Usual 321 - Euler Angles $R = R_z(\psi) \cdot R_y(\theta) \cdot R_x(\phi)$

ψ : yaw
θ : pitch
ϕ : roll

Betaflight convention from Mahony $R = R_z(\underbrace{-\text{heading}}_{\psi}) \cdot R_y(\underbrace{\text{pitch}}_{\theta}) \cdot R_x(\underbrace{\text{roll}}_{\phi})$

Betaflight convention board alignment $R = R_z(-\psi) \cdot R_y(-\theta) \cdot R_x(\phi)$

$$\left| \begin{array}{l} = R_z^T(\psi) \cdot R_y^T(\theta) \cdot R_x^T(\phi) \\ = \left(R_x(\phi) \cdot R_y(\theta) \cdot R_z(\psi)\right)^T \end{array} \right|$$

R is rMat from imu.c

$$R = \begin{pmatrix} {}^B c_{xE}{}^T \\ {}^B c_{yE}{}^T \\ {}^B c_{zE}{}^T \end{pmatrix} = \begin{pmatrix} * & * & * \\ * & * & * \\ {}^B c_{z,xE} & {}^B c_{z,yE} & {}^B c_{z,zE} \end{pmatrix}$$

this vector is independent from yaw

we can also construct it from roll and pitch readings only!

$${}^B c_{zE} = \begin{pmatrix} -\sin(\text{pitch}) \\ \cos(\text{pitch}) \cdot \sin(\text{roll}) \\ \cos(\text{roll}) \cdot \sin(\text{pitch}) \end{pmatrix}$$

1 drone flat when FC mounted
calculate $e_z = g\, e_{zE}(\text{roll}, \text{pitch})$ ← this is our z-axis

2 drone on nose
calculate $e_x = -g\, e_{zE}(\text{roll}, \text{pitch})$ ← mind the sign, this is our x-axis

3 $e_y = e_z \times e_x$ ← this is our y-axis

4 $R = \begin{pmatrix} e_x^T \\ e_y^T \\ e_z^T \end{pmatrix} = \begin{pmatrix} e_{x,x} & e_{x,y} & e_{x,z} \\ e_{y,x} & e_{y,y} & e_{y,z} \\ e_{z,x} & e_{z,y} & e_{z,z} \end{pmatrix}$

5 convert $R \to q$ (quaternion) $q = (q_w\ q_x\ q_y\ q_z)$
↳ this is the orientation without rounding

6 create a set of possible rotations
$\bar{q}_i \in S$ like $\bar{q}_1 =$ { insert the rotation you want allow
$\bar{q}_2 =$
$\bar{q}_3 =$
$\vdots$
$\bar{q}_n =$

7 search the quaternion from $\bar{q}_i$
where $\varphi = 2 \cdot \arccos\left(q_w \cdot \bar{q}_{i,w} + q_x \cdot \bar{q}_{i,x} + q_y \cdot \bar{q}_{i,y} + q_z \cdot \bar{q}_{i,z}\right)$
is the smallest $\to \tilde{q}$

8 convert $\tilde{q} \to \begin{pmatrix} \phi \\ \theta \\ \psi \end{pmatrix}$

9 insert $\begin{pmatrix} -\phi \\ -\theta \\ -\psi \end{pmatrix}$ into board alignment