Efficiently Retrieving Images that We Perceived as Similar

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Abstract

Despite growing interest in using sparse coding based methods for image classification and retrieval, progress in this direction has been limited by the high computational cost for generating each image's sparse representation. To overcome this problem, we leverage sparsity-based dictionary learning and hash-based feature selection to build a novel unsupervised way to efficiently pick out a query image's most important high-level features that can determine to which group we would visually perceived as similar. The preliminary results based on L1 feature map show the method's efficiency and high accuracy from the visual cognitive perspective. Finally, we consider a more general problem of how to make the pre-learned dictionary to adaptively refine the features contained according to past queries.

Motivation and Introduction

Similar image retrieval has become an important problem with many real-world applications in artificial intelligence field. To be able to process the growing amount of data, more efficient and reliable algorithms are needed. Until now, there is still a lack of an effective guideline to decide similarity for a computer, though the problem posts no difficulty to human beings. This motivated us to incorporate the biology-inspired sparse coding and hashing techniques for more intuitive, real time retrieval results. There are many researches studying about how to make image retrieval effective. Conventionally, there are three steps in large-scale content-based image retrieval when given a set of indexed images and a query image. The first is feature extraction. Many complex approaches are developed to find effective image representation to encode a variety of images. Secondly, dimension reduction is important to speed up the retrieval process. Finally, effective metric is needed to compute the similarity between features. Compared to the traditional framework we propose a different solution without the part of feature extraction to solve this problem by the plausible model of visual cortexsparse coding.

Sparse representation based on an *overcomplete* basis (Olshausen and Field 1996), inspired by mammalian striate cortex mechanism from neural science community has been widely applied in many computer science fields, such as data compression, speech recognition and image denoising, etc. (Sivaram 2010), (Wright et al. 2009). One important property of sparse coding is that it can extract from data higher-level features that are actually more cognitively effective than hand-picked ones by simulating partial activity of neurons. According to promising neural science theory and the high performance of algorithms developed within decades, we assume that sparse coding which simulates mammalian visual cortex activities is a very efficient approach to find the latent features compared to traditional unsupervised learning such as PCA. We also assume that neuron simulation-based approach for image representation is better than other widely used computer vision features including SIFT (Lowe 1999), GIST (Oliva et al. 2001), HOG (Dalal et al. 2005) and etc. because we have our visual system as promising evidence to support.

Some people have images search problem with the representation of sparse codes proposed by (Ge et al. 2013). However, finding sparse codes has high computational costs on doing effective real time search. We propose a novel approach to solve this problem by using overcomplete basis in dictionary rather than computing sparse codes and we will show that our approach is effective in natural image.

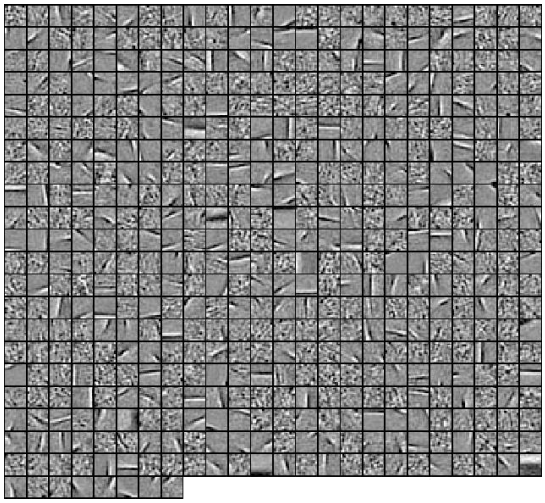

Figure 1: The Learned Dictionary

Preprocessing-Unsupervised dictionary learning

Sparse-based dictionary learning has proven been effective in natural images which are mostly scene image. Given input unlabeled scene images, the effective sparse coding proposed by (Lee et al. 2007) captures succinct feature with higher meanings and generate a dictionary with overcomplete bases which are effective to represent the image in data set given the corresponding sparse code. The basic descriptions such as edges and line segments are efficiently encoded into atoms of dictionary so we will pre-trained the dictionary as our dimension reduction projection bases.

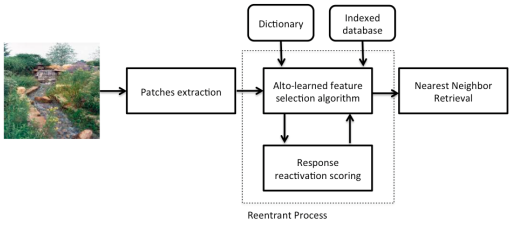

Figure 2: Precision and Recall Curve

System framework

Given a query natural image, we firstly decorrelate the image to equalize the variance which is also employed in preprocessing for dictionary due to potential factual and corrupted and this also roughly simulate spatial-frequency reponse characteristic of retinal ganglion cells proposed by (Olshausen 1997) in our cognitive system. We then uniformly select several image patches to extract a certain pattern of the image. We feed all extracted vectors into our auto-learned feature selection algorithms to encode the data. Finally, we use L2 distance as default metric to compute similarity score. The system diagram is shown in Figure 2.

Auto-learned feature selection algorithms

Since our retrieval framework encode the image pattern of natural images into sparsity-based dictionary, we are motivated to select effective feature, especially those have high response to patches of natural images. Inspired by localitive sensitive hashing proposed by (Andoni et al. 2008), where high dimensional data can be projected to lower dimensional space with similarity preserving promise, we propose our novel algorithm to find out the atom of feature pattern in the dictionary to perform our hash-based dimensional reduction.

Firstly, we project our patches vector onto the atom of dictionary to get the highest values of the result for each vector of patches and have another zero array with the same size. We call those atoms strong responsive to the corresponding patches vector. Then, we set the value of each patches vector at corresponding atom of dictionary to be one.

Secondly, we substract the strong responsive atom from the corresponding patches vector in order to select second strong responsive atom with respect to the corresponding patches vector.

Iteratively, we will rank out the top n strong responsive atoms as our output for each patch vector. By this way, we can encode the raw data directly by the ranking of the response of corresponding atom based on sparsity based dictionary and we will show that the result has some effects consistent with our visual system.

```
Projection = abs(Data*Dictionary)
loop{
    id_column = max_column {projection}
    for i in all patches{
        outputCode(i, id_colmun) = 1
        maxValue = projection(i, id_column)
        reduction(:, i) = maxValue*Dictionary(:, id_column)
    }
    newData = newData – reduction';
    projection = abs(newData*Dictionary)

}
```

Figure 3: Auto-learned feature selection algorithm (ALFSA)

Response Reactivation Scoring

```
loop{
    scoring = zeros( length of total number );
    for i = 1 : reentrantNumber{
        index = index of closet element
        scoring(index) = scoring(index)*1.2
    }
    scoring = scoring*0.9
}
```

Figure 4: Response Reactivation Scoring

Experimental results

We evaluate our approach on a subset of scene images which is a version of MIT SUN dataset, SUN397 scene benchmark, from (!!!). Our subdataset consist of 3,583 scene images that have been grouped into 10 different classes: bamboo_forest, beach, botanical_garden, corridor, cottage_garden, hayfield, mountain_snowy, waterfallBlock, wheat_field, wine_cellearBarrelStorage. Original images in the dataset have different sizes so we resize them into the size of 200x200 pixels. Rather than represent them with the state of the art manual-turned feature, we extract small 14x14 pixels image patches directly by uniform random selection. We call our auto-learned feature selection method ALFS and we will evaluate our method in two parts, the improvement, from naive method to our design alogrithm showing the progress,under our sparsity dictionary and the comparison with the well known human-turned global feature, GIST.

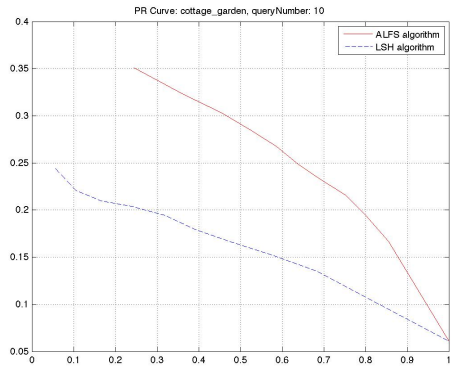

Figure 5: Precision and recall curve

Improvement under sparsity dictioanry framework

Under our sparsity dictioanry framework inspired from neuron activity, we implemented two encoding method: one is our novel ALFS algorithm, which is called Neuron_ALFS in figures. Another one is inspired from localitive sensitive hashing method, projecting the raw images patches onto the learned dictionary, which is our first method to explore the effectiveness of image retrieval under such a novel sparsity dictionary framework. Although LSH-based method requires Gaussian random distribution, it also works fair to be discriminative under our sparse coding framework by simple hash projection on learned dictionary. While we apply this method on our learned basis vector with normal distribution, certain latent similar feature seems to be preserved after the projection to retrieve similar images. We call this naive idea inspired from traditional LSH as Neuron_LSH in figures.

Comparison with Human-tuned feature methods

Due to our scene dataset, to be fair, we employ GIST features to do the evaluation. For comparison, we extract GIST features proposed by (!!!) directly from 200x200 pixels images Due to the most state of the art working under different framework from us, we compare our ALFS method with LSH-based scheme under our spetial sparse coding framework as the baseline and we will show how much we have improved under this novel framework for image retrieval as an example.

not in the paper

We obtained the precision and recall curves by averaging the results of all testing images in every class.

Some points: 1. how do we improve the method under the sparsity dictionary framework 2. the average performance for each query to each category, just to name a few 3. the overall average performance mixing all different kinds of queries to each category.

Figure 3 demonstrates Precision & Recall curves.

- show the recall and precision for some image
- show the result images

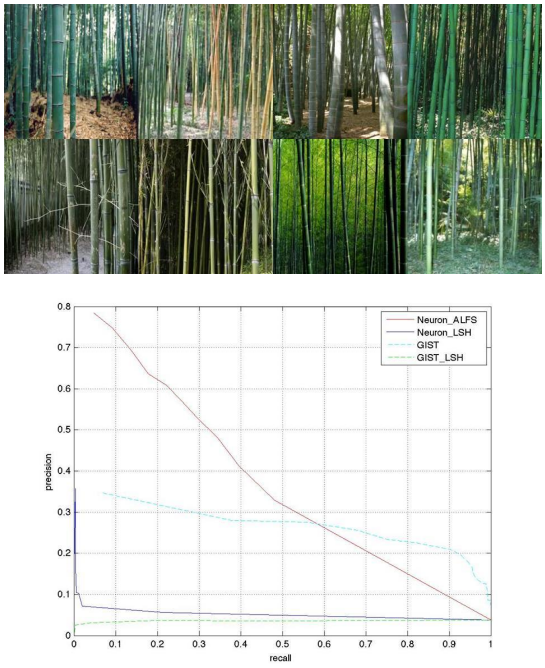

Figure 6: bamboo forest

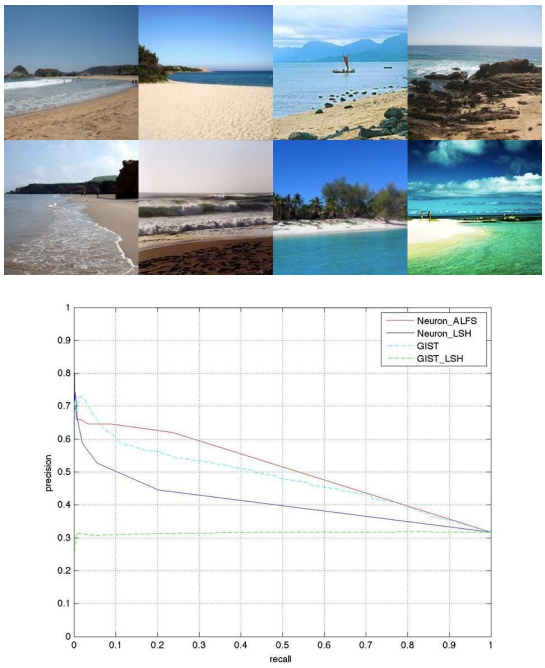

Figure 7: beach

Conclusion

Rather than traditional human-turned feature extraction our cognitive system based on sparse coding successfully combine proposed novel auto-learned feature selection algorithm with sparsity-based dictionary to create ouw own discrim-

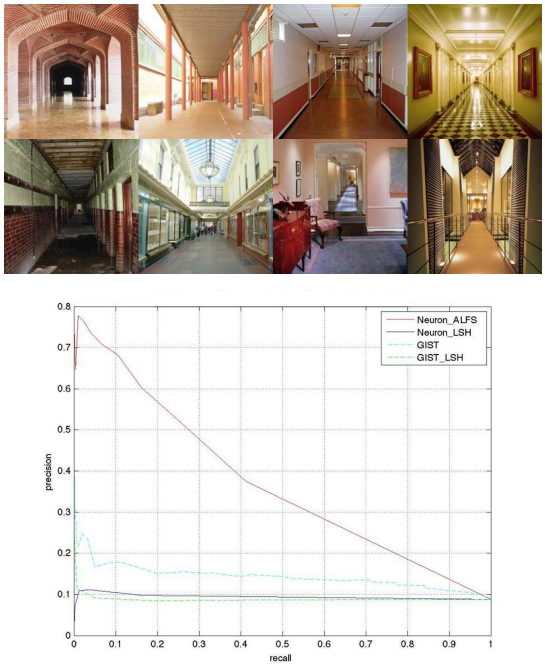

Figure 8: jpg

inative code to retrieve natural images with high performance. The sparsity-based dictionary which capture basic elements consisting a natural image is a well learned structure to encode images. Although it needs more powerful algorithm and research in large-scale image retrieval or other big data, this is the promising direction of relative application.

Discussion

How to work with big data?

When the world is filled with big data, effective approach is needed to deal with such a challenge. Large-scale image with effective and reliable performance is one of examples. Recently, we are attempting to address an open question if there is new approach based our framework to handle this old but not well-solved problem. Our work lies in how we design the connection between visual neuron encoding simulation and image retrieval problem and how we investigate an effective large-sale image retrieval new candidate.

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key sentence

Critical question or point we had better contain or answer:

- **software systems: emulate actual neurophysiological mechanisms and algorithms that support human cognition**
- **what are the emerging machine learning technologies that address the big data challenges implied by cognitive computing applications?**
- **How can cognitive computing techniques improve human computation, and what demands do the latter put on the former?**
- **Sparsity-based techniques and process unstructured data**

Our point:

- **sparse coding**
- **images patches rather than human-turned feature extraction**
- **unsupervised dictionary learning**
- **hashing rather than sparse code computing**
- **large-scale data search (future work and our vision)**
- **effective similarity preservation by auto-learned feature selection algorithm**

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Acknowledgments

AAAI is especially grateful to Peter Patel Schneider for his work in implementing the aaai.sty file, liberally using the ideas of other style hackers, including Barbara Beeton. We also acknowledge with thanks the work of George Ferguson for his guide to using the style and BibTeX files — which has been incorporated into this document — and Hans Guesgen, who provided several timely modifications, as well as the many others who have, from time to time, sent in suggestions on improvements to the AAAI style.

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