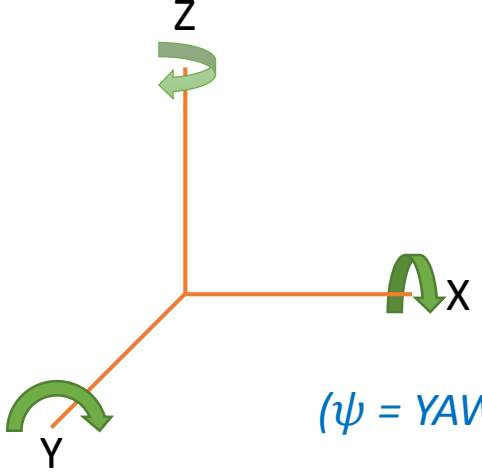

$$V_G = \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}$$

(ψ = YAW, Ø = ROLL,θ = PITCH)

Small-angle approximation

$$\sin\theta \cong \theta$$

$$\cos\theta \cong 1 - \frac{\theta^2}{2} \cong 1 - 0 \cong 1$$

$$\tan\theta \cong \theta$$

$$R_x(\emptyset) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\emptyset & -\sin\emptyset \\ 0 & \sin\emptyset & \cos\emptyset \end{bmatrix}$$ 繞X軸旋轉, 即Roll

$$R_y(\theta) = \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix}$$ 繞Y軸旋轉, 即Pitch

$$R_z(\psi) = \begin{bmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix}$$ 繞Z軸旋轉, 即YAW

Apply Small-angle approximation

$$R_x(\emptyset) = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & -\emptyset \\ 0 & \emptyset & 1 \end{bmatrix}$$ 繞X軸旋轉, 即Roll

$$R_y(\theta) = \begin{bmatrix} 1 & 0 & \theta \\ 0 & 1 & 0 \\ -\theta & 0 & 1 \end{bmatrix}$$ 繞Y軸旋轉, 即Pitch

$$R_z(\psi) = \begin{bmatrix} 1 & -\psi & 0 \\ \psi & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$ 繞Z軸旋轉, 即YAW

(ψ = YAW, ∅ = ROLL, θ = PITCH)

$$V_G = \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}$$

$$V_{new\_G} = R_x(\emptyset) \cdot R_y(\theta) \cdot R_z(\psi) \cdot V_G$$

$$V_{new\_G} = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\emptyset & -\sin\emptyset \\ 0 & \sin\emptyset & \cos\emptyset \end{bmatrix} \cdot \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \cdot \begin{bmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}$$

$$V_{new\_G} \cong \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & -\emptyset \\ 0 & \emptyset & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & 0 & \theta \\ 0 & 1 & 0 \\ -\theta & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & -\psi & 0 \\ \psi & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}$$

$$V_{new\_G} \cong \begin{bmatrix} 1 & 0 & \theta \\ \emptyset\theta & 1 & -\emptyset \\ -\theta & \emptyset & 1 \end{bmatrix} \cdot \begin{bmatrix} 1 & -\psi & 0 \\ \psi & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}$$

$$V_{new\_G} \cong \begin{bmatrix} 1 & -\psi & \theta \\ \emptyset\theta + \psi & -\emptyset\theta\psi + 1 & -\emptyset \\ -\theta + \emptyset\psi & \theta\psi + \emptyset & 1 \end{bmatrix} \cdot \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}$$

$$V_{new\_G} \cong \begin{bmatrix} 1 & -\psi & \theta \\ \cancel{\theta\emptyset} + \psi & \cancel{-\emptyset\theta\psi} + 1 & -\emptyset \\ -\theta + \cancel{\emptyset\psi} & \cancel{\theta\psi} + \emptyset & 1 \end{bmatrix} \cdot \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix}$$

$$V_{new\_G} \cong \begin{bmatrix} 1 & -\psi & \theta \\ \psi & 1 & -\emptyset \\ -\theta & \emptyset & 1 \end{bmatrix} \cdot \begin{bmatrix} X_G \\ Y_G \\ Z_G \end{bmatrix} \cong \begin{bmatrix} \boldsymbol{X_G - \psi Y_G + \theta Z_G} \\ \boldsymbol{Y_G + \psi X_G - \emptyset Z_G} \\ \boldsymbol{Z_G - \theta X_G + \emptyset Y_G} \end{bmatrix}$$

Small-angle approximation

$$\sin\theta \cong \theta$$

$$\cos\theta \cong 1 - \frac{\theta^2}{2} \cong 1 - 0 \cong 1$$

$$\tan\theta \cong \theta$$

$\emptyset\theta\psi \cong 0$,
$\emptyset\theta \cong 0$,
$\emptyset\psi \cong 0$,
$\theta\psi \cong 0$

```
int vector[3] = {0, 0, 1};
int x_g = vector[0];
int y_g = vector[1];
int z_g = vector[2];
int yaw = 1, pitch = 1, roll = 1;

/* Small-angle approximation matrix rotation */
vector[0] = vector[0] - yaw * y_g + pitch * z_g;  /* x_g_new */
vector[1] = vector[1] + yaw * x_g - roll * z_g;   /* y_g_new */
vector[2] = vector[2] - pitch * x_g + roll * y_g; /* z_g_new */
```