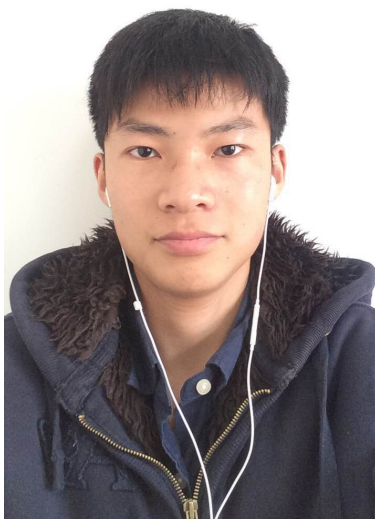


Assignment4: Harris Corner Detection

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2/20/17



1 Implementation

1.1 "Corners" measure

- (a) Please refer to my matlab file
- (b) I use the central different filters designed in HW01. X-filter: $1/2 * [-1, 0, 1]$, y-filter: $1/2 * [-1; 0; 1]$, and manually filter the gray scale image to get the I_x and I_y . Please refer to my matlab code.
- (c) Please refer to my matlab code
- (d) After testing, I choose σ to be 2, and the size of the Gaussian filter is therefore 8. Please refer to my matlab code.
- (e), (f) Please refer to my matlab code

1.2 Corner extraction

- (a) I use the function `ordfilt2` to get the local maximum, and then perform matrix calculation to filter out those that are not maximum, generating single dots. Please refer to my matlab code.
- (b) I use the `find` function to find the coordinates of the corner points. Please refer to my matlab code for implementation details.

I_x : 2 250 218 155 156 104 60 24 217 187 156 131 104 83 84 60 43 185 158 128 129 106 81 62
41 24 217 155 104 187 131 60 83 43 40 24 81 62 128 106 184 157 59 43 83 103 130 154 186 187 216
24 40 62 80 105 127 157 183 42 59 82 102 129 153 23 39 39 185 214 79 126 182

I_y : 2 4 61 79 79 93 106 115 115 123 127 134 137 144 144 146 152 172 178 179 179 184 185
189 190 193 223 225 227 227 228 229 230 232 269 271 271 273 273 275 275 277 311 312 317 317
322 323 329 330 331 348 349 356 357 364 366 375 377 391 394 403 406 416 420 423 427 428 432
437 442 459 479

- (c) Below is the superimposed image. Corners are marked with blue dots.



2 Rotation and Scaling

Rotate Below is the superimposed image using the function created above. The original image has been rotated for 30 degrees. Please refer to my matlab code for implementation details.



Resize Below is the superimposed image using the function created above. The original image has been scaled to 4 times bigger. The image on the PDF has been resized for displaying purpose. Please refer to my matlab code for implementation details.



Discussion It looks to me that both the rotated image and the resized image have been corrected processed to detect corners. In the rotated image, we can see more "false" corners being detected at the borders. This is probably because after rotation, I have created a lot of black parts. Thus at the boarder between the black part and the image, the differences in gradient is big, creating a lot of false positives.

In the resized image, the result of detection is almost the same as the original one without changing any parameters. This is actually a surprising result for me since I know that after we resize the image to a bigger size, the corners will become less "sharp", thus reducing the ability of Harris corner detector to detect corners. In this case, it's possible that a 4 times enlargement is not enough to make the corners undetectable in my case of parameters.

3 Grad Credits: SURF

SURF: Speeded up Robust Features

It has been a long-term question in the field of computer vision to find correspondences between images of the same scene. In order to find discrete image correspondences, three major steps should be followed. First of all, interest points should be selected at various locations in the image. These points are selected by detectors and the most important feature of a detector is its repeatability, which means a detector should reproducibly find the same interest point under different viewing environment. Second, the surrounding feature vectors of an interest point are called descriptors. They are supposed to be distinctive and robust to noise and errors. Finally, a matching step is applied to descriptors within different images based on distance calculation. In this paper, the authors proposed modified algorithms and model that focus on scale invariance and lead to more efficient detectors and descriptors but still keep them distinctive and repeatable.

Many state-of-the-art detectors and descriptors are described in literatures. So far, the most popular detector is the Harris corner detector, which is based on the eigenvalues of the second-moment matrix. However, Harris is not scale-invariant, which makes it less stable. Another researcher proposed the Hessian detector based on automatic scale selection. Hessian is then further modified to become more repeatable and robust. In terms of descriptors, feature descriptors focusing on the distribution of smaller-scale features (SIFT) perform better than other descriptors. SIFT becomes

even faster and more distinctive after refinement. Nevertheless, SIFT and its variants possess high dimensionality in the matching step.

In this paper, the authors proposed a new detector-descriptor set made up of a “Fast-Hessian” detector and a SURF descriptor with less dimension and less computational time. The Fast-Hessian detector is based on Hessian detector with the discretized and cropped Gaussian filters replaced by box filters. This is because aliasing always occur as long as the resulting images are sub-sampled. Furthermore, box filters are combined with integral images, which change the scale space analysis method from reducing image size repeatedly to up-scaling the filter size. When compared with the SIFT descriptor, the SURF descriptors proposed in this paper further break down the complexity in two steps. The first step is to fix the rotation. Researchers calculate the Haar-wavelet responses of a certain radius $6s$ around an interest point. s is the scale where the interest point is detected. In such way, only 6 operations are needed to calculate the wavelet response. The response is further computed and weighted to find the dominant orientation. The second step is to build a region aligned to the dominant orientation and extract the SURF descriptor from it. In order to fulfill this step, the constructed region is broken down into 4×4 sub-regions. Within each sub-region, a few simple features are computed with horizontal and vertical Haar wavelet responses calculated. These distances are weighted by Gaussian to increase robustness. A multi-dimensional descriptor vector is then calculated. Various parameters are tested to get the most distinctive descriptors with less dimensionality. The 4×4 sub-regions with 64 dimensions perform the best. In the matching step, indexing with the sign of Laplacian is added without extra computational cost. It distinguishes bright blobs in dark backgrounds from the opposite situation. The actual matching only considers features if they have the same type of contrast, which reduces matching time but increases performance.

SURF's performance is tested with both standard evaluation and real world recognition application. For the standard evaluation, zoom and rotation as well as lighting changes are tested. The proposed Fast-Hessian detector performs 5 times faster than other modified Hessian detectors with same level of repeatability. The SURF descriptors outperform other descriptors in a significant way. For the object recognition test, SURF descriptor behaves at least 5% more accurate than other major descriptors. Overall, SURF detectors and descriptors are faster and more accurate than other schemes.