Classifying an image with accuracy and speed

The value of parts-based representations

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The Problem

- The amount of image and video data on the Internet is exploding:
  - Imageshack has 20 billion images in its inventory
  - Facebook has 15 billion, growing at 850 million per month
- The most prevalent method to index images is social tagging, which is unreliable and not comprehensive.
- Images are expensive to maintain, and expensive to serve
- They represent a potential liability to content owners.
- Without indexing, there is no easy way to monetize the images by placing relevant ads

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How images are stored and processed

Computer

- Serial storage and processing
- Data stored by pixels and frames
- Retrieval is based on index lookup
- Easy to answer storage queries (“Where is this file located?”)
- Difficult to answer pattern queries (“Is this a motorcycle or a boat?”)

Brain

- Parallel storage and processing
- Data stored by features and patterns
- Retrieval is based on pattern reconstruction
- Difficult to answer storage queries (“where is this memory located?”)
- Easy to answer pattern queries: (“Is this is motorcycle or a boat?”)

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Learning to find patterns in images

- Feature extraction using “basis images”
  - The input image is represented by a linear combination of basis images
  - Each basis image is the same size
  - Each basis image provides a “feature” (or a set of features)

- Operating procedure:
  - Start with a set of training images
  - The basis images are of the same size as the input images
  - Use a learning heuristic (analogous to PCA) to figure out the optimal basis images for the input image set
  - Assign constraints based on observations from neuroscience: firing rates of neurons are never negative

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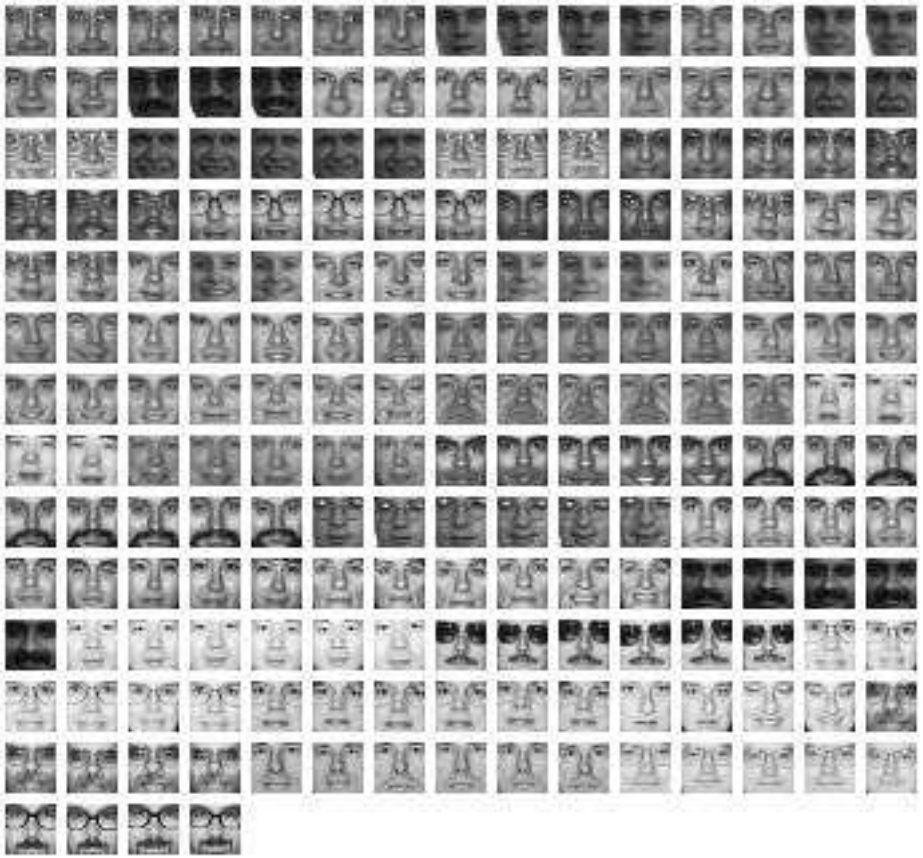
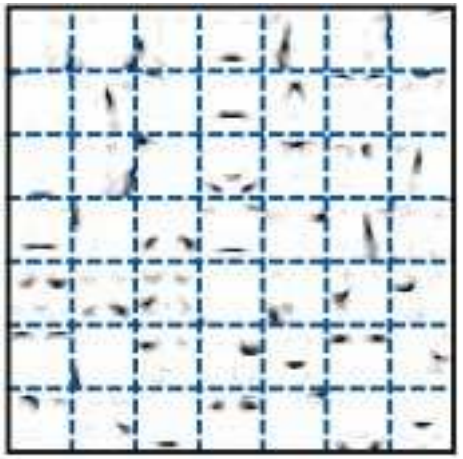
Basis image calculation example

Input face images (3431 total)



Basis images (49)



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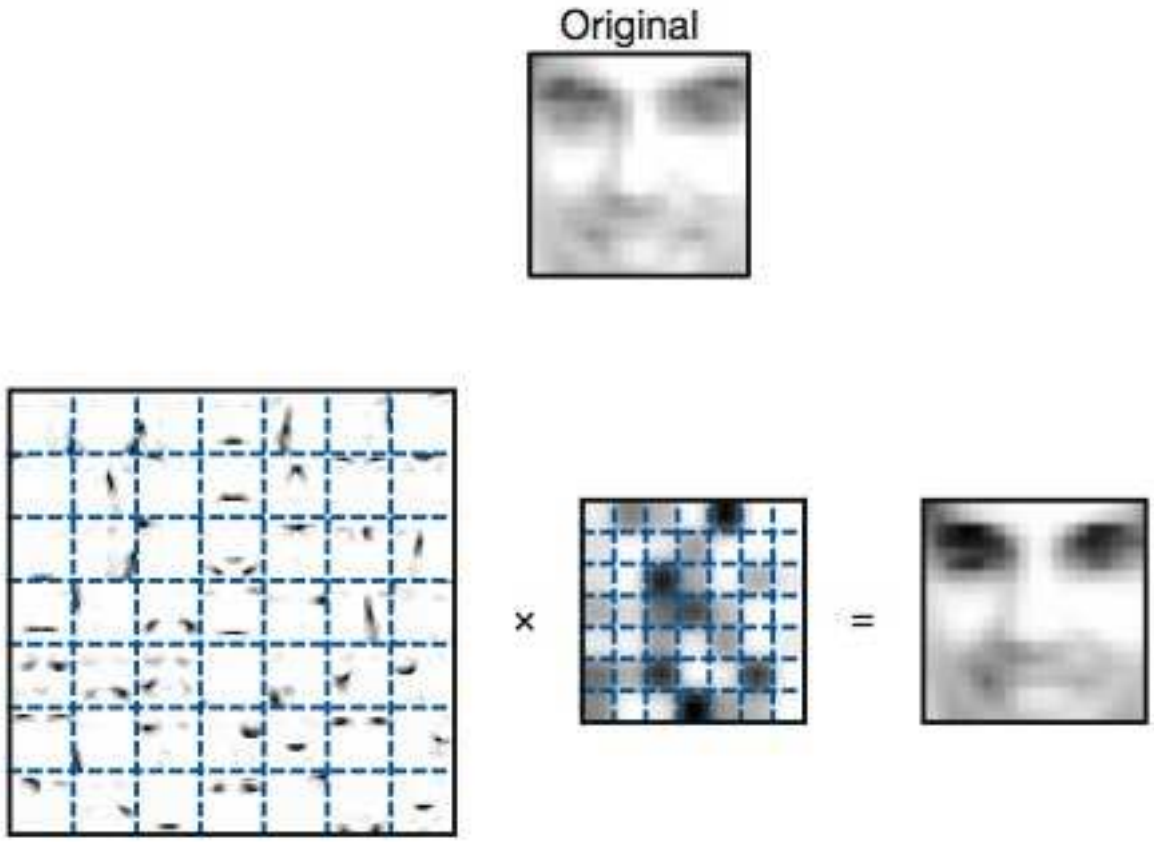
How the process works (reconstruction)



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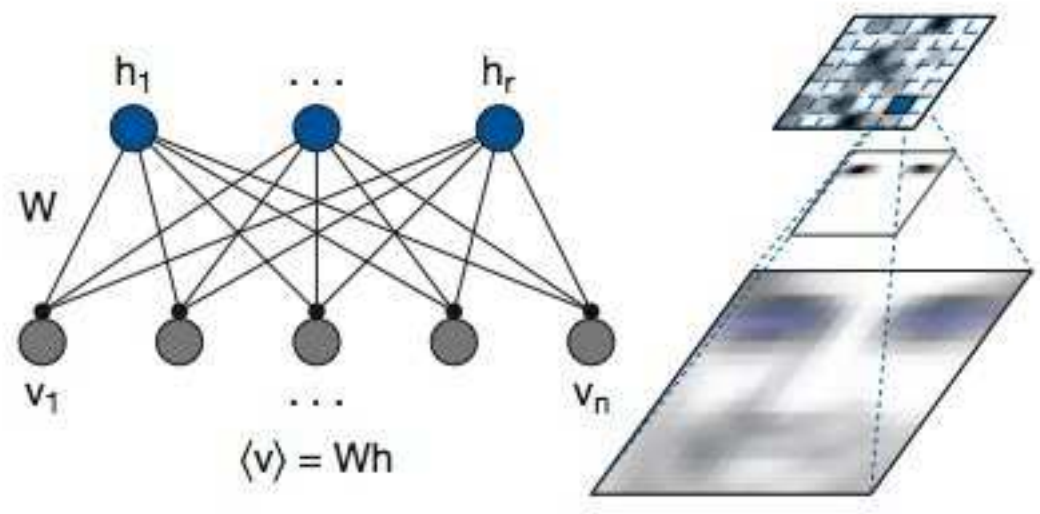
Hidden variables model (neural network)



- $h_1 \ldots h_r$ = hidden layer neuron strengths
- W = weight matrix (basis images)
- $v_1 \ldots v_n$ = image pixel values

Advantages of parts-based feature extraction

- Searches use feature vectors based on patterns in actual image data, instead of associated text.
- Helps with database and file-based storage: instead of storing the complete image, we can store the feature vector for the image.
- Pattern-based searches are much more accurate than using pixel-based searches.
- Heavy computation is restricted to the point of database creation, and can be accelerated with parallelization.
- Dramatically reduces the dimensionality of search (25-50 features vs. 100K pixels), so searches are faster and less expensive.

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