16-720: Assignment 1

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1.0: Filter Properties

- There are four different kinds of filters. Each filter is included at 5 scales to capture its feature invariant of the scale.
- The first type of filter is *Gaussian*. It tries to capture blobs with a high intensity center (intensity decreases away from the center) at various scales.
- The second type of filter is *Log*. It tries to capture blobs with a low intensity center (intensity increases away from the center) at various scales.
- The third type of filter is the *Derivative of Gaussian* in the X direction. It captures changes in intensity in the direction of the X axis.
- The fourth type of filter is the *Derivative of Gaussian* in the Y direction. It captures changes in intensity in the direction of the Y axis.

1.1: extractFilterResponses

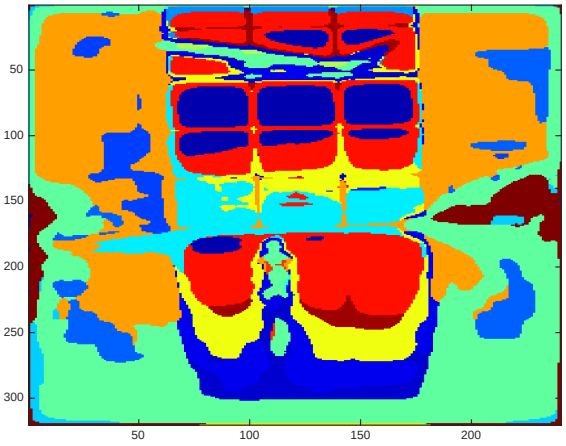
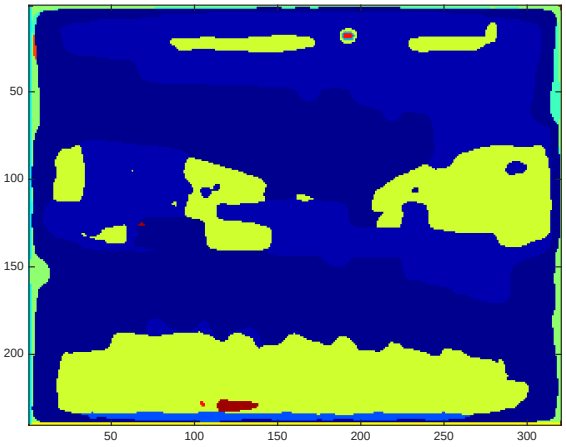
Included in `code/extractFilterResponses.m` file

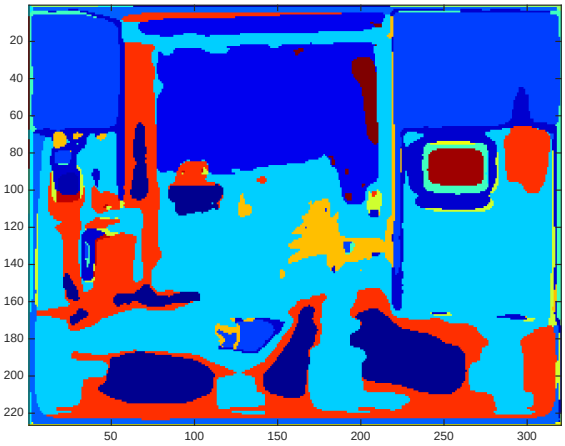
1.2: extractFilterBankAndDictionary

Included in `code/extractFilterBankAndDictionary.m` file

1.3: getVisualWords

Included in `code/getVisualWords.m` file. Results for an image per category are visualized in table (1).

Original Image	Visual WordMap
	
	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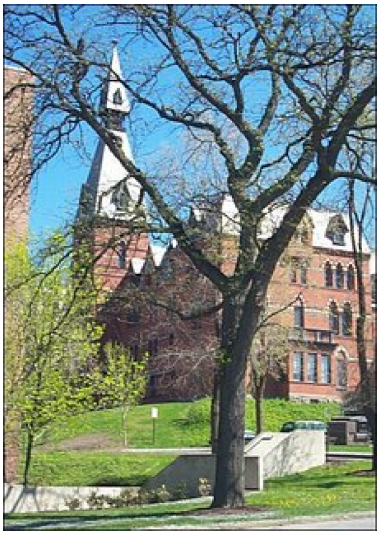

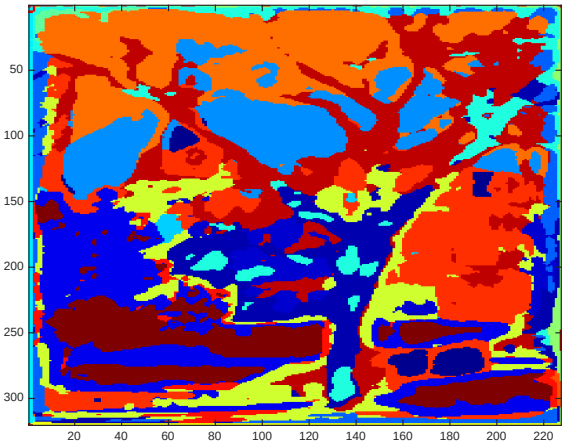
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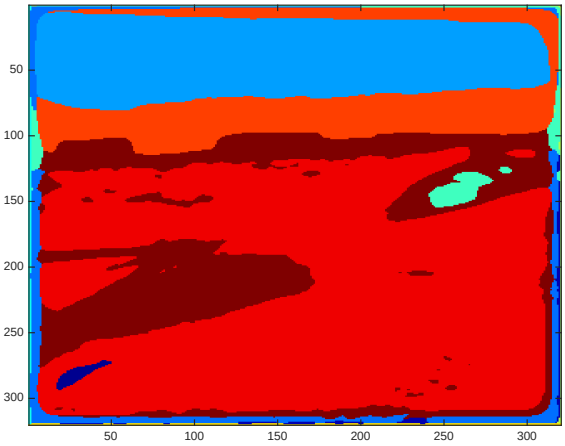
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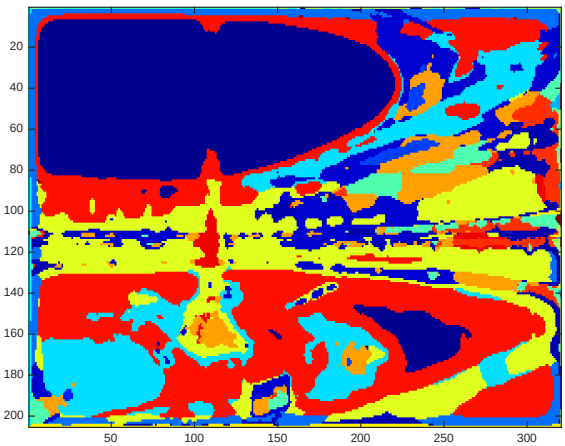
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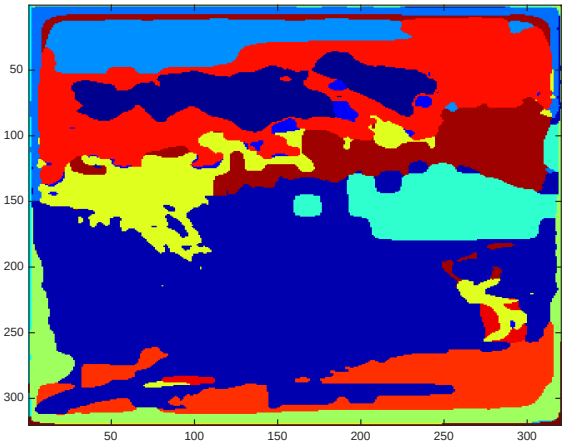
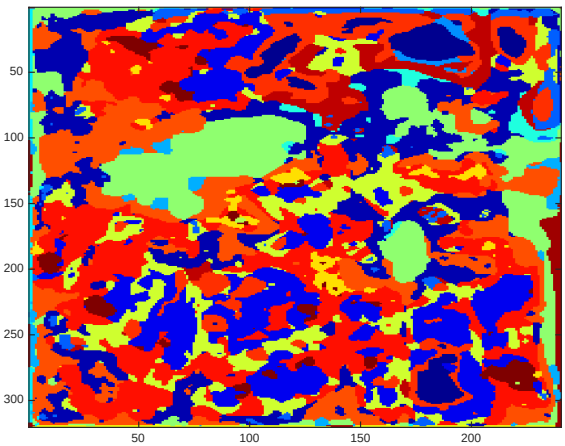
	
	

Table 1: Output of `getVisualWords`

2.1: getImageFeatures

Included in `code/getImageFeatures.m` file

2.2: getImageFeaturesSPM

Included in `code/getImageFeaturesSPM.m` file. It is coded using recursion for readability.

2.3: distanceToSet

Included in `code/distanceToSet.m` file. It uses *bsxfun* for improving performance.

2.4: buildRecognitionSystem

Included in `code/buildRecognitionSystem.m` file

2.5: evaluateRecognitionSystem

Included in `code/evaluateRecognitionSystem.m` file

The accuracy obtained was 51.88%. As we see later, this can be improved to around 61% using the spearman distance metric and $K = 19$ in the KNN classification.

The per class accuracy was as follows:

1	2	3	4	5	6	7	8
airport	auditorium	bedroom	campus	desert	football stadium	landscape	rainforest
55	70	35	40	70	35	30	80

The confusion matrix is as follows:

```
11     3     3     2     0     3     1     3
 1    14     4     0     3     1     1     0
 4     1     7     1     1     0     0     0
 0     0     1     8     1     2     6     0
 1     2     5     2    14     3     3     1
 0     0     0     4     0     7     0     0
 0     0     0     3     1     3     6     0
 3     0     0     0     0     1     3    16
```

3.1: Problems in Accuracy

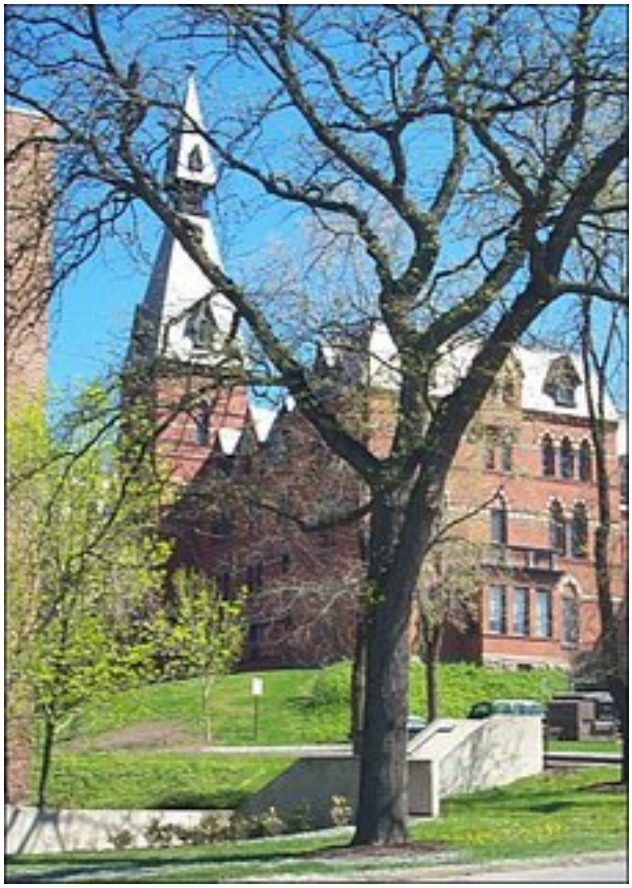
As we can see from the per class accuracy given above, classes with a significantly low accuracy are bedroom, landscape, and football stadium. The highest cross-category number in the confusion matrix is 6 for landscape-campus pair, indicating that many landscape photos are getting confused as campuses. Below are the mistakes that were reported in the classification. The first mistake in each category is in bold font and accompanied by the corresponding image.

Mistake on airport/sun_aerinlrdodkqnypz.jpg classified as auditorium (very plausible)

Mistake on airport/sun_aetygbcukodnyxkl.jpg classified as bedroom
Mistake on airport/sun_aevitxnlfjzhdnti.jpg classified as bedroom
Mistake on airport/sun_aevyxplabnmalatl.jpg classified as bedroom
Mistake on airport/sun_aexdiixgtdqjzjpl.jpg classified as rainforest
Mistake on airport/sun_aexxslabfmbsumkp.jpg classified as rainforest
Mistake on airport/sun_aeyqkdhbapysbwbv.jpg classified as desert
Mistake on airport/sun_afacqjwmeipxtsdu.jpg classified as rainforest
Mistake on airport/sun_afbxsdfksjhcunpb.jpg classified as bedroom
Mistake on auditorium/sun_aadrvlcduunrbpul.jpg classified as airport

Mistake on auditorium/sun_abjkjhdyminvtxsm.jpg classified as airport
Mistake on auditorium/sun_abnptawlxcjefrmi.jpg classified as airport
Mistake on auditorium/sun_abufkgwvilfzdqys.jpg classified as desert
Mistake on auditorium/sun_acsdhbbsybcyxnel.jpg classified as bedroom
Mistake on auditorium/sun_acsxxurtqimfqbog.jpg classified as desert
Mistake on bedroom/sun_aafesxmciavqmkxw.jpg classified as campus

Mistake on bedroom/sun_aaoqcwcewjvnfeps.jpg classified as auditorium
Mistake on bedroom/sun_aaprepyzloaivblt.jpg classified as desert
Mistake on bedroom/sun_aarvhntgsdfxgmmb.jpg classified as auditorium
Mistake on bedroom/sun_aauzqebrqbqgzece.jpg classified as airport
Mistake on bedroom/sun_aaxfqfzrjwrlfwuf.jpg classified as auditorium
Mistake on bedroom/sun_aaxspwgpppcwlqht.jpg classified as airport
Mistake on bedroom/sun_aazccosvjonbhrff.jpg classified as desert
Mistake on bedroom/sun_abfukgjexiwonarv.jpg classified as auditorium
Mistake on bedroom/sun_abgsudgeaejqbwtn.jpg classified as desert
Mistake on bedroom/sun_abkzhpaluuxwcfdk.jpg classified as desert
Mistake on bedroom/sun_abpmyykpuijkvxbq.jpg classified as desert
Mistake on bedroom/sun_absevjzddeawnmko.jpg classified as airport
Mistake on campus/sun_abpxvcuxhqldcvln.jpg classified as football_stadium



Mistake on campus/sun_abslhphpiejdjmpz.jpg classified as football_stadium
Mistake on campus/sun_abwbqwhaqxskvyat.jpg classified as football_stadium
Mistake on campus/sun_aczmgnjjiykpqyts.jpg classified as bedroom
Mistake on campus/sun_adiqdyqsqarvtact.jpg classified as landscape
Mistake on campus/sun_agjdyybkyzxpqips.jpg classified as desert
Mistake on campus/sun_agruqaefvrvumwod.jpg classified as landscape
Mistake on campus/sun_ahdehpqieqxgehgy.jpg classified as landscape
Mistake on campus/sun_ahprylpgnmgqiyuz.jpg classified as airport
Mistake on campus/sun_ahsxqcejwxphkyih.jpg classified as desert
Mistake on campus/sun_ajrlkrwvvsenzpyt.jpg classified as airport
Mistake on campus/sun_akguesajnqnoyszx.jpg classified as football_stadium
Mistake on desert/sun_acztaebqvjaggqyh.jpg classified as auditorium

Mistake on desert/sun_adbymuzeqfdwlerv.jpg classified as auditorium
Mistake on desert/sun_aggpnmjzyopfvkxd.jpg classified as auditorium
Mistake on desert/sun_aiatoxvclffgxjts.jpg classified as campus
Mistake on desert/sun_aijjkofxcvbaoewh.jpg classified as bedroom
Mistake on desert/sun_aimopcdnurqckhhc.jpg classified as landscape
Mistake on football_stadium/sun_aahvylyxdakauexd.jpg classified as airport

Mistake on football_stadium/sun_abcyqxcuxdpbmgkn.jpg classified as airport
Mistake on football_stadium/sun_ajersoqqetrcgtkd.jpg classified as landscape
Mistake on football_stadium/sun_akgsvnkdoawntqoj.jpg classified as desert
Mistake on football_stadium/sun_aliwekqtpmatjrfk.jpg classified as campus
Mistake on football_stadium/sun_ampjzbnckfgejpsl.jpg classified as desert
Mistake on football_stadium/sun_anzijotshmbcendh.jpg classified as auditorium
Mistake on football_stadium/sun_apugcjcmszqqdwxw.jpg classified as rainforest
Mistake on football_stadium/sun_arjxmegqfeavsozz.jpg classified as landscape
Mistake on football_stadium/sun_asqkycmnpaeazziw.jpg classified as landscape

Mistake on football_stadium/sun_atcbgeektodzgvyu.jpg classified as airport
Mistake on football_stadium/sun_ayhhjsfptncuadib.jpg classified as desert
Mistake on football_stadium/sun_bauycdcdmruicjvw.jpg classified as campus
Mistake on landscape/sun_absddryibdeqqvqf.jpg classified as campus

Mistake on landscape/sun_abvvlqznpdszhjnh.jpg classified as rainforest
Mistake on landscape/sun_adbbdotjpvckknnr.jpg classified as campus
Mistake on landscape/sun_adbtakwewxdagnxp.jpg classified as campus
Mistake on landscape/sun_adqxdqlbhuiagrqt.jpg classified as rainforest
Mistake on landscape/sun_aduxybjjxgfhwggu.jpg classified as rainforest
Mistake on landscape/sun_aefbezeufxvlpxgd.jpg classified as desert
Mistake on landscape/sun_aeldkedqeopyedlo.jpg classified as campus
Mistake on landscape/sun_aewjouuoxozhzmsx.jpg classified as auditorium
Mistake on landscape/sun_afhhnevciblqzhjp.jpg classified as campus
Mistake on landscape/sun_afiznkgdkgugndcx.jpg classified as desert
Mistake on landscape/sun_afjdogbpwckftyfl.jpg classified as desert
Mistake on landscape/sun_afliehgwaoiynwcw.jpg classified as airport
Mistake on landscape/sun_ahekiunfgsyehcbg.jpg classified as campus
Mistake on rainforest/sun_aalbylumieujfxrc.jpg classified as desert

Mistake on rainforest/sun_aangkajdydimnqru.jpg classified as airport
Mistake on rainforest/sun_abafooecdwxfwlob.jpg classified as airport
Mistake on rainforest/sun_abuyerbrwfrujntz.jpg classified as airport

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3.2: Improvements in Accuracy

To improve accuracy, I considered varying the number of neighbors in the KNN classification and the distance metric used to calculate the nearest neighbors. This made a huge difference to the accuracy of the algorithm. The results are shown in figure (1); please zoom if the image is not clear. The X axis is the number of nearest neighbors used in the KNN classification, and the Y axis shows the corresponding accuracy. The four curves correspond to four distance metrics - euclidean distance, cityblock distance (also known as manhattan distance), cosine distance, and spearman correlation distance. As we can see from the figure, the accuracy results from the spearman distance metric uniformly dominate other distance metrics at all K. Using spearman distance and $K = 19$, we get the best accuracy of 61.25%. When $K > 6$, spearman distance metric generally gives good accuracy results between 58.75% and 61.25%.

Potential speed improvements that I was not able to implement include (i) performing SVD on the filter bank to reduce the number of filters used or (ii) decomposing axis-aligned separable filters into their X- and Y-axis aligned components and applying them separately. All filters in the provided filter bank are separable and rank-1.

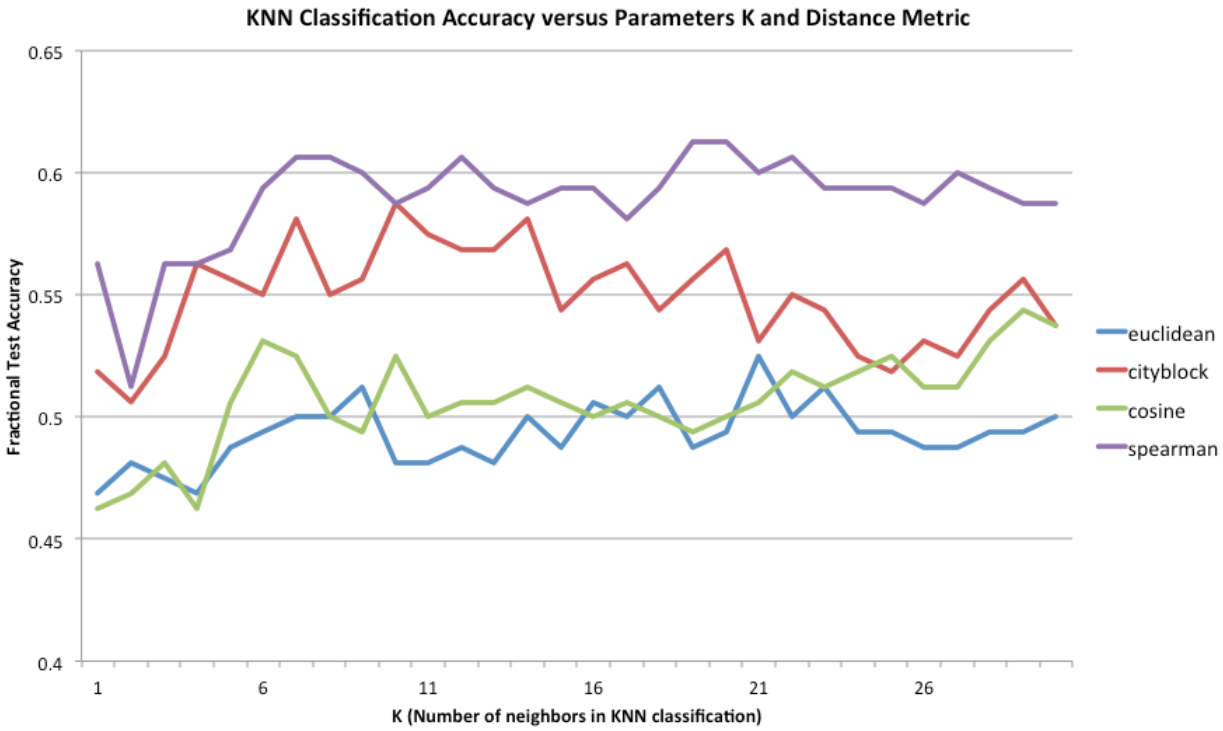

Figure 1: KNN Classification Accuracy versus Parameters K and Distance Metric