Hierarchical Classification of Images by Sparse Approximation

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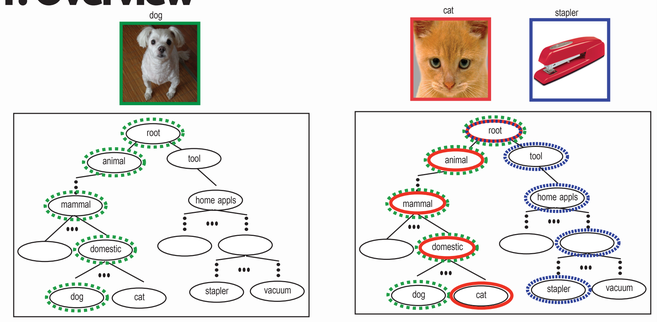
1. Overview

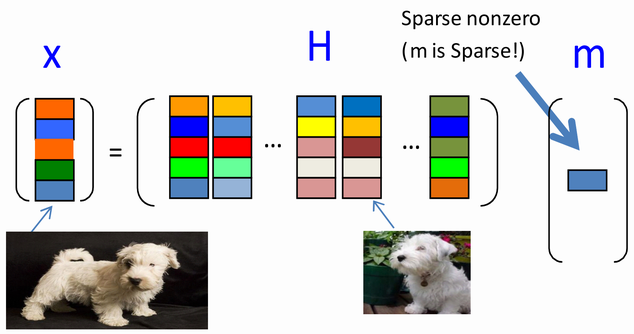


- A new hierarchical classification scheme by sparse approximation
  - Leverages large scale hierarchical data to enable accurate hierarchical classification
  - Introduce a distance function that takes into account the hierarchical structure of the visual categaories
  - Define two images to be similar if they share a similar path in the hierarchy

- Achieves better performances than flat 1-vs-N classification

2. Representation

- We assume that the database contains a dominant object.



H : Model matrix from all images in the training set

m : mixing vector

- BoW (pyramid) representation is used to model images.
- Each column of H is an histogram of codewords

- Goal: Estimate m, s.t. $x=Hm$

3. Flat Sparse Approximation

Problem 0. $\min \|m\|_0 \quad \text{subject to} \quad \|Hm-x\|_2 \le \varepsilon.$

- Ideal Sparse Approximiation, but NP-hard

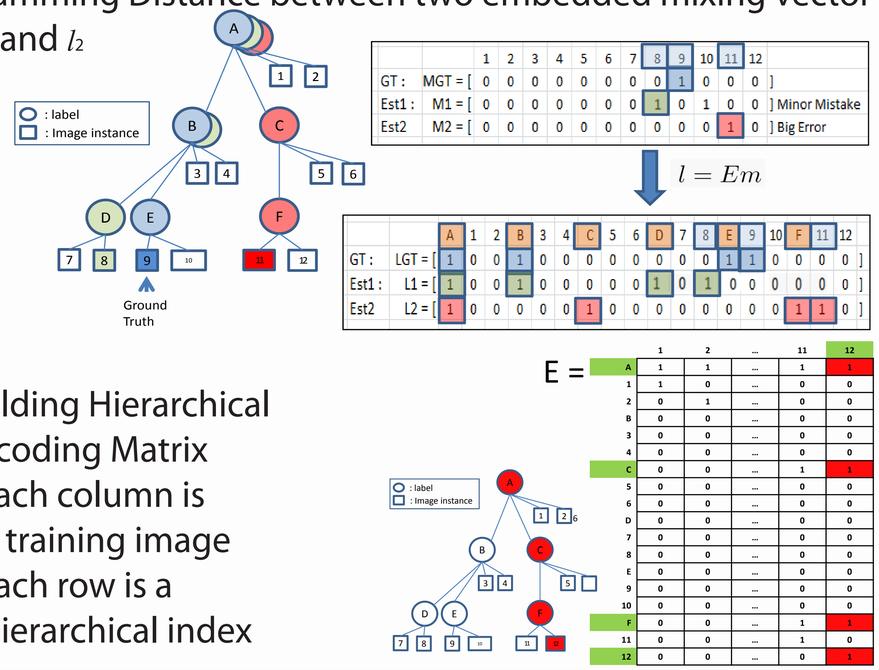
Problem 1. $\min \|m\|_1 \quad \text{subject to} \quad \|Hm-x\|_2 \le \varepsilon.$

- Convex Optimization problem
- When m is sparse, the solution is same to the $Problem\ 0$.
- It guarantees that $\|\hat{m}-m_{GT}\|_p \le e_1$, p=1 or 2
- Orthogonal Matching Pursuit (OMP) can solve this problem

4. Hierarchical Embedding

- Distance Metric for Hierarchical Data

Hamming Distance between two embedded mixing vector l_1 and l_2



- Building Hierarchical Encoding Matrix
  - Each column is a training image
  - Each row is a hierarchical index

5. Hierarchical Sparse Approximiation

Problem 2. $\min \|\ell\|_1 \quad \text{subject to} \quad \|\Phi\ell-x\|_2 \le \varepsilon$

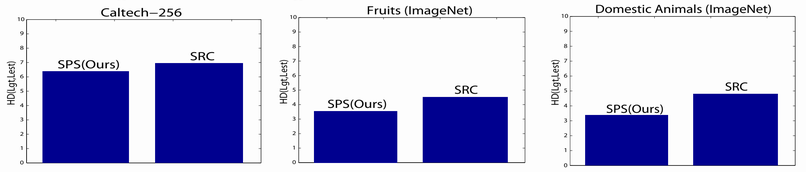
- Solved by Tree Orthogonal Matching Pursuit (TOMP)

6. Classification Algorithm

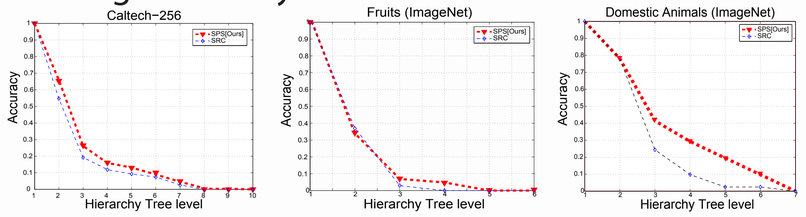
1. Extract a histogram of codewords 'x' from a query image.
2. Generate $\hat{\ell}$ by solving the problem 2. (Note: $\hat{\ell}$ takes continuous value.)
3. Convert $\hat{\ell}$ to binary values (0, 1) by using a learned threshold. This allows to determine a path in the hierarchy. (Note: Thressholds are learned with SVM on a validation set.)
4. The path on the hierarch provides classification results.

7. Results

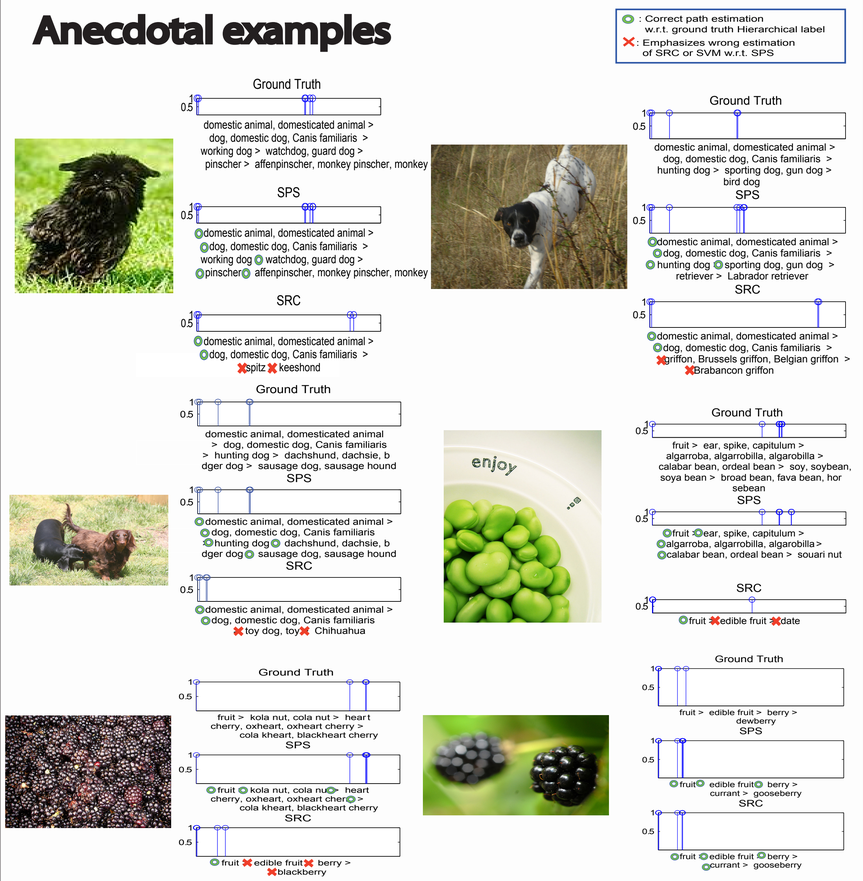
- Average hamming distance



- Average accuracy for different hierarchical levels



Anecdotal examples



8. Conclusion

- New framework for hierarchical classification using sparse approximation
- Hierarchical structure used to enhance classification accuracy.

References

[1] J. Wright et al., PAMI 2009
[2] C. La and M.N. Do, ICIP 2006