Non-Learning Based Image Processing Techniques for Finger Counting

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1 Introduction

Finger counting, also known as finger detection or hand gesture recognition, plays a vital role in various human-computer interaction applications. The ability to accurately count the number of fingers held up in a hand image has practical significance in fields such as virtual reality, robotics, and sign language interpretation. By utilizing non-learning based image processing techniques, we aim to develop a robust and efficient solution for finger counting.

This report focuses on applying non-learning techniques to count the number of fingers in a color image of a cropped hand. We explore the use of digital image processing algorithms and methods to detect and quantify the fingers held up in the hand image. By leveraging image enhancement, segmentation, and contour analysis techniques, we aim to develop an effective solution that can handle varying hand orientations, shapes, and sizes.

2 Dataset

The dataset used for this project was obtained from Kaggle, a popular platform for hosting machine learning datasets. The dataset was acquired by searching for relevant databases on "dataset-search.research.google.com" using the keyword "fingers". The dataset consists of images featuring a single left or right hand with no other objects. The dataset is categorized based on the number of fingers raised, including the following categories: no finger raised, 1 finger raised, 2 fingers raised, 3 fingers raised, 4 fingers raised, and 5 fingers raised.

The dataset exhibits diversity in terms of hand orientations, shapes, and sizes, ensuring a comprehensive representation of real-world scenarios. This variety is crucial for evaluating the generalization capability and robustness of the finger-counting solution. By incorporating hands with different orientations, shapes, and sizes, the proposed solution can be assessed for its ability to count fingers accurately across various hand configurations.

Care was taken to ensure the dataset was balanced across all finger count categories to maintain fairness and minimize bias. This ensures that the proposed solution is evaluated using a representative distribution of finger configurations. By including a range of hand appearances and orientations, the dataset reflects the challenges encountered in real-world finger-counting scenarios. The images within the dataset will be utilized to evaluate the performance of the proposed non-learning-based image processing techniques.

3 Approach Description

The following steps are involved in the finger-counting approach:

1. **Image Smoothing:** Apply a Gaussian filter to the original image to reduce noise and enhance the quality of the image. This step aims to improve subsequent processing steps.

2. **Thresholding:** Apply Otsu thresholding to convert the smoothed image into a binary image. This technique automatically determines an optimal threshold value to separate the hand region from the background.

3. **Hole Closing:** Close gaps in the hand region using morphological operations, specifically the closing operation. This step helps to remove small holes or gaps within the hand, making it a solid region.

4. **Contour Filtering:** Identify the contours in the thresholded image. Since the image typically contains only one contour corresponding to the hand, this step can be omitted if we assume a single hand in the image.

5. **Convex Hull and Defects:** Compute the convex hull and defects of the filtered contours. The convex hull represents the outer boundary of the hand, while the defects correspond to the concave regions between fingers.

6. **Finger Counting:** In our approach, we analyze the hand contour and defects to count the number of fingers accurately. We introduce a validation process to determine which defects represent fingers. This validation step involves considering the angle between adjacent fingers and the depth of each defect.

   By evaluating the angle between adjacent fingers, we can differentiate between valid finger defects and other irregularities in the hand contour. Valid finger defects are expected to exhibit specific angle ranges that correspond to the natural bending of fingers. This angle-based validation helps refine the finger counting process and improves the accuracy of finger identification.

   Additionally, we take into account the depth of each defect to distinguish between actual finger defects and false positives caused by noise or artifacts in the image. The depth of a defect provides valuable information about the prominence of the concave region between fingers. By setting appropriate thresholds for the depth, we can filter out erroneous detections and ensure that only valid finger defects are considered during the counting process.

   By incorporating these additional validation steps based on the angle between adjacent fingers and the depth of the defects, our finger counting approach enhances accuracy and reliability. This methodology minimizes the chances of miscounting due to erroneous detections, improving the overall performance of the finger counting system in various hand configurations and imaging conditions.

   Since our approach heavily relies on the presence of defects, it is important to acknowledge that it may encounter challenges in differentiating between scenarios where no finger is raised and when only one finger is raised. To address this potential limitation, we have incorporated an additional step in our finger counting algorithm.

   In this step, we examine the area of the hand contour and compare it to the average palm area. If the area of the hand contour is greater than the average palm area, we make the assumption that it is most likely a scenario where only one finger is raised. Conversely, if the area of the hand contour is smaller or equal to the average palm area, we infer that no finger is raised.

   This additional step allows us to make an informed estimation in cases where the defects may not be clearly distinguishable or when the hand shape does not exhibit prominent concave regions. By leveraging the hand contour area, we introduce a heuristic rule that assists in differentiating between the absence of raised fingers and the presence of a single raised finger.

4 Results

We evaluated the effectiveness of our finger counting approach by testing it on a dataset of 210 hand images. These images were loaded into the system, and the finger counting algorithm was applied to predict the number of fingers held up in each image. We compared the predicted finger counts with the ground truth labels for evaluation purposes.

Our approach achieved an accuracy of 75% on the dataset, indicating that it accurately predicted the number of fingers held up in the majority of the images. This demonstrates the effectiveness of our non-learning based image processing techniques in solving the finger counting problem.

While achieving a 75% accuracy is a significant milestone, we acknowledge that there is still room for improvement in our finger counting solution. During the evaluation, we noticed that the accuracy was mainly affected by images with hands that lacked significant defects on the contours. In such cases, where the hand shape does not exhibit pronounced concave regions or defects, accurately segmenting the hand and identifying the individual fingers becomes more challenging.

To address this limitation, future enhancements can focus on leveraging additional hand features beyond the presence of defects. For example, analyzing finger length, width, or curvature could provide valuable cues for accurate finger identification and counting, even in the absence of distinct defects. Incorporating contextual information such as the position and orientation of the hand may also help improve accuracy in cases where defects are not present.

5 Conclusion

In this project, we developed a non-learning-based finger counting solution to accurately count the number of fingers held up in a color image of a cropped hand. By applying image smoothing, thresholding, hole closing, contour filtering, and finger counting techniques, along with hand contour analysis, defect identification, and heuristic rules, we have achieved promising results in accurately counting fingers.