Solution Manual for Introduction to Robotics Mechanics and Control 4th Edition Craig 0133489795 9780133489798

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Chapter 2 : Spatial Transformations

1. a) Use (2.3) to obtain

$$ {}^{A}_{B}R = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 0 & 1 \\ 0 & -1 & 0 \end{bmatrix} $$

   b) Use (2.74) to get

$$ \alpha = 90 \text{ degrees} $$
$$ \beta = 90 \text{ degrees} $$
$$ \gamma = -90 \text{ degrees} $$

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2. a) Use (2.64) to obtain

$$ {}^{A}_{B}R = \begin{bmatrix} .330 & -.770 & .547 \\ .908 & .418 & .0396 \\ -.259 & .483 & .837 \end{bmatrix} $$

   b) Answer is the same as in (a) according to (2.71)

3. Use (2.19) to obtain the transformation matrices. The rotation is X-Y-Z fixed angles, so use (2.64) for that 3×3 submatrix, with angles

$$ \gamma = 0 \text{ degrees} $$
$$ \beta = -\sin^{-1}\frac{\text{tripod\_height}}{\text{distance\_along\_optical\_axis}} = -\sin^{-1}\frac{1.5}{5} = -107 \text{ degrees} $$

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$\alpha_C = 0$ degrees
$\alpha_D = 120$ degrees
$\alpha_E = 240$ degrees

The position vectors to the camera-frame origins are

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$$
{}^B P_{CORG} = \begin{bmatrix} \text{horizontal\_distance} \\ 0 \\ \text{tripod\_height} \end{bmatrix} = \begin{bmatrix} 4.77 \\ 0 \\ 1.50 \end{bmatrix}
$$

$$
{}^B P_{DORG} = \begin{bmatrix} \text{horizontal\_distance} \times \cos \alpha_D \\ \text{horizontal\_distance} \times \sin \alpha_D \\ \text{tripod\_height} \end{bmatrix} = \begin{bmatrix} -2.39 \\ 4.13 \\ 1.5 \end{bmatrix}
$$

$$
{}^B P_{EORG} = \begin{bmatrix} \text{horizontal\_distance} \times \cos \alpha_E \\ \text{horizontal\_distance} \times \sin \alpha_E \\ \text{tripod\_height} \end{bmatrix} = \begin{bmatrix} -2.38 \\ -4.13 \\ 1.50 \end{bmatrix},
$$

where $\text{horizontal\_distance} = \sqrt{(\text{distance\_along\_optical\_axis})^2 - (\text{tripod\_height})^2}$. Combining the rotation and translation yields the transformation matrices via (2.19) as

$$
{}^B_C T = \begin{bmatrix} -.300 & 0 & -.954 & 4.77 \\ 0 & 1.00 & 0 & 0 \\ .954 & 0 & -.300 & 1.50 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

$$
{}^B_D T = \begin{bmatrix} .150 & -.866 & .477 & -2.39 \\ -.260 & -.500 & -.826 & 4.13 \\ .954 & 0 & -.300 & 1.50 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

$$
{}^B_E T = \begin{bmatrix} .150 & .866 & .477 & -2.39 \\ .260 & -.500 & .826 & -4.13 \\ .954 & 0 & -.300 & 1.50 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

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4. The camera-frame origin is located at ${}^B P_{CORG} = [7 \quad -2 \quad 5]^T$. Use (2.19) to get the transformation, ${}^B_C T$. The rotation is Z-Y-X Euler angles, so use (2.71) with

$\alpha = 0$ degrees
$\beta = -110$ degrees
$\gamma = -20$ degrees

to get

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$$
{}^{B}_{C}T = \begin{bmatrix} -.342 & .321 & -.883 & 7.00 \\ 0 & .940 & .342 & -2.00 \\ .940 & .117 & -.321 & 5.00 \\ 0 & 0 & 0 & 1 \end{bmatrix}
$$

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5. Let

$$ {}^{B}P_1 = {}^{B}P_0 + 5\,{}^{B}V_0 = [9.5 \quad 1.00 \quad -1.50]^T $$

The object's position in {A} is

$$ {}^{A}P_1 = {}^{A}_{B}T\,{}^{B}P_1 = [-4.89 \quad 2.11 \quad 3.60]^T $$

6. (2.1)

$$ R = \mathrm{rot}(\hat{Y}, \varphi)\,\mathrm{rot}(\hat{Z}, \theta) $$

$$ = \begin{bmatrix} c\varphi & 0 & s\varphi \\ 0 & 1 & 0 \\ -s\varphi & 0 & c\varphi \end{bmatrix} \begin{bmatrix} c\theta & -s\theta & 0 \\ s\theta & c\theta & 0 \\ 0 & 0 & 1 \end{bmatrix} $$

$$ = \begin{bmatrix} c\varphi\, c\theta & -c\varphi\, s\theta & s\varphi \\ s\theta & c\theta & 0 \\ -s\varphi\, c\theta & s\varphi\, s\theta & c\varphi \end{bmatrix} $$

7. (2.2)

$$ R = \mathrm{rot}(\hat{X}, 60)\,\mathrm{rot}(\hat{Y}, -45) $$

$$ = \begin{bmatrix} 1 & 0 & 0 \\ 0 & .500 & -.866 \\ 0 & .866 & .500 \end{bmatrix} \begin{bmatrix} .707 & 0 & -.707 \\ 0 & 1 & 0 \\ .707 & 0 & .707 \end{bmatrix} $$

$$ = \begin{bmatrix} .707 & 0 & -.707 \\ -.612 & .500 & -.612 \\ .353 & .866 & .353 \end{bmatrix} $$

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8. (2.12) Velocity is a "free vector" and only will be affected by rotation, and not by translation:

$$ {}^{A}V = {}^{A}_{B}R\,{}^{B}V = \begin{bmatrix} .707 & 0 & -.707 \\ -.612 & .500 & -.612 \\ .353 & .866 & .353 \end{bmatrix} \begin{bmatrix} 30.0 \\ 40.0 \\ 50.0 \end{bmatrix} $$

$$ = [-14.1 \quad -29.0 \quad 62.9]^T $$

9. (2.31)

$$ {}^{C}_{B}T = \begin{bmatrix} 0 & 0 & -1 & 2 \\ .500 & -.866 & 0 & 0 \\ -.866 & -.500 & 0 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

10. (2.37) Using (2.45) we get that

$$ \begin{bmatrix} .25 & .87 & .43 & 5.0 \end{bmatrix} $$

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$$^{B}P_{AORG} = -{}^{A}_{B}R^{T}\,{}^{A}P_{AORG} = -\begin{bmatrix} .94 & & \\ .43 & -.50 & .75 \\ .86 & .00 & -.50 \end{bmatrix} \begin{bmatrix} -4.0 \\ 3.0 \end{bmatrix} = \begin{bmatrix} -6.4 \\ -2.8 \end{bmatrix}$$

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