Computer Vision in 3D

Lab. No. : 1 - THEORY

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1.	a) ☐	b) ☐	c) ☐	d) ☐
2.	a) ☐	b) ☐	c) ☐	d) ☐
3.	a) ☐	b) ☐	c) ☐	d) ☐
4.	a) ☐	b) ☐	c) ☐	d) ☐
5.	a) ☐	b) ☐	c) ☐	d) ☐

Theory: Optical Flow

1. Optical flow is

   (a) the absolute value of the spatial orientation of a small patch in an image sequence.

   (b) the absolute velocity of a small patch in a frame of an image sequence.

   (c) the velocity of a small patch in a frame of an image sequence.

   (d) the spatial orientation of a small patch in a frame of an image sequence.

2. If you must associate the appearance of food to spatio-temporal iso-curves that the Lucas-Kanade algorithm is designed for, which one would you select?

   (a) iso-curves as bubles of a milk-shake

   (b) iso-curves flat as in still water (i.e. no iso-curves)

   (c) iso-curves as in lasagne plates

   (d) iso-curves as in a (non-cooked) spaghetti bundle

3. Let $f(x, y, t)$ represent the gray values of an image sequence. Which expression states that the gray values of a point does not change, if one travels in the direction determined by the velocity vector in the coordinate space $(x, y, t)^T$?

   (a) $\frac{\partial f}{\partial t} + v_y \frac{\partial f}{\partial x} + v_x \frac{\partial f}{\partial y} = 0$

   (b) $v_x \frac{\partial f}{\partial t} + v_y \frac{\partial f}{\partial x} + \frac{\partial f}{\partial y} = 0$

   (c) $v_x \frac{\partial f}{\partial t} + \frac{\partial f}{\partial x} + v_y \frac{\partial f}{\partial y} = 0$

   (d) $\frac{\partial f}{\partial t} + v_x \frac{\partial f}{\partial x} + v_y \frac{\partial f}{\partial y} = 0$

4. Let $f(x_k, y_k, t_0)$ be gray-values of an image-sequence at point $k \in \{1 \cdots N\}$. in a spatial neighborhood, and define the matrices

$$\mathbf{d} = \begin{pmatrix} \frac{\partial f(x_1,y_1,t_0)}{\partial t} \\ \frac{\partial f(x_2,y_2,t_0)}{\partial t} \\ \vdots \\ \frac{\partial f(x_N,y_N,t_0)}{\partial t} \end{pmatrix}, \qquad \mathbf{D} = \begin{pmatrix} \frac{\partial f(x_1,y_1,t_0)}{\partial x} & \frac{\partial f(x_1,y_1,t_0)}{\partial y} \\ \frac{\partial f(x_2,y_2,t_0)}{\partial x} & \frac{\partial f(x_2,y_2,t_0)}{\partial y} \\ \vdots & \vdots \\ \frac{\partial f(x_N,y_N,t_0)}{\partial x} & \frac{\partial f(x_N,y_N,t_0)}{\partial y} \end{pmatrix}$$

   If v_x, and v_y are the components to of the velocity, which equation and method can estimate them (in the total-least square error sense)?

   (a) $\mathbf{D} \begin{pmatrix} v_x \\ v_y \end{pmatrix} = \mathbf{0}$ and svd decomposition of $\mathbf{D}$.

   (b) $[\mathbf{D}, -\mathbf{d}] \begin{pmatrix} v_x \\ v_y \\ 1 \end{pmatrix} = \mathbf{0}$ and svd decomposition of $[\mathbf{D}, -\mathbf{d}]$.

(c) $\mathbf{D}^T\mathbf{D}\begin{pmatrix} v_x \\ v_y \end{pmatrix} = \mathbf{0}$ and svd decomposition of $\mathbf{D}^T\mathbf{D}$.

(d) $\mathbf{D}\begin{pmatrix} v_x \\ v_y \end{pmatrix} = \mathbf{d}$ and svd decomposition of $[\mathbf{D}, \mathbf{d}]$.

5. Let $f(x_k, y_k, t_0)$ be gray-values of an image-sequence and g be a 3D Gaussian. How is the time derivative f approximated (in the Lucas-Kanade method)?

   (a) $\partial f(x_k, y_k, t_0)/\partial t = (\partial g/\partial t) * g * [f(x_k, y_k, t_0 + 1) - f(x_k, y_k, t_0)]$

   (b) $\partial f(x_k, y_k, t_0)/\partial t = g * [f(x_k, y_k, t_0 + 1) - f(x_k, y_k, t_0)]$

   (c) $\partial f(x_k, y_k, t_0)/\partial t = f * \partial g/\partial t$

   (d) $\partial f(x_k, y_k, t_0)/\partial t = f(x_k, y_k, t_0 + 1) - f(x_k, y_k, t_0)$

Computer Vision in 3D: multiple choice quiz

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4. a) ☐ b) ☐ c) ☐ d) ☐

5. a) ☐ b) ☐ c) ☐ d) ☐

Practice: Optical Flow by Lucas-Kanade algorithm

1. How-many frames of an image sequence do you need to compute the optical flow by using Lucas-Kanade algorithm
   (a) 1
   (b) 2
   (c) 3
   (d) all frames

2. Which is true for the dimension of the neighborhood used to compute the spatial derivatives in Lucas-Kanade algorithm (x=column, y=row, t=frame)?
   (a) The dimension is 2: x and y.
   (b) The dimension is 3: x, y, and t.
   (c) The dimension is 1: either x, y, or t.
   (d) The dimension is 1: either x or y.

3. What applies to spatial derivation implementation?
   (a) each derivation is implemented as a single convolution using a true 2D filter.
   (b) each derivation is implemented as two succesive convolutions with true 2D filters.
   (c) each derivation is implemented as two succesive convolutions but with two different 1D filters.
   (d) each derivation is implemented as two succesive convolutions using the same 1D filter.

4. Which spatial pattern fitting inside a local image, causes Lucas-Kanade method to fail to calculate the optical-flow?
   (a) random noise
   (b) orthogonal edges
   (c) an edge
   (d) none of the above

5. What will be the consequence to the motion of a spatial pattern, if you increase the σ_1, used in derivation filters?
   (a) low-frequency (spatial) patterns moving slowly will be detected easier than the high-frequency patterns moving slowly.
   (b) high-frequency patterns moving slowly will be detected easier than patterns moving slowly.

(c) high-frequency patterns will be detected easier than low-frequency patterns when moving.

(d) motion of low-frequency patterns will be detected easier than the motion of high-frequency patterns.

Computer Vision in 3D

Lab. No. : 2 - THEORY

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3. a) ☐ b) ☐ c) ☐ d) ☐
4. a) ☐ b) ☐ c) ☐ d) ☐
5. a) ☐ b) ☐ c) ☐ d) ☐

Theory: Motion Estimation by Structure Tensor

1. Which of the following 3D patterns is NOT linearly symmetric ($\boldsymbol{r}$ is the pixel-coordinate vector) ?

   (a) $1+\sin(\boldsymbol{k}^T\boldsymbol{r})$

   (b) $(\boldsymbol{k}^T\boldsymbol{r})^2+|\boldsymbol{u}^T\boldsymbol{r}|$ where $\boldsymbol{k}$ and $\boldsymbol{u}$ are parallel

   (c) $\sin(\boldsymbol{k}^T\boldsymbol{r})+\sin(\boldsymbol{u}^T\boldsymbol{r})$ where $\boldsymbol{k}$ and $\boldsymbol{u}$ are parallel

   (d) $\sin(\boldsymbol{k}^T\boldsymbol{r})+\sin(\boldsymbol{u}^T\boldsymbol{r})$ where $\boldsymbol{k}$ and $\boldsymbol{u}$ are orthogonal

2. The 3D-Fourier transform of the image $\exp(-|\boldsymbol{k}^T\boldsymbol{r}|^2/(2\sigma^2))+\exp(-|\boldsymbol{u}^T\boldsymbol{r}|^2/(2\sigma^2))$ where $\boldsymbol{k}^T\boldsymbol{u}=0 \quad \boldsymbol{k},\boldsymbol{u},\boldsymbol{r}\in E_3$, and $\boldsymbol{r}$ is the pixel-coordinate, is concentrated to a ...

   (a) line through origin

   (b) ball surface with origin as center

   (c) plane through origin

   (d) orthogonal lines as in checkerboard

3. Assume that

   $$\boldsymbol{S}=\int \boldsymbol{\omega}\boldsymbol{\omega}^T|F|^2 d\boldsymbol{\omega}$$

   To fit a plane in the spectral domain, we need to minimize

   (a) $\boldsymbol{k}^T\boldsymbol{S}\boldsymbol{k}$

   (b) $\boldsymbol{k}^T(\boldsymbol{I}\text{trace }(\boldsymbol{S})-\boldsymbol{S})\boldsymbol{k}$

   (c) $\boldsymbol{k}^T(\boldsymbol{S}\text{trace }(\boldsymbol{I})-\boldsymbol{S})\boldsymbol{k}$

   (d) $\boldsymbol{k}^T(\boldsymbol{I}\text{trace }(\boldsymbol{S})+\boldsymbol{S})\boldsymbol{k}$

4. Let the 3D structure tensor be $\boldsymbol{S}$ with eigenvalues $0\le\lambda_3\le\lambda_2\le\lambda_1$ and the corresponding eigenvectors $\boldsymbol{u}_3,\boldsymbol{u}_2,\boldsymbol{u}_1$, respectively. The spectral decomposition of $\boldsymbol{S}$ means that

   (a) determinant of $\boldsymbol{S}$ equals $\lambda_1\lambda_2\lambda_3$.

   (b) $\boldsymbol{S}$ equals $\lambda_1\lambda_2\boldsymbol{u}_1\boldsymbol{u}_2^T+\lambda_1\lambda_3\boldsymbol{u}_1\boldsymbol{u}_3^T+\lambda_2\lambda_3\boldsymbol{u}_2\boldsymbol{u}_3^T$.

   (c) Trace($\boldsymbol{S}$) equals $\lambda_1+\lambda_2+\lambda_3$.

   (d) $\boldsymbol{S}$ equals $\lambda_1\boldsymbol{u}_1\boldsymbol{u}_1^T+\lambda_2\boldsymbol{u}_2\boldsymbol{u}_2^T+\lambda_3\boldsymbol{u}_3\boldsymbol{u}_3^T$.

5. In the TV-image we have a moving line (locally) if the structure tensor of the (local) image has

   (a) the middle eigenvalue is not zero and equals to the largest eigenvalue, whereas the smallest eigenvalue equals to zero.

(b) all eigenvalues are much larger than zero.

(c) the smallest and the middle eigenvalue both equal to zero, and the remaining eigenvalue is non-zero.

(d) the smallest eigenvalue is negative, and the remaining two are strictly positive.

Computer Vision in 3D

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2. a) ☐ b) ☐ c) ☐ d) ☐

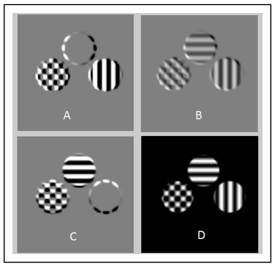
3. a) ☐ b) ☐ c) ☐ d) ☐

4. a) ☐ b) ☐ c) ☐ d) ☐

5. a) ☐ b) ☐ c) ☐ d) ☐

Practice: Optical Flow by 3D-Structure-Tensor

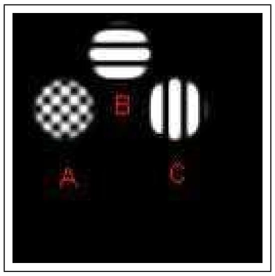
1. In the Figure below you can see three familliar images from the excercise. Three of



them are gradient components(A, B and C), and one is the original image (D). Select the correct labeling

   (a) $A = \frac{df}{dx}$, $B = \frac{df}{dt}$, $C = \frac{df}{dy}$
   (b) $A = \frac{df}{dy}$, $B = \frac{df}{dt}$, $C = \frac{df}{dx}$
   (c) $A = \frac{df}{dt}$, $B = \frac{df}{dx}$, $C = \frac{df}{dy}$
   (d) $A = \frac{df}{dx}$, $B = \frac{df}{dy}$, $C = \frac{df}{dt}$

2. we have the three objects A, B, C in the figure below.



All 3 objects move with the same velocity in the direction $-45°$, i.e. towards bottom-right. Which motion direction will be possible to compute near the center of each object?

   (a) A: $-45°$, B: $-90°$, C: no-motion
   (b) A: $-45°$, B: $0°$, C: $-90°$
   (c) A: $-45°$, B: $-90°$, C: $0°$
   (d) A: $-45°$, B: no-motion, C: $-90°$

3. Assume that the we know the 3D-structure tensor **S** for a spatio-temporal function $f(x, y, t)$ in a local image. Which one tests that the local image is `a constant image`, given that `sumeig` is the sum of eigenvalues, `lambdamin` is the smallest eigenvalue, theta lambdamid is the middle eigenvalue, `lambdamax` is the largest eigenvalue, and `EPSILON` is a small number close to zero?

   (a) `if sumeig <EPSILON disp('...local-image is constant');`

   (b) `if lambdamid <EPSILON disp('...local-image is constant');`

   (c) `if lambdamin <EPSILON disp('...local-image is constant');`

   (d) `if lambdamid+lambdamin <EPSILON disp('...local-image is constant');`

4. Assume that the we know the 3D-structure tensor **S** for a spatio-temporal function $f(x, y, t)$ in a local image and we know that we do not have a constant image. Which one tests that the local image is *a pattern of moving points in the spatial domain*, given that `sumeig` is the sum of eigenvalue, `lambdamin` is the smallest eigenvalue, `lambdamid` is the middle eigenvalue, `lambdamax` is the largest eigenvalue, and `GAMMA` is a number close to 1?

   (a)
   ```
   if (eigenvalsmax-eigenvalsmin) /(eigenvalsmax+eigenvalsmin) > GAMMA
   disp('...moving points')
   ```

   (b)
   ```
   if (eigenvalsmax-eigenvalsmid) /(eigenvalsmax+eigenvalsmid) > GAMMA
   disp('...moving points')
   ```

   (c)
   ```
   if (eigenvalsmid-eigenvalsmin) /(eigenvalsmid+eigenvalsmin) > GAMMA
   disp('...moving points')
   ```

   (d)
   ```
   if (sumeig) > GAMMA
   disp('...moving points')
   ```

5. assume that the eigenvalues of the structure tensor S corresponding to a local spatio-temporal neighborhood $f(x, y, t)$ are ordered as $0 \leq lambdamin \leq lambdamid \leq lambdamax$ and their corresponding eigenvectors are $emin$, $\mathbf{e}mid$, and $\mathbf{e}max$, respectively. How would you estimate the normal velocity of the line (in matlab), if you concluded that the local image is such a pattern?

   (a)
   ```
   denom=(emin(1)^2+emin(2)^2);
   if denom>0
    velocity=- (emin(3)/denom)*[ emin(1); emin(2)];
   end
   ```

   (b)
   ```
   denom=(emid(1)^2+emid(2)^2);
   if denom>0
    velocity=- (emin(3)/denom)*[ emin(1); emin(2)];
   end
   ```

(c)
```
denom=(emax(1)^2+emax(2)^2);
if denom>0
 velocity=- (emax(3)/denom)*[ emax(1); emax(2)];
end
```

(d)
```
denom=(emid(1)^2 +emid(2)^2+ +emid(3)^2);
if denom>0
 velocity=- (emin(3)/denom)*[ emin(1); emin(2)];
end
```

Computer Vision in 3D

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2. a) b) c) d)

3. a) b) c) d)

4. a) b) c) d)

5. a) b) c) d)

Theory: Camera Calibration

1. The goal of camera calibration is to
   (a) compute the hard-wired parameters and the pose of the camera by image processing.
   (b) identify different objects by image processing
   (c) adjust the camera such that the picture-colors agree with the colors of the objects.
   (d) align the objects such that they have the same depth relative to the camera.

2. Choose the alternative that applies to a camera.
   (a) Extrinsic parameters can not be used to compute the orientation of a camera relative to a wall on which the world-coordinates are attached .
   (b) Extrinsic parametes include the orientation of a camera relative an external coordinate frame.
   (c) Extrinsic parameters of a camera include its volume and weight.
   (d) The model of a camera, e.g. Sony, Axis, etc, are part of its external parameters.

3. Assuming that f is the focal-length of a digital camera, and its pixels being quadratic with side-length s, then a distorsion-free, perspective-model of it comprises a matrix transformation. Which statement applies to the transformation?
   (a) The transformation is $\begin{pmatrix} f/s & 0 & c_0 \\ 0 & f/s & r_0 \\ 0 & 0 & 1 \end{pmatrix}$ where c_0, r_0 represent the centroid of the image brightness.
   (b) The transformation is $\begin{pmatrix} -f/s & 0 & c_0 \\ 0 & -f/s & r_0 \\ 0 & 0 & 1 \end{pmatrix}$ where c_0, r_0 are offsets of the optical-axis from the image-center.
   (c) The transformation is $\begin{pmatrix} -s/f & 0 & c_0 \\ 0 & -s/f & r_0 \\ 0 & 0 & 1 \end{pmatrix}$ where c_0, r_0 are offsets of the optical-axis from the image-center.
   (d) The transformation is $\begin{pmatrix} -f/s & 0 & c_0 \\ 0 & -f/s & r_0 \\ 0 & 0 & 1 \end{pmatrix}$ where c_0, r_0 represent the centroid of the image brightness.

4. Homogeneous coordinates representation of a vector has
   (a) one dimension more than the normal representation of the vector.

(b) one dimension less than the normal representation of the vector.

(c) the same number of dimensions as the normal representation of the vector.

(d) two more dimensions than the normal representation of the vector, if the vector is complex.

5. The following steps (given at random order) are involved to obtain intrinsic and extrinsic parameters of a camera.
A: Scalar products of (3D) vectors
B: Reshape a vector to a matrix
C: Apply an eigen analysis method, for example SVD
D: Establish correspondances of world and image points
Which alternative orders them appropriately?

   (a) We apply first **D**, followed by **B,A,C**

   (b) We apply first **D**, followed by **C,B,A**

   (c) We apply first **D**, followed by **C,A,B**

   (d) We apply first **C**, followed by **D,B,A**

Computer Vision in 3D

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3. a) b) c) d)
4. a) b) c) d)
5. a) b) c) d)

Practice: Camera Calibration

1. You were supposed to identify 14 points by clicking (NPOINTS) in an image. What does NPOINTS (=14) represent?
   (a) the number of steps in the stair.
   (b) the number of 3D-points.
   (c) the number of equations obtained.
   (d) none of the others.

2. Assume that you constructed your correspondence equation as $\mathbf{Bm} = \mathbf{0}$. Which must always be true about the *size* of $\mathbf{B}$?
   (a) $N \times 12$ with $12 \leq N$.
   (b) $2N \times 12$ with $7 \leq N$.
   (c) $N \times 6$ with $12 \leq N$.
   (d) $2N \times 6$ with $7 \leq N$.

3. Suppose that you have constructed a correspondence matrix $\mathbf{B}$ and you wish to solve the equation $\mathbf{Bm} = \mathbf{0}$ by svd decomposition. Assume that you have already obtained the decomposition via the matlab command

   ```
   [U, S, V]=SVD(B)
   ```

   and that you checked that the obtained output fulfills $\mathbf{USV}^T = \mathbf{B}$. What command would yield the correct $\mathbf{m}$?
   (a) $m = U(:, 14);$
   (b) $m = U(14, :);$
   (c) $m = V(12, :);$
   (d) $m = V(:, 12);$

4. Suppose that you have obtained a 3×4 parameter matrix M. Now you wish to normalize it using (matlab command) " **M= M / gamma;**". How would you define 'gamma' ?
   (a) `gamma=sign(M(3,4))*norm(M(1,1:3));`
   (b) `gamma=sign(M(1,1))*norm(M(1,1:3));`
   (c) `gamma=sign(M(3,4))*norm(M(3,1:3));`
   (d) `gamma=sign(M(1,1))*norm(M(3,1:3));`

5. Suppose that you have obtained an extrinsic parameters matrix `ME`. How would you check if it is a realistic one by matlab?

   (a) It is realistic if `M(:,1:3)'* M(:,1:3)` equals approximately $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

   (b) It is realistic if `M(:,2:4)'* M(:,2:4)` equals approximately $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

   (c) It is realistic if `M(:,1:3)* M(:,1:3)` equals approximately $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

   (d) It is realistic if `M(:,2:4)* M(:,2:4)` equals approximately $\begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}$

Computer Vision in 3D

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2.	a) ☐	b) ☐	c) ☐	d) ☐
3.	a) ☐	b) ☐	c) ☐	d) ☐
4.	a) ☐	b) ☐	c) ☐	d) ☐
5.	a) ☐	b) ☐	c) ☐	d) ☐

Theory: Stereo/Epipolar geometry

1. The goal of triangulation in a stereo system is to

   (a) compute the hard-wired parameters of the stereo system by identifiying triangles.

   (b) identify objects with triangular shape by image processing.

   (c) reconstruct the position vector of a 3D point in the frame of one of the cameras

   (d) control a camera such that one point has the same coordinates in both cameras

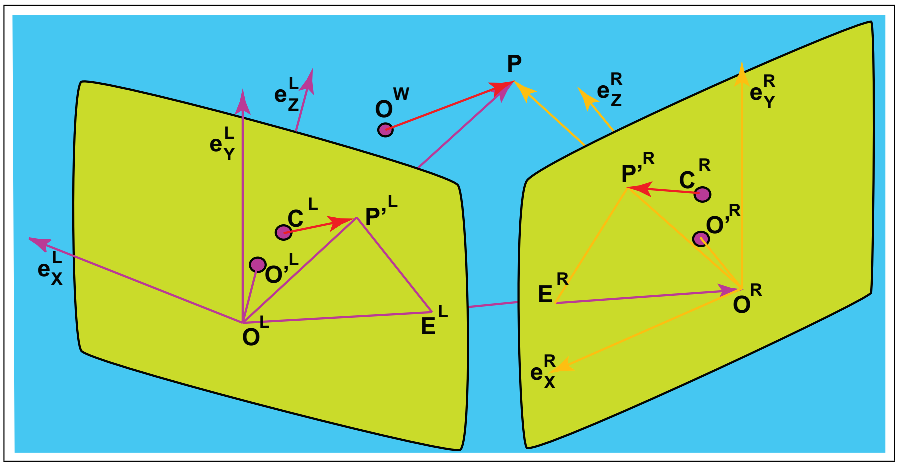
2. 

Figure 1: A stereo system

The following equations represent reconstruction by a certain stereo system with L, R referring to left and right cameras respectively,

$$\boldsymbol{A}\boldsymbol{p} = \boldsymbol{0}, \qquad \text{with} \qquad \boldsymbol{A} = \begin{bmatrix} \boldsymbol{T}^L \boldsymbol{M}^L \\ \boldsymbol{T}^R \boldsymbol{M}^R \end{bmatrix}. \tag{1}$$

Then given, Fig. 1, choose the statement that applies for this stereo system.

   (a) The quantity $\boldsymbol{T}^L$ is a vector representing $(\overrightarrow{E^L P'^L})$ in column/row coordinates of the left camera and in homogenous coordinates

   (b) The quantity $\boldsymbol{T}^R$ is a matrix that encodes the vector $(\overrightarrow{E^R P'^R})$ in column/row coordinates of the right camera

   (c) The quantity $\boldsymbol{T}^R$ is a vector representing $(\overrightarrow{C^R P'^R})$ in column/row coordinates of the right camera and in homogeneous coordinates

   (d) The quantity $\boldsymbol{T}^L$ is a matrix that encodes the vector $(\overrightarrow{C^L P'^L})$ in column/row coordinates of the left camera

3. Choose the statement that applies for the stereo system (Eq. **??**).

(a) Reconstruction is not perfect in practice, the direction of $\boldsymbol{M}_E\tilde{\boldsymbol{p}}$ minimizes $\|\tilde{\boldsymbol{A}}\tilde{\boldsymbol{p}}\|$.

(b) Reconstruction is not perfect in practice, the direction of $\tilde{\boldsymbol{p}}$ minimizes $\|\tilde{\boldsymbol{A}}\tilde{\boldsymbol{p}}\|$.

(c) Reconstruction can be perfect, if and only if the norm of $\boldsymbol{M}_E\tilde{\boldsymbol{p}}$ can be made 1 and $\tilde{\boldsymbol{p}}$ minimizes $\|\tilde{\boldsymbol{A}}\tilde{\boldsymbol{p}}\|$.

(d) Reconstruction can be perfect, if and only if the norm of $\tilde{\boldsymbol{p}}$ can be made 1 and $\tilde{\boldsymbol{p}}$ minimizes $\|\tilde{\boldsymbol{A}}\tilde{\boldsymbol{p}}\|$.

4. Let a stereo system be characterized by a rotation matrix $\vec{R}$ such that $\boldsymbol{R}(\overrightarrow{O^LP})_L = (\overrightarrow{O^LP})_R$, and by a displacement vector $\boldsymbol{t} = (X, Y, Z)^T = (\overrightarrow{O^RO^L})_R$, such that the matrix $\boldsymbol{T}$ is determined by the elements of $\boldsymbol{t}$ as

$$\boldsymbol{T} = \begin{pmatrix} 0 & -Z & Y \\ Z & 0 & -X \\ -Y & X & 0 \end{pmatrix} \tag{2}$$

Then, two points P'^L and P'^R in the left and the right camera coordinates are images of the same world point P if and only if

(a) $(\overrightarrow{O'^LP'^L})_L^T\ \boldsymbol{R}^T\boldsymbol{T}^{-1}\ (\overrightarrow{O'^RP'^R})_R = 0$,

(b) $(\overrightarrow{O'^RP'^R})_R^T\ \boldsymbol{T}^{-1}\boldsymbol{R}\boldsymbol{T}\ (\overrightarrow{O'^LP'^L})_L = 0$,

(c) $(\overrightarrow{O'^RP'^R})_R^T\ \boldsymbol{T}\boldsymbol{R}\boldsymbol{T}^T\ (\overrightarrow{O'^LP'^L})_L = 0$,

(d) $(\overrightarrow{O'^LP'^L})_L^T\ \boldsymbol{R}^T\boldsymbol{T}^T\ (\overrightarrow{O'^RP'^R})_R = 0$,

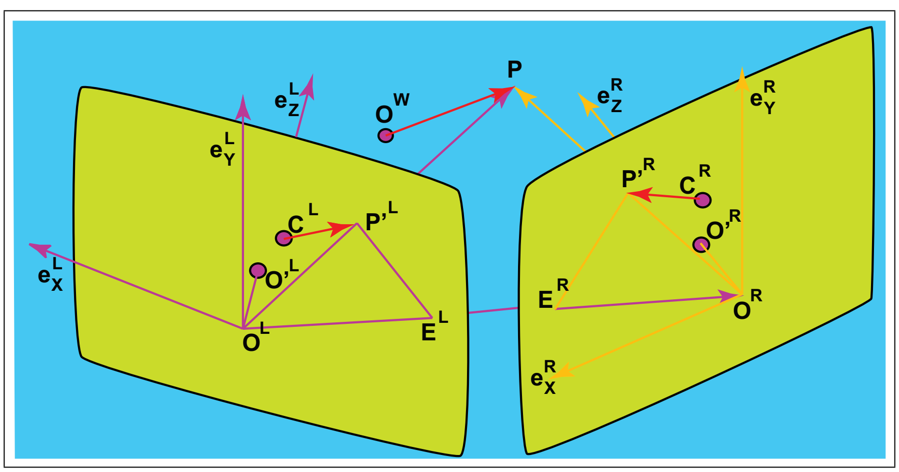
5. 

Figure 2: A stereo system

Referring to the stereo system in Fig. 2, two points P'^L and P'^R in the left and the right image digital (column/row) coordinates are the images of the same world point P if and only if

(a) $(\overrightarrow{C^R P'^R})_{RD}^T \boldsymbol{E} (\overrightarrow{C^L P'^L})_{LD} = 0$, with $\boldsymbol{E}$ being the essential matrix.

(b) $(\overrightarrow{C^R P'^R})_{RD}^T \boldsymbol{F} (\overrightarrow{C^L P'^L})_{LD} = 0$, with $\boldsymbol{F}$ being the fundamental matrix.

(c) $(\overrightarrow{C^R P'^R})_{RD}^T \boldsymbol{E} \boldsymbol{F} (\overrightarrow{C^L P'^L})_{LD} = 0$, with $\boldsymbol{E}$ and $\boldsymbol{F}$ being the essential, and the fundamental matrix, respectively.

(d) $(\overrightarrow{C^R P'^R})_{RD}^T (\boldsymbol{M}_I^R)^{-T} \boldsymbol{E} \boldsymbol{F} (\boldsymbol{M}_I^L)^{-1} (\overrightarrow{C^L P'^L})_{LD} = 0$, with $\boldsymbol{F}$ and $\boldsymbol{M}_I^{\cdot}$ being the essential, and the intrinsic matrices, respectively.

Computer Vision in 3D

Lab. No. : 4 - P R A C T I C E

Personal Identity Number:

Name:

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Date and Signature: ________________________________ ________________________________

1. a) b) c) d)

2. a) b) c) d)

3. a) b) c) d)

4. a) b) c) d)

5. a) b) c) d)

Practice: Stereo/Epipolar geometry

1. Fig. 1 shows 4 possible stereo configurations (A,B,C and D) with 4 different possible epipolar lines patterns. The image frame of the epipolar lines comes from the camera marked with "i". Which are the correct pairs:

   (a) A4, B2, C1, D3

   (b) A1, B3, C4, D2

   (c) A4, B2, C3, D1

   (d) A1, B3, C2, D4

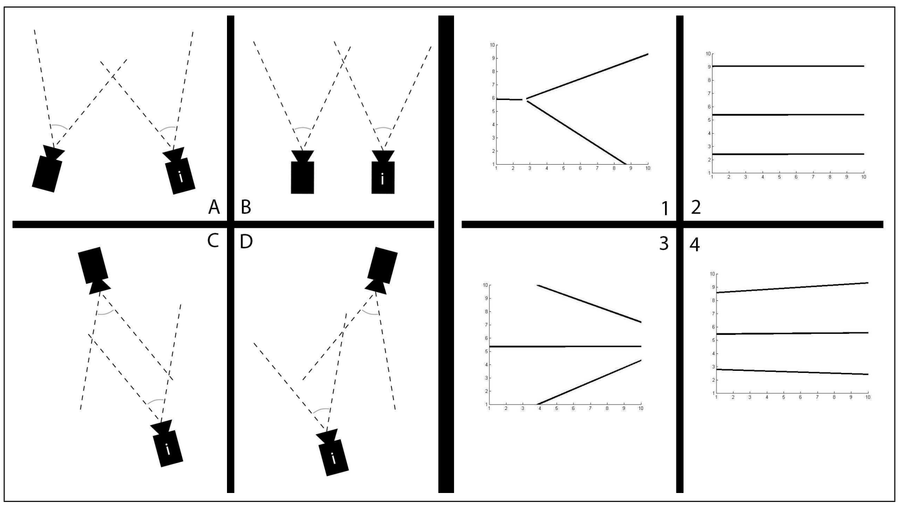

Figure 1: several possible stereo configurations, with possible epipolar lines

2. "F" is a fundamental matrix, and "pl" and "pr" are matrices containing coordinates of the left and right image respectively. Which of the following lines of code gives the parameters of the k:th epipolar line in the **LEFT IMAGE**:

   (a) pr(k,:)*pl(k,:)';

   (b) pr(k,:)'*pl(k,:);

   (c) pr(k,:)*F;

   (d) F*pl(k,:)';

3. Fig. 2 illustrates a flat-world example with a pin-hole camera model, with the y axis of the camera as the optical axis. The red dot is a point to be projected on the 1D camera plane(illustrated by the blue line). The origin of the camera frame is the center of projection. What will be the pixel index of the projection of the red dot?

   (a) 100
   (b) 50
   (c) 0
   (d) 10

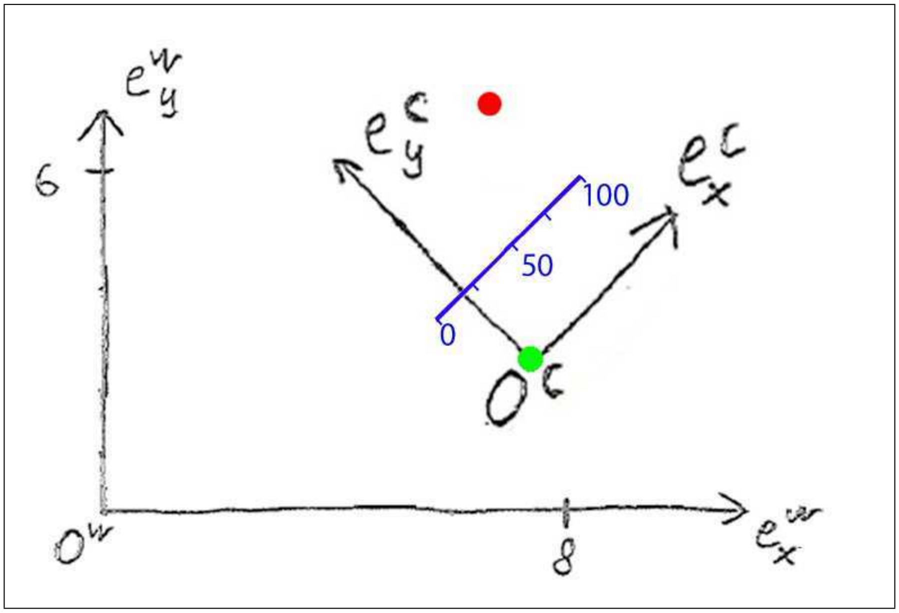

Figure 2: Camera in a flat world

4. Assume that you have a fundamental matrix F, a point in the left frame: pl and an epipolar line in the right frame (see Fig. 1 for an example). The line has two unique points: its ends. What is true for the end points of the epipolar line? They correspond to...

   (a) ... visibly distinct points (in the right camera) of the world that will project onto "pl" in the left frame.

   (b) ... two positions where

   ```
   [U,S,V]=svd(F);
   F=V(:,9);
   ```

   (c) ... two positions where

   ```
   [U,S,V]=svd(F);
   F=U(:,9);
   ```

   (d) ... the estimates of epipoles in the system

5. Matrices have the power to perform many kinds of transformations. However, there is ONE operation in the following list, that can not be performed by matrix multiplication, UNLESS we have homogenous coordinates.

   (a) Rotation

   (b) Translation (addition of constant vector)

   (c) Identity (keep vector without modifying it)

   (d) Scaling (make vectors bigger or smaller, while keeping direction)