Hash Bit Selection: a Unified Solution for Selection Problems in Hashing

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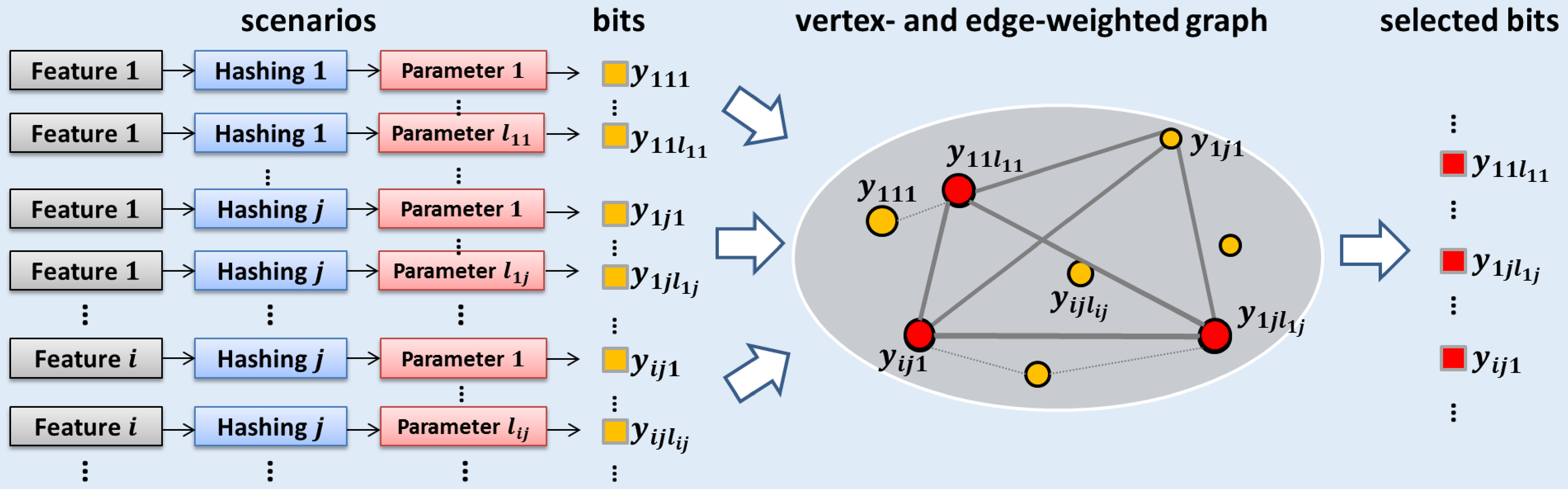
1. Overview

● **Problem:** to apply hashing techniques successfully, there are several important issues remaining open in selecting features, hashing algorithms, parameter settings, kernels, etc.

● **Motivation:** similar to feature selection, give a unified solution that can directly ***select the most desirable subset of hash bits*** from different bit sources, targeting the specific scenario.

● **Scenarios:** hashing with multiple features, multiple hashing algorithms, multi-bit hashing algorithms, etc.



2. Hash Bit Selection

● **Goal:** to exploit a small bit subset $\mathcal{S}$ (of size l) from the pooled L types of bits with index set $V = \{1, \ldots, L\}$

● **Criteria:** two properties critical for compact hash codes

A. similarity preservation: $\pi_i = \exp\left(-\gamma \mathbf{y}_i \mathcal{L} \mathbf{y}_i^T\right)$

B. mutual independence: $a_{ij} = \exp\left[-\lambda \sum_{b_i, b_j} p(b_i, b_j) \log \frac{p(b_i, b_j)}{p(b_i)p(b_j)}\right]$

● **Formulation:** a quadratic programming (QP) solved efficiently

$$\begin{array}{ll} \max & \frac{1}{2}\mathbf{x}^T \hat{A} \mathbf{x} \\ \text{s.t.} & \mathbf{x} \in \Omega \end{array}$$

$$\Omega = \{\mathbf{x} \in \{0,1\}^L : |\mathbf{x}|_0 = l\} \xrightarrow{\text{relax}} \{\mathbf{x} \in \mathbb{R}^L : \mathbf{x} \geq 0 \text{ and } \mathbf{1}^T\mathbf{x} = 1\}$$

Cohesiveness between bits: $\hat{A} = \Pi A \Pi$, satisfying:

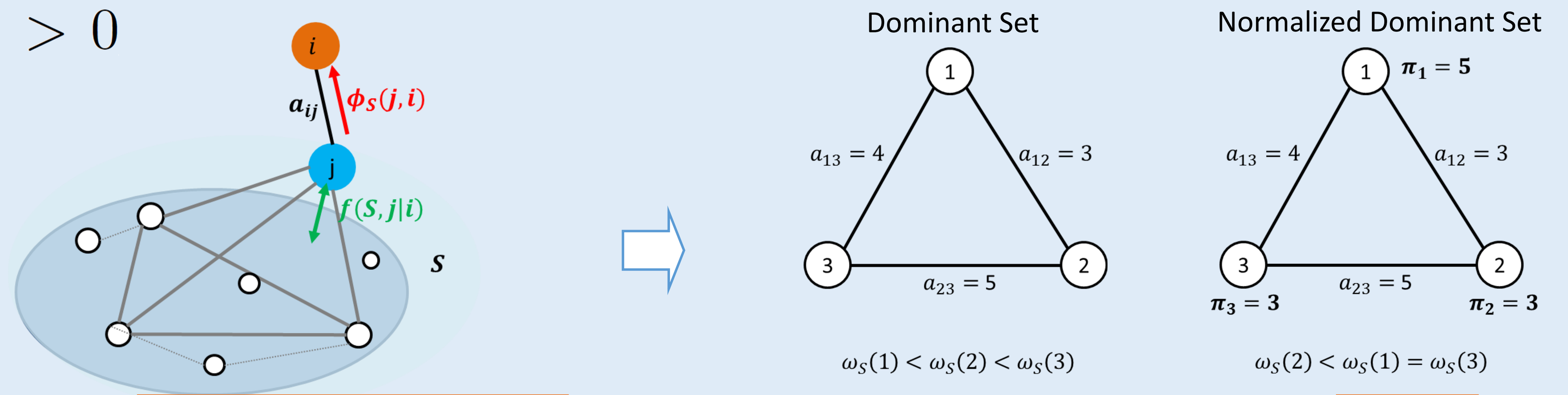
$$\hat{A}_{ij} \geq 0, \hat{A}_{ij} = \hat{A}_{ji}, \text{ and } \hat{A}_{ij} \propto \pi_i, \pi_j \text{ and } a_{ij}$$

3. Theoretic Analysis

● **Graph representation:** represent the pooled bits as a vertex-weighted and undirected edge-weighted graph $G = (V, E, A, \pi)$

● **Normalized dominant set (NDomSet):** bit selection is equivalent to the discovery of a normalized dominant set that has high internal vertex weights and edge weights

● **Induced vertex weights:** naturally score each vertex, and a NDomSet has $w_S(i) > 0$

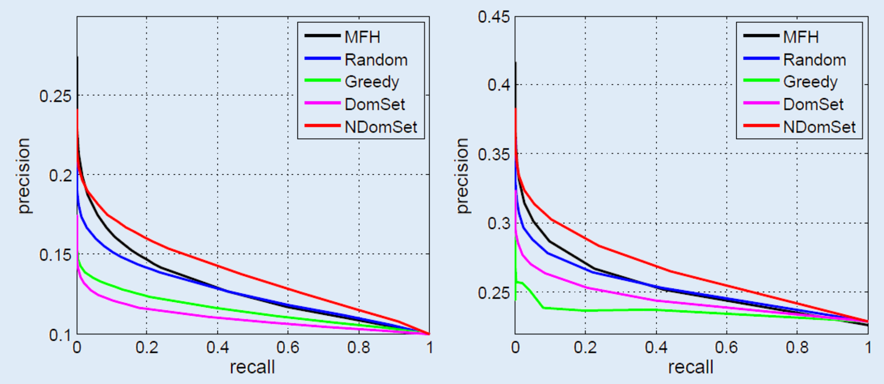


external connection $\phi_S(j,i) = \frac{\pi_j}{\pi_i}(a_{ji} - f(S,j|i))$ induced vertex weights $w_S(i) = \sum_{j \in S\setminus\{i\}} \phi_{S\setminus\{i\}}(j,i) w_{S\setminus\{i\}}(j)$

● **Connections with QP:** the non-zero elements of the local optima of the QP problem form the normalized dominant set

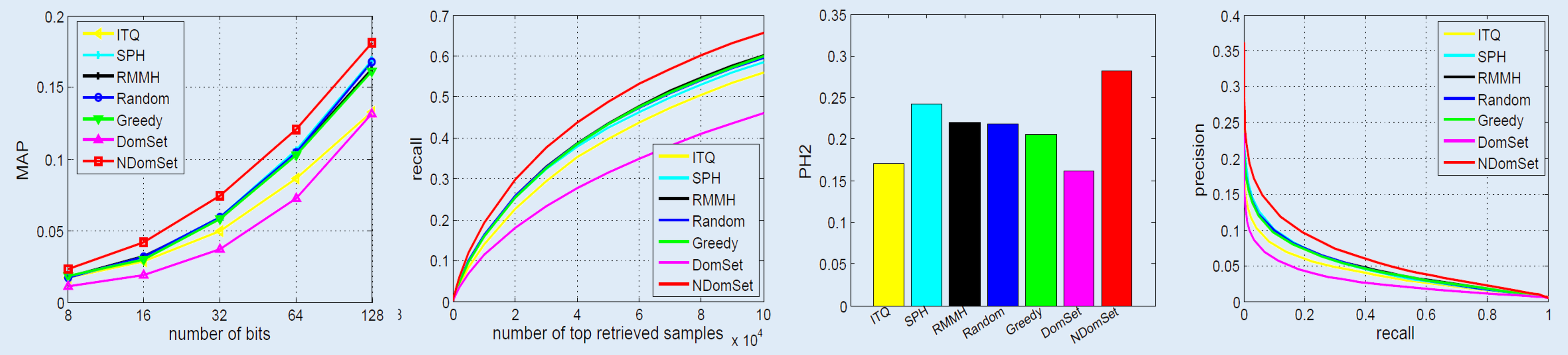
4. Experimental Results

● **with multiple features:** CIAFR-10 and NUS-WIDE

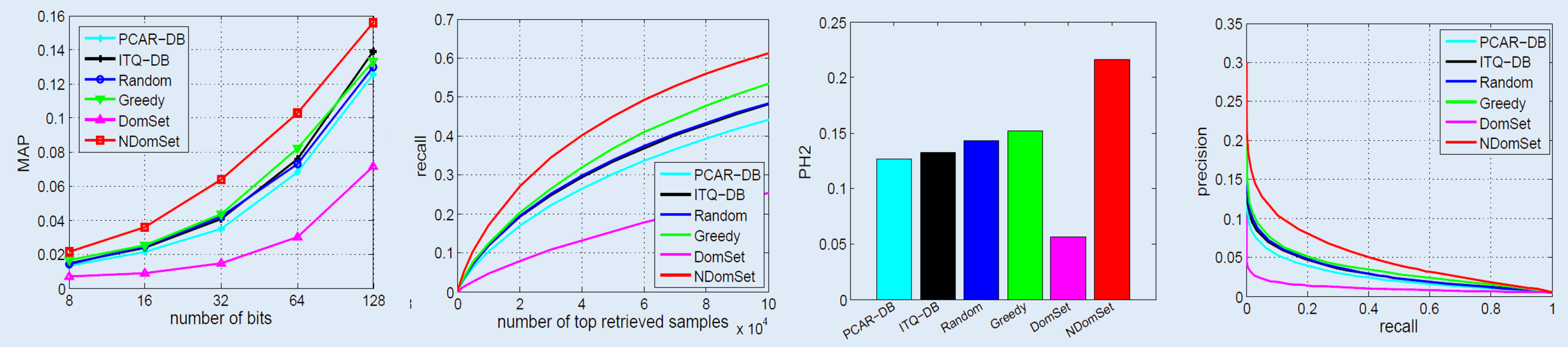


500 BITS	CIFAR-10		NUS-WIDE	
	32	64	32	64
MFH [18]	13.44±0.09	12.74±0.04	25.28±0.37	25.91±0.37
RANDOM	13.30±0.74	14.32±0.42	25.69±0.51	26.34±0.56
GREEDY	12.17±0.42	12.92±0.41	23.91±0.37	24.16±0.36
DOMSET	11.19±0.06	11.97±0.06	24.66±0.49	25.66±0.51
NDOMSET	**14.80**±0.34	**15.64**±0.35	**27.17**±0.23	**27.74**±0.16

● **Over multiple hashing algorithms:** GIST-1M



● **Over multi-bit hashing algorithms:** GIST-1M



Our proposed method performs significantly better than existing approaches

5. Summary and Conclusions

- Propose a generic bit selection unifying various scenarios
- Consider two important criteria tailored for hashing performance
- Formulate the problem as a quadratic programming and reveal its nature via the normalized dominant set
- More information http://www.nlsde.buaa.edu.cn/~xlliu