Clustering Face Carvings: Exploring the Devatas of Angkor Wat

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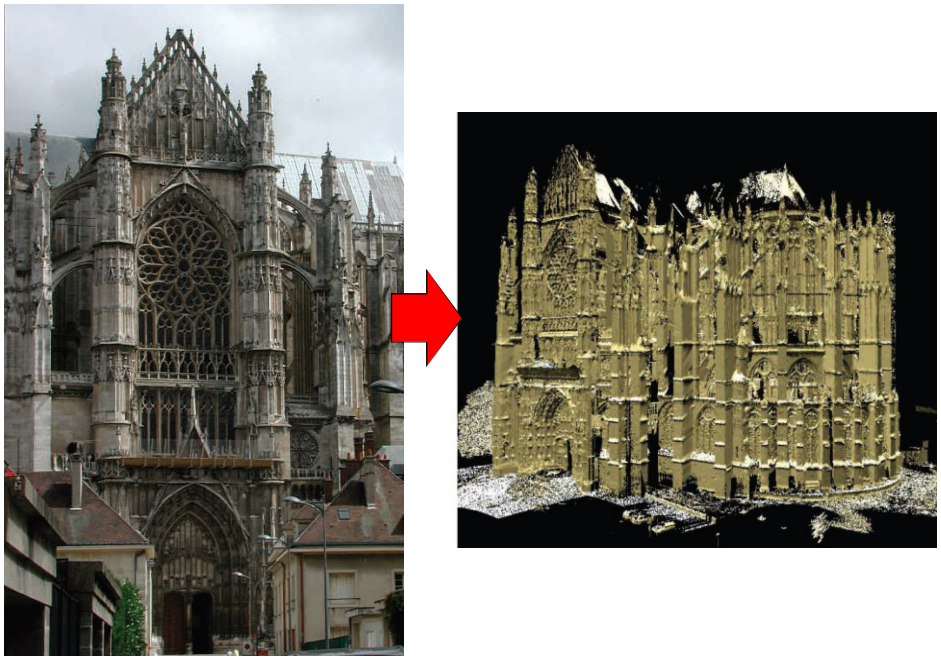
Cultural Heritage

- Use of computer vision, pattern recognition, and computer graphics for understanding and preserving heritage sites
  - Restoration of manuscripts
  - Reconstruction of monuments
  - Virtual walkthrough
  - Virtual museum
  - Quantitative measurement & analysis



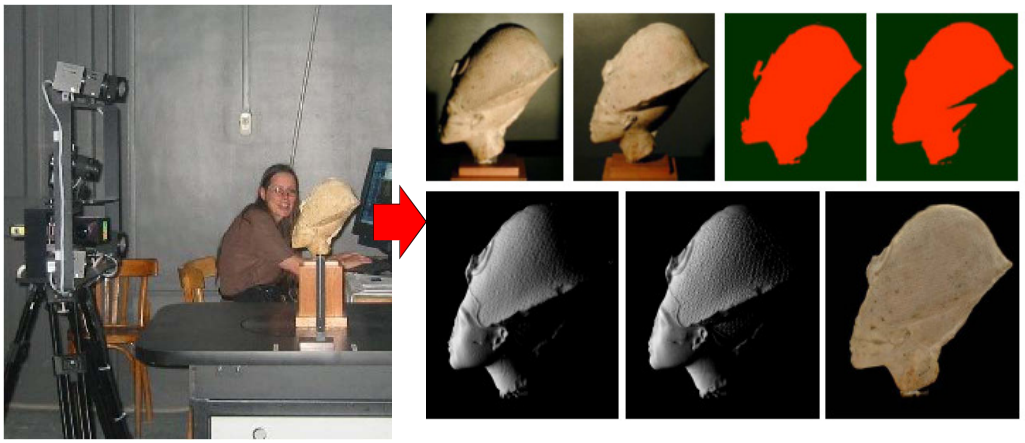


Image from:
(top) P. Allen et al., "New methods for digital modeling of historic sites," IEEE CGA, 2003
(bottom) H Rushmeier et al., "Design and Use of an In-Museum System for Artifact Capture," CVPRW 2003

Angkor Wat

Hindu temple built by a Khmer king ~1,150AD; Khmer kingdom declined in the 15th century; French explorers discovered the hidden ruins in the late 1800's

Apsaras of Angkor Wat

Angkor Wat contains the most unique gallery of ~2,000 women, called devatas, depicted as detailed full body portraits

Questions remain about who these women were:

- Do they represent different ethnic groups?
- Does their location in the temple have meaning?
- How many sculptors were used to create the carvings?

Kent Davis, Biometrics of the Godesess, DatAsia, Aug 2008
S. Marchal, Costumes et Parures Khmers: D'apres les devata D'Angkor-Vat, 1927

Exploratory Data Analysis

- Define a similarity measure between faces
- Use the similarity matrix to obtain facial groupings
- Groups will suggest hypotheses to domain experts

Comparing two faces

- Facial similarity can be based on:
  - Texture
  - Shape
- Texture is not applicable due to porus nature of stone
- Only shape is used

Different stone material lead to different appearances

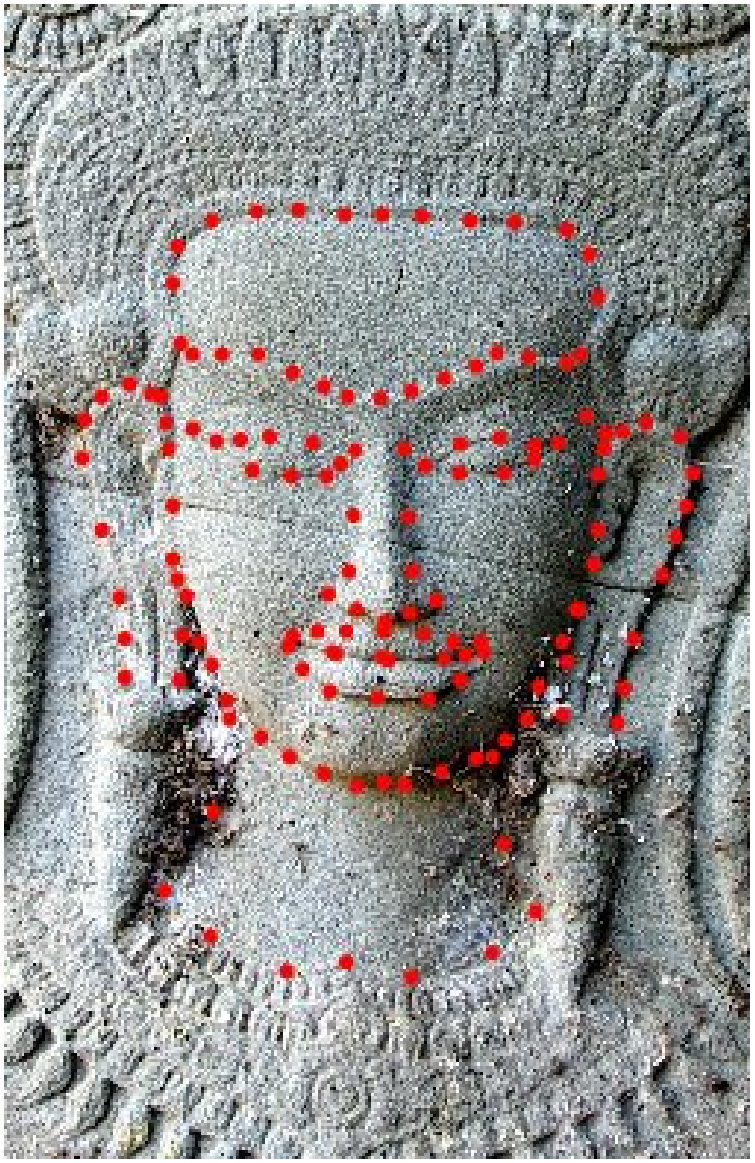
Porous nature of stones limits the use of texture

Face Shape Information

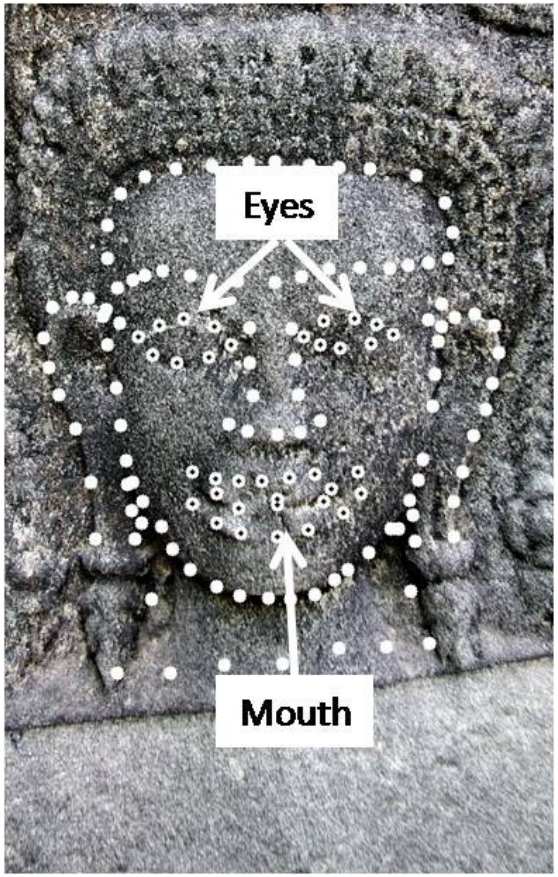
- Shape is described in the form of landmarks
- Facial landmarks are marked manually:
  - ASM and AAM cannot be used due to (i) texture inconsistencies, (ii) carving degradation

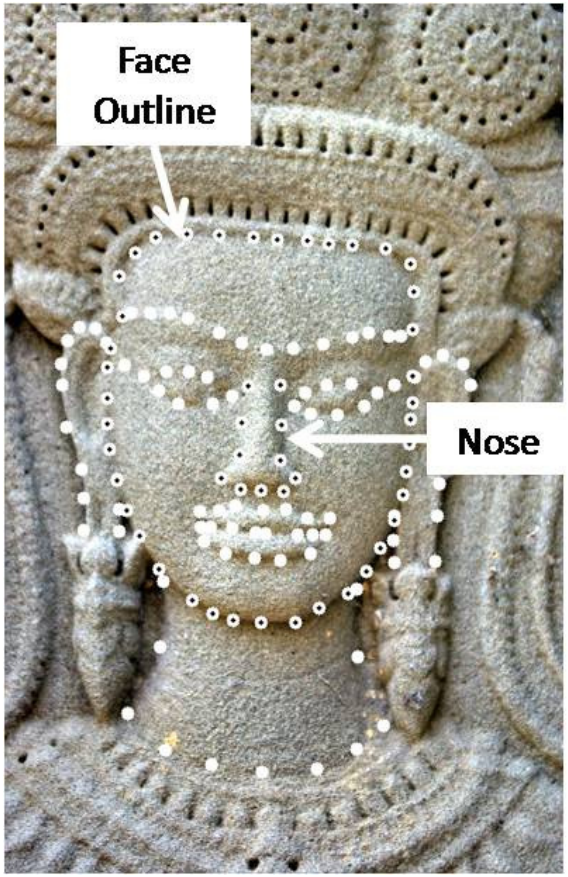
Carvings degraded over time

Facial Landmarks



140 landmark points





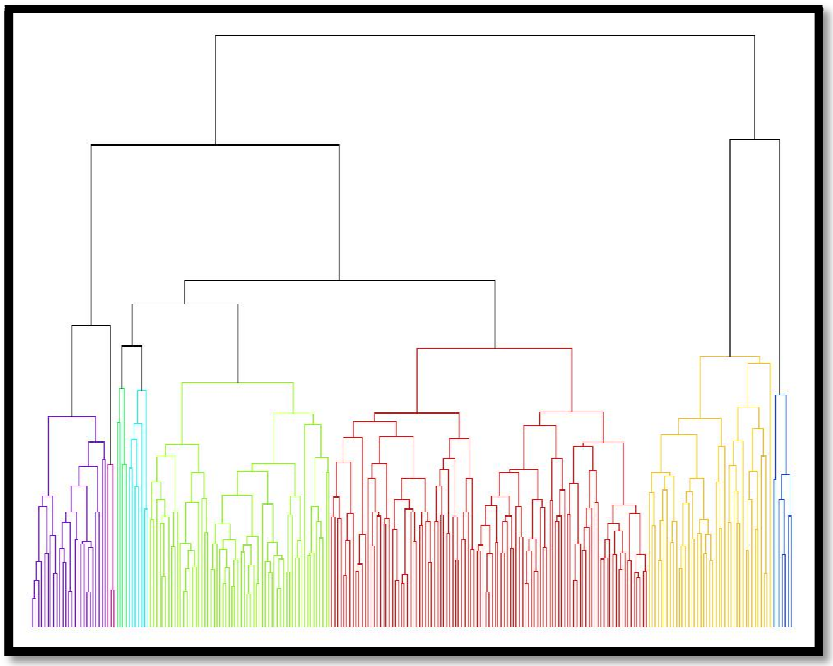
Use of facial components (eyes, nose, mouth, face outline) allows domain experts to assign them different weights

Point Distribution Models (PDM)

- Each facial component is represented as PDM:
  1. Perform Procustes Analysis to rigidly align the component landmarks in two faces
     - Remove translational component
     - Normalize scale
     - Least Squares minimization on angle parameter in the rotation matrix
  2. Perform PCA on aligned landmarks
  3. Project landmarks into a subspace spanned by top P eigenvectors
     - 95% of data variance is retained

Clustering Face Carvings

- Use face similarity measure to find clusters
- Clusters are analyzed by domain experts (archaeologists, ethnologists) to answer
  - Do they represent different ethnic groups?
  - Does their location in the temple have meaning?
  - How many sculptors were used to create the carvings?



Clustering Face Carvings

For each facial component k (eyes, nose, etc.), the similarity matrix is constructed as:

$$S_k(i,j) = 1 - \frac{\|b_i^k - b_j^k\|_2 - \min(S_k)}{\max(S_k) - \min(S_k)}$$

where b_i is the PDM feature vector for the ith face carving.

Total similarity matrix S computed by

$$S = \sum_{k=1}^{K} w_k S_k$$

s.t. $0 \leq w_g \leq 1$, and $\sum_{k=1}^{K} w_k = 1$.

w_k is a weight vector controlled by domain expert to alter the importance of each facial component

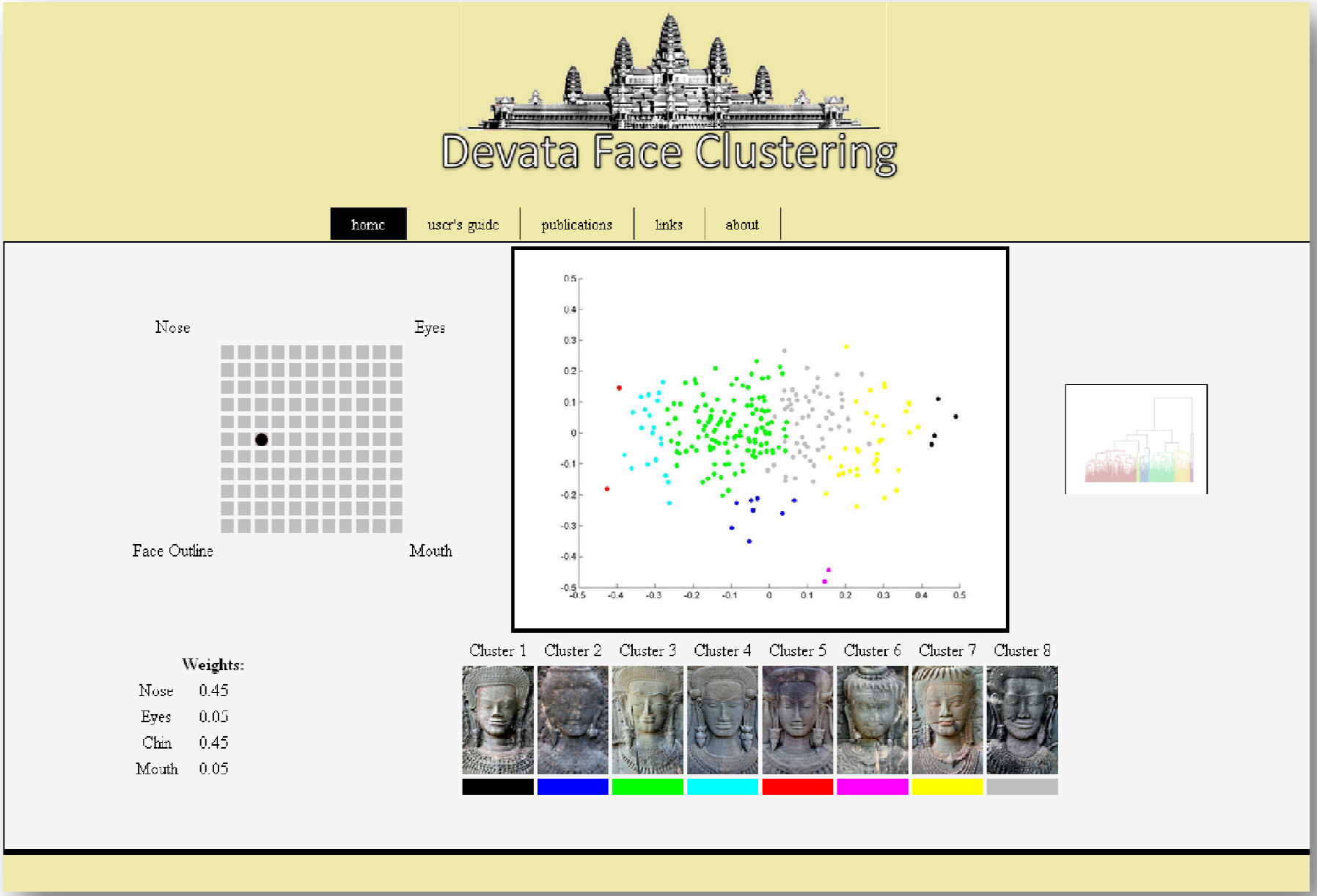
Visualization of Clustering

- Web-based interface allows domain experts to explore different clusterings
  - http://www.cse.msu.edu/~klarebre/angkor/cluster/index.html
- Users can assign weights to facial components
- Weights determine the similarity matrix
- Multi-dimensional scaling of the similarity matrix helps to visualize clusters in 2D or 3D
- Prototype face from each cluster is shown
  - Users can view all the faces in a cluster by clicking on its prototype

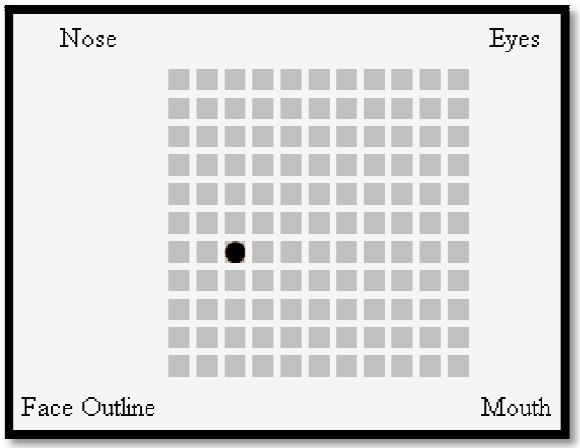
Experimental Results

- Proposed clustering framework was used to analyze a collection of 252 face images from the West Gopura (or entrance pavilion)
- Used four facial components: eyes, nose, mouth, and face outline
- Complete-Link clustering

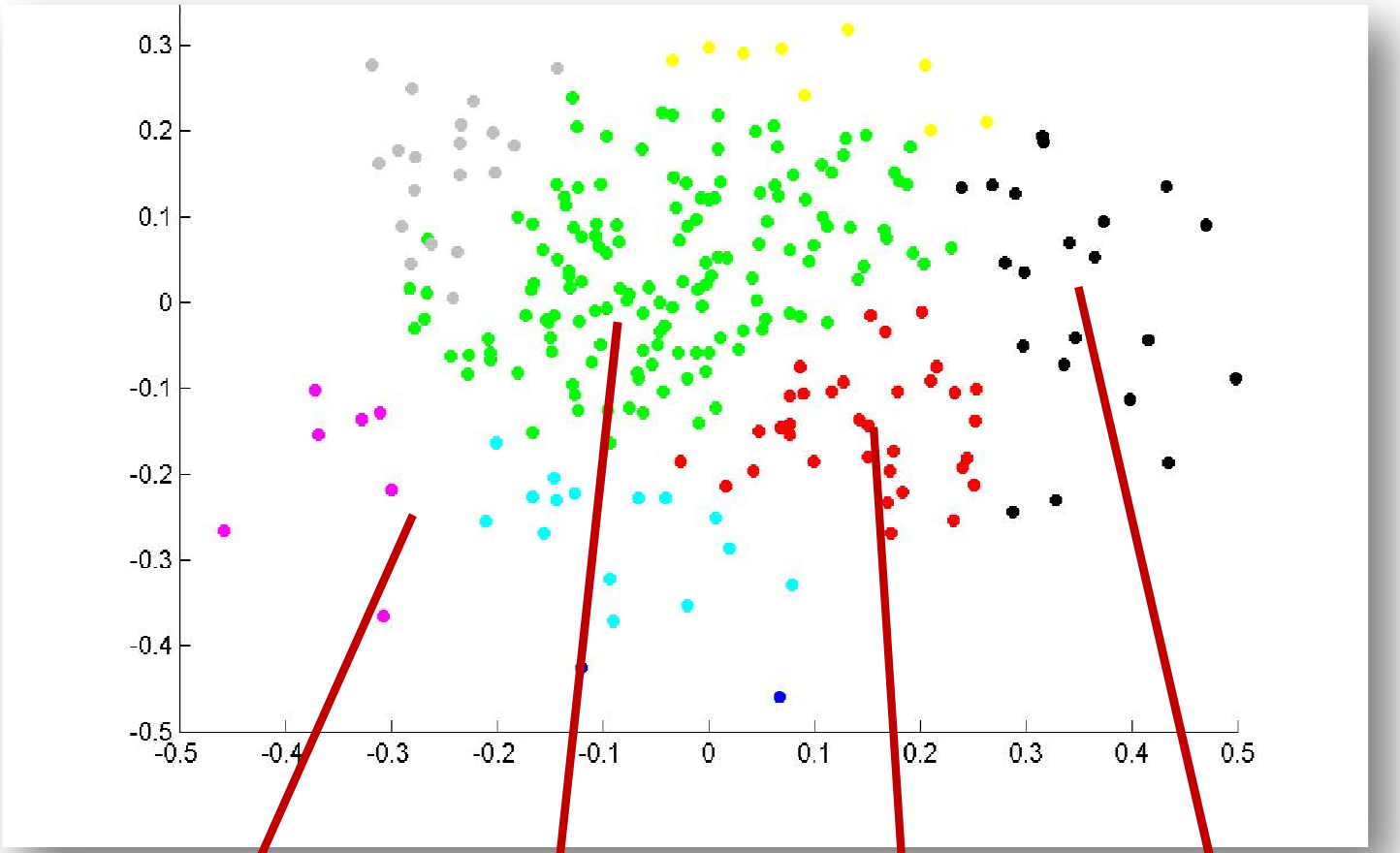
Web Interface

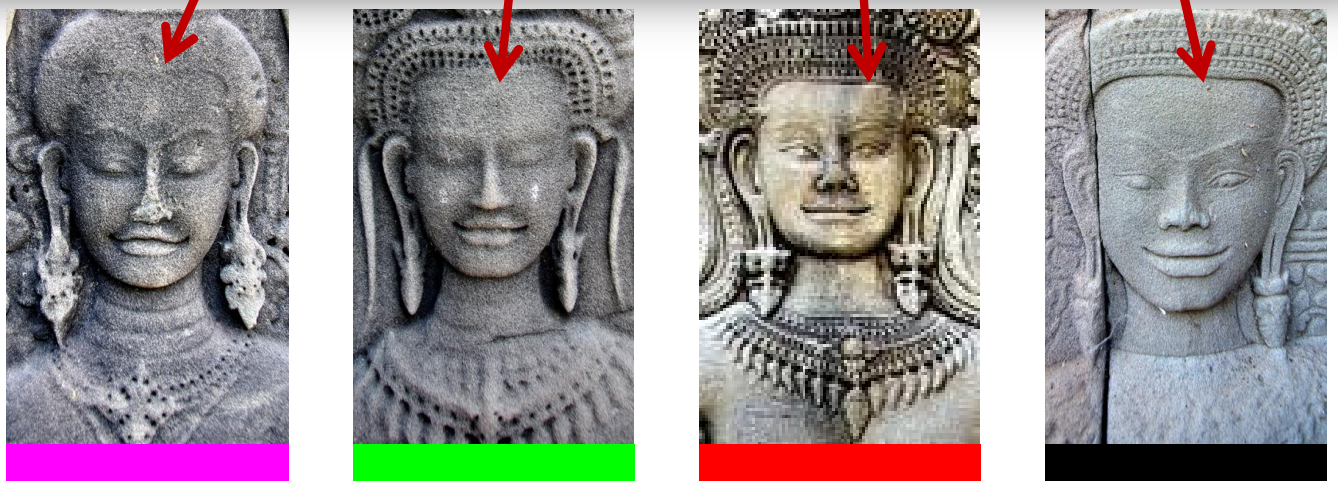


Cluster Prototypes



Weights:	
Nose	0.36
Eyes	0.00
Chin	0.54
Mouth	0.10





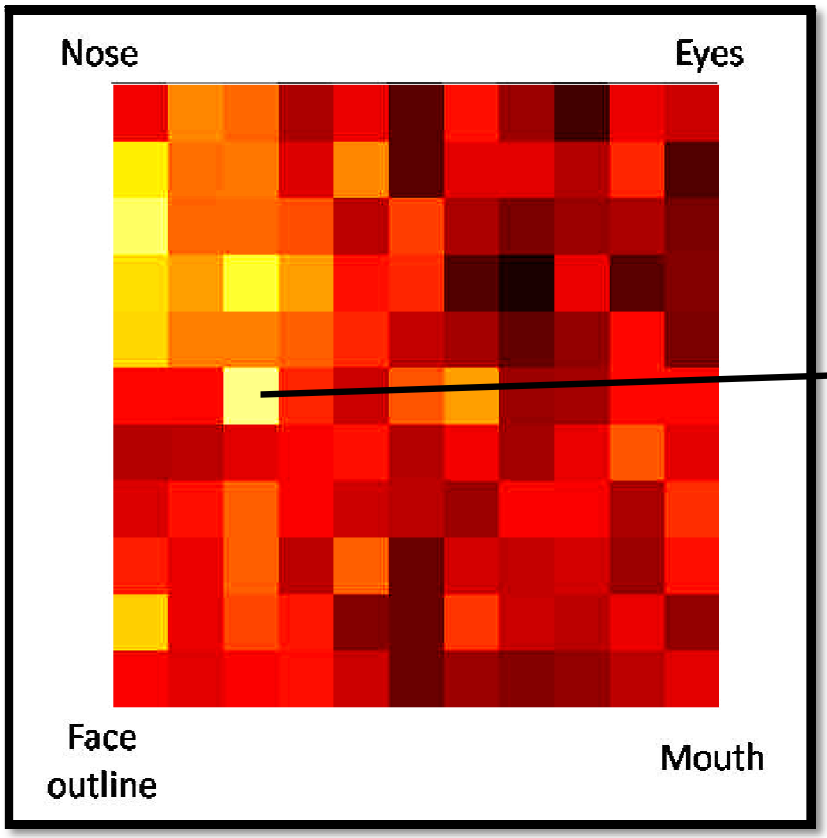
Ground Truth

- True groupings not known
- Faculty and students at the Khmer Arts Academy, Phnom Penh identified 243 pairs of similar faces

Khmer Arts Academy

Evaluation

- Which weight combination satisfies the most "must-link" pairs?
- Heat map displays the performance



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Corresponds to ~50% of 243 constraints satisfied

Summary and Future Work

- Proposed a methodology to analyze facial carvings of Angkor Wat
  - Similarity computed in terms of facial components
  - Domain experts can assign weights to components
  - A visualization tool displays various clusterings
  - Methodology applicable to other monuments
- Future work
  - Obtain feedback from domain experts
  - Semi supervised clustering with must-link constraints
  - Expand the study to include additional face carvings

Questions?