Efficiently Retrieving Images that We Perceived as Similar

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

As the amount of digital data grows in unprecedented speed, new opportunities come with new challenges. The real value of big data lies in the ability to extract from it meaningful, even insightful information, rather than the "big" itself. Furthermore, many applications also require information to be retrieved *fast*. *Efficient* similar image retrieval thus becomes an important problem in the field of artificial intelligence with many real-world applications. The task is closely related to the nature of *human cognition* since any definition of *similarity* is meaningful only when it coincides with human feeling. Though the similar-or-not decision comes intuitively in no time for human, to find a well-defined decision guideline for computers is extremely hard. To resolve this stark discrepency that can inhibit human-machine cooperation, in this paper, we propose a novel method that emulates actual neurophysiological mechanisms including *sparse coding* in primary visual cortex (V1), *synaptic plasticity*, and *mutual inhibition* between neurons.

Given unlabeled data, *sparse coding* provides a class of algorithms capable of extracting higher-level features that are actually more cognitively effective than hand-picked ones by emulating partial activity of neurons. The features can be regarded as the most representative building blocks by which the input data can be reconstructed most *efficiently* – highest accuracy with fewest elements used. The features form the bases resemble the *receptive fields* of neurons of in the visual cortex, making sparse coding a more appropriate medium than other widely-used computer vision features such as SIFT (Lowe 1999), GIST (Oliva et al. 2001), HOG (Dalal et al. 2005) etc., to bridge human cognition and algorithmic way of learning.

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.

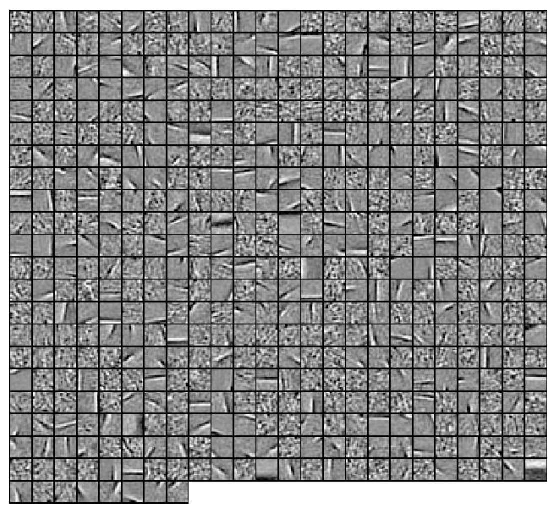

Figure 1: The Learned Dictionary

Offline 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.

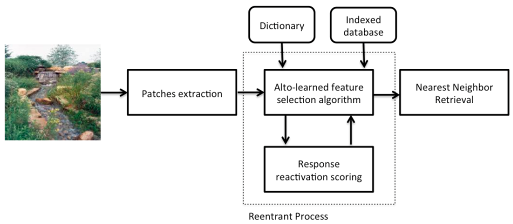

Figure 2: Precision and Recall Curve

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.

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

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 discriminative 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.

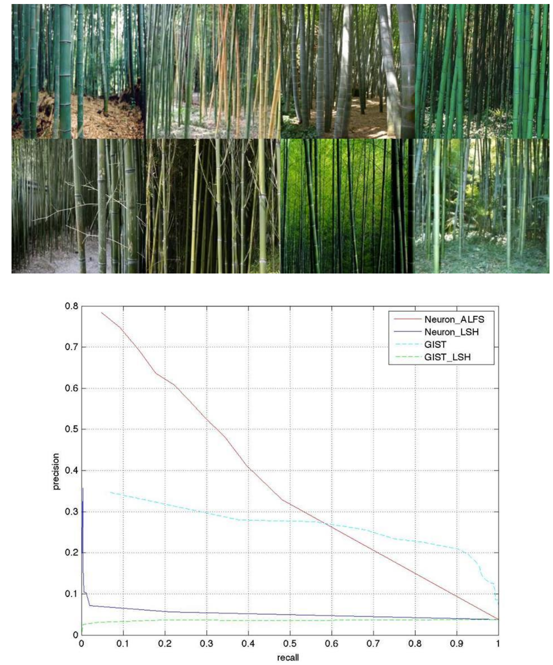

Figure 5: bamboo forest

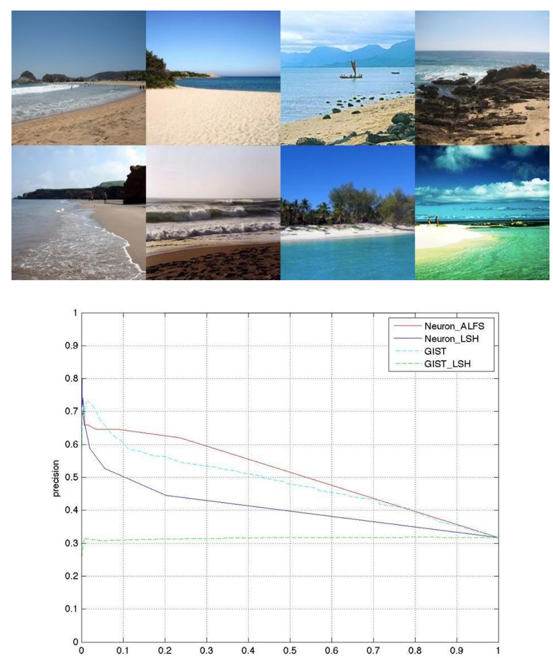

Figure 6: beach

Dictionary is trained off-line, and can take full advantage of the large amount of data.

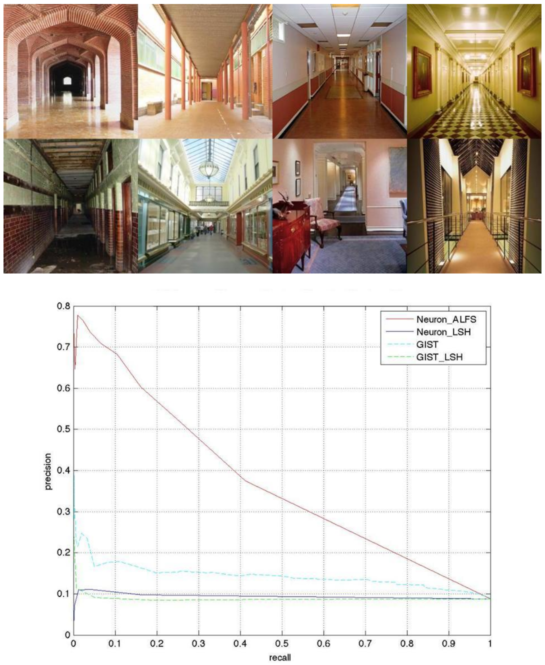

Figure 7: jpg

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Dalal, Navneet, and Bill Triggs. ”Histograms of oriented gradients for human detection.” Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on. Vol. 1. IEEE, 2005.

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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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Engelmore, R., and Morgan, A. eds. 1986. *Blackboard Systems.* Reading, Mass.: Addison-Wesley.

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Robinson, A. L. 1980a. New Ways to Make Microcircuits Smaller. *Science* 208: 1019–1026.

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Hasling, D. W.; Clancey, W. J.; and Rennels, G. R. 1983. Strategic Explanations in Consultation. *The International Journal of Man-Machine Studies* 20(1): 3–19.

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Clancey, W. J. 1979b. Transfer of Rule-Based Expertise through a Tutorial Dialogue. Ph.D. diss., Dept. of Computer Science, Stanford Univ., Stanford, Calif.

Forthcoming Publication
Clancey, W. J. 1986a. The Engineering of Qualitative Models. Forthcoming.

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> This is an example of an extract or quotation. Note the indent on both sides. Quotation marks are not necessary if you offset the text in a block like this, and properly identify and cite the quotation in the text.

Footnotes

Avoid footnotes as much as possible; they interrupt the reading of the text. When essential, they should be consecutively numbered throughout with superscript Arabic numbers. Footnotes should appear at the bottom of the page, separated from the text by a blank line space and a thin, half-point rule.

Headings and Sections

When necessary, headings should be used to separate major sections of your paper. Remember, you are writing a short paper, not a lengthy book! An overabundance of headings will tend to make your paper look more like an outline than a paper.

First-level heads should be twelve-point Times Roman bold type, mixed case (initial capitals followed by lower case on all words except articles, conjunctions, and prepositions, which should appear entirely in lower case), with fifteen-point leading, centered, with one blank line preceding them and three additional points of leading following them. Second-level headings should be eleven-point Times Roman bold type, mixed case, with thirteen-point leading, flush left, with one blank line preceding them and three additional points of leading following them. Do not skip a line between paragraphs. Third-level headings should be run in with the text, ten-point Times Roman bold type, mixed case, with twelve-point leading, flush left, with six points of additional space preceding them and no additional points of leading following them.

Section Numbers The use of section numbers in AAAI Press papers is optional. To use section numbers in LaTeX, uncomment the setcounter line in your document preamble and change the 0 to a 1 or 2. Section numbers should not be used in short poster papers.

Section Headings. Sections should be arranged and headed as follows:

Acknowledgments. The acknowledgments section, if included, appears after the main body of text and is headed "Acknowledgments." This section includes acknowledgments of help from associates and colleagues, credits to sponsoring agencies, financial support, and permission to publish. Please acknowledge other contributors, grant support, and so forth, in this section. Do not put acknowledgments in a footnote on the first page. If your grant agency requires acknowledgment of the grant on page 1, limit the footnote to the required statement, and put the remaining acknowledgments at the back. Please try to limit acknowledgments to no more than three sentences.

Appendices. Any appendices follow the acknowledgments, if included, or after the main body of text if no acknowledgments appear.

References The references section should be labeled "References" and should appear at the very end of the paper (don't end the paper with references, and then put a figure by itself on the last page). A sample list of references is given later on in these instructions. Please use a consistent format for references. Poorly prepared or sloppy references reflect badly on the quality of your paper and your research. Please prepare complete and accurate citations.

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The illustration number and caption should appear under the illustration. Labels, and other text in illustrations must be at least nine-point type.

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Journal Article
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Magazine Article
Hasling, D. W.; Clancey, W. J.; and Rennels, G. R. 1983. Strategic Explanations in Consultation. *The International Journal of Man-Machine Studies* 20(1): 3–19.

Proceedings Paper Published by a Society
Clancey, W. J. 1983b. Communication, Simulation, and Intelligent Agents: Implications of Personal Intelligent Machines for Medical Education. In Proceedings of the Eighth International Joint Conference on Artificial Intelligence, 556–560. Menlo Park, Calif.: International Joint Conferences on Artificial Intelligence, Inc.

Proceedings Paper Published by a Press or Publisher
Clancey, W. J. 1984. Classification Problem Solving. In *Proceedings of the Fourth National Conference on Artificial Intelligence,* 49–54. Menlo Park, Calif.: AAAI Press.

University Technical Report
Rice, J. 1986. Poligon: A System for Parallel Problem Solving, Technical Report, KSL-86-19, Dept. of Computer Science, Stanford Univ.

Dissertation or Thesis
Clancey, W. J. 1979b. Transfer of Rule-Based Expertise through a Tutorial Dialogue. Ph.D. diss., Dept. of Computer Science, Stanford Univ., Stanford, Calif.

Forthcoming Publication
Clancey, W. J. 1986a. The Engineering of Qualitative Models. Forthcoming.

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LaTeX is a difficult program to master. If you've used that software, and this document didn't help or some items were not explained clearly, we recommend you read Michael Shell's excellent document (testflow doc.txt V1.0a 2002/08/13) about obtaining correct PS/PDF output on LaTeX systems. (It was written for another purpose, but it has general application as well). It is available at www.ctan.org in the tex-archive.

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.

The preparation of the LaTeX and BibTeX files that implement these instructions was supported by Schlumberger Palo Alto Research, AT&T Bell Laboratories, Morgan Kaufmann Publishers, The Live Oak Press, LLC, and AAAI Press. Bibliography style changes were added by Sunil Issar. \pubnote was added by J. Scott Penberthy. George Ferguson added support for printing the AAAI copyright slug. Additional changes to aaai.sty and aaai.bst have been made by the AAAI staff.

Thank you for reading these instructions carefully. We look forward to receiving your electronic files!