**LLC: Accurate, Multi-purpose Learnt Low-dimensional Binary Codes**

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### Multiclass Classification: Trade-offs

Linear Classifier: $\mathbb{R}^{d \times L} \rightarrow \text{compute & memory scale as } O(d \times L)$

Alternatives:

- **Trees / ANNS**
- **Embeddings**
- **Projection Classifier**

**LLC (Ours):** Accurate, Multi-purpose Learnt Low-dimensional Binary Codes

- Efficient Multiclass Classification
  - ImageNet-1K with 20 bits
  - Decoding schemes for compute & accuracy trade-offs

- Efficient Retrieval
  - ImageNet-100 with 10 bits
  - Potential for low-latency high recall retrieval in search

- Out-of-Distribution (OOD) Detection
  - Out-of-the-box without tuning for threshold

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### Multiclass Classification: Output Codes

One-hot vector per class; very sparse, can we do better?

Error Correcting Output Codes – Class $\rightarrow$ Instance Codes

**Can we learn accurate & tight output codes without using any side information?**

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### LLC: Phase 1 – Codebook Learning

Learnt end-to-end - $F, P \& B(C) - w/ (SGD)$

Binarization is learnt through Straight Through Estimator

- **Deep Featurizer**
- **Projection**
- **Binarized Classifier**

**LLC (Ours):**

- Heat Maps: Comparison for ImageNet-1K
  - 20-bits produce a visually $\approx$ heat map as 2048-dim real rep.

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### LLC: Phase 2 – Instance Code Learning

Warm start w/ $F, P$: generate $k \approx \log(L)$ dim instance rep. $B(C) \in \mathbb{R}^{k \times L}$ - target output labels per class $B(C_y)$

Solve the multi-label problem as $k$ binary classif. problems

Binarize the predictions to obtain instance codes ($\mathbb{B}^k$)

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### LLC: Image Classification for ImageNet-1K

Comparison across 20-bit codebooks using ResNet50

2048-dim real representation + linear classifier: 77%

<table>
<thead>
<tr>
<th>Codebook</th>
<th># Unique Codes</th>
<th>ED Accuracy (%)</th>
<th>MHD Accuracy (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random</td>
<td>1000</td>
<td>64.07</td>
<td>66.91</td>
</tr>
<tr>
<td>CCA</td>
<td>813</td>
<td>55.17</td>
<td>57.03</td>
</tr>
<tr>
<td>SVD</td>
<td>969</td>
<td>65.12</td>
<td>69.18</td>
</tr>
<tr>
<td>LLC (Ours)</td>
<td>1000</td>
<td>68.82</td>
<td>74.57</td>
</tr>
</tbody>
</table>

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### LLC: Image Retrieval for ImageNet-100

MAP@1000 for retrieval using ResNet50 & AlexNet

**ResNet50**

<table>
<thead>
<tr>
<th>Rep.</th>
<th>LLC (1-bit)</th>
<th>Real (16-bits)</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 dims</td>
<td>-</td>
<td>50.41</td>
</tr>
<tr>
<td>16 dims</td>
<td>64.07</td>
<td>66.57</td>
</tr>
<tr>
<td>64 dims</td>
<td>67.73</td>
<td>77.94</td>
</tr>
</tbody>
</table>

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**Heat Maps: Comparison for ImageNet-1K**

Comparison across 2-bit codebooks using ResNet50

2048-dim real representation + linear classifier: 77%