BOOSTED DICTIONARIES FOR IMAGE RESTORATION BASED ONSPARSE REPRESENTATIONS

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Sparse Models vs. Representations

- Better encoding or "Representation" schemes perform better for a given best sparse model called the "Dictionary".
- Recent results show that a simple k-means based dictionary or just using random examples from the training data perform well [1].
- **Weak Sparse Models:**
  - Weaker models from small subsets of training data.
  - *Can we combine **multiple weak sparse models** to improve performance?*
- **Weak Representations:**
  - 1-sparse representations / Correlate-and-Maximize.
  - *Can we combine **multiple weak representations** from **weak sparse models** to improve performance?*
- **Ensemble Approach:**
  - For the data x, compute L sparse approximations, each using a different dictionary $\mathbf{D}_{l+1}$

$$\{\mathbf{D}_1\mathbf{a}_1, \mathbf{D}_2\mathbf{a}_2, \ldots, \mathbf{D}_L\mathbf{a}_L\}$$

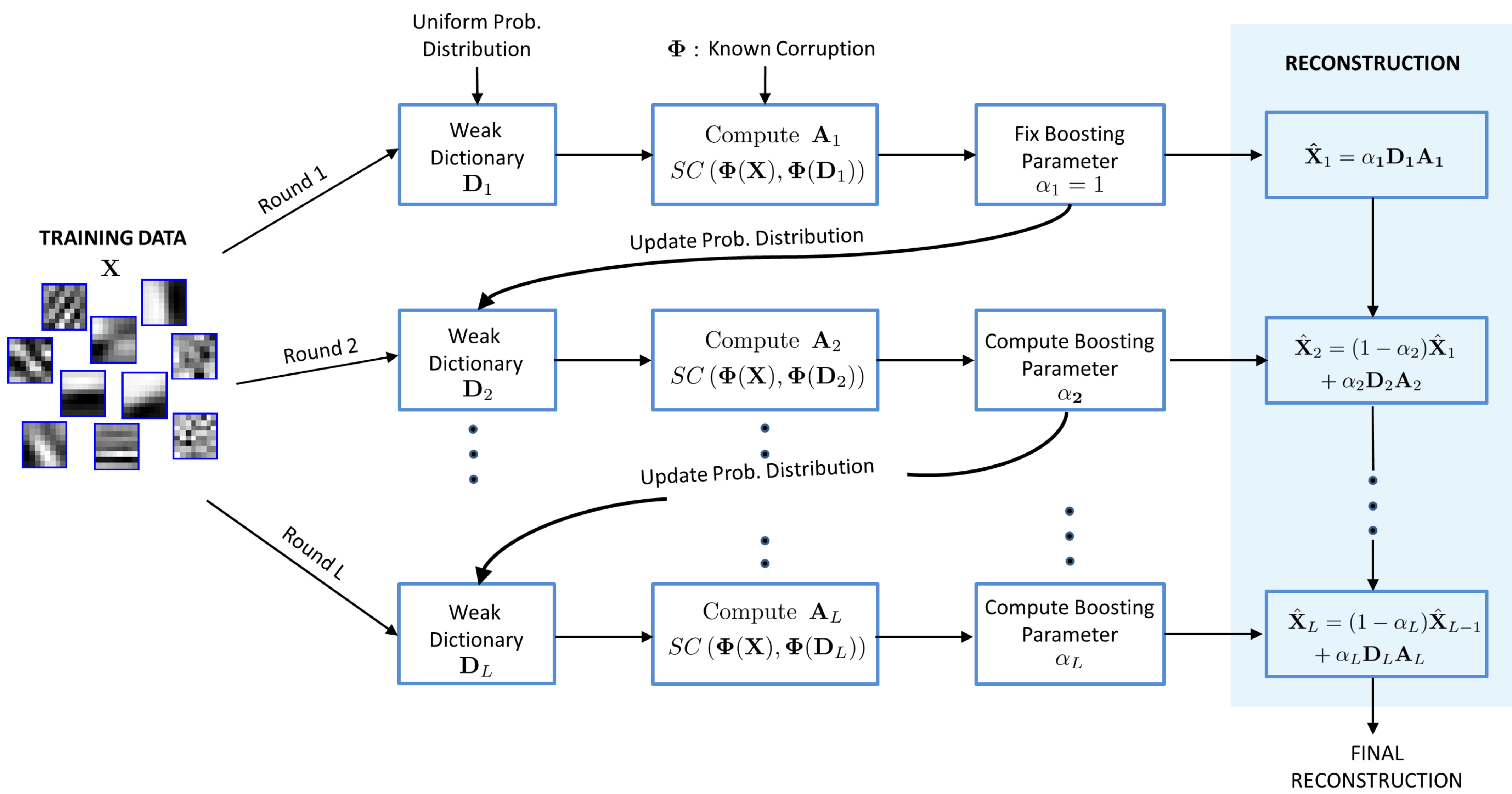
  - The ensemble approximation of x is the linear combination

$$\sum_{l=1}^{L} \boxed{\beta_l}\mathbf{D}_l\mathbf{a}_l$$

Parameters of the ensemble

- **Advantages of Ensemble Approach[2]:**
  - **Statistical:** Better approximation of test data.
  - **Computational:** Avoid local optimal in large datasets.
  - **Representational:** Overcomes hypothesis space limitations of single model.

Application: Image Restoration



- **Degradation Aware Boosting:**
  - Random-projection based compressive sensing. Measurement matrices have i.i.d. Gaussian entries.
  - Boosted dictionaries optimized to degradation. Knowledge of only the form of degradation is sufficient.

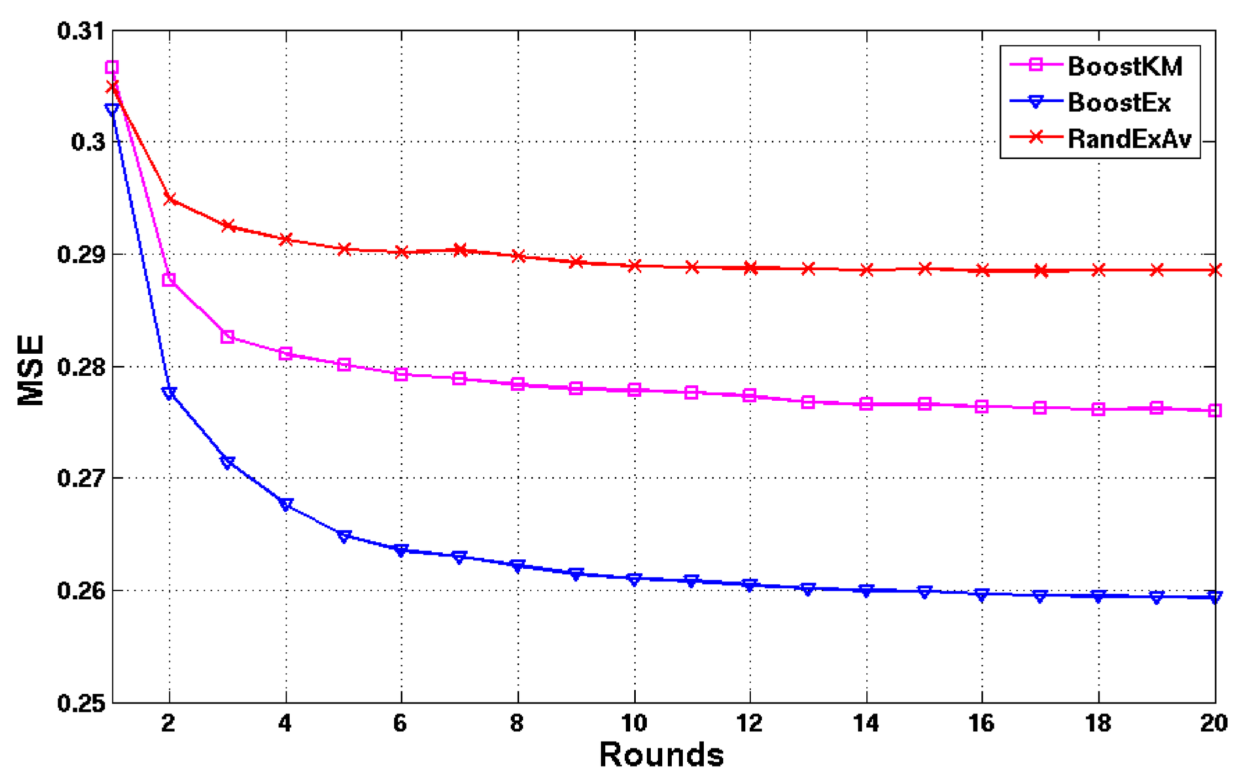
- **Weak Dictionaries Used:**
  - Boosted Example Selection (**BoostEx**)
    - In each round, $\mathbf{D}_l$ is a normalized set of K examples chosen according to $\{p(\mathbf{x}_i)\}$
  - Boosted K-Means (**BoostKM**)

$$\min_{\{\boldsymbol{\mu}_k\}_{k=1}^K, \{\mathcal{M}_k\}_{k=1}^K} \sum_{k=1}^{K} \sum_{i \in \mathcal{M}_k} p(\mathbf{x}_i)\|\mathbf{x}_i - \boldsymbol{\mu}_k\|_2^2$$

    - Dictionary elements are just the normalized initial cluster centers.
- **Weak Representations and Boosting[3]:**
  - Greedy forward selection model

$$\mathbf{X}_l = (1-\alpha_l)\mathbf{X}_{l-1} + \alpha_l\mathbf{D}_l\mathbf{A}_l$$

  - Final approximation is an affine combination of the individual approximations.
  - The weights $\{\alpha_l\}$ have a one-to-one mapping to $\{\beta_l\}$.
  - $\mathbf{D}_{l+1}$ is chosen to well-represent samples poorly approximated by $\mathbf{D}_l$



Error convergence of proposed ensemble models

Compressed Recovery Of Standard Images: PSNR (Db)

Image	Number Of Measurements (N)								
	N = 8			N=16			N=32		
	Alt-Opt	KM-Boost	EX-Boost	Alt-Opt	KM-Boost	EX-Boost	Alt-Opt	KM-Boost	EX-Boost
Barbara	21.39	21.82	**22.05**	22.65	23.37	**23.76**	24.94	25.64	**26.34**
Boat	23.35	**23.91**	23.82	25.72	26.38	**26.42**	28.54	28.83	**29.32**
Couple	23.41	**24.04**	23.94	25.74	**26.51**	**26.51**	28.62	29.18	**29.60**
Fingerprint	18.40	**19.16**	18.83	21.52	**22.70**	22.34	24.97	**26.17**	26.16
House	24.84	**25.52**	25.29	27.73	**28.62**	28.44	30.97	31.66	**31.97**
Lena	25.51	**26.16**	25.94	28.12	**28.86**	28.82	30.99	31.50	**31.85**
Man	24.18	**24.75**	24,69	26.43	27.10	**27.23**	29.27	29.74	**30.24**
Peppers	21.54	**22.11**	21.99	24.08	24.60	**24.66**	27.20	27.34	**27.89**

[1] Coates, Adam, and Andrew Y. Ng. "The importance of encoding versus training with sparse coding and vector quantization." International conference on machine learning. Vol. 8. 2011.
[2] Dietterich, Thomas G. "Ensemble methods in machine learning." Multiple classifier systems. Springer Berlin Heidelberg, 2000. 1-15.
[3] Freund, Yoav, Robert Schapire, and N. Abe. "A short introduction to boosting."Journal-Japanese Society For Artificial Intelligence 14.771-780 (1999): 1612.

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