Exercise: Transformations, Quaternions and Homogeneous Representation (Fall 2021)

Meeting for questions: 01.09.2021 or 25.10.2021 (via zoom)
Early deadline: 01.10.2021 (via email: federico.magistri@uni-bonn.de)
Regular deadline: 15.11.2021 (via e-campus)

A Translation and Rotation

1. **2** Consider a point $\boldsymbol{p}$ with coordinates $\boldsymbol{p} = [-0.8, 1.3, -0.5]^T$, provide the coordinates of the transformed points $\boldsymbol{p}'$, $\boldsymbol{p}''$, $\boldsymbol{p}'''$, $\boldsymbol{p}''''$ after applying the following transformation:
   (a) translation $\mathcal{T}_t$ with translation vector $\boldsymbol{t} = [1, 0, -1]^T$
   (b) rotation $\mathcal{R}_y(\phi)$ with $\phi = 30$
   (c) rotation $\mathcal{R}_z(\phi_1)$ followed by $\mathcal{R}_x(\phi_2)$ with $\phi_1 = -60$ and $\phi_2 = 45$
   (d) translation $\mathcal{T}_t$ as in (a) followed by a rotation $\mathcal{R}_y(\phi)$ as in (b)

2. **2** Convert the following rotation

$$\mathcal{R} = \begin{bmatrix} 0 & -1 & 0 \\ \frac{\sqrt{2}}{2} & 0 & -\frac{\sqrt{2}}{2} \\ \frac{\sqrt{2}}{2} & 0 & \frac{\sqrt{2}}{2} \end{bmatrix}$$

   using the following representation:
   (a) Euler-Angles with the first rotation around the x-axis, second around y and third around z
   (b) Axis-Angle in the minimal form

3. **6** Check if the following matrices are true rotation matrices

$$\mathcal{M}_1 = \begin{bmatrix} \frac{\sqrt{3}}{2} & -\frac{1}{2} & 0 \\ \frac{1}{4} & \frac{\sqrt{3}}{4} & -\frac{\sqrt{3}}{2} \\ \frac{\sqrt{3}}{4} & \frac{3}{4} & \frac{1}{2} \end{bmatrix} \qquad \mathcal{M}_2 = \begin{bmatrix} 0 & -\frac{\sqrt{2}}{2} & -\frac{\sqrt{2}}{2} \\ -\frac{\sqrt{2}}{2} & \frac{1}{2} & -\frac{1}{2} \\ \frac{\sqrt{2}}{2} & \frac{1}{2} & -\frac{1}{2} \end{bmatrix} \qquad \mathcal{M}_3 = \begin{bmatrix} \frac{\sqrt{3}}{2} & \frac{1}{4} & \frac{1}{2} \\ \frac{\sqrt{2}}{2} & -\frac{\sqrt{2}}{2} & \frac{1}{4} \\ \frac{-\sqrt{3}}{2} & \frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix}$$

B Quaternions

4. **5** Given the quaternions $\mathbf{q}_1 = [0, 1, 2, 1]^T$ and $\mathbf{q}_2 = [3, 1, 2, 2]^T$
   (a) compute the quaternion resulting by the sum of $\mathbf{q}_1$ and $\mathbf{q}_2$
   (b) compute the inverse of $\mathbf{q}_2$
   (c) compute $\mathbf{q}_1$ times the inverse of $\mathbf{q}_2$

5. **5** Given a rotation $\mathcal{R}_x(\phi)$ with $\phi = 70$ in euclidean form
   (a) compute the quaternion $\mathbf{q}_1$ that represent such rotation
   (b) given a point χ with euclidean coordinates $\boldsymbol{x} = [-2, 1, -1]^T$, apply the rotation $\mathbf{q}_1$ to the point χ in quaternion form
   (c) apply to point χ the transformation resulting from $\mathbf{q}_1$ followed by $\mathbf{q}_2 = [-1, 2, 0, 1]^T$

C Homogeneous Representation

6. **5** Given the points $\boldsymbol{x}_1$ and $\boldsymbol{x}_2$ with their Euclidean coordinates

$$\boldsymbol{x}_1 = \begin{bmatrix} -1 \\ 3 \end{bmatrix} \qquad \boldsymbol{x}_2 = \begin{bmatrix} 4 \\ 1 \end{bmatrix} \tag{1}$$

and the line $\boldsymbol{l}_0$

$$\boldsymbol{l}_0 : y = 6 - x. \tag{2}$$

Determine both, the homogeneous and Euclidean representation

(a) of the line $\boldsymbol{l}_1$ passing the points $\boldsymbol{x}_1$ and $\boldsymbol{x}_2$

(b) of $\boldsymbol{x}_3$, the intersection point of the line $\boldsymbol{l}_0$ and $\boldsymbol{l}_1$

(c) determine if χ_4 with coordinates $\boldsymbol{x}_4 = [1, -5]^T$ lies on ℓ_1

7. **5** Given a point χ with coordinates $\boldsymbol{x} = [1, -1, 2]^T$, compute and apply the following transformations in homogeneous representation:

(a) translation $\mathcal{T}_t$ with translation vector $\boldsymbol{t} = [-1, 1, 2]^T$

(b) rotation $\mathcal{R}_x(\phi)$ with $\phi = 30$

(c) the rigid body transformation resulting from (a) and (b)

(d) the transformation given by $\mathcal{H}_2$ followed $\mathcal{H}_1$ with:

$$\mathcal{H}_1 = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & -1 \\ 0 & -\frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & 2 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \mathcal{H}_2 = \begin{bmatrix} \frac{\sqrt{3}}{2} & -\frac{1}{2} & 0 & 0 \\ \frac{1}{2} & \frac{\sqrt{3}}{2} & 0 & 1 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$