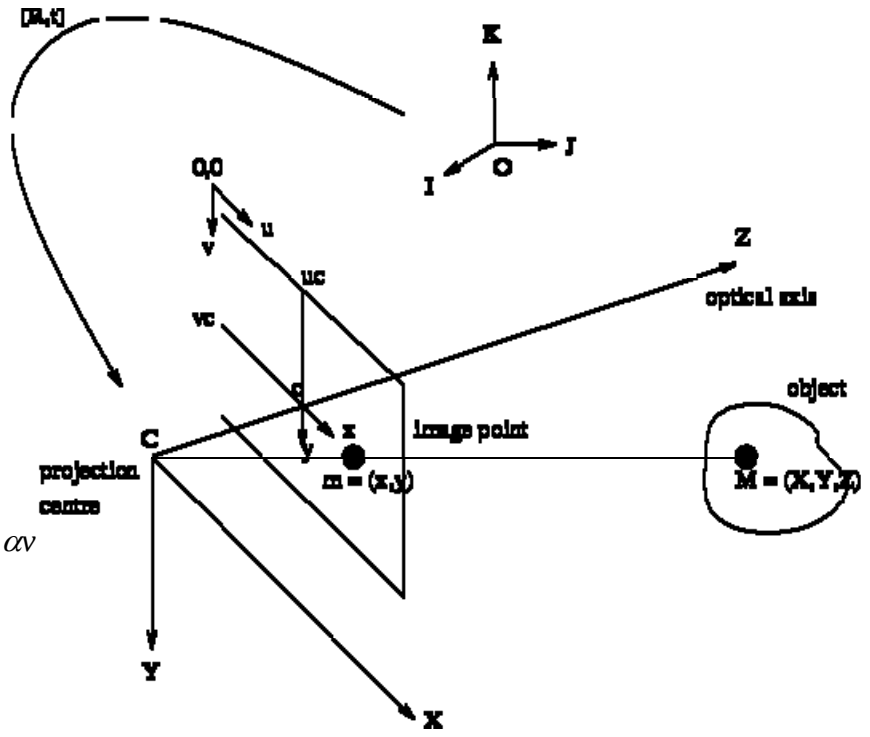

– These (f,u,v,uc,uv) are intrinsic parameters – they do not rely on the 3D scene

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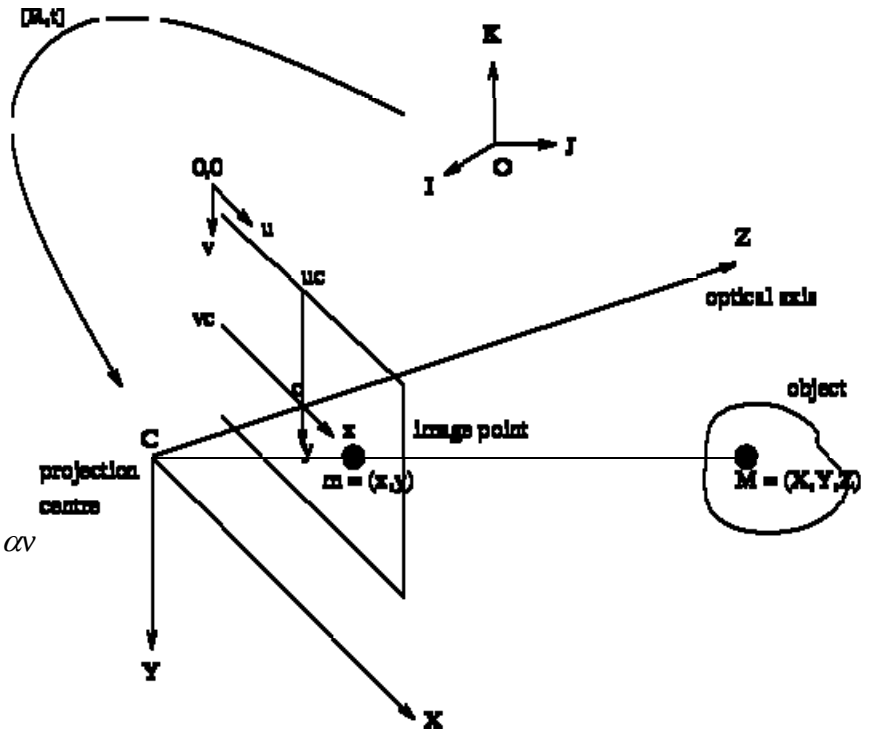

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- Extrinsic?(rely on 3D scene)
  - Rotation and translation from I,J,K to X,Y,Z

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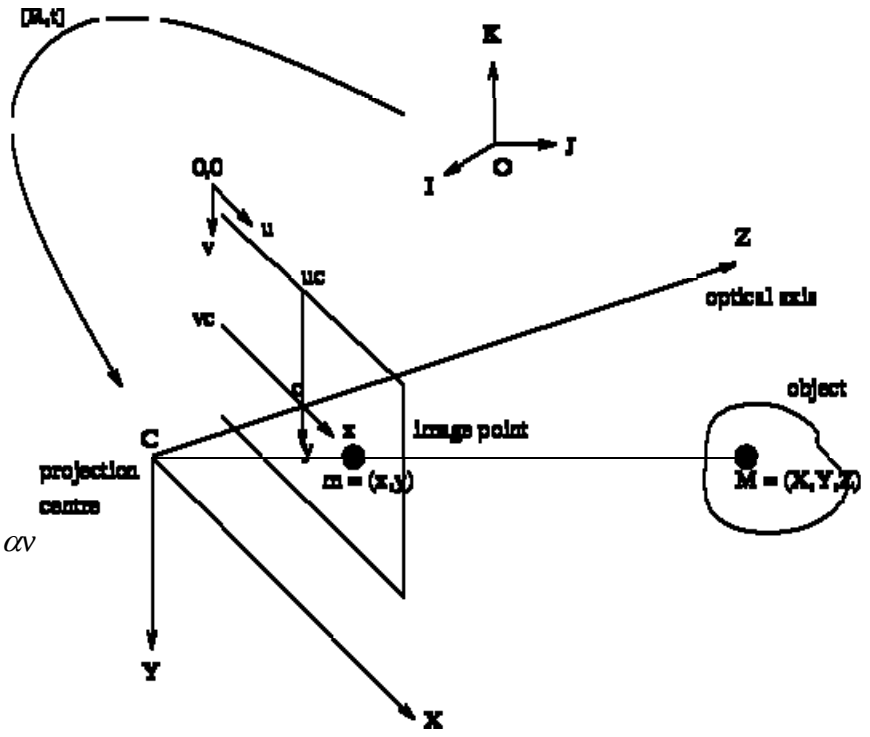

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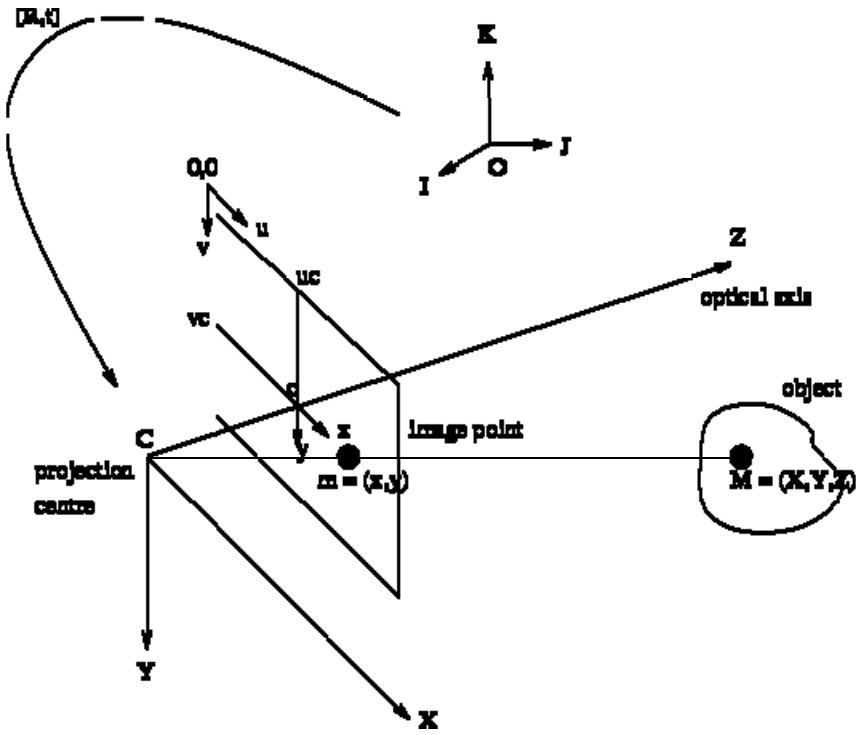
$$K = \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix}$$

R is 3x3 rotation, 3DOF
t is a 3x1 translation, 3DOF

Calibration– more

- Camera calibration

$$\begin{bmatrix} f/\Delta u & 0 & u_c & 0 \\ 0 & f/\Delta v & v_c & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \qquad K = \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix}$$

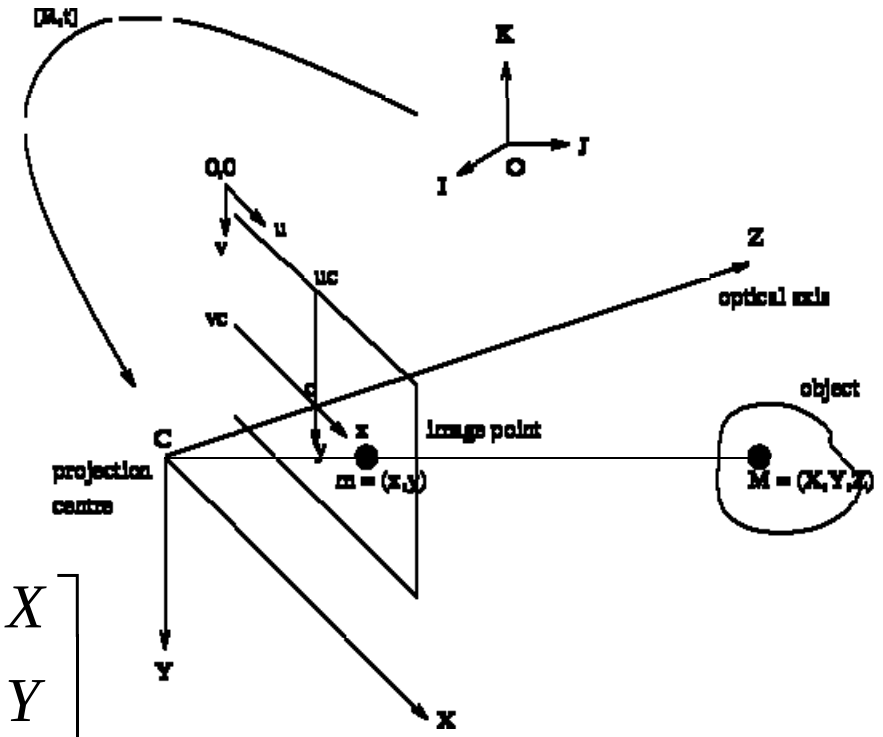


Calibration– more

- Camera calibration

$$\begin{bmatrix} f/\Delta u & 0 & u_c & 0 \\ 0 & f/\Delta v & v_c & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \qquad K = \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix}$$

internal external



$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} f/\Delta u & 0 & u_c & 0 \\ 0 & f/\Delta v & v_c & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

Multiply out…

$$\begin{bmatrix} su \\ sv \\ s \end{bmatrix} = \begin{bmatrix} f/\Delta u & 0 & u_c & 0 \\ 0 & f/\Delta v & v_c & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \cdot \begin{bmatrix} R & t \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} X \\ Y \\ Z \\ 1 \end{bmatrix}$$

$$\begin{bmatrix} su_i \\ sv_i \\ s \end{bmatrix} = \begin{bmatrix} p_{11} & p_{12} & p_{13} & p_{14} \\ p_{21} & p_{22} & p_{23} & p_{24} \\ p_{31} & p_{32} & p_{33} & p_{34} \end{bmatrix} \cdot \begin{bmatrix} X_i \\ Y_i \\ Z_i \\ 1 \end{bmatrix}$$