Image Segmentation: Evaluation and Results

Project Overview

This report documents the implementation and evaluation of three image segmentation techniques: Threshold Segmentation, Region Growing Segmentation, and Watershed Segmentation. The tasks were carried out on grayscale images from the "human_ht29_colon_cancer_2_images" dataset, and the results were evaluated against the ground truth images provided in "human_ht29_colon_cancer_2_foreground". The evaluation utilized metrics including Pixel Accuracy (PA), Mean Accuracy (MA), Intersection over Union (IoU), Precision, Recall, and F-measure.

Note: The images obtained from the results are not included in this document as they serve primarily for evaluating metrics. If needed, they can be found in the 'output_masks' folder of the project.

Segmentation Techniques

1. Threshold Segmentation

- **Methodology**: Implemented Otsu's thresholding method to separate the foreground from the background based on pixel intensity.
- **Post-processing**: None applied.
- **Results**:
    - **Average Metrics**:
        - Pixel Accuracy (PA): 0.8932
        - Mean Accuracy (MA): 0.7669
        - Intersection over Union (IoU): 0.5321
        - Precision: 0.9947
        - Recall: 0.5340
        - F-measure: 0.6598

2. Region Growing Segmentation

- **Methodology**: Applied Region Growing with a dynamic threshold of 5, using the image center as the seed point.
- **Post-processing**: None applied.
- **Results**:
    - **Average Metrics**:
        - Pixel Accuracy (PA): 0.1515
        - Mean Accuracy (MA): 0.1353

        - Intersection over Union (IoU): 0.0295
        - Precision: 0.1375
        - Recall: 0.0805
        - F-measure: 0.0502

3. Watershed Segmentation

- **Methodology**: Implemented a simplified Watershed algorithm to label regions based on intensity gradients.
- **Post-processing**: None applied.
- **Results**:
    - **Average Metrics**:
        - Pixel Accuracy (PA): 0.5155
        - Mean Accuracy (MA): 0.5211
        - Intersection over Union (IoU): 0.1565
        - Precision: 0.1902
        - Recall: 0.5297
        - F-measure: 0.2490

Evaluation and Analysis

Performance Comparison

1. **Threshold Segmentation**:
    - Achieved the best overall performance, particularly excelling in Pixel Accuracy (0.8932) and Precision (0.9947).
    - Its Recall (0.5340) and IoU (0.5321) indicate a reasonable balance between true positive and false negative detections.
2. **Region Growing Segmentation**:
    - Performed poorly across all metrics. Its low Pixel Accuracy (0.1515) and IoU (0.0295) suggest significant over-segmentation or under-segmentation issues.
3. **Watershed Segmentation**:
    - Achieved moderate performance, with strengths in Mean Accuracy (0.5211) and Recall (0.5297).
    - Lower Precision (0.1902) and IoU (0.1565) highlight issues with false positives.

Observations

- **Threshold Segmentation** is highly effective for images with distinct intensity differences between foreground and background.
- **Region Growing Segmentation** struggled due to its sensitivity to the initial seed point and intensity variations within the image.
- **Watershed Segmentation** provided a trade-off between the two, but lacked the robustness of Threshold Segmentation.

Conclusion

Based on the evaluation metrics, Threshold Segmentation emerged as the most reliable method for this dataset, achieving the highest accuracy and precision. Watershed Segmentation showed potential but requires further refinement, such as better initialization and gradient-based post-processing. Region Growing, while conceptually simple, is unsuitable for this type of dataset without significant enhancements.

Recommendations

- **Post-processing**: Incorporating morphological operations (e.g., opening, closing) can potentially enhance the performance of all methods.
- **Future Work**: Experiment with hybrid approaches, combining the strengths of Threshold and Watershed Segmentation.
- **Applications**: Threshold Segmentation is recommended for tasks requiring high accuracy in clearly defined images, while Watershed could be explored for gradient-rich or noisy datasets.

References:

1. Gonzalez, R. C., & Woods, R. E. (2018). *Digital Image Processing* (4th Edition).
2. Metrics calculation and methodology adapted from the provided "Segmentation Metrics" document.
3. Dataset: Human HT29 Colon-Cancer Images, Broad Bioimage Benchmark Collection.