Computer Vision – 2025 Spring Semester

Homework 2

Harris Corner Detection

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1) Discuss the results of **blurred images** and **detected edges** between different kernel sizes of Gaussian filter.

a) **What is the Gaussian filter?**
The Gaussian filter is one of linear smoothing filters. The core idea is to average all of the neighbor pixels based on the Gaussian distribution to achieve the purpose of reducing noise and smoothing images.
In theory, Gaussian filters can effectively remove the random noise, especially in the pre-processing stage of image processing. It will help to reduce the error detected by the noise of edge detection.The shape of filters decide on its standard deviation (σ) and kernel size. The larger σ will make the filter effect obvious, but may lose the image details.

b) **The effect of kernel size on blurred images:**
In my experiments, kernel size directly effective the filter effect and the subsequent gradient calculation:
5×5 kernel size
The lower kernel size can retain more detailed information of the image and is more sensitive to changes near the edges, so it can maintain the image local feature more accurately. But it also means that the noise may not be completely suppressed, so when I use the lower kernel size, it may maintain some unnecessary detail and generate more non-real edges in edge detection.
10×10 kernel size
The higher kernel size makes the filter effect smoother. It can significantly reduce the high frequency noise in the image, but also blur some important detail. For

example, when the kernel size is 5 , the school name in English ”National Yang Ming Chiao Tung University” is clearly visible. In contrast, when the kernel size is 10 , the school name appears too blurred to be distinguished clearly.

c) **The subsequent impact of smoothing effect on edge detection:**
Gaussian filtering, as a pre-step in edge detection, is important to using Sobel edge detection on the subsequent.In my implementation results, when the kernel size is 5, the edges of the image are more clearly, especially the edge of the building, flags pattern, and the school name.
However, when increasing the kernel size to 10, the edges become blurry, the school name and the flags look less sharp. In addition, some of the edges show a thicker outline, while the finer details disappear.

	kernel size = 5	kernel size = 10
blurred images		
detected edges		

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

The window size used in computing the structure tensor significantly affects the detection of edges and corners.

3×3 window:

The structure tensor calculated by 3×3 window is highly sensitive to small details, making it ideal for capturing edge and corner. However, if the window size is set too small, it may easily be affected by local noise and lead to false detections.

30×30 window:

Bigger window size means integrating more pixels when calculating. It applies stronger spatial averaging, leading to smoother and more stable detections but at the cost of missing small-scale details.

For example, in the left image, you can see there are a lot of corner points distributed in the edge of the building, flag pattern, windows, and around the school name. It shows that a smaller window size can capture more details. However, it may generate some corner points in the non-important region.

In comparison, in the right image, the corner points significantly reduced. Only focus on the main structural points of the building, roughly around the profile, flag and boundaries of school name text. Large window perform gradient averages over a wider region, thus ignoring subtle details and retaining only the main structural features. This makes the detection results more stable and more anti-noise capability, but the features in the details may be smoothed out.

window size 3×3	window size 30×30
	

3)Discuss the effect of **non-maximal suppression**.

a) **What is Non-Maximum Suppression(NMS)?**

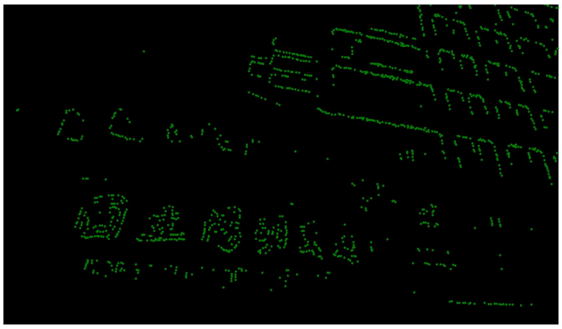
Non-Maximum Suppression(NMS) is an approach that is commonly used in edges and corner detection. The target is to retain the local maximum from the candidate points. For corner detection, candidates often have multiple duplicate responses in one region. NMS retains the strongest response points by comparing corner points in the neighborhood, to make the detection results more accurate.

b) **Experiment analysis**

When applying NMS to corner detection, the results show obvious differences. As shown in the figure (w/o NMS), the building, flags, and school name are almost filled with a large number of dense and repetitive corner points.

In this case, although it is possible to ensure that there are no missing potential corner points, many redundancy or low-quality response points are introduced, resulting in overcrowding of the image information. So it may be difficult to identify representative features from it.

In contrast, in the result processed with NMS (w/NMS), you can see the corner points in the figure are greatly reduced, only representative corner locations such as windows outlines and text edges are retained. It effectively eliminates repeated and noise points, so even though the corner points are more sparse, they are also more accurate and stable.

w/o NMS	w/NMS
	

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

a) **The influence of Rotation and Scaling to image characteristics.**

Rotation: In theory, image rotation only changes the coordinate, but does not change the relative relationship between pixels. Therefore, in gradient calculation and structure tensor, the relative position and angle between each corner point should remain unchanged.But if the rotation causes the image content to change and reduce part of it, the points in that part cannot be detected.

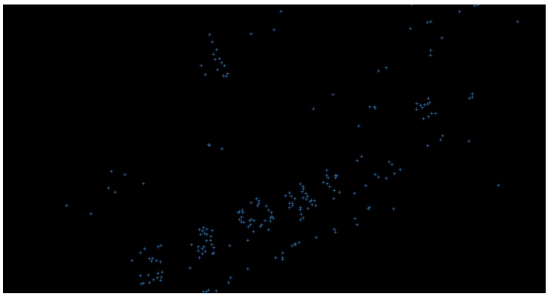
Scaling: Conversely, scaling changes the overall scale of the image, which may cause the original local details to become blurred or changed after resampling. It will affect the structure of Gaussian smooth, gradient calculating and structure tensor and change the result of corner detection.

b) Experiment analysis

This experiment performs two geometric transformations on the original image, one is rotation 30 degrees (w/rotation), another is shrinking to 0.5 times the original size (w/scaling). I observe the results of Harris corner detection under these conditions.

For the left image, when the image rotates 30 degrees, Harris corner detector can detect most of the corner points corresponding to the original image. Although the position of the corner points is spatially changed due to the image rotation, most corner points near the school name and the building are still stable. This shows that the **Harris corner detection has a certain degree of invariance to rotation**. That is, it can maintain the position (relative to content) and corner where the same feature is detected when the image rotates. This is because Harris calculates features through local gradient changes, based on the structure tensor maintains consistency of feature intensity under rotation.

However, after the image scaling, the number of corner points are significantly reduced, and most corner points become messy compared to the original image. This shows that the **Harris corner detection does not have scale-invariant**. The reason is that the Harris algorithm uses fixed-size window to perform gradient statistics and detect corners. When the image size is reduced, the original details are compressed or blurred, so the fixed-size window can not cover enough areas to detect the same feature structure.

w/rotation	w/scaling
	

References

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Karim, Abdul Amir A., and Rafal A. Sameer. "Improvement of Harris Algorithm Based on Gaussian Scale Space." Engineering and Technology Journal 37.1B (2019): 1-5.