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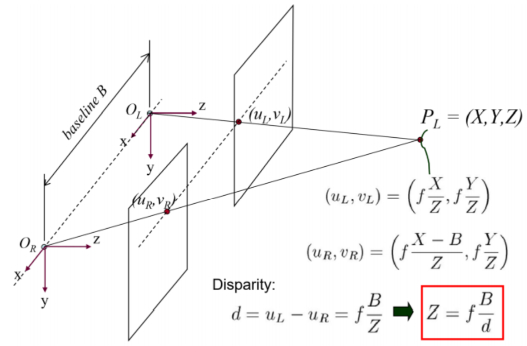
Q1

a)

according to



Depth Z=f*B/d=50cm

b)

$$k=\begin{matrix} 500 & 0 & 0 \\ 0 & 520 & 0 \\ 0 & 0 & 1 \end{matrix}$$

$$r=\begin{matrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{matrix} \qquad t=\begin{matrix} 251 \\ 250 \\ 1 \end{matrix}$$

$$\text{locationP1} = k[r|t] * p1 = \begin{bmatrix} 500 & 0 & 251 & 0 \\ 0 & 520 & 253 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} [36,34,100,1]^T$$

=[43100, 42980, 100]

=[431,429,1]

Q2

a)

0

a)

9	3
4	9

b)

[0.130, 0.2173, 0.261, 0.391]

Q3

a)

Lucas-Kanade algorithm is robost to the noise

The movement should be slow and gentel before and after the two frames. To

overcome the large-scale movement of the target, the image pyramid method can be used for tracking.
The brightness is constant, and there is no brightness change from t to t + 1
Spatial location should be the same, the adjacent points of the pixels do not change.

b)
because the surface is Lambertian surface, in this case, it uniformly reflected incident light, which means if the surface is smooth the intensity of reflected ray are the same. In this question, we used to detect the geometric information. In an uneven object. In bulge surface, the intensity of reflected ray is strong. In concave surface the intensity of reflected ray is weak.
According to the equation R(p,q)= $\frac{1+p_S p+q_S q}{\sqrt{1+p^2+q^2}\sqrt{1+p_S^2+q_S^2}}$
(p,q,-1) represent the surface normal
(p_s,q_s,-1) represent the light source direction
Given observed E(x,y), find p,q that minimize energy $\mathcal{E} = \int \left((I(x,y) - R(p,q))^2 + \lambda \left(p_x^{\ 2} + p_y^{\ 2} + q_x^{\ 2} + q_y^{\ 2} \right) \right) dx\,dy$
Use Euler Lagrange equations to get a PDE
We can calculate the surface normal

Q4
a)
Fundamental Matrix represent the extrinsic relationship relay on the rotation matrix and transform matrix, which is the relation of corresponding points in camera coordinate system. It use epipolar constrain to limit the one corresponding point to the epipolar line in the another graph. The camera have same postures.
Homography Matrix is use one point in a graph corresponding to the corresponded point in another graph. The camera can have different postures.

b)
epipolar lines are parrlel to the image. The corresponding point must located in the epipolar line of that point. Because the epipolar contrain make the corresponding point must located in the epipolar line of that point. Because two camera are pallel in the same plane, the intrinsic parameters and extrinsic parameters are the same.

Q5
1.
We have the world and image coordinate of 12 point as p1 … p12.
First we set the coordinate of center in image as (0,0), transfer the point coordinate to our hyphothsis. Calculate the T_norm $= \begin{bmatrix} w+h & 0 & w/2 \\ 0 & w+h & h/2 \\ 0 & 0 & 1 \end{bmatrix}$^-1 and S_norm.

$$\mathbf{S}_{\mathrm{norm}} = \begin{bmatrix} \mathbf{V}\,\mathrm{diag}(\lambda_1^{-1}, \lambda_2^{-1}, \lambda_3^{-1})\mathbf{V}^{-1} & -\mathbf{V}\,\mathrm{diag}(\lambda_1^{-1}, \lambda_2^{-1}, \lambda_3^{-1})\mathbf{V}^{-1}\boldsymbol{\mu}_{\mathbf{X}_i} \\ 0 & 1 \end{bmatrix}$$

$$\mathbf{V}\,\mathrm{diag}(\lambda_1, \lambda_2, \lambda_3)\mathbf{V}^{-1} = \mathrm{eig}\left(\sum_i \left(\mathbf{X}_{i,\mathrm{nonhom}} - \boldsymbol{\mu}_{\mathbf{X}_i}\right)\left(\mathbf{X}_{i,\mathrm{nonhom}} - \boldsymbol{\mu}_{\mathbf{X}_i}\right)^T \right)$$

For each image coordinate, multipled by T_norm, for each world coordinate, multipled by S_norm.
Construct matrix A with shape 2n*12, n represent the number of points.

For each point is $\begin{bmatrix} 0 & 0 & 0 & 0 & -w_iX_1 & -w_iX_2 & -w_iX_3 & -w_i & y_iX_1 & y_iX_2 & y_iX_3 & y_i \\ w_iX_1 & w_iX_2 & w_iX_3 & w_i & 0 & 0 & 0 & 0 & -x_iX_1 & -x_iX_2 & -x_iX_3 & -x_i \end{bmatrix}$. Calculate SVD of matrix A, got U, sigma, and V. P is the last column of V. then reshape to [3,4].
P including intrinsic information, including k, rotation, transform matrix.
2.
And we need to know the coordinate of corresponding point. We calculate homograph matrix to transfer one point to another.

First, choose 4 correspoding points, calculate T_norm= [$\begin{matrix} w+h & 0 & w/2 \\ 0 & w+h & h/2 \\ 0 & 0 & 1 \end{matrix}$]^-1.

Then, for each image coordinate, multipled by T_norm,
Constract matrix A with shape 2n*9, n represent the number of point, each point is
[0 0 0 -xi -yi -1 yi'xi yiyi yi'
Xi yi 1 0 0 0 -xi'xi -xi'yi -xi']

Calculate SVD of matrix A, got U, S, V. the homograph matrix is the last column of V.
Then reshape H to shape (3*3)

3.
To calculate the depth value of each pixel, we have the coordinate of two camera C1, C2. Coordinate of corresponding point which we want to know the depth, p p'. length of baseline in two camera B. and the focal length f.
P=(u, v) P'=(u', v')
U=f*x/z, v= f*y/z , u' =f*(x-B)/z, v'=f*y/z
Z represent the depth of that point.
Z=f*B/(u-u')

Q6
Assume the direction of sun in 1PM and 2PM as (ps1,qs1,-1), (ps2,qs2,-1). And we have the reflect rate kd.
I=kd*N*L I represent the intensity of the image, kd is the reflect rate, N is the surface normal, L is light source direction. Then we can calculate the reflect rate and the surface normal(p,q).

I(x,y) = $\frac{1+p_S p+q_S q}{\sqrt{1+p^2+q^2}\sqrt{1+p_S^2+q_S^2}}$

In this case, for each pixel in image, replace the direction of sun(ps2,qs2,-1) to(ps1,qs1,-1). Then we got the image at 1PM.

I(x,y) = $\frac{1+p_{S2} p+q_{S2} q}{\sqrt{1+p^2+q^2}\sqrt{1+p_{S2}^2+q_{S2}^2}}$