$x \in [l, r]$ $\quad x' \in [-1, 1]$

$ax + b = x'$

$al + b = -1$

$ar + b = 1$

$a(r - l) = 2$

$a = \frac{2}{r - l}$

$b = 1 - ar$

$= 1 - \frac{2ar}{r - l}$

$= -\frac{r + l}{r - l}$

$x' = ax + b$

$= \frac{2x - r - l}{r - l}$

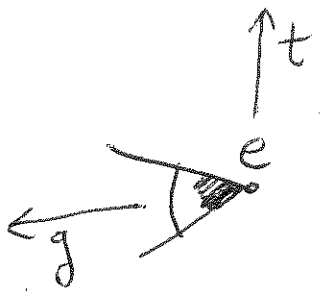
$y \in [b, t]$ $\quad y' \in [-1, 1]$

$y' = \frac{2y - b - t}{t - b}$

$z' = \frac{2z - n - f}{n - f}$

$$\begin{pmatrix} \frac{2}{r-l} & 0 & 0 & -\frac{r+l}{r-l} \\ 0 & \frac{2}{t-b} & 0 & -\frac{t+b}{t-b} \\ 0 & 0 & \frac{2}{n-f} & -\frac{n+f}{n-f} \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

Morthe



$\|\vec{u}\| = 1$

$\|\vec{w}\| = 1$

$\|\vec{v}\| = 1$

$\vec{w} \cdot \vec{v} = 0$

$\vec{w} \cdot \vec{u} = 0$

$\vec{v} \cdot \vec{u} = 0$

$w = back$

$v = up$

$u = right$

$$w = \frac{-g}{\|g\|}$$

$$u = \frac{t \times w}{\|t \times w\|}$$

$v = w \times u$

$\|v\| = \|w\| \|u\| \sin\theta$

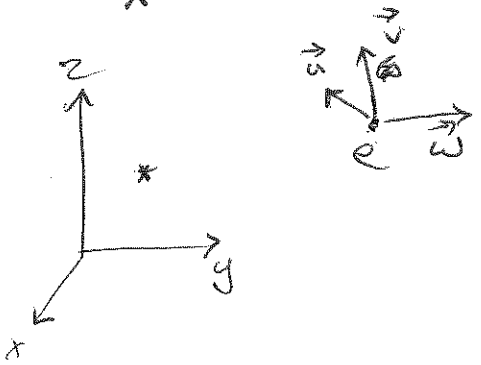
$\theta = \frac{\pi}{2}$

$\sin\frac{\pi}{2} = 1$

$i \times i$

$(x, y, z) \rightarrow (x', y', z')$

$\vec{x} \qquad \vec{x'}$



$$\vec{x} = x' \cdot \vec{u} + y' \vec{v} + z' \vec{\omega} + \vec{e}$$

$$\vec{x} = \underbrace{\left(\vec{u} \mid \vec{v} \mid \vec{\omega}\right)}_{M} \begin{pmatrix} x' \\ y' \\ z' \end{pmatrix} + \vec{e} = M \vec{x'} + \vec{e}$$

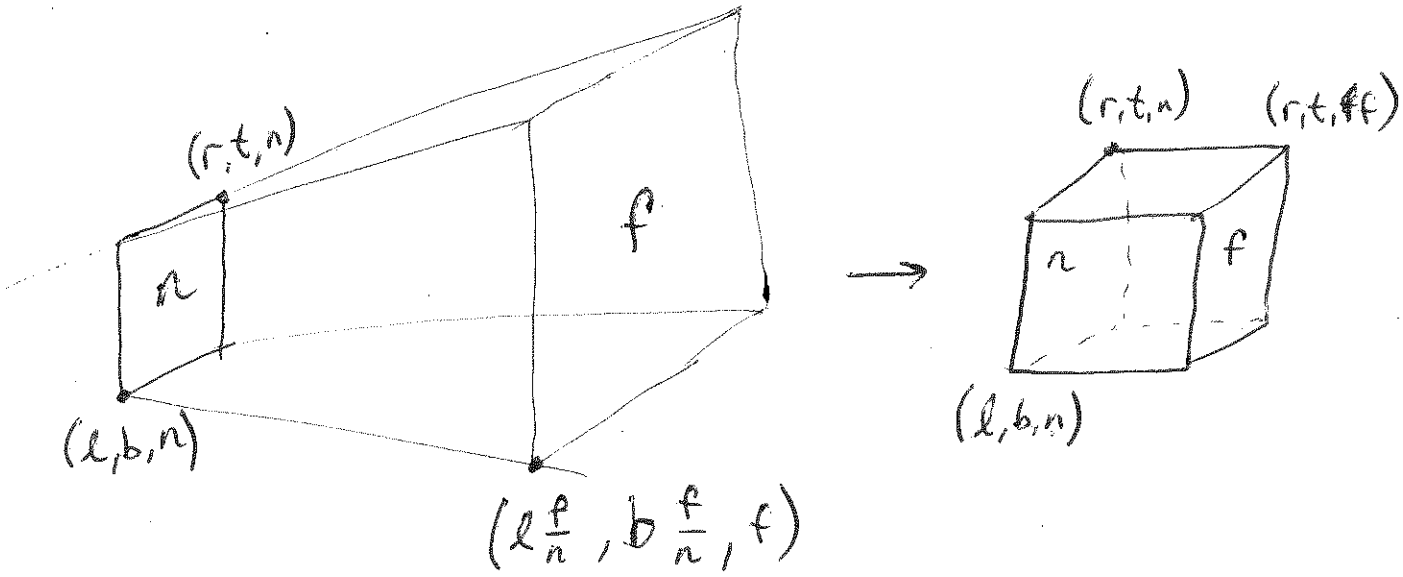
$$\vec{x} - \vec{e} = M \vec{x'}$$

$$\vec{x'} = M^T (\vec{x} - \vec{e})$$

$$M_{cam} = \left(\begin{array}{c|c} M^T & -M^T \vec{e} \\ \hline 0 & 1 \end{array}\right)$$

$d = n$

$$\begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} \rightarrow \begin{pmatrix} \frac{n}{z}x \\ \frac{n}{z}y \\ ? \\ 1 \end{pmatrix} \equiv \begin{pmatrix} x \\ y \\ z \\ \frac{z}{n} \end{pmatrix} = \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ * & * & * & * \\ 0 & 0 & \frac{1}{n} & 0 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix}$$



$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & a & b \\ 0 & 0 & \frac{1}{n} & 0 \end{pmatrix} \begin{pmatrix} x \\ y \\ z \\ 1 \end{pmatrix} = \begin{pmatrix} x' \\ y' \\ z' \\ w' \end{pmatrix}$$

$$z \rightarrow \begin{pmatrix} x \\ y \\ az+b \\ \frac{z}{n} \end{pmatrix} \qquad \frac{az+b}{z/n} = \bar{z} \qquad \begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & \frac{n+f}{n} & -f \\ 0 & 0 & \frac{1}{n} & 0 \end{pmatrix}$$

$n \rightarrow n$
$f \rightarrow f$

$$n = \frac{an+b}{n/n} \qquad f = \frac{af+b}{f/n}$$

$$af+b = \frac{f^2}{n}$$

$$n = an+b$$