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Epipolar Geometry

12 questions

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1 point

1.
Consider two images x_1, x_2 of the same point p from two camera positions with relative pose $(R, T) \in SE(3)$, where $R \in SO(3)$ is the relative orientation and $T \in \mathbb{R}^3$ is the relative position. Then, x_1, x_2 always satisfy

- [ ] $x_2^T \widehat{T} R x_1 = 0$
- [ ] $x_2^T \widehat{T} x_1 = 0$
- [ ] $x_2^T R x_1 = 0$
- [ ] $x_2^T x_1 = 0$

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2.
Let $\hat{} : \mathbb{R}^3 \to \mathbb{R}^{3\times3}$ defined by

$$u = \begin{bmatrix} u_1 \\ u_2 \\ u_3 \end{bmatrix} \mapsto \widehat{u} = \begin{bmatrix} 0 & -u_3 & u_2 \\ u_3 & 0 & -u_1 \\ -u_2 & u_1 & 0 \end{bmatrix}$$

If R is a rotation matrix, which of the following properties hold ?

- [ ] $\widehat{u}u = 0$
- [ ] $\widehat{u}^T = -\widehat{u}$

- [ ] $u^T \hat{u} = 0$
- [ ] $R^T \hat{u} R = \widehat{R^T u}$

1 point

3.
Let two cameras with poses $g_1 = (R_1, T_1) \in SE(3)$ and $g_2 = (R_2, T_2) \in SE(3)$. Note that the poses are such that a point X_w in the world frame is transformed to the camera frame as $X_c = R^T(X_w - T)$. Which of the following matrices are valid essential matrices, that is they satisfy $x_1^T E x_2 = 0$ for all point correspondences $x_1 \leftrightarrow x_2$? For convenience let $T_{ij} \doteq T_j - T_i$ and $R_{ij} \doteq R_i^T R_j$.

- [ ] $E = R_1^T \widehat{T_{12}} R_2$
- [ ] $E = \widehat{R_1^T T_{12}} R_{12}$
- [ ] $E = \widehat{R_1^T T_{21}} R_{12}$
- [ ] $E = R_1^T \widehat{T_{21}} R_2$

1 point

4.
The relative pose between two views is $(R, T) \in SE(3)$ where $R = I$ and T corresponds to a translation of 1m in the direction of the z-axis, which of the following is a valid essential matrix? Hint: use the fact that $E = \widehat{T} R$.

- ( ) $E = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$
- ( ) $E = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$

$$E = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{bmatrix}$$

1
point

5.
The relative pose between two views is $(R, T) \in SE(3)$ where $R = I$ and T corresponds to a translation of 1m in the direction of the x-axis, which of the following is a valid essential matrix? Hint: use the fact that $E = \widehat{T}R$.

- $$E = \begin{bmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$
- $$E = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 0 & 0 \\ -1 & 0 & 0 \end{bmatrix}$$
- $$E = \begin{bmatrix} 0 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{bmatrix}$$

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6.
A nonzero matrix $E \in \mathbb{R}^{3\times3}$ is a an essential matrix if and only if E has a singular value deocmposition (SVD) $E = U\Sigma V^T$ with

- $\Sigma = \mathrm{diag}(\sigma, \sigma, 0\}$ for some $\sigma > 0$ and $U, V \in SO(3)$.
- $\Sigma = \mathrm{diag}(\sigma, 0, 0\}$ for some $\sigma > 0$ and $U, V \in SO(3)$.
- $\Sigma = \mathrm{diag}(\sigma, \sigma, 0\}$ for some $\sigma < 0$ and $U, V \in SO(3)$.
- $\Sigma = \mathrm{diag}(\sigma, 0, 0\}$ for some $\sigma < 0$ and $U, V \in SO(3)$.

1

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7.

Given a real matrix $F \in \mathbb{R}^{3\times3}$ with SVD $F = U\text{diag}(\lambda_1, \lambda_2, \lambda_3)V^T$ with $U, V \in SO(3)$, $\lambda_1 \geq \lambda_2 \geq \lambda_3$, then the essential matrix that minimizes the error $\|E - F\|_F^2$ is given by

- ◯ $E = U\text{diag}(\sigma, 0, 0)V^T$ with $\sigma = (\lambda_1 + \lambda_2 + \lambda_3)/2$.
- ◯ $E = U\text{diag}(\sigma, \sigma, 0)V^T$ with $\sigma = (\lambda_1 + \lambda_2)/2$.
- ◯ $E = U\text{diag}(\sigma, 0, 0)V^T$ with $\sigma = (\lambda_1 + \lambda_2)/2$.
- ◯ $E = U\text{diag}(\sigma, \sigma, 0)V^T$ with $\sigma = (\lambda_1 + \lambda_2 + \lambda_3)/2$.

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8.

How many point correspondences are required to obtain an essential matrix using the linear algorithm?

- ◯ 4
- ◯ 5
- ◯ 6
- ◯ 8

1
point

9.

Which of the following are valid essential matrices?

- ☐ $E = \begin{bmatrix} 0 & 0 & 0 \\ 1/\sqrt{2} & 0 & -1/\sqrt{2} \\ 0 & 1 & 0 \end{bmatrix}$
- ☐ $E = \begin{bmatrix} 0 & 1 & 0 \\ 1/\sqrt{2} & 0 & -1/\sqrt{2} \\ 0 & 1 & 0 \end{bmatrix}$

- [ ] $E = \begin{bmatrix} 2 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

- [ ] $E = \begin{bmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$

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10.

Suppose we know the camera motion always moves on a plane, say the XY- plane. The essential matrix $E = \widehat{T}R$ has the special form

- ( ) $E = \begin{bmatrix} a & 0 & 0 \\ 0 & b & 0 \\ 0 & c & d \end{bmatrix}, \qquad a, b, c, d \in \mathbb{R}$

- ( ) $E = \begin{bmatrix} 0 & a & 0 \\ b & 0 & 0 \\ c & 0 & d \end{bmatrix}, \qquad a, b, c, d \in \mathbb{R}$

- ( ) $E = \begin{bmatrix} 0 & 0 & a \\ 0 & 0 & b \\ c & d & 0 \end{bmatrix}, \qquad a, b, c, d \in \mathbb{R}$

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11.

Now, assuming the same scenario as in the previous question, which of the following solutions for (R, T) in terms of a, b, c, d are valid? Assume that $a^2 + b^2 = 1$ and $c^2 + d^2 = 1$.

- ( ) $T = \begin{bmatrix} -b \\ a \\ 0 \end{bmatrix}, \qquad R = \begin{bmatrix} -bd - ac & -ad + bc & 0 \\ ad - bc & -bd - ac & 0 \\ 0 & 0 & 1 \end{bmatrix}$

- ( ) $T = \begin{bmatrix} -b \\ a \\ 0 \end{bmatrix}, \qquad R = \begin{bmatrix} bd - ac & -ad - bc & 0 \\ ad + bc & bd - ac & 0 \\ 0 & 0 & 1 \end{bmatrix}$

$$T = \begin{bmatrix} -b \\ a \\ 0 \end{bmatrix}, \qquad R = \begin{bmatrix} -bd + ac & -ad + bc & 0 \\ ad + bc & -bd - ac & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

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point

12.
In general, given a normalized essential matrix, we get m distinct poses (R, T) and by enforcing the positive depth constraint, we end up with n valid poses. Which of the following is true?

- $(m, n) = (4, 2)$
- $(m, n) = (4, 1)$
- $(m, n) = (2, 1)$
- $(m, n) = (8, 2)$

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8 questions unanswered

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