

# 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 discrepancy 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.

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 cortex sparse 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.

## 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

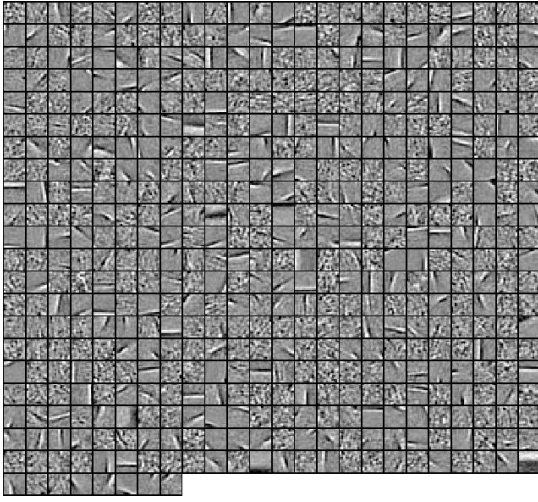


Figure 1: The Learned Dictionary

as our dimension reduction projection bases.

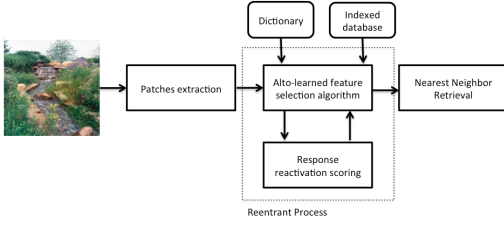


Figure 2: Precision and Recall Curve

## System framework

Given a query natural image, we firstly decorrelate the image to equalize the variance which is also employed in pre-processing for dictionary due to potential factual and corrupted and this also roughly simulate spatial-frequency response 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 subtract 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{
    idcolumn = maxcolumn{projection}
    for i in all patches{
        outputCode(i, idcolumn) = 1
        maxValue = projection(i, idcolumn)
        reduction(:, i) = maxValue*Dictionary(:, idcolumn)
    }
    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\_cellarBarrelStorage. 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-tuned 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 algorithm showing the progress, under our sparsity dictionary and the comparison with the well known human-tuned global feature, GIST.

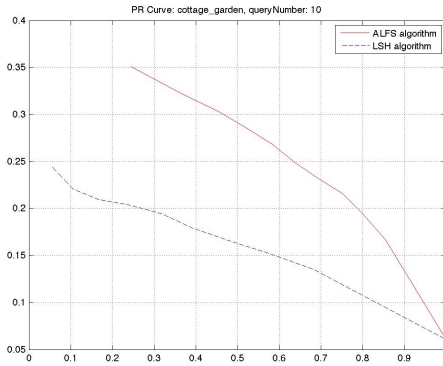


Figure 5: Precision and recall curve

### Improvement under sparsity dictionary framework

Under our sparsity dictionary framework inspired from neuron activity, we implemented two encoding methods: one is our novel ALFS algorithm, which is called Neuron\_ALFS in figures. Another one is inspired from local sensitive hashing method, projecting the raw image 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 fairly 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 spatial 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

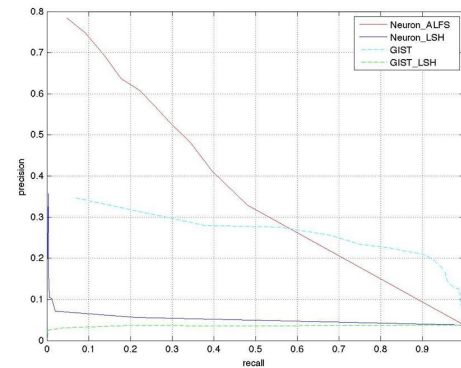


Figure 6: bamboo forest

## Conclusion

Rather than traditional human-tuned feature extraction our cognitive system based on sparse coding successfully combines proposed novel auto-learned feature selection algorithm with sparsity-based dictionary to create our own discriminative code to retrieve natural images with high performance. The sparsity-based dictionary which captures basic elements consisting of 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 on our framework to handle this

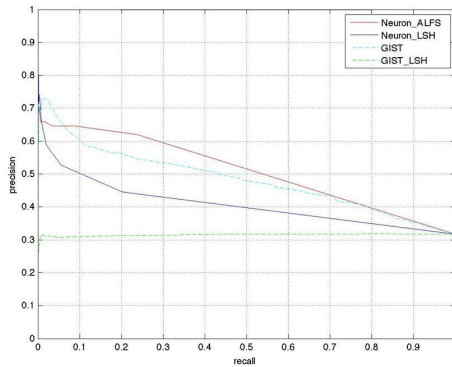


Figure 7: beach

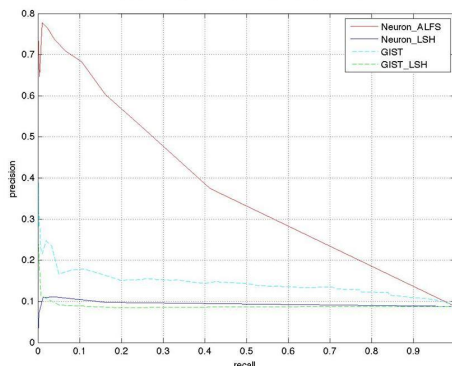


Figure 8: jpg

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.

Dictionary is trained off-line, and can take full advantage

of the large amount of data.

## References

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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**

#### *Book with Multiple Authors*

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

#### *Journal Article*

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#### *Magazine Article*

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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.

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```
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The abstract must be placed at the beginning of the first column, indented ten points from the left and right margins. The title Abstract should appear in ten-point bold type, centered above the body of the abstract. The abstract should be set in nine-point type with ten-point leading. This concise, one-paragraph summary should describe the general thesis and conclusion of your paper. A reader should be able to learn the purpose of the paper and the reason for its importance from the abstract. The abstract should be no more than two hundred words in length. (Authors who are submitting short one- or two-page extended extracts should provide a short abstract of only a sentence or so.) **Do not include references in your abstract!**



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Figures, drawings, tables, and photographs should be placed throughout the paper near the place where they are first discussed. Do not group them together at the end of the paper. If placed at the top or bottom of the paper, illustrations may run across both columns. Figures must not invade the top, bottom, or side margin areas. Figures must be inserted using the `\usepackage{graphicx}`. Number figures sequentially, for example, figure 1, and so on.

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```
\bibliographystyle{aaai} \bibliography{bibfile1,bibfile2,...}
```

The list of files in the `\bibliography` command should be the names of your BibTeX source files (that is, the `.bib` files referenced in your paper).

The following commands are available for your use in citing references:

`\cite`: Cites the given reference(s) with a full citation. This appears as “(Author Year)” for one reference, or “(Author Year; Author Year)” for multiple references.

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`\citeauthor`: Cites the given reference(s) with just the author

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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.

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

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By using the PDF<sup>A</sup>T<sub>E</sub>X program instead of straight L<sup>A</sup>T<sub>E</sub>X or T<sub>E</sub>X, you will probably avoid the type 3 font problem altogether (unless you use a package that calls for metafont). PDFL<sup>A</sup>T<sub>E</sub>X enables you to create a PDF document directly from L<sup>A</sup>T<sub>E</sub>X source. The one requirement of this software is that all your graphics and images must be available in a format that PDFL<sup>A</sup>T<sub>E</sub>X understands (normally PDF).

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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 BibT<sub>E</sub>X 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 Bib $\TeX$  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 Isar. `\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.

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