$$\begin{bmatrix} u \\ v \end{bmatrix} = W(x, \theta) = \pi\left(K\left(R_\theta x + t_\theta\right)\right)$$

Rodrigue's Formula:

$$\theta = |r| \qquad \bar{r} = \frac{r}{|r|}$$

$$R = \cos(\theta) I + \left(1 - \cos(\theta)\right) \bar{r} \bar{r}^T + \sin\theta \, \bar{r}^\wedge$$

$$\min_\theta \frac{1}{2} \sum_x \left\| I(W(x, \theta)) - I_0(u, v) \right\|_2^2 = \min_\theta \frac{1}{2} \sum_x \| f(\theta) \|_2^2$$

$$I(W(x, \theta')) \approx I(W(x, \theta)) + \nabla I \frac{\partial W}{\partial \theta}(\theta' - \theta), \quad \theta' = \theta + \Delta\theta$$

$$= W(x, \theta)) + J_\theta \Delta\theta$$

$$\frac{\partial F}{\partial \theta} = 0 \Rightarrow J_\theta f(\theta) + J_\theta J_\theta^T \Delta\theta = 0$$

$$J_\theta J_\theta^T \Delta\theta = -J_\theta f(x)$$

$$= -J_\theta\left(I(W(x, \theta)) - I_0(u, v)\right)$$

$$J_\theta = \frac{\partial I(W(x, \theta))}{\partial W(x, \theta)} \cdot \frac{\partial W(x, \theta)}{\partial \theta} = \nabla I \cdot \frac{\partial W}{\partial \theta}$$

$$e(T) = I_1(p_1) - I_2(u) \qquad \frac{\partial e}{\partial T} = -\frac{\partial I_2}{u}\,\frac{\partial u}{\partial q}\,\frac{\partial q}{\partial \delta\xi},$$

grayscale gradient

$$q = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \qquad \frac{\partial u}{\partial q} = \begin{bmatrix} \frac{\partial u}{\partial X} & \frac{\partial u}{\partial Y} & \frac{\partial u}{\partial Z} \\ \frac{\partial v}{\partial X} & \frac{\partial v}{\partial Y} & \frac{\partial v}{\partial Z} \end{bmatrix} = \begin{bmatrix} \frac{f_x}{Z} & 0 & -\frac{f_x X}{Z^2} \\ 0 & \frac{f_y}{Z} & -\frac{f_y Y}{Z^2} \end{bmatrix}$$

$$\frac{\partial q}{\partial \delta\xi} = \begin{bmatrix} I_3 & -q^\wedge \end{bmatrix}$$

$$\frac{\partial u}{\partial \delta\xi} = \begin{bmatrix} \frac{f_x}{Z} & 0 & -\frac{f_x X}{Z^2} \\ 0 & \frac{f_y}{Z} & -\frac{f_y Y}{Z^2} \end{bmatrix} \begin{bmatrix} & 0 & Z & -Y \\ I_3 & -Z & 0 & X \\ & Y & -X & 0 \end{bmatrix}$$

$$= \begin{bmatrix} \frac{f_x}{Z} & 0 & -\frac{f_x X}{Z^2} & -\frac{f_x XY}{Z^2} & f_x + \frac{f_x X^2}{Z^2} & -\frac{f_x Y}{Z} \\ 0 & \frac{f_y}{Z} & -\frac{f_y Y}{Z^2} & -f_y - \frac{f_y Y^2}{Z^2} & \frac{f_y XY}{Z^2} & \frac{f_y X}{Z} \end{bmatrix}$$

2×6