Project 5 Image Feature Extraction

Due : 23:59,April 27

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1 Q1

1.1 Background

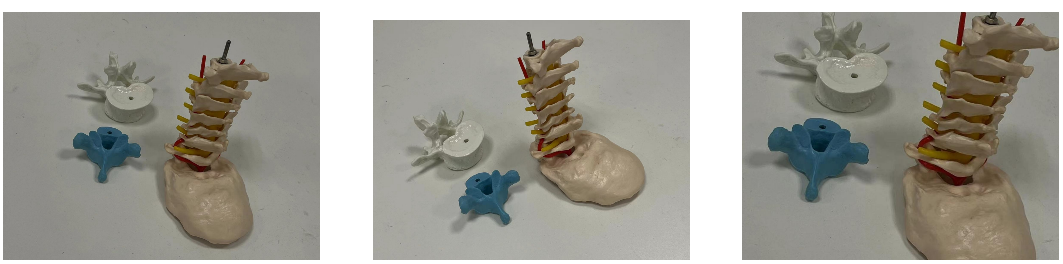
Image feature extraction is the core task in computer vision and image processing. Different feature extraction algorithms have different characteristics and application scenarios. In this task, we will apply the following feature extraction algorithms and evaluate their performance:

1. Harris corner detection: Local feature extraction based on corner detection
2. SIFT (Scale-invariant Feature Transform) : Feature extraction based on Scale invariance
3. ORB (Oriented FAST and Rotated BRIEF) : Fast feature extraction based on FAST corner points and BRIEF descriptors

1.2 Task

(a) chess (b) lake

Figure 1: Two images used for feature extraction



(a) Initial (b) Rotated view (c) Scaled

Figure 2: Images for feature points matching

1. Apply these 3 feature extraction algorithms (Harris corner, SIFT, ORB) to the 2 images in Figure 1. Show the results with the extracted feature points. Analyze the distribution and characteristics of the features extracted by different algorithms. Evaluate the number of feature points and processing time.
2. Apply **SIFT** to the images in Figure 2 and match the features points. Draw lines between matched points of to show the two set of correspondence between **figure 2a and figure 2b**, **figure 2a and figure 2c**. Evaluate the number of matching pairs (choose appropriate distance threshold).

1.3 Evaluation

1. Calculate the number of feature points and processing time for each feature extraction algorithms on the two images.
2. Calculate the number of matching key points between the two set of correspondence (Initial and Rotated view; Initial and Scaled).

1.4 Discussion

You need to answer these following question in your report:

1. Discuss how the different algorithms affect the distribution and characteristics of the key points in Task 1. Discuss the performance of the three algorithms and analyze their advantages, disadvantages, applicable scene.
2. Discuss what makes these key points significant and how SIFT ensures scale and rotation invariance in Task 2. Discuss how SIFT helps in identifying correspondences between these images.

2 Q2

2.1 Background

Gray level co-occurrence matrix refers to a common method to describe texture by studying the spatial correlation properties of gray levels. In 1973, Haralick et al. [1] proposed the gray level co-occurrence matrix to describe texture features. Since the texture is formed by the repeated occurrence of gray distribution in space, there will be a certain gray relationship between two pixels separated by a certain distance in the image space, that is, the spatial correlation of gray levels in the image.

Fingerprint extraction is a critical task in biometric systems, aiming to capture unique ridge patterns for identification. A key step in this process is fingerprint segmentation, which separates the foreground (ridge areas) from the background noise to ensure accurate feature analysis. Additionally, ridge orientation field estimation is essential, as it represents the directional flow of ridges and is used to enhance feature extraction algorithms, such as SIFT or ORB, by providing structural context. Together, these steps form the foundation for robust fingerprint feature extraction, linking low-level image processing to high-level biometric recognition.

In this section, we will apply and discuss GLCM in image texture analysis. Also the key processing steps in fingerprint extraction will be involved to practicing feature extracton.

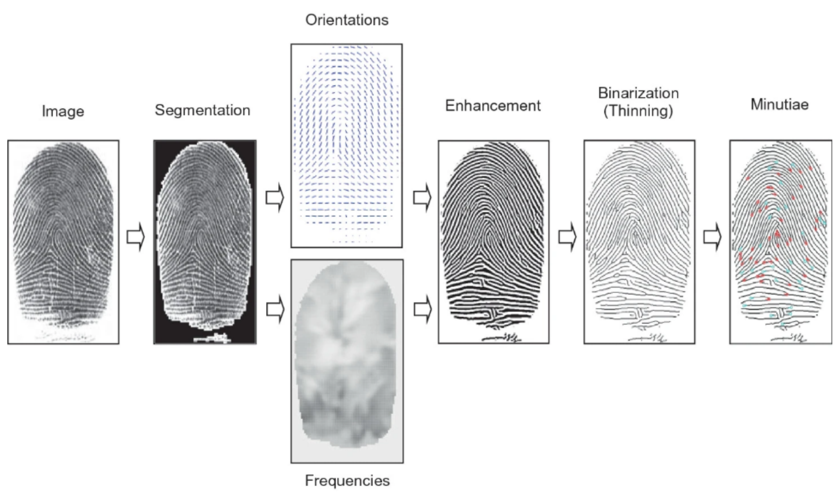


Figure 3: A typical process for extracting detail points from a fingerprint

2.2 Task

Figure 4: Three images of different texture

1. Please show the gray-level co-occurrence matrix of three images in figure 4 at the bias Angle of 0°, bias distance of 1 and gray level of 16 respectively, and calculate the scalar

(a) fingerprint (b) GT mask

Figure 5: Fingerprint image and the ground truth of segmentation

properties such as contrast, dissimilarity, homogeneity, ASM, and correlation. Hint: You need to transfer the image to gray and resize to 512*512.

2. Try different bias angles, calculate the scalar properties at different angles, and discuss the influence of the change of bias angle on texture analysis.
3. Implement the fingerprint region segmentation based on Gray Level Co-occurrence Matrix (GLCM) [2] [3] to figure 5a, and then compare to the ground truth (figure 5b). You need to show the intermediate process, and describe the parameters you chose and discuss why you chose these parameters.

   (**Hint:** figure 6 shows s an example of segmentation using GLCM. Given a grayscale fingerprint image, showed the original fingerprint image with grid lines, (b) showed the feature map calculated by the GLCM contrast property, (c) showed the mask obtained by thresholding from feature map, (d) showed the segmentation result.)
4. Based on the segmentation result, apply estimation of local ridge direction for further extracting the fingerprint features. You should show result similar to figure 7

   (**Hint:** you can follow these steps:

   (a) Apply Sobel operator to compute the gradients of the image at each point (x, y) in both direction.

   (b) A simple way is to use arctangent of ∇_y / ∇_x to compute θ . However, it is recommend to average local gradient estimation to ensure continuity and avoid precision issues (for example, calculate the inner direction in local sliding window).

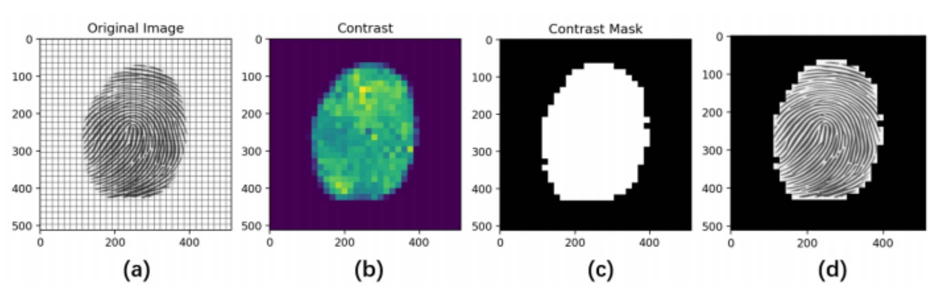


Figure 6: The example segmentation process

2.3 Evaluation

1. Calculate the scalar properties in **Task 2.2.1&2.2.2** such as contrast, dissimilarity, homogeneity, ASM, and correlation.

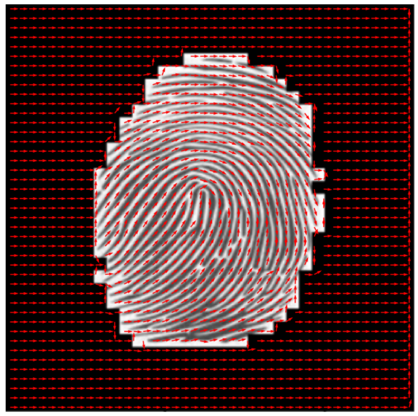


Figure 7: Orientation filed over the segmentation mask

2. Calculate the Dice between ground truth and mask obtained by GLCM segmentation in **Task 2.2.3** .

2.4 Discussion

You need to answer these following question in your report:

1. Discuss the influence of the change of bias Angle on texture analysis using GLCM in **Task 2.2.2**
2. Discuss your choice of parameters in the segmentation process in **Task 2.2.3**

3 Bonus

The bonus part is a further exploration of **Task 2.2.3**. One of the most difficult type of fingerprint segmentation, on-site fingerprints, involves more noise of the background , which makes it more difficult to segment fingerprint. Some researchers has used methods like **total variation** to solve it[4]. Try total variation or other techniques to implement on-site fingerprints. Show the segment result similar to figure 8.

Reference for methods: Fingerprint Analysis and Representation [5]

Figure 8: On-site fingerprint segmentation example

4 Submission Package

Submit a zip file includes:

1. A pdf report

2. A folder of source code with a README.md
3. A folder of images. They should be able to reproduce the numbers in your report.

Note that any missing of above items will lead to at least 20% points deduction.

5 Grading Rules

1. Running the code successfully. (40pts)
2. The performance of your algorithm, evaluating by Dice. (20pts)
3. The report of this project. (40pts)
4. Bonus algorithm. (20pts)

References

[1] Robert M Haralick, K Shanmugam, and IH Dinstein. Textural features for image classification, ieee transaction on systems, man and cybernitics, vol. *SMC*, 3(6):610–621, 1973.

[2] Mahdi Maktabdar Oghaz, Mohd Aizaini Maarof, Mohd Foad Rohani, Anazida Zainal, and Syed Zainudeen Mohd Shaid. An optimized skin texture model using gray-level co-occurrence matrix. *Neural Computing and Applications*, 31:1835–1853, 2019.

[3] Saliha Aouat, Idir Ait-Hammi, and Izem Hamouchene. A new approach for texture segmentation based on the gray level co-occurrence matrix. *Multimedia Tools and Applications*, 80(16):24027–24052, 2021.

[4] Jiangyang Zhang, Rongjie Lai, and C-C Jay Kuo. Adaptive directional total-variation model for latent fingerprint segmentation. *IEEE Transactions on Information Forensics and Security*, 8(8):1261–1273, 2013.

[5] Davide Maltoni, Dario Maio, Anil K Jain, and Jianjiang Feng. Fingerprint analysis and representation. In *Handbook of fingerprint recognition*, pages 115–216. Springer, 2022.