tImage Formation and Features

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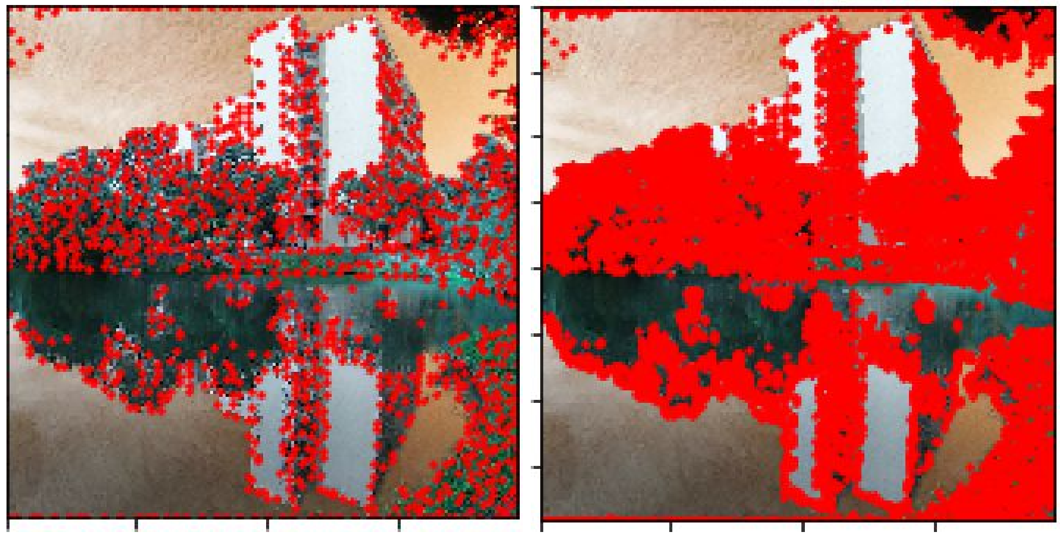
1. Harris Corner Detection
    1. Discuss the results of blurred images and detected edges between different kernel sizes of Gaussian filter.


kernel_size=5(left). kernel_size=10(right).

As we can see, the image through the Gaussian blur with large kernel size is much blur.

Due to the larger kernel size, the convolution affect more pixels in each iteration. And thus, it generates the vaguer image.

2. Discuss the difference between 3x3 and 30x30 window sizes of structure tensor.



window size 30*30(left). Window size 3*3(right).

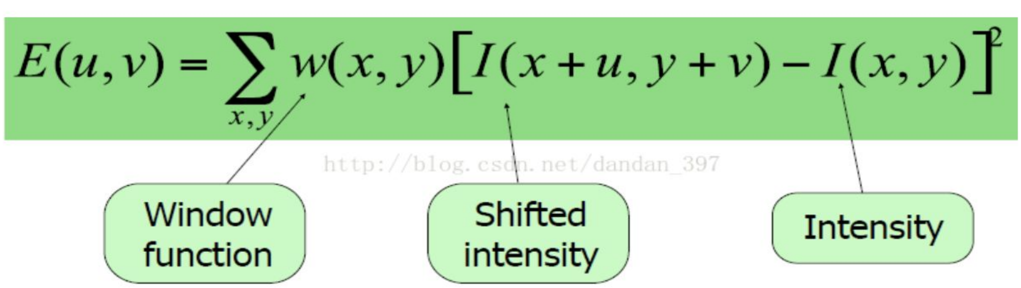
According to the results, the image generate fewer points in the image with large window size. The reason why the image with large window size has fewer points is that we can consider larger range when doing maximum in NMS, and by that, we can eliminate more points.

```
mask1 = (R > 5e-6)
mask2 = (np.abs(ndi.maximum_filter(R, size) - R) < 1e-14)
mask = (mask1 & mask2)
```

3. Discuss the effect of non-maximal suppression.

   We first observe the intensity variance at each pixels according ot the formula below.

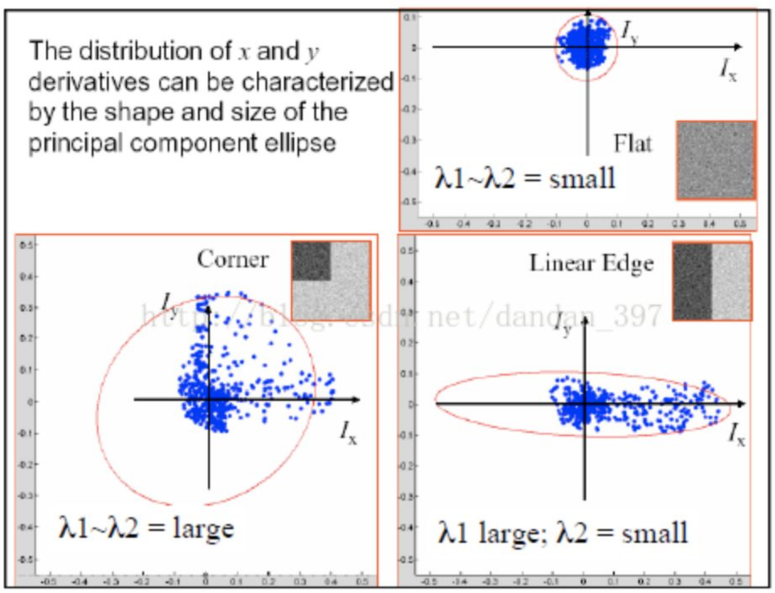
$$E(u,v) = \sum_{x,y} w(x,y)\left[I(x+u,y+v) - I(x,y)\right]^2$$



Then, we alter the formula through taylor extension.

$$
\begin{aligned}
E(u,v) &\approx \sum_{x,y} w(x,y)[\overbrace{I(x,y) + uI_x + vI_y}^{I(x+u,y+v)\ \ \textit{First order approx}} - I(x,y)]^2 \\
&= \sum_{x,y} w(x,y)[uI_x + vI_y]^2 \\
&= (u \quad v)\sum_{x,y} w(x,y)\begin{bmatrix} I_x I_x & I_x I_y \\ I_x I_y & I_y I_y \end{bmatrix}\begin{pmatrix} u \\ v \end{pmatrix}
\end{aligned}
$$

We call the part in the blue circle structure tensor.



In order to find corners, we need to choose the pixel with both larger lamba1, lamb2(eigenvalue). As a result. Structure tensor help us to detect corner features.

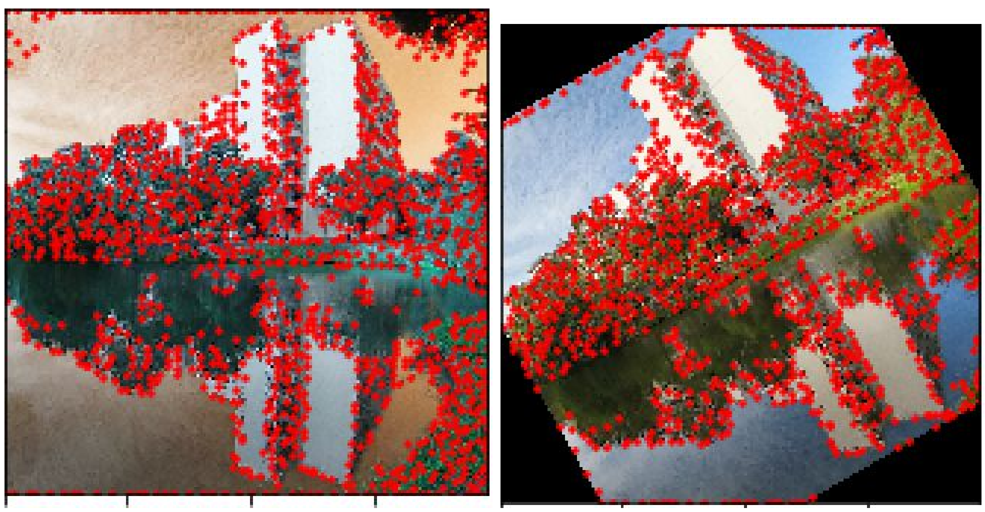
Measure of corner response:

$$R = \det M - k\left(\operatorname{trace} M\right)^2$$

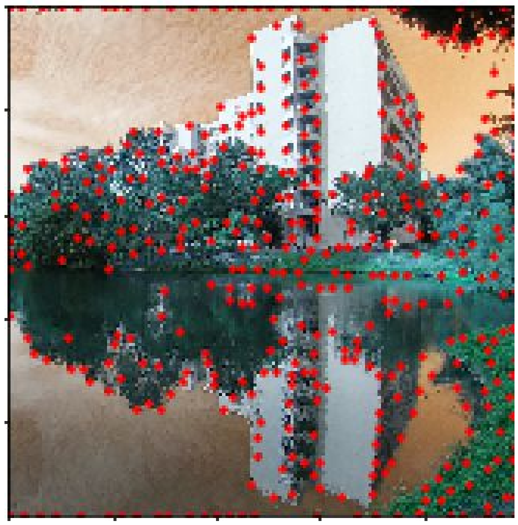
$$\det M = \lambda_1 \lambda_2$$
$$\operatorname{trace} M = \lambda_1 + \lambda_2$$

(k is an empirically determined constant; k = 0.04 - 0.06)

4. Discuss the results of rotated and scaled image. Is Harris detector rotation-invariant or scale-invariant? Explain the reason.



Orignial image(left). Rotated(30) image(right).



Resized(*0.5) image

As we can see, the marked points' position is invariant when rotated or resized. As a result, Harris detector is rotation-invariant or scale-invariant. Since we catch the features by doing convolution with gaussion filter and NMS, also, the both method are rotated-invariant and resized-invariant, the final results are rotated-invariant and resized-invariant.

2. Image Sensing Pipeline (ISP)
    1. Why sensors need to use CFA (Color Filter Array) such as Bayer patterns to store color information? Explain how it works, too.

       First of all, to make avoid the expense of digital camera. The camera today are mainly used CMOS or CCD. Since it is quite difficult and expensive to make a color sensor array (CMOS or CCD) to catch full color (which contains red, green, blue)image, we use color filter array to transform image to a mosaicked image.

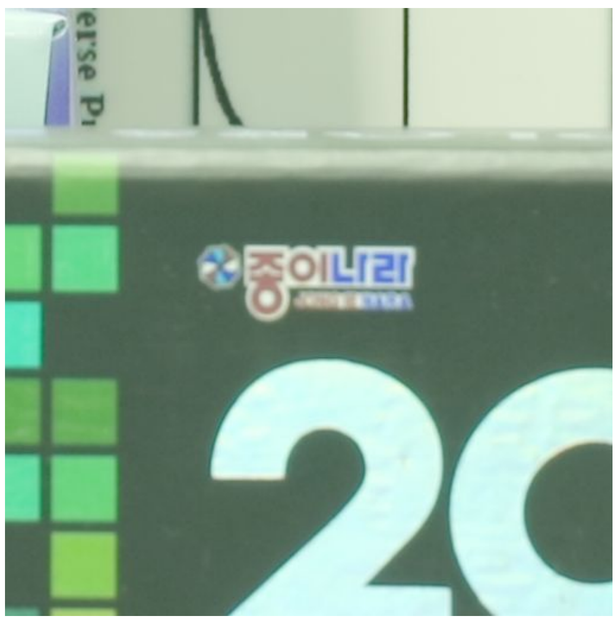
       Then, we explain the theory, the full color image contain the image with 3 channels(R, G, B), in order to receive the information of images, we need to build 3 sensor array to obtain the light. By CFA, we do mosaic on image, which can make a single sensor with cell receiving only single color. And it become much more cheap.

    2. Give/Describe two other methods which can perform de-mosaicing and are not mentioned in the slide.
        i. Edge-adaptive Demosaicing Methods: Estimating the green plane before R and B ones is mainly motivated by the double amount of G samples in the

CFA image. A fully populated G component plane will subsequently make the R and B plane estimation more accurate. As a consequence, the G component estimation quality becomes critical in the overall demosaicing performance, since any error in the G plane estimation is propagated in the following chrominance estimation step.

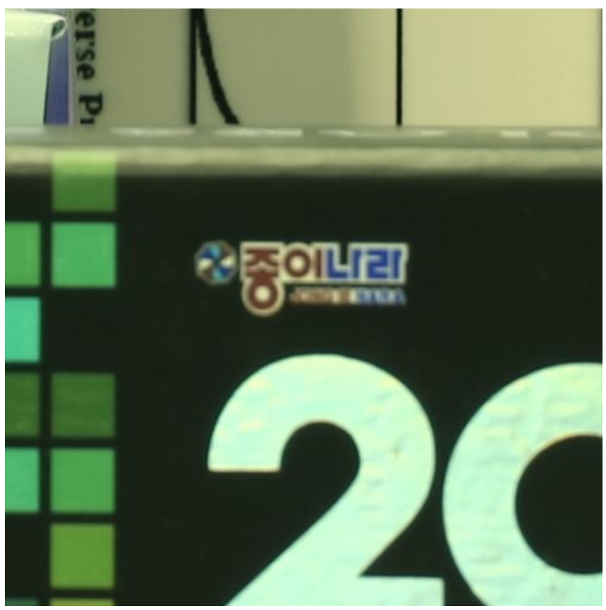
ii. Gradient-based Methods: Gradient computation is a general solution to edge direction selection. Hibbard's method (1995) uses horizontal and vertical gradients, computed at each pixel where the G component has to be estimated, in order to select the direction which provides the best green level estimation.

3. Show the image results of each step as p.13-14 in hw1_tutorial.pdf.
    i. Inverse Tone Mapping



    ii. from RGB to CIE XYZ

iii. Color Correction

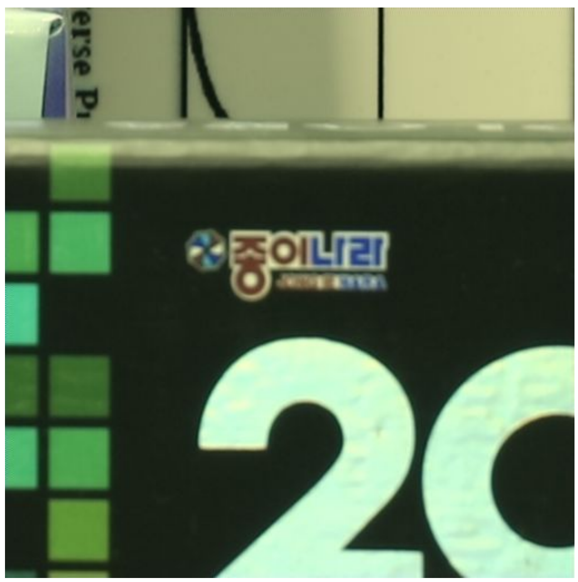


iv. Mosaic

v. Inverse AWB

vi. AWB

vii. Demosaic



viii. Color Correction

ix. from XYZ to RGB

x. Tone Mapping

You can see the result when running my hw1_2.

4. In recent AI de-noising methods, in order to generate paired data for training, we will add synthetic noise to clean image on RAW domain instead of RGB domain. Explain the reason.

   Recently, since we mainly obtain our image data by camera, also, camera nowadays are most use mosaic method receive image by single filter sensor array, we get our image data set with raw images. As a result, we do not want do extra process to transform image on RAW domain instead of RGB domain. So we simply add sysnthetic noise to clean image on RAW domain.