Practical Exercise – Visual SLAM module 2023

Send your solution to:
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SUBJECT: Visual SLAM TP 2023

Planar Homography Tracking

General objective:

The aim of this practical is to get some hands-on experience with a direct planar homography tracking algorithm to track planar patches across sequences of images. This could be useful for stabilising a AUV with respect to its environment for tasks like underwater inspection.

The code base is provided and you will be required to complete some core functions for the planar Homography-tracking algorithm. This will allows to sequentially determine the location of a planar patch throughout an image sequence via a non-linear iterative minimisation procedure.

The direct planar tracking algorithm functions as follows:

1. Select a patch in the first image as a reference patch using a mouse.
2. Initialise the first estimate of the Homography **H** = ***I*** (identity).
3. Warp the current image using the current estimate of **H**.
4. Compute the error between the reference patch and the warped patch.
5. Compute the update of **H** according to the pseudo inverse of the Jacobian times the error.
6. If the update is still large then repeat to 3.

Code and Sequence:

Obtain a copy of the « Cyclopes » source code and sequences.

Two sequences are provided :
1. A color monocular underwater sequence found in the directory : IMAGES_smallRGB
2. A greyscale stereo sequence found in the directory : Versialles_canyon.

The main file to execute the code is:

cyclopes/examples/TrackImageSL3/mainTrackImageSL3.m

Inside this file is a function *test()* at the end of the file which contains all the parameters for this program. Modify the paths of the sequence and the source code to suit your installation.

Question 1 :

At the core of a planar Homography tracker is the geometric warping function:

$$\mathbf{p}_2 = \mathbf{H}\mathbf{p}_1$$

Implement this function in the directory: cyclopes/warp

The file WarpSL3.m should perform the geometric warping of 2D points from the Reference Image to the Current Image according to the current estimate of H. Note that the image coordinates of the Reference patch are stored in :
ReferenceImage.P.U(ReferenceImage.index)
ReferenceImage.P.V(ReferenceImage.index)
where *ReferenceImage.index* is an index of the chosen pixels.

Don't forget to normalise the homogeneous warped point so that $z = 1$.

Note also that the warping function may take some points outside the image.

The results should be stored in :
WarpedImage.P.U(WarpedImage.index)
WarpedImage.P.V(WarpedImage.index)
where *WarpedImage.index* is an index of the pixels within the target region and which are inside the image.

For the program to function correctly, it is necessary to have a binary Mask image that shows which pixels are being used. This code is included at the end of the file.

Question 2 :

The planar Homography tracker also requires an intensity warping function:

$\mathbf{I}_2 = \mathbf{I}_1(\mathbf{p}_2)$

Implement this function in the directory: *cyclopes/warp*

The file *WarpImageSL3.m* should take the warped 2D points from question 1 and interpolate the current image at those locations. Hint, Matlab has the *interp2()* inbuilt function. Note that the Matlab i*nterp2()* function doesn't interpolate on the border pixels in the image.

Add the border pixels to the index: *WarpedImage.visibility_index*

Test that the warping function works when **H**=***I***.

Question 3 :

Implement the stopping criterion for the non-linear iterative minimisation. This requires modifying the file t*rack/TrackImageSL3.m*

It is also possible to use several stopping criterion simultaneously.

Question 4 :

Test the tracking of a patch up to the end of the sequence using different options.

- Try tracking using CurrentJacobian, ReferenceJacobian and ESM algorithm. What differences can you note?
- Try tracking using the M-estimator, How does this affect the minimisation? What does the choice of the Tukey or Huber weighting functions do?

Question 5 :

This question concerns a sequence of stereo images. You will find in the Versailles Canyons sequence both Left and Right images of a stereo pair.

In the previous exercise, a monocular sequence was used to perform image-to-image tracking/registration. This sequence was acquired at 30Hz and only a small displacements are observed between successive images. The initial guess of the Homography was therefore the Identity matrix.

- Track the same patch in both left and right images. Is this Homography the same for both Left and Right images?

Bonus :

- Modify the code to “register” or “track” a patch from the Left image to the Right image for each image pair in the sequnce. Note that the Left and right images are separated by a larger dispacement. This will require making an initial guess of the Homography matrix.
- Is the computed Left-to-Right Homography the same for each stereo pair of images in the sequence?

Question 6 :

Investigate the effect of changing the reference patch each image or keeping it for as long as possible

- Plot the the norm of the error after minimisation across the sequence using the two techniques.
- Comment on their difference.
- Devise a method for detecting when to change the reference patch.

Question 7: Challenge

Deviser une implementation basé sur les avancées precedents qui permet de faire le suivi d'un patch plan sur le sequence sous marin : IMAGES_smallRGB

L'objectif sera de suivre le patch le plus longtemps possible dans le sequence.

Faire un video du resultat avec un descriptif de l'approche implementé et l'envoyer à Andrew.Comport@cnrs.fr pour evaluation.

Question 8 :

(optional)
Augmented Reality: use the estimated Homographies to render a virtual object in the scene.