3D Measurement Exercise

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Abstract

The purpose of this exercise is to introduce, the estimation of 3D information from image data, in practice. The exercise is restricted to pair of images, and an emphasis is made on the effect of measurement noise and different configuration. Through out this exercise it is assumed, that the data has been corrected for inner orientation, thus effectively *the cameras are described by their outer orientation*. It should be noted that as part of this exercise it is also assumed that the students increase their familiarity with the pinhole camera model. The main reference for this exercise is Chapter 13 of [1], at it assumed that they are carried out in MatLab.

1 Setting Up the Cameras

In this exercise 3 cameras, $\mathbf{A_1}, \mathbf{A_2}, \mathbf{A_3}$, are used. Their outer orientation are given by (see Chapter 4 of [1]):

	Ω, Φ, K	X_0, Y_0, Z_0
A_1	$-\frac{\pi}{2}, 0, 0$	$0, 0, 0$
A_2	$-\frac{\pi}{2}, -\frac{\pi}{12}, 0$	$-5, 0, 1$
A_3	$-\frac{\pi}{2}, 0, 0$	$0.1, 0, 0.1$

Assume that the inner orientation has been corrected for and as such can be described by the unit matrix.

1. Implement the camera matrix for all 3 cameras. [1]
2. Check that the 3D point $X_1 = \begin{bmatrix} 2 \\ 10 \\ 4 \\ 1 \end{bmatrix}$ projects to:
   A_1: $x_{11} = [0.2000 - 0.4000]^T$
   A_2: $x_{21} = [1.1914 - 0.3823]^T$
   A_3: $x_{21} = [0.1900 - 0.3900]^T$
3. Give a verbal/intuitive explanation of the 3 cameras location and viewing direction.

2 3D Solver

Implement a function `X=Est3D(x1,A1,x2,A2)`, which given the projection of a 3D point in two images, `x1,x2`, and the respective camera matrices `A1,A2` estimates

[1]Accompanying this exercise is a function `Rot.m` which produces a rotation matrix given the angles Ω, Φ, K .

the position of the 3D point. Test on cameras 1 and 2 that the projections of $X_1 = \begin{bmatrix} 2 \\ 10 \\ 4 \\ 1 \end{bmatrix}$ actually leads to X_1 when using `Est3D`.

1. Estimate the 3D point, X_2, observed at $x_{12} = [-0.6000, -0.2000]^T$ and $x_{22} = [0.7481, 0.0000]^T$ in cameras 1 and 2 respectively.
2. Estimate the 3D point, X_2, 'observed' in camera 3. Denote this by x_{32}.
3. And again, find the 3D point, X_3, observed at $x_{13} = [-0.0600, -0.0200]^T$ and $x_{23} = [0.3113, 0.0000]^T$ in cameras 1 and 2 respectively.
4. Where is this 3D point, X_3, 'observed' in camera 3 ? Denote this by x_{33}.
5. And for the last time, estimate the 3D point, X_4, observed at $x_{14} = [-0.3900, -0.3900]^T$ and $x_{24} = [1.0442, -0.2367]^T$ in cameras 1 and 2 respectively.
6. Project the found 3D point X_4 into cameras 1 and 2, and comaper the results with the values given in question 5. Explain !

3 Accuracy

In order to get a feel for the effects of measurement accuracy, which will be present i *all* real data, this last part of the exercise will touch on this. Here, the uncertainty is simulated by permuting the observations, but it should be noted that with real data the permutation is not know.

1. Permute the observation of X_2 in cameras 2 and 3, x_{22} and x_{32} respectively, by adding 0.1 to all the coordinates. Denote these permutations by $\bar{x}_{22}$ and $\bar{x}_{32}$.
2. Re–estimate the 3D position of of X_2 based on x_{12} and $\bar{x}_{22}$. Naturally using cameras 1 and 2.
3. Re–estimate the 3D position of of X_2 based on x_{12} and $\bar{x}_{32}$.
4. Compare the estimates from question 2. and 3. with the 'ground truth' based on x_{12} and x_{22} (no $^-$). Explain !
5. Calculate the basis to distance ratio for camera 1 and 2 with 3D point X_2. Do the same for cameras 1 and 3.
6. Again but with X_3. Permute x_{23} by adding 0.1 to all the coordinates and re-estimate based on x_{13} and $\bar{x}_{23}$ and camera 1 and 2.
7. Compare the result with the 'ground truth' estimate of X_3. Compare this error with the error made with camera 1 and 2 using X_2. Explain !

References

[1] Editor J.M. Carstensen. *Digital Image Processing*. Tehnical University of Denmark, 1999.