Spatially Aware Dictionary Learning and Coding for Fossil Pollen Identification

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Why do we care about identifying pollen?

- Pollen grains are ubiquitous and well preserved in the fossil record.
- Identification of pollen samples allows for analysis of plant biodiversity and evolution, understanding history of long-term climate change, dating of rock strata, etc...
Skilled experts train for years and make subtle distinctions between 100s of species.

Figure 1. Sketch showing the measurements taken from specimens of *Picea* pollen in equatorial view (after Lindbladh et al., 2002). Grain length (A), corpus height (B), corpus width (C), depth of saccus attachment (D), cap thickness (E), saccus width (F) and saccus height (G).
Challenge: Automating species-level identification

Distinguish pollen from three different species of spruce tree

- Large within-class variation
- Small between-class differences in shape and texture
Identification by patch-match sparse coding

- Code appearance of test image using sparse combinations of patches from labeled training examples
- Classify using SVM based on code activations

Our methodology

- All patches are represented by CNN features at hidden layers.
Identification by patch-match sparse coding

1. Automatic patch exemplar selection (dictionary learning) based on discriminative and generative criteria

Our contribution

Automatically selected patches
Identification by patch-match sparse coding

1. Automatic patch exemplar selection

2. Spatially-aware sparse coding (SACO)
   - penalize dictionary elements from distant spatial locations
Spatially aware coding (SACO)

\[ \arg\min_a \| x - Da \|_2^2 + \lambda_1 \| \text{diag}(w) a \|_1 \]
Good classification performance

Represent patch using CNN feature extractor (VGG19)
Global average pooling of sparse codes + linear SVM

<table>
<thead>
<tr>
<th></th>
<th>SRC</th>
<th>VGG19+SVM</th>
<th>FV+SVM</th>
<th>SACO-I</th>
<th>SACO-II</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>62.04</td>
<td>65.11</td>
<td>61.46</td>
<td>83.21</td>
<td>86.13</td>
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</tbody>
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Substantially outperforms standard CNN and Fisher-vector based approaches!