MCEN90018 Advanced Fluid Dynamics

Assignment 1 - 2022

Part I - Mars Navcam Images

You have been provided with a left and right image from Hazard avoidance cameras of the Mars Spirit Rover:
`Assignment_1_images_2022/Mars/mars_L.JPG`
`Assignment_1_images_2022/Mars/mars_R.JPG`

(1a) Using cross-correlation, determine the horizontal displacement (range map) between common features in the stereo image pair. I suggest to break up the left image into 32×32 pixel windows, and then cross-correlate these against the right image. Plot the range map as colour contours (where the colour indicates the horizontal pixel displacement Δi of common features between the left and right images). Compare to the raw image and discuss. Note that there will be some features that fail to correctly correlate. Discuss these areas, and discuss how to improve the correlation or reduce the identification of spurious shifts. **(20 Marks)**

(1b) All of the correlatable features are located on the surface. However, this is not the case for a mystery feature. Find and identify this feature (to do this, you may need to implement some of the measures discussed in 1a to improve the accuracy of the range map). **(10 Marks)**

(1c) Highlight on the images a feature on the ground that is at the same approximate range from the imaging system as the mystery feature. What does this tell about the hidden feature from (1b)? **(5 Marks)**

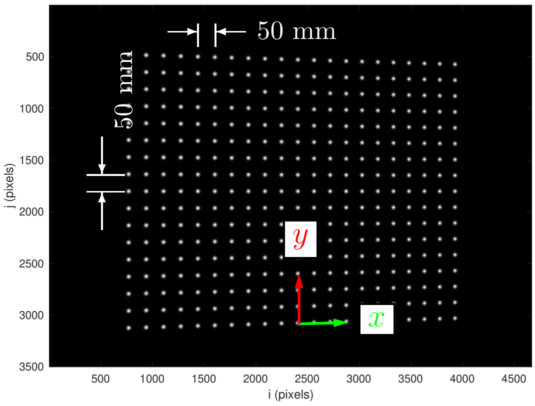
Part II - Stereo Vision System

In the folder `Assignment_1_images_2022/calibration_images`, you have been provided with a number of stereo calibration images. These images are from a left and right camera, viewing the same calibration target at a stereo angle of approx $\pm 9°$. The calibration target has white dots spaced by 50 mm in the x (horizontal) and y (vertical) directions. The calibration target is shifted to various z locations, starting at a distance of 2 m from the camera, and shifted in 20 mm increments towards the camera (in the negative z direction). The calibration file names contain the name of the stereo camera (i.e `_left` or `_right`) and the z location of the calibration target (i.e `_z2000`)

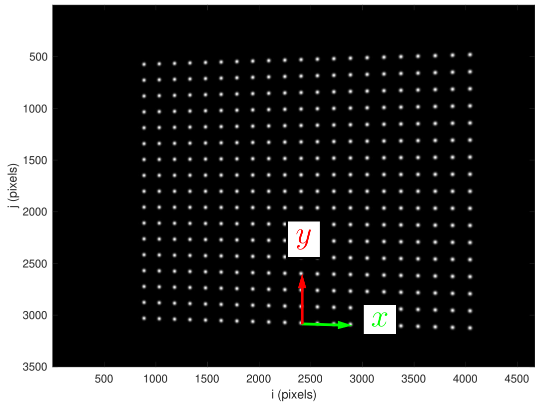
Use these calibration images to calibrate the camera system. You will need to first locate in pixel space all of the dots on the calibration target. Cross-correlation is an ideal tool for this, correlating the following template with the images should return peaks in the correlation matrix corresponding to the dot locations.

```
% make a template which is a 2D Gaussian dot
dsize = 15;
sigi = dsize./2.5;
```

`cal_image_left_z2000.tiff`



`cal_image_right_z2000.tiff`




```
sigj = dsize./2.5;
[it jt] = meshgrid([-dsize:1:dsize], [-dsize:1:dsize]);
template = 255*exp(-(((it).^2)./(2*sigi.^2) + ((jt).^2)./(2*sigj.^2)));
```

(2a) Plot two figures, showing the pixel locations for (a) the left and (b) right camera calibration points for all provided calibration stereo pairs (points for all 6 z locations should be shown on each plot). Colour these calibration points differently for each z location. **(10 Marks)**

Each of the identified dots has a known (x, y, z) in real space (in mm). The datum is as shown in figure 1, with $x = 0$ mm, $y = 0$ mm located at the 11^{th} dot from the left, in the lowest row of dots. The coordinates of each common dot from the left image (i_l, j_l) and the right image (i_r, j_r) are uniquely associated with a given (x, y, z) in real space. For example the coordinates of the lowest left-hand dot in the left and right images shown in Figure 1 correspond to the real space coordinates (-500, 0, 2000). To calibrate the system, we wish to find:

$$
\begin{aligned}
x &= f(i_l, j_l, i_r, j_r) \\
y &= f(i_l, j_l, i_r, j_r) \\
z &= f(i_l, j_l, i_r, j_r)
\end{aligned}
\tag{1}
$$

You could attempt a 4D interpolation (for example using the matlab command `griddatan`) which will contain inaccuracies. Or, preferably you could fit a 4D surface to the data (using the matlab command `nlinfit` or even `polyfitn`). A surface fit is the best, and typically for this case a 2nd order surface fit will suffice. In this instance

$$
\begin{aligned}
x = {} & A_1 + A_2 i_l + A_3 j_l + A_4 i_r + A_5 j_r + A_6 i_l j_l + A_7 i_l i_r + A_8 i_l j_r + A_9 j_l i_r \ldots \\
& + A_{10} j_l j_r + A_{11} i_r j_r + A_{12} i_l^2 + A_{13} j_l^2 + A_{14} i_r^2 + A_{15} j_r^2
\end{aligned}
\tag{2}
$$

A similar equation would exist for y and z (with different coefficients).

You are welcome to use any fit that you think gives the best results. I suggest that you test how well you have determined the functions given in equation (1), by using one of the calibration pairs (where you know the true (x, y, z) real space coordinates) and seeing how well your interpolant / function fit actually performs.

The test scan

(2b) Now consider the stereo pair of images given in:
`Assignment_1_images_2022/test_images/test_left.tiff`
`Assignment_1_images_2022/test_images/test_right.tiff`
425 dots (in a 25×17 array) are projected using lasers onto an unknown surface. Determine the real space coordinates (x, y, z) in mm for each of the dots and explain in as much detail as you can the geometry that they describe. **(25 Marks)**

Mystery geometry

(2c) Consider the stereo pair of mystery images given in:
`Assignment_1_images_2022/test_images/mystery_left_2022.tiff`
`Assignment_1_images_2022/test_images/mystery_right_2022.tiff`
taken with the same camera set up. Find the hidden geometry within the images.
(25 Marks)

Part III - Peer review

(3a) Scientific papers are peer-reviewed to assess the quality of the work, the findings, the rigour of the methodology and their suitability for publication. The peer review process has been a part of scientific communication, possibly, since 1731 [1]. For this assignment, you will participate in a peer-review process. Prior to submission, you will share your report with another team of your choosing. The 'reviewers' should read the report and provide feedback on areas of improvements such as: clarity of the arguments, suitability of the conclusions, readability of the figures/tables etc. The ?reviewees? should address this feedback in their report by making suitable changes and/or providing more context that back their assertions/arguments.

Document the peer-review process as an appendix to the assignmment submission (max 2 pages). Include the reviewers remarks as separate points (in red text), and your response to each remark (in regular, black text). **(5 Marks)**

References

[1] Spier, R., 2002, The history of the peer-review process. TRENDS in Biotechnology, 20(8), 357-358.