Incremental Learning of NCM Forests

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Overview

- Problem
- Random Forest
  - NCM Forest
- Results
- Conclusion
Problem: Large-scale image classification

- Image datasets are becoming large
  - Social media + cheap devices
  - Thousands of categories
  - Millions of images

- Manual annotation is
  - ... boring
  - ... expensive

- We need to annotate these images automatically.
- … and incrementally: add new classes
Problem: Image classification pipeline

Features (image as vector) → Model

Class label (here: “tiger”)
Problem: Incremental Learning

- **Initial Classes:**
  - **Class 1**
  - **Class k**

- **Initial Training:**
  - Initial model $M_0$
  - System is initially trained.

- **Incremental Training:**
  - Updated model $M_1$
  - System is updated with the new class.
Random Forest

- Classification framework proposed by Breiman et al. [1]
- Combine responses of multiple decision trees
  - Each tree usually over-fits, but a combined result is good!

- Advantages:
  - Inherently multi-class
  - Very fast for many applications
    - Theoretically logarithmic in number of features
  - Easily parallelizable
Random Forest: Training

- Training
  - A certain number of decision trees are trained independently in a recursive manner.
Random Forest: Training

- Node training
  - Generate randomly a pool of splitting function for a node
  - Pick a splitting function that optimizes some criterion
    - In our case: class entropy of samples going “left” and “right”, respectively
Random Forest: Training

- Leaves
  - Too few samples (e.g., 10)
  - Compute class probabilities given the samples that ended up at the leaf
Random Forest: Testing

- Push an image through each tree independently
- Average over class probabilities at each leaf
NCM Forest

- **NCM** = Nearest Class Mean
- Use nearest-class-mean classifiers as splitting functions

**Advantages:**
- Work well for large data sets [3]
- Fast to train
- Easy to update
  - Very handy for incremental learning!
NCM Forest: Training

- At each node:
  - Compute mean of each class
  - Subsample the set of classes, pick only a few
NCM Forest: Training

- At each node (cont’d)
  - Randomly assign each class mean a label “left” or “right”
  - Compute class histograms of the samples going “left” and “right”, respectively
NCM Forest: Training

- At each node (cont’d)
  - Pick an assignment for which sum of the entropies is minimal
    - Weight by number of samples
NCM Forest: Incremental learning

- Update leaf statistics
- Incrementally grow trees
- Randomly pick a subset of inner nodes and update their NCMs
- Randomly pick a subset of sub-trees, re-train them completely
- (Please consult the paper for more details)
Results

- On Image net 2010 (ILSVRC ‘10)
  - Challenging and well-established
  - 1000 classes
  - 1.2 million images
  - Average accuracy as performance measure
  - Publicly available features

<table>
<thead>
<tr>
<th>Method</th>
<th>Avg. accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional random forests with axis-aligned splits [1]</td>
<td>0.06</td>
</tr>
<tr>
<td>Multi-class SVM [2]</td>
<td>0.04</td>
</tr>
<tr>
<td>NCM</td>
<td>0.07</td>
</tr>
<tr>
<td>Learned metric + NCM [3]</td>
<td>0.13</td>
</tr>
<tr>
<td>NCM Forest (ours)</td>
<td>0.12</td>
</tr>
</tbody>
</table>
Results

- Incremental learning
  - Initial number of classes: 10, final number of classes: 1000

<table>
<thead>
<tr>
<th>Update strategy</th>
<th>Time (per tree)</th>
<th>Average accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Re-train NCM Forest from scratch</td>
<td>4 days</td>
<td>0.12</td>
</tr>
<tr>
<td>Update leaf statistics</td>
<td>21s</td>
<td>0.03</td>
</tr>
<tr>
<td>Incrementally grow tree</td>
<td>15min</td>
<td>0.08</td>
</tr>
<tr>
<td>Update inner nodes</td>
<td>77min</td>
<td>0.09</td>
</tr>
<tr>
<td>Re-train subtrees</td>
<td>16 hrs</td>
<td>0.10</td>
</tr>
</tbody>
</table>
Conclusion

- We introduced nearest-class-mean (NCM) classifiers into the random forest framework
  - → NCM Forest

- NCM Forests can handle large-scale image classification

- NCM Forest allow us to choose between different update strategies
  - A single node is very easy to update
  - Choose between efficiency and accuracy
Thank you for your attention!

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“Incremental Learning of NCM Forests for Large-scale Image Classification”, Ristin et al., CVPR ‘14
Citations