① $f = \frac{50}{1000}$ m $\quad \left(\frac{50}{1000}\cdot\frac{10}{20}, \frac{50}{\frac{1000}{200}}\cdot\frac{5}{20}\right) \rightarrow \boxed{\left(\frac{1}{40}, \frac{1}{80}\right)}$

- $[O_x, O_y]$ → Principal point
- $S_x f$ & $S_y f$ → focal length • S_x & S_y represent # of pixels in horizontal or vertical direction / meter
- S_x / S_y → aspect ratio
- S_θ → skew of pixel
- K → intrinsic (internal to camera) matrix
- Π_0 → canonical projection → Transformation of a scene to standard

$u^I = s_x u_m^c + O_x \qquad v^I = s_y v_m^c + O_y$

Normalized coordinates to (0,0) being top left

$$p^c z \begin{bmatrix} u^I \\ v^I \\ 1 \end{bmatrix} = \begin{bmatrix} s_x f & s_\theta f & O_x \\ 0 & s_y f & O_y \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} I_3 & O_3 \end{bmatrix} p^w c$$

② $$20 \begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} = \begin{bmatrix} 800\left(\frac{50}{1000}\right) & 0 & 320 \\ 0 & 800\left(\frac{50}{1000}\right) & 240 \\ 0 & 0 & 1 \end{bmatrix} p^c c$$

$$\begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} = \begin{bmatrix} 2 & 0 & 16 \\ 0 & 2 & 12 \\ 0 & 0 & 1/20 \end{bmatrix} \begin{bmatrix} 10 \\ 5 \\ 20 \end{bmatrix}$$

$$\begin{bmatrix} 20 + 0 + 16\cdot 20 \\ 0 + 10 + 240 \\ 0 + 0 + 1 \end{bmatrix} = \begin{bmatrix} 340 \\ 250 \\ 1 \end{bmatrix} \rightarrow \boxed{(340, 250)}$$

③ $K = \begin{bmatrix} 40 & 0 & 320 \\ 0 & 40 & 240 \\ 0 & 0 & 1 \end{bmatrix}$

④ $P_{c2}\begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} = \begin{bmatrix} 40 & 0 & 320 \\ 0 & 40 & 240 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 10 \end{bmatrix}\begin{bmatrix} 2 \\ 3 \\ 50 \\ 1 \end{bmatrix}$

$\begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 10 \end{bmatrix}\begin{bmatrix} 2 \\ 3 \\ 50 \\ 1 \end{bmatrix}\begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} = \begin{bmatrix} 40 & 0 & 320 \\ 0 & 40 & 240 \\ 0 & 0 & 1 \end{bmatrix}\begin{bmatrix} 2 \\ 3 \\ 60 \end{bmatrix}$

get P_{c2}

$60\begin{bmatrix} u' \\ v' \\ 1 \end{bmatrix} = \begin{bmatrix} 80 + 320 \cdot 60 \\ 40 \cdot 3 + 240 \cdot 60 \\ 60 \end{bmatrix}$

$u' = \frac{80}{60} + 320 \qquad v' = \frac{120}{60} + 240$

$321.\overline{33} \qquad = 242$

$(321.\overline{33}, 242)$

⑤

$$u^I = \left[(1 + 0.0001r^2 + 0.0000002r^4)(400 - 320) + 320 \right]$$

$$v^I = \left[\quad \text{"} \quad (350 - 240) + 240 \right]$$

$$r^2 = (400 - 320)^2 + (350 - 240)^2 = 136.015$$

$u^I = 6024 \qquad v^I = 8083$ $\boxed{(6024, 8083)}$