Spatially Aware Dictionary Learning and Coding for Fossil Pollen Identification

Shu Kong[1], Surangi Punyasena[2], Charless Fowlkes[1]

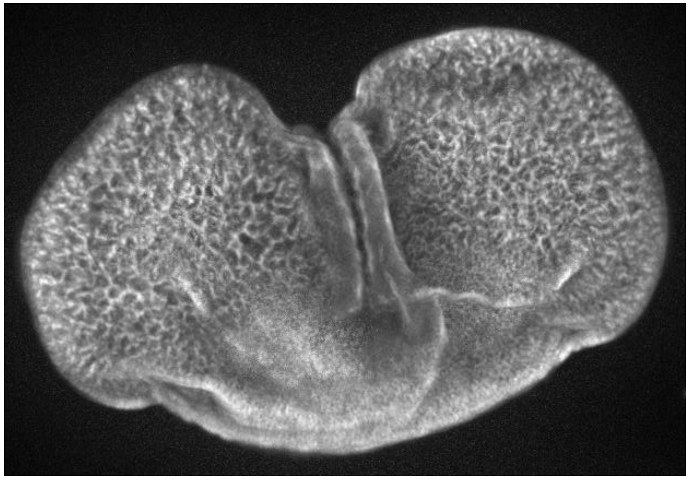
[1]Department of Computer Science, UC Irvine

[2]Department of Plant Biology, UIUC

Why do we care about identifying pollen?

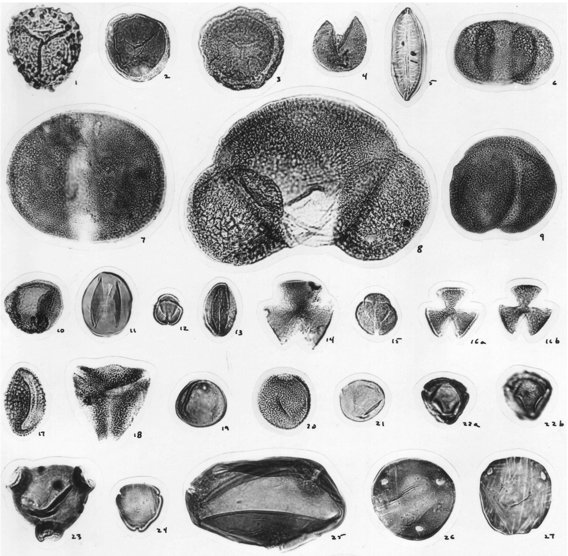
- Pollen grains are ubiquitous and well preserved in the fossil record

- Identification of pollen samples allows for analysis of plant biodiversity and evolution, understanding history of long-term climate change, dating of rock strata, etc...



Current identification is done “by eye”

Skilled experts train for years and make subtle distinctions between 100s of species.



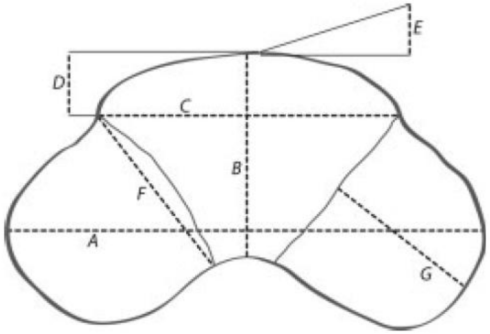


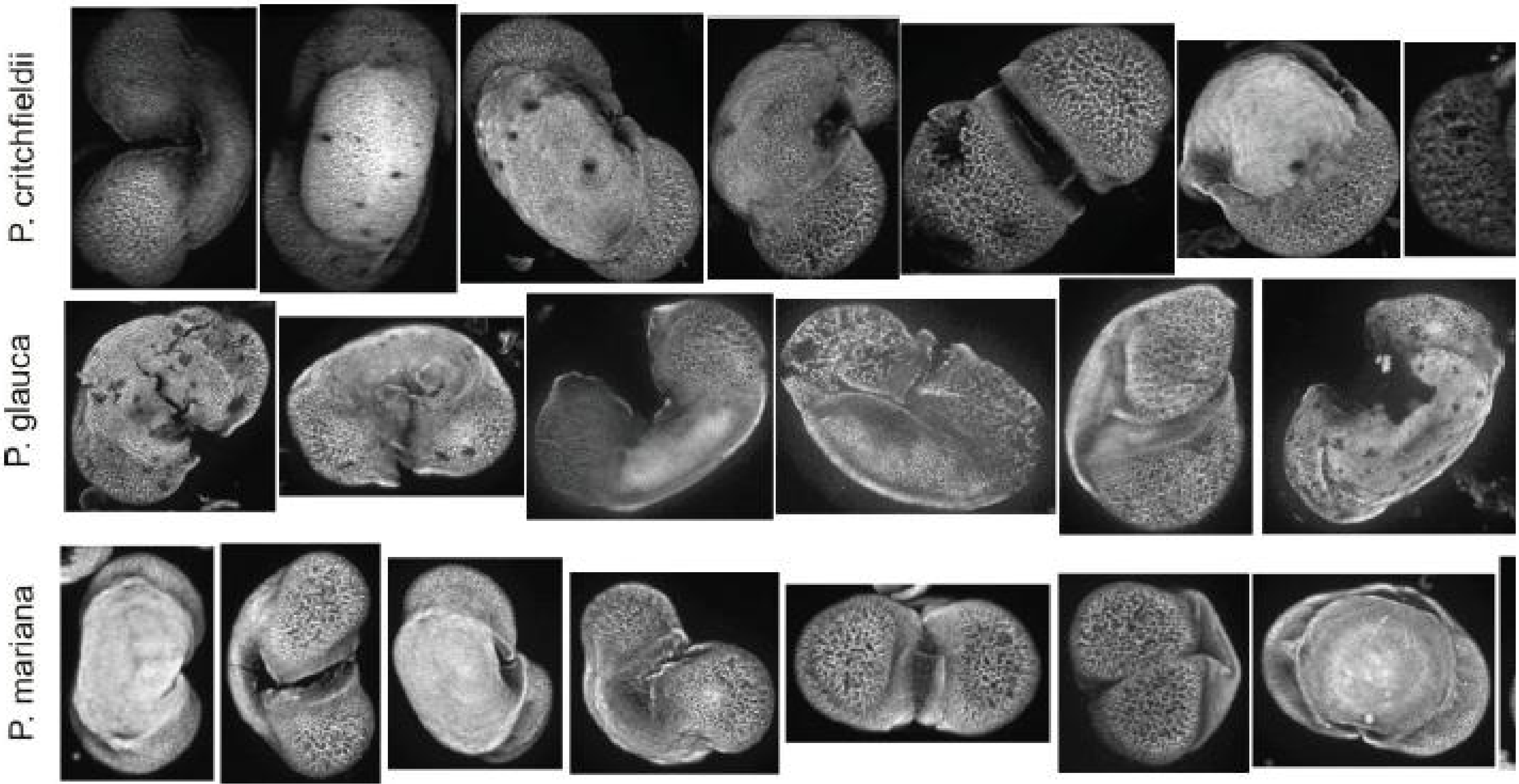
Figure 1. Sketch showing the measurements taken from specimens of *Picea* pollen in equatorial view (after Lindbladh *et al.*, 2002). Grain length (*A*), corpus height (*B*), corpus width (*C*), depth of saccus attachment (*D*), cap thickness (*E*), saccus width (*F*) and saccus height (*G*).

photo credited by Surangi W. Punyasena

Challenge: Automating species-level identification

Distinguish pollen from three different species of spruce tree

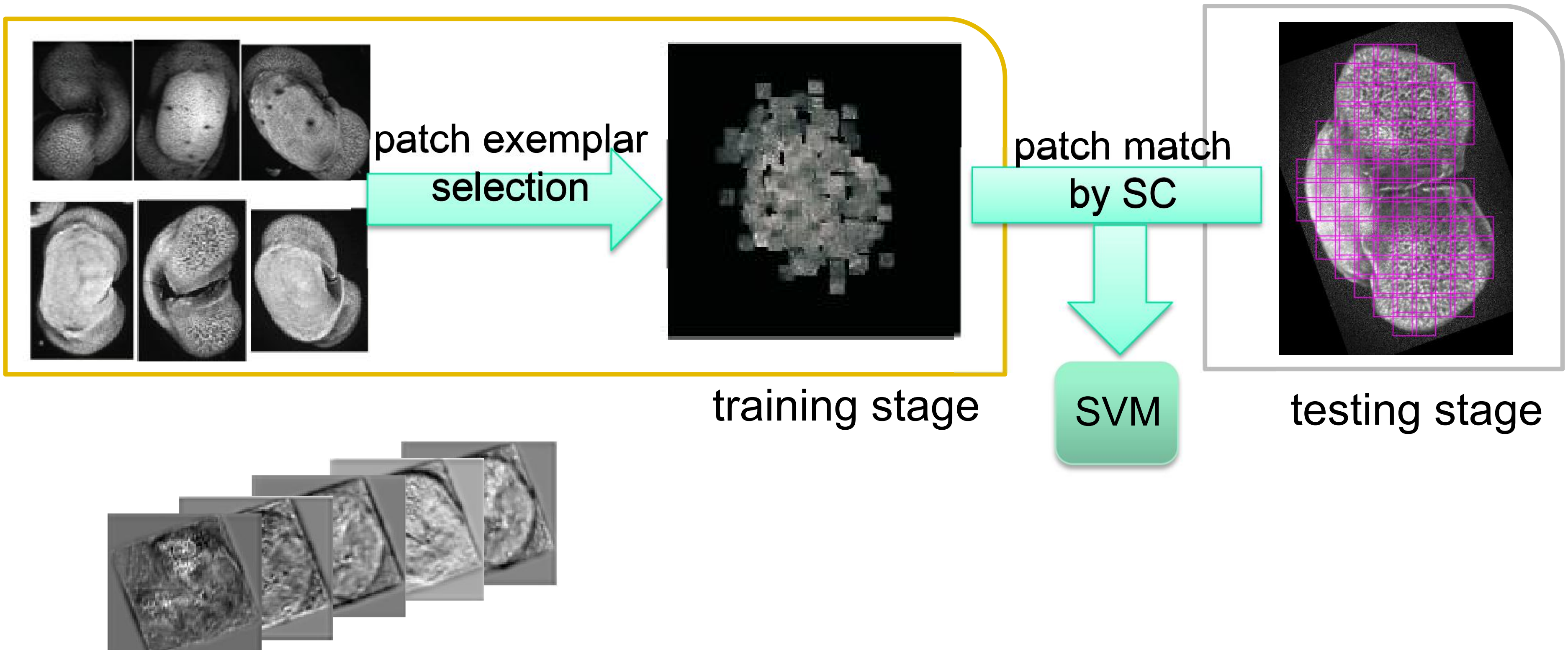
- Large within-class variation
- Small between-class differences in shape and texture



Our methodology

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 activiations



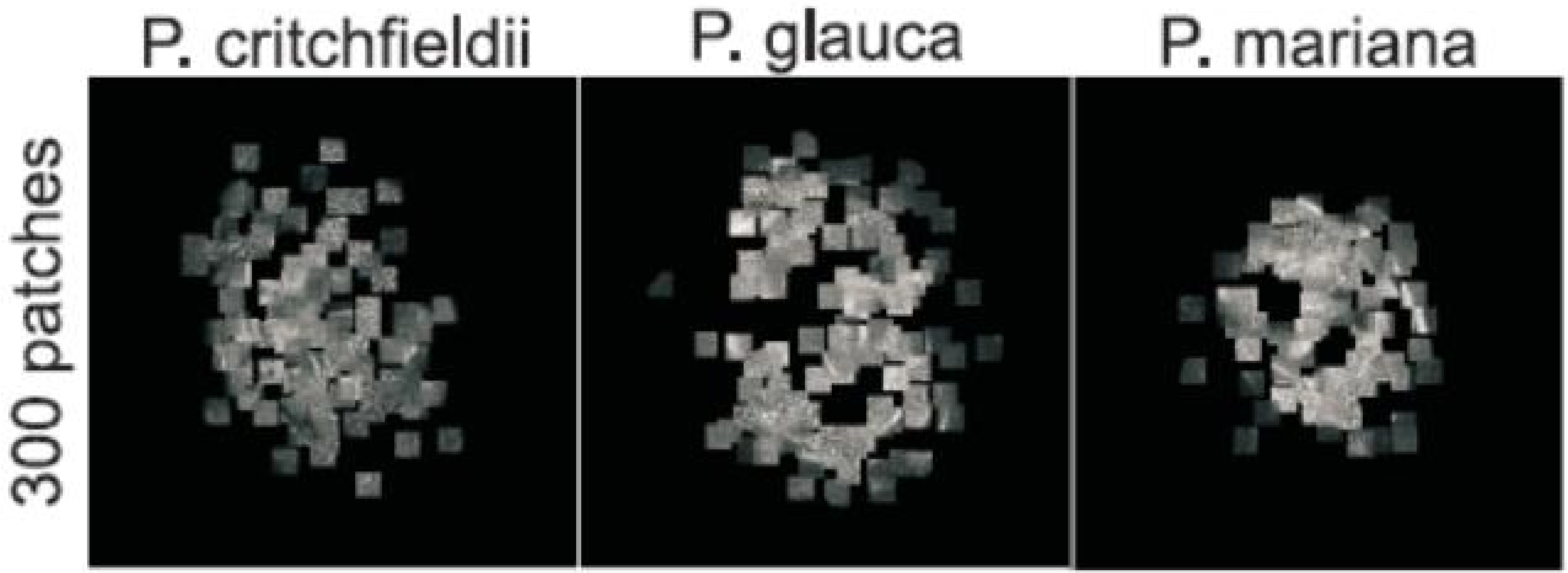
all patches are represented by CNN features at hidden layers

Our contribution

<u>Identification by patch-match sparse coding</u>

1. Automatic patch exemplar selection (dictionary learning)

   based on discriminative and generative criteria

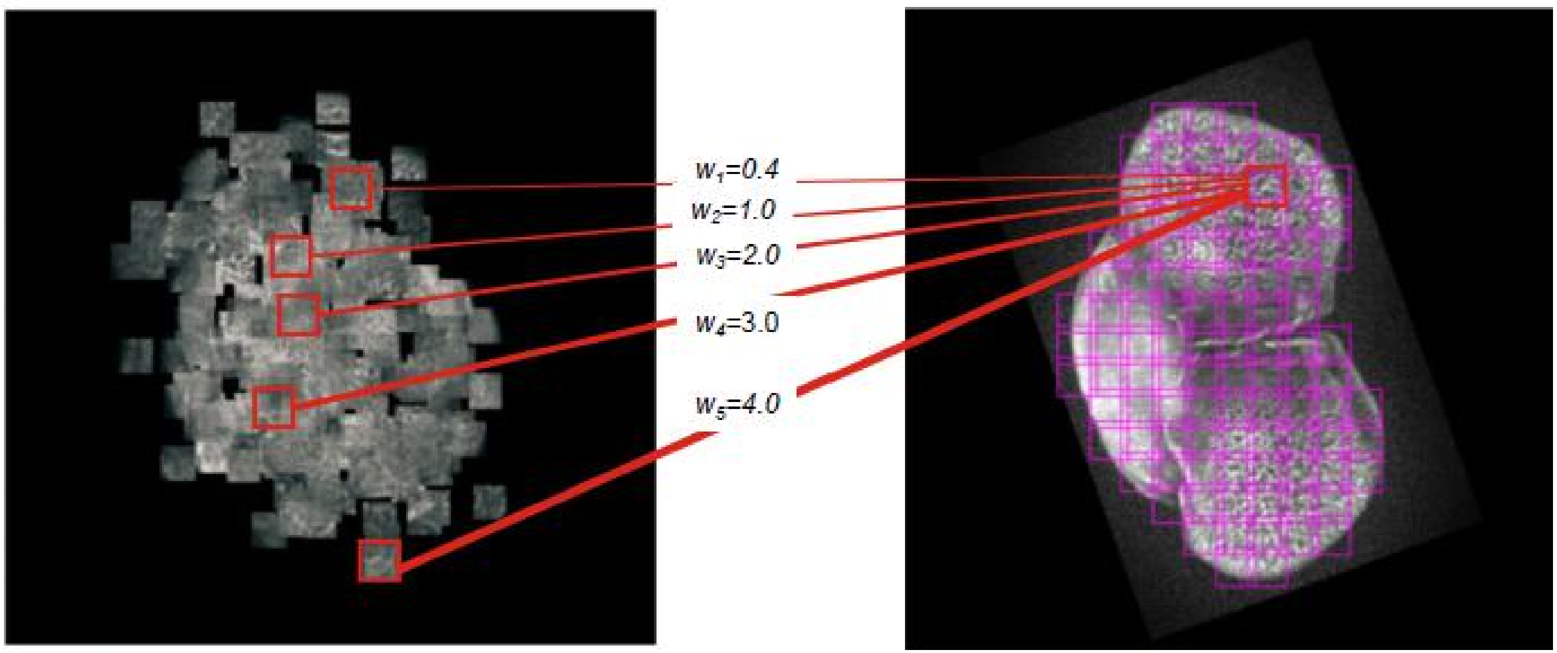


Automatically selected patches

Our contribution

<u>Identification by patch-match sparse coding</u>

1. Automatic patch exemplar selection
2. Spatially-aware sparse coding (SACO)
   - penalize dictionary elements from distant spatial locations

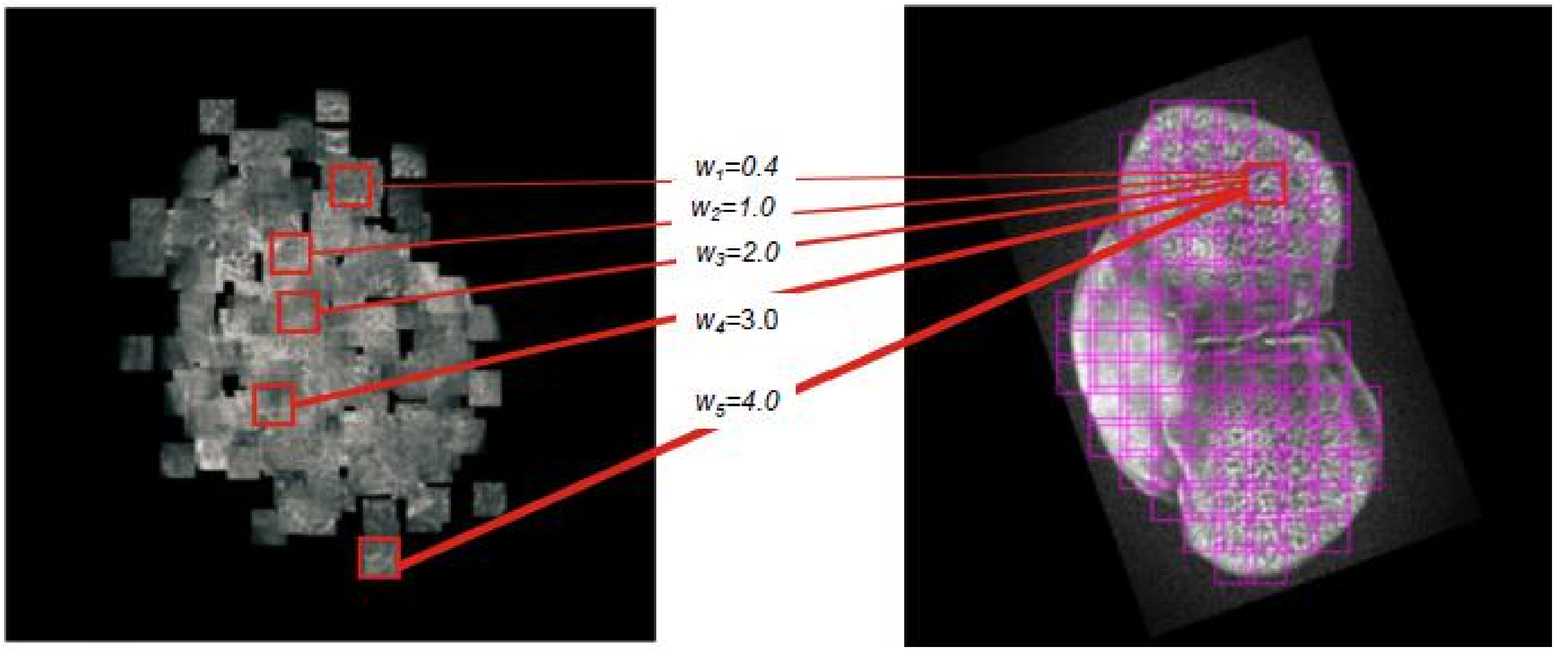


Spatially aware dictionary

Test image

UCIrvine
University of California, Irvine

Spatially aware coding (SACO)



Spatially aware dictionary

Test image

Spatial weights

$$\underset{\mathbf{a}}{\operatorname{argmin}} \|\mathbf{x} - \mathbf{D}\mathbf{a}\|_2^2 + \lambda_1 \|\mathrm{diag}(\mathbf{w})\mathbf{a}\|_1$$

Exemplar patches (dictionary)

Test patch

UCIrvine
University of California, Irvine

Good classification performance

Represent patch using CNN feature extractor (VGG19)

Global average pooling of sparse codes + linear SVM

SRC	VGG19+SVM	FV+SVM	SACO-I	SACO-II
62.04	65.11	61.46	83.21	86.13

Substantially outperforms standard CNN and Fisher-vector based approaches!

Thank you!

Shu Kong[1], Surangi Punyasena[2], Charless Fowlkes[1]

[1]Department of Computer Science, UC Irvine

[2]Department of Plant Biology, UIUC