CS5187 ASSIGNMENT 1

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1 PROOF

A. Show that a 2D Gaussian filter is separable into two 1D Gaussian filters.

$G_\sigma = \frac{1}{2\pi\sigma^2}\exp^{-\frac{x^2+y^2}{2\sigma^2}} = \frac{1}{\sqrt{2\pi}\sigma}\exp^{-\frac{x^2}{2\sigma^2}} \times \frac{1}{\sqrt{2\pi}\sigma}\exp^{-\frac{y^2}{2\sigma^2}}$

B. Derive the 1st derivative of 2D Gaussian filter.

$\frac{\partial G_\sigma}{\partial x} = \frac{1}{2\pi\sigma^2}\exp^{-\frac{x^2+y^2}{2\sigma^2}} \times (-\frac{2x}{2\sigma^2}) = -\frac{xG_\sigma}{\sigma^2}$

$\frac{\partial G_\sigma}{\partial y} = \frac{1}{2\pi\sigma^2}\exp^{-\frac{x^2+y^2}{2\sigma^2}} \times (-\frac{2y}{2\sigma^2}) = -\frac{yG_\sigma}{\sigma^2}$

C. Derive the 2nd derivative of 2D Gaussian filter.

$\frac{\partial G_\sigma}{\partial x^2} = -\frac{1}{\sigma^2}(G_\sigma + x\frac{\partial G_\sigma}{\partial x}) = -\frac{G_\sigma}{\sigma^2}(1 - \frac{x^2}{\sigma^2})$

$\frac{\partial G_\sigma}{\partial y^2} = -\frac{1}{\sigma^2}(G_\sigma + y\frac{\partial G_\sigma}{\partial y}) = -\frac{G_\sigma}{\sigma^2}(1 - \frac{y^2}{\sigma^2})$

D. Derive the Laplacian of Gaussian (LoG) filter.

$LoG(x,y) = \frac{\partial G_\sigma}{\partial x^2} + \frac{\partial G_\sigma}{\partial y^2} = -\frac{G_\sigma}{\sigma^2}(2 - \frac{x^2+y^2}{\sigma^2})$

$\frac{\partial LoG(x,y)}{\partial x} = -\frac{xG_\sigma}{\sigma^4}(4 - \frac{x^2+y^2}{\sigma^2})$

$\frac{\partial LoG(x,y)}{\partial y} = -\frac{yG_\sigma}{\sigma^4}(4 - \frac{x^2+y^2}{\sigma^2})$

2 CONVOLUTION

A. Display the 48 image filters in the report.

Please see from Figure 1 to Figure 5.

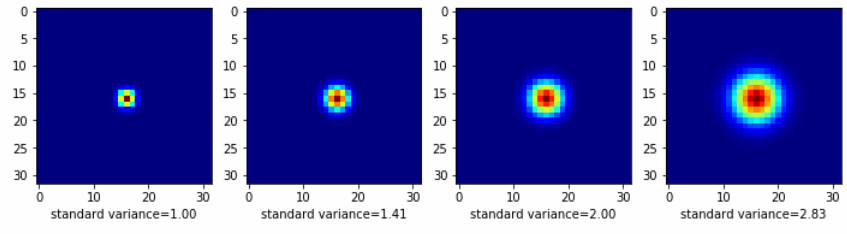

Figure 1: 4 gaussian filters.

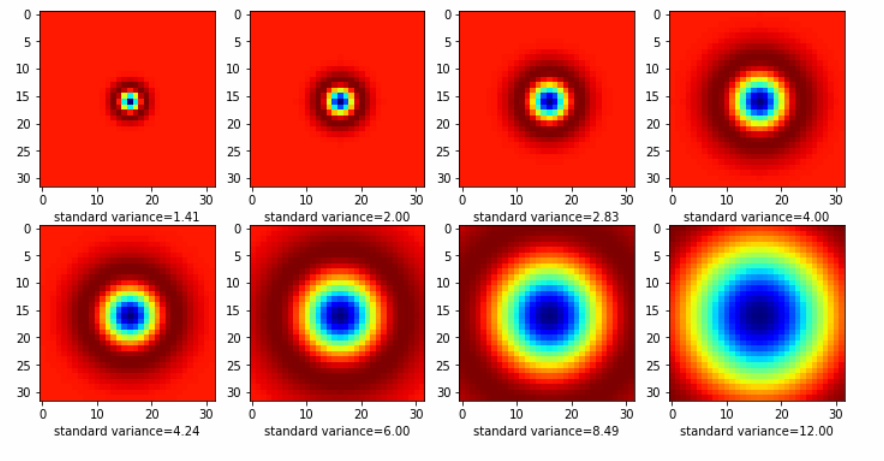

Figure 2: 8 LoG filters.

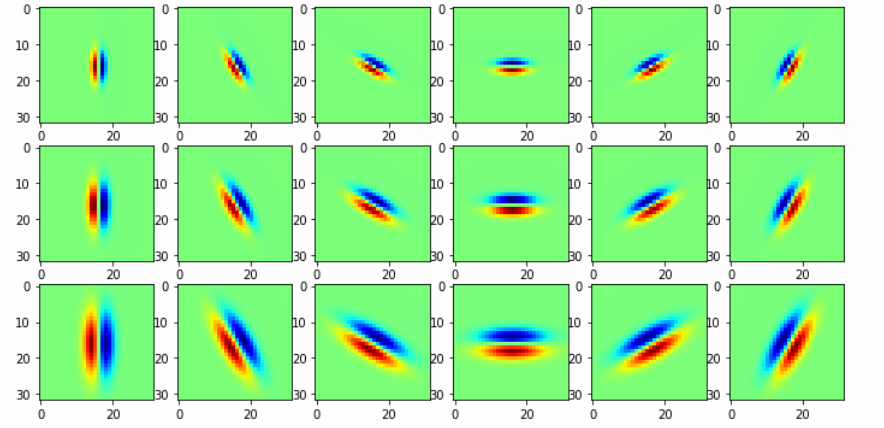

Figure 3: 18 1st x-directional derivation of gaussion filters.

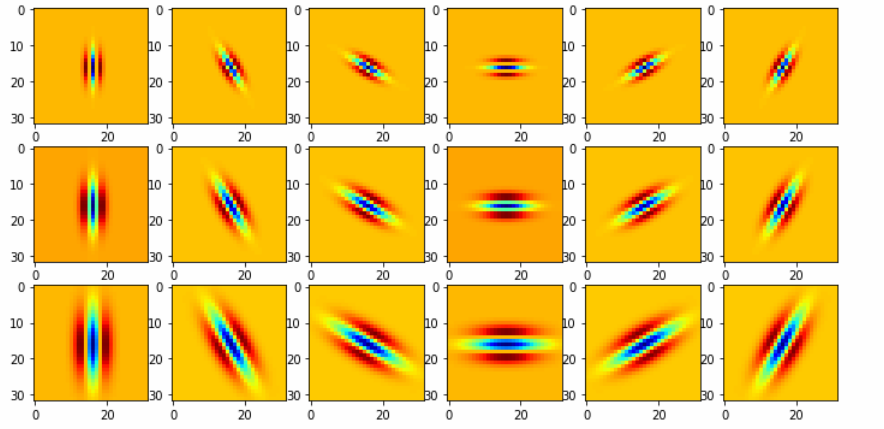

Figure 4: 18 2nd x-directional derivation of gaussion filters.

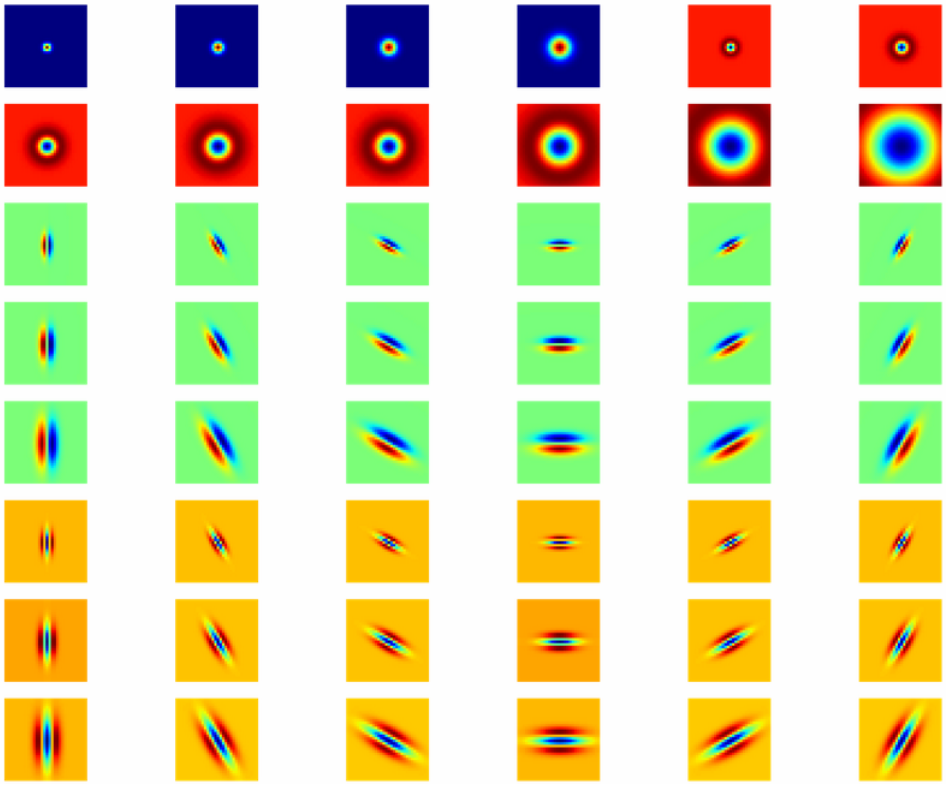

Figure 5: Filter Bank.

B. Display the 48 image responses of the images "leapord.jpg" and "panda.jpg" after performing convolution with the filter bank.
Please see from Figure 6 to Figure 9.

C. Compute the mean and variance of each image response to form a vector of length 96 elements. Write down the filter that gives the largest value of mean and the filter that gives the largest value of variance for "leapord.jpg" and "panda.jpg" in the report.
The gaussion filter with $\sigma = 2\sqrt{2}$ gives the largest mean value for both images, and the gaussion filter with $\sigma = 1$ gives the largest variance value for both images.

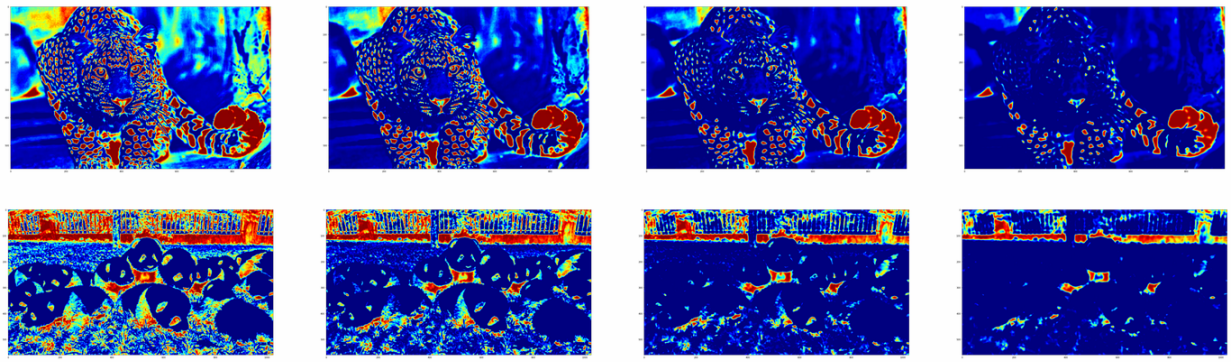

Figure 6: 4 gaussian filters.

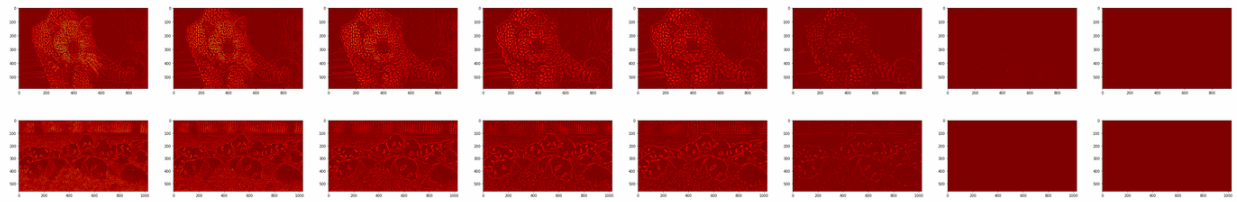

Figure 7: 8 LoG filters.

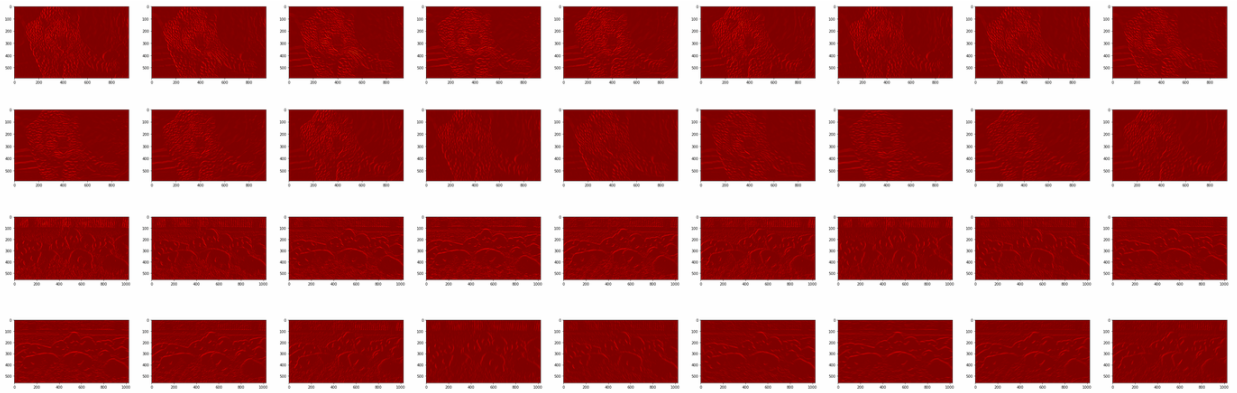

Figure 8: 18 1st x-directional derivation of gaussion filters.

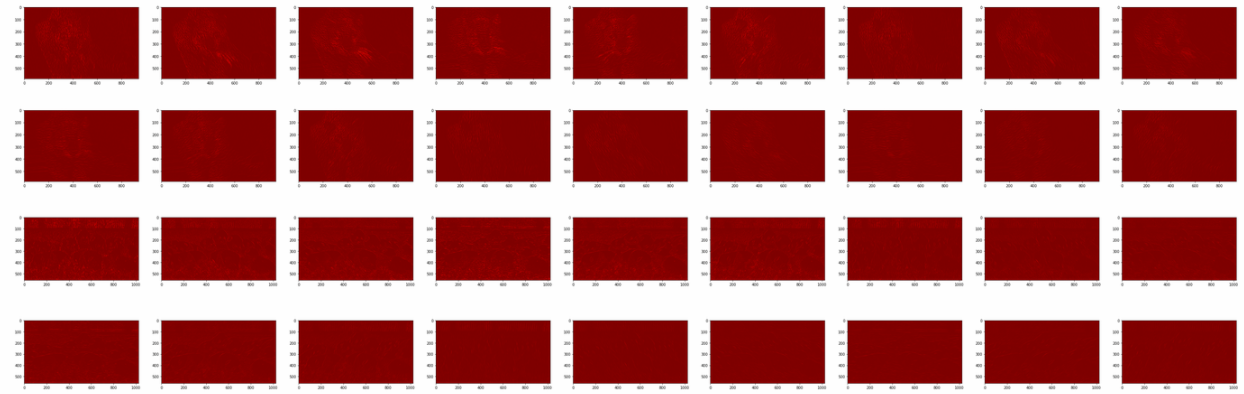

Figure 9: 18 2nd x-directional derivation of gaussion filters.

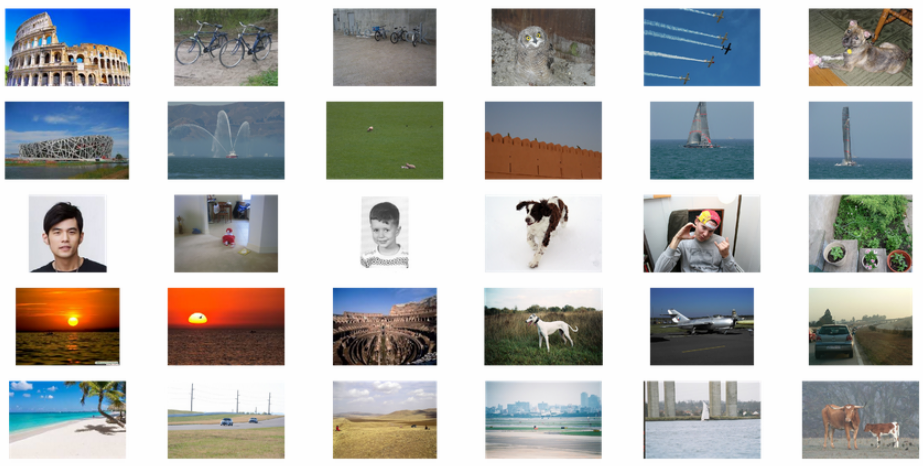

Figure 10: Top 5 retrieval results using filter bank.

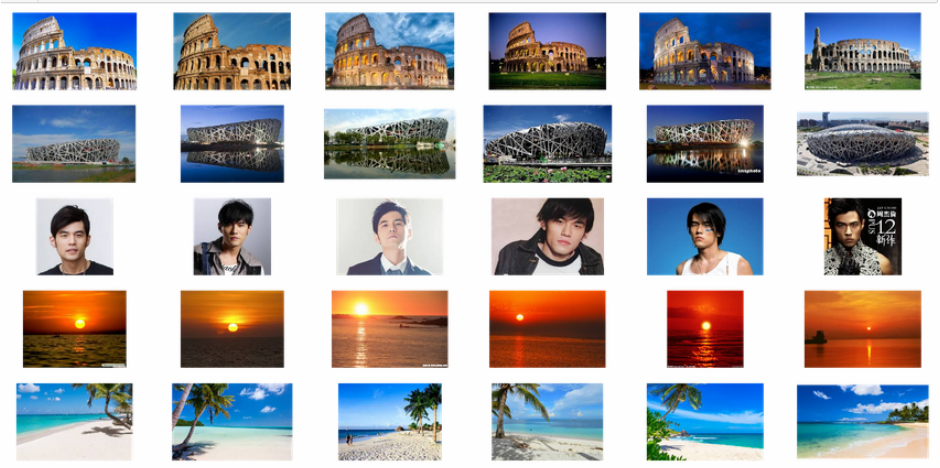

Figure 11: Top 5 retrieval results using ResNet50 features.

3 IMAGE RANKING

The code of this part is implemented in "ImageRanking.ipynb" and cosine similarity is applied as distance metric. Top 5 retrieval results are showed in Figure 10.

4 METHOD COMPARISON

A. Two feature extraction methods.
Average pooling layer features of ResNet50 and ResNet101 are extracted for comparision, and top 5 retrieval results are showed in Figure 11 and Figure 12 respectively.
B. Compare the retrieval result with the performance obtained in Part-3.
From the top 5 retrieval results, we can draw the conclusion that both ResNet50 and ResNet101 features, which is based on deep learning, outperform filter bank greatly. The retrieval results of filter bank are quite limited, and only the fourth query seems reasonable while only one similar image is retrieved. On the contrary, deep features perform quite well which are able to make the postive images rank high. Last but not least, results of ResNet50 and ResNet101 features share high similarity while still contains some diff-

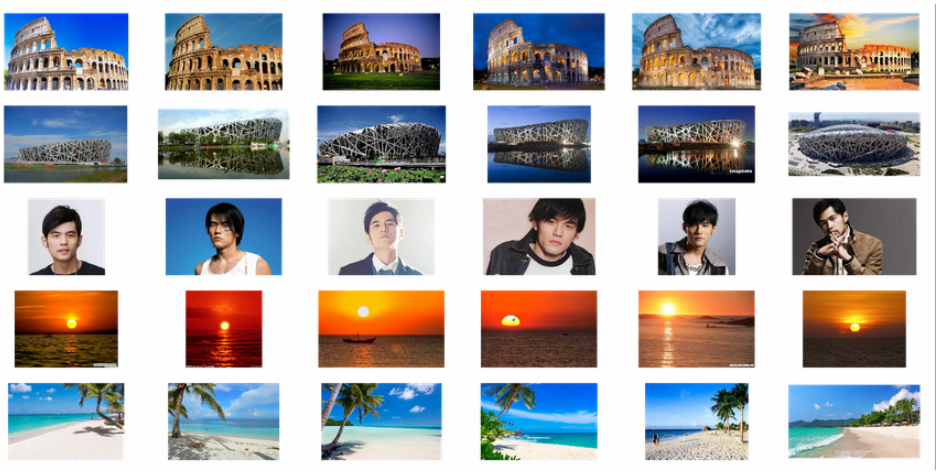

Figure 12: Top 5 retrieval results using ResNet101 features.

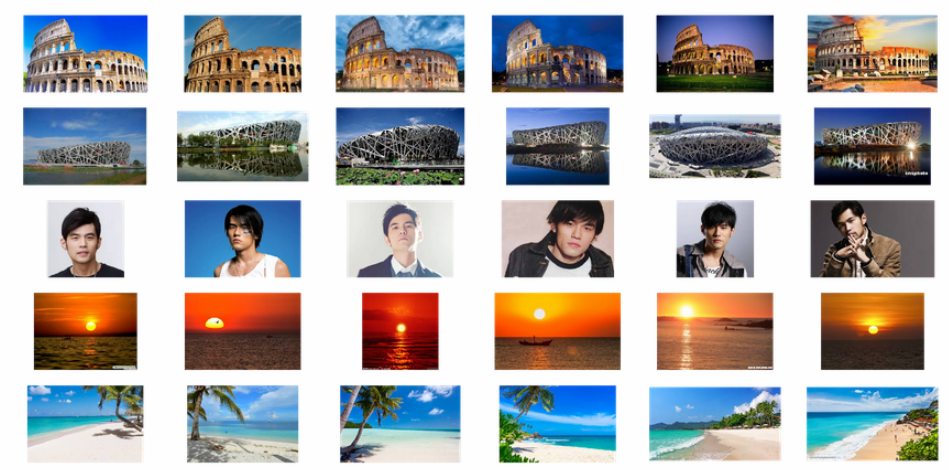

Figure 13: Top 5 retrieval results by fusing filter bank and ResNet101 features.

enence, for example, the top 1 ranking of Jay Chow is different.

C. Propose a method to fuse (or combine) the results in Part-3 and Part-4. Show the five most similar images of each query.

The similarity scores of filter bank and ResNet101 are averages. Top 5 retrieval results are showed in Figure 13. We can see filter bank can influence the ranking. For the third query, top 5 results have no changes, but others all have some changes, for example, the retrieved top 1 of fourth query is different. Personally, I think the fused results are better.

5 COMPETITION

I choose the fusion of ResNet 101 features and filter bank. The reason is just stated in the previous part, the fusion method gives a better top 5 retrieval results from the appearance similarity of the queries. In my opinion, the filter bank can give a supplement for the deep features, i.e., filter bank is able to capture something deep features can not.