$$P = RTS \qquad \tilde{v}' = P\tilde{v}$$

$$R = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$T = \begin{pmatrix} 1 & 0 & t_x \\ 0 & 1 & t_y \\ 0 & 0 & 1 \end{pmatrix}$$

$$S = \begin{pmatrix} s_x & 0 & 0 \\ 0 & s_y & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$TS = \begin{pmatrix} s_x & 0 & t_x \\ 0 & s_y & t_y \\ 0 & 0 & 1 \end{pmatrix}$$

$$RTS = \begin{pmatrix} s_x\cos\theta & -s_y\sin\theta & t_x\cos\theta - t_y\sin\theta \\ s_x\sin\theta & s_y\cos\theta & t_x\sin\theta + t_y\cos\theta \\ 0 & 0 & 1 \end{pmatrix}$$

$$M = \underbrace{RTS}_{P} M$$

$$P^{-1} = S^{-1} T^{-1} R^{-1}$$

$$PP^{-1} = RTS\, S^{-1} T^{-1} R^{-1}$$

$$= I = I = I$$

$$P^{-1} P = S^{-1} T^{-1} R^{-1} RTS = I_3$$

$$R_\theta^{-1} = R_{-\theta} = R_\theta^T = \begin{pmatrix} \cos\theta & \sin\theta & 0 \\ -\sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$T^{-1} \begin{pmatrix} t_x \\ t_y \end{pmatrix} = T \begin{pmatrix} -t_x \\ -t_y \end{pmatrix}$$

$$S^{-1} \begin{pmatrix} s_x \\ s_y \end{pmatrix} = S \begin{pmatrix} 1/s_x \\ 1/s_y \end{pmatrix}$$

① $x_d\left(1+k_1\left(x_d^2+y_d^2\right)\right) = x_u$

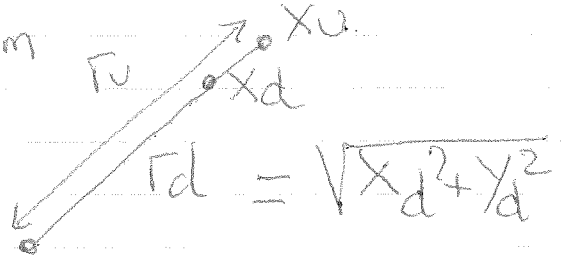
② $y_d\left(1+k_1\left(x_d^2+y_d^2\right)\right) = y_u$

k_1 # mm^{-2}

$r_d = 500 \times 5.10^{-3} mm$

$\delta = r_u - r_d$

$= 0.01 mm$



$r_d = \sqrt{x_d^2+y_d^2}$

P

$① + ②$ ⟶ $\left(x_d^2+y_d^2\right)\left(1+k_1\left(x_d^2+y_d^2\right)\right)^2 = x_u^2+y_u^2$

$r_d^2\left(1+k_1 r_d^2\right)^2 = r_u^2$

$\left(1+k_1 r_d^2\right)^2 = \left(\frac{r_u}{r_d}\right)^2 = \left(1+\frac{\delta}{r_d}\right)^2$

$k_1 = \frac{\delta}{r_d^3}$

$= \frac{0.01}{(2.5)^3} mm^{-2}$

$= 0.4 . 10^{-4} mm^{-2}$