CENG 483

Introduction to Computer Vision

Fall 2022-2023

Take Home Exam 1

Instance Recognition with Color Histograms

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1 3D Color Histogram

- For the 3D color histogram without grid division, I used the quantization intervals of 2, 4, 8 and 16. Here are the top-1 accuracy results for each interval on every query dataset:
  - For quantization interval 2:
    - Top-1 accuracy of the query-1 dataset is: 0.94
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.07
  - For quantization interval 4:
    - Top-1 accuracy of the query-1 dataset is: 1.0
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.145
  - For quantization interval 8:
    - Top-1 accuracy of the query-1 dataset is: 1.0
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.12
  - For quantization interval 16:
    - Top-1 accuracy of the query-1 dataset is: 1.0
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.125
- For the query set 2, since the corresponding query images of the support images are left-rotated version of them and there is not any grid division, it is expected to have 100% accuracy on all of the query sets. For query set 1, query images are zoomed versions of support images hence except the quantization interval of 2 where pixel dissimilarities at the edges of the images affected the accuracy, 100% accuracy is expected. In query set 3, color similarities are very low and there is not any increase/decrease observed in top-1 accuracies.

2 Per Channel Color histogram

- For the per channel color histogram without grid division, I used the quantization intervals of 2, 4, 8, 16 and 32. Here are the top-1 accuracy results for each interval on every query dataset:
  - For quantization interval 2:
    - Top-1 accuracy of the query-1 dataset is: 0.59
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.04
  - For quantization interval 4:
    - Top-1 accuracy of the query-1 dataset is: 0.925
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.14
  - For quantization interval 8:
    - Top-1 accuracy of the query-1 dataset is: 0.96
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.135
  - For quantization interval 16:
    - Top-1 accuracy of the query-1 dataset is: 0.965
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.14
  - For quantization interval 32:
    - Top-1 accuracy of the query-1 dataset is: 0.965
    - Top-1 accuracy of the query-2 dataset is: 1.0
    - Top-1 accuracy of the query-3 dataset is: 0.145
- For query set 2, although the images are rotated, occurrence numbers of each color channel values are the same hence for all quantization interval, accuracies are 100%. For query set 1, zoomed images in the query set have slight differences than the actual images and this difference can be observed when the quantization interval is 2. For query set 3, color dissimilarities is high but as the interval expands, probability of having the same histograms increased.

Quantization intervals of 16 and 4 are used in per channel and 3d histograms for grid based feature extraction respectively.

3 Grid Based Feature Extraction - Query set 1

Give your top-1 accuracy for all of the configurations below.

3.1 2×2 spatial grid

- 3d color histogram: 0.84
- per-channel histogram: 0.995

3.2 4×4 spatial grid

- 3d color histogram: 0.575
- per-channel histogram: 1.0

3.3 6×6 spatial grid

- 3d color histogram: 0.51
- per-channel histogram: 1.0

3.4 8×8 spatial grid

- 3d color histogram: 0.44
- per-channel histogram: 1.0

3.5 Questions

- What do you think about the cause of the difference between the results?
  - Query set 1 has the zoomed images of the support set and even if the images are divided into cells, each respective cells will be similar color counts hence the histograms will become similar, making the accuracies close to 100%. On the other hand as the cells increase the actual pixel differences inside the cells affects the accuracy scores.
- Explain the advantages/disadvantages of using grids in both types of histograms if there are any.
  - For images that only differ by resolution, it can be advantageous to use per channel color histogram since even the grid based feature extraction is used, accuracy scores still remain high. In case of 3d color histograms, it is crucial to increase the cell count since it can yield misleading results when less cells are used.

4 Grid Based Feature Extraction - Query set 2

Give your top-1 accuracy for all of the configurations below.

4.1 2×2 spatial grid

- 3d color histogram: 0.87
- per-channel histogram: 0.435

4.2 4×4 spatial grid

- 3d color histogram: 0.635
- per-channel histogram: 0.36

4.3 6×6 spatial grid

- 3d color histogram: 0.515
- per-channel histogram: 0.3

4.4 8×8 spatial grid

- 3d color histogram: 0.465
- per-channel histogram: 0.26

4.5 Questions

- What do you think about the cause of the difference between the results?
  - If the whole image is considered, color histograms of each kind would be identical but as the images are divided into grids, compared parts of images becomes different. Therefore, for both histogram types, as the cells increase, accuracy results decrease.
- Explain the advantages/disadvantages of using grids in both types of histograms if there are any.
  - Query set 2 has the left rotated versions of the support images and using grids could falsify the results because each time, the comparison is made with different parts of the image. It is the same case for the 3d color histograms. For both types of histograms on rotated images, grid usage would become a disadvantage.

5 Grid Based Feature Extraction - Query set 3

Give your top-1 accuracy for all of the configurations below.

5.1 2×2 spatial grid

- 3d color histogram: 0.09
- per-channel histogram: 0.265

5.2 4×4 spatial grid

- 3d color histogram: 0.08
- per-channel histogram: 0.395

5.3 6×6 spatial grid

- 3d color histogram: 0.075
- per-channel histogram: 0.44

5.4 8×8 spatial grid

- 3d color histogram: 0.065
- per-channel histogram: 0.465

5.5 Questions

- What do you think about the cause of the difference between the results?
  - Query set 3 has major pixel differences than the support image set. For the 3d color histogram, as the image is divided into more cells, the rgb color combinations become more different and the accuracy scores decrease. As for the per channel histogram, dividing into cells makes each corresponding channel values of the pixels get closer. Thus the accuracy results increased.
- Explain the advantages/disadvantages of using grids in both types of histograms if there are any.
  - When the compared images have major color differences, it may be useful to use per channel histogram with more grid cells to get an idea of the color distribution of the images. The 3d histograms are more useful while considering the color distribution of the image as a whole.

6 Additional Comments and References

- Implementation specifics and references:
  - Used **matplotlib.image** module to convert image to 3D numpy array.
  - At the beginning of each querying, the support set is cached into a array.
  - Used broadcasting for histogram extraction from images/cells.
  - Top-1 accuracy scores for a desired configuration is gathered by giving the configuration as input to the program.
  - Grid implementation is embedded into the main loop for no-grid implementation.
  - **np.linalg** module is used for l1 normalization implementation.
- Additional comments:
  - Per channel color histogram is useful considering the general layout of the rgb values of the pixels but it may give false results when the occurrences of channel values of completely different images are similar. In such a case grid usage will be necessary to acquire more accurate results.
  - 3D color histogram can eliminate the case of similar channel values but it may perform badly on different resolutions and color layouts.
  - Both histograms performs poorly under grid based feature extraction where images are rotated.