3D Shape Representation and Analysis of the Human Body and 3D Retrieval Interfaces

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Introduction (I)

- Large number of 3D models created every day and stored in databases → 3D scanning technologies +CAD
- Understanding the 3D shape of these models is essential to many scientific activities
- These 3D databases require method for storage, indexing, searching, clustering, retrieval and recognition
- Searching a database of 3D objects which are similar to a given 3D object is an important problem
  - Also called query by example (QBE) approach

Introduction (II)

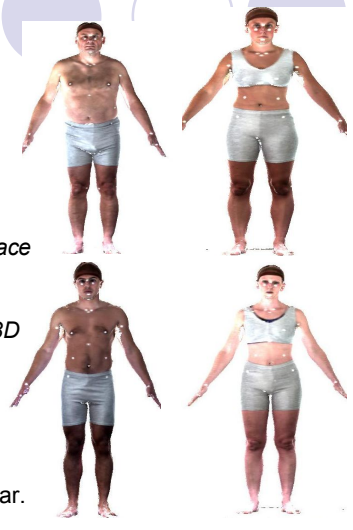
- We have developed techniques for searching a 3D human database
- Implemented methods for retrieval and clustering based on both body and head shape

CAESAR --3D human database

3D Scans of people in 3 postures
Standing, seated,

73 Anthropometry Landmarks
Of ~4500 people

- *Civilian American and European Surface Anthropometry Resource Project—CAESAR*
- *The most comprehensive source for 3D body measurement data*
- *U.S. Air Force's Computerized Anthropometric Research and Design (CARD) Lab*
- Available from www.sae.org/technicalcommittees/caesar.htm

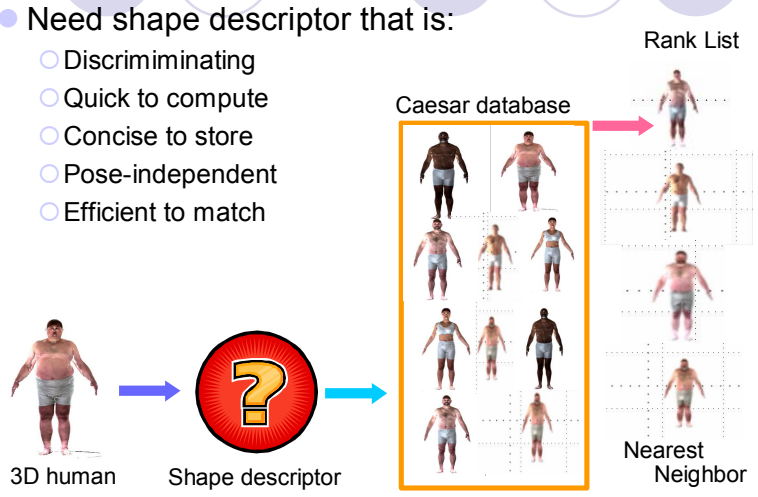


Shape Descriptor

- CAESAR human bodies have over 250,000 grid point
- To be used effectively for indexing, clustering and retrieval, require a compact representation
- Developed two shape descriptor based on human head shape,
- and two shape descriptor based on human body shape

Research Challenge

- Need shape descriptor that is:
  - Discrimiminating
  - Quick to compute
  - Concise to store
  - Pose-independent
  - Efficient to match



Head shape: PCA based

3D Surface Normalization and Registration

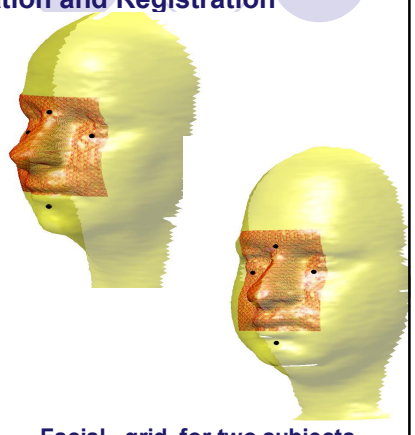
- We use Landmark pts L1, L2, L3, L4 to properly position and align the 3D face surface using iterative method.
- Interpolate to regular rectangular grid, size is proportional to distance |L3 - L2|
- The PCA recognition method is a nearest neighbor classifier operating in the PCA subspace

Distance measure in our study:

L1 distance
L2 distance $d(S_i, S_j) = \sum_{k=1}^{K} |S_i - S_j|$
Mahalanobis distance

$$d(S_i, S_j) = -\sum_{k=1}^{K} (1/\sqrt{\lambda_k}) S_i S_j$$

k th eigenvalue corresponding to the k th eigenvector

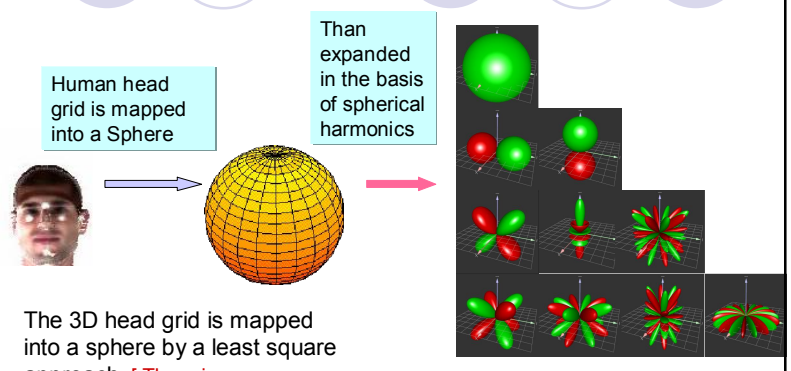


Facial grid for two subjects

Head Shape: Spherical harmonics based

Human head grid is mapped into a Sphere

Than expanded in the basis of spherical harmonics

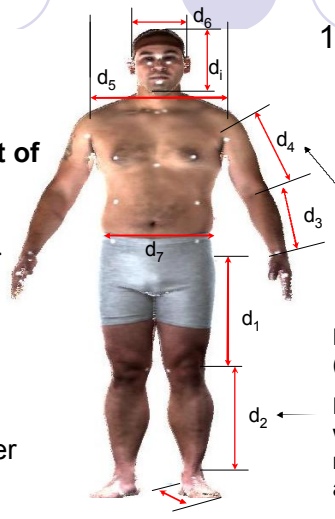


The 3D head grid is mapped into a sphere by a least square approach. [There is convergence problem for ~10% of head grids, maybe because of voids in the 3D grid]

Body Shape: Distance based descriptor

15 distances

Body shape descriptor consist of of distances b/w landmark pts
d = {d_1,d_2,d_3, d_4 …}

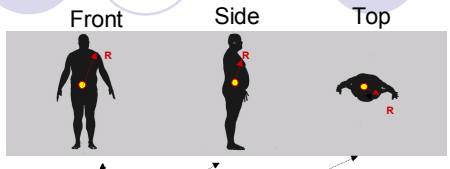


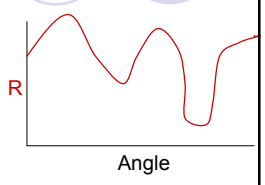
Distances:
d_1 hip to knee
d_2 knee to ankle
d_3 wrist to elbow
d_4 elbow to shoulder
etc

Rigid Connections (Bones)

Distances are some what Invariant to movement, position, and pose

Body Shape: Silhouette Fourier descriptor





Pose dependent

Subject 00082 is rendered in three view as silhouette

- The silhouettes are then represented as R(radius) of the outer contour
- Then encoded as Fourier descriptors as features for later similarity based retrieval.
- The theory is that 3D models are similar, if they also look similar from different viewing angles.

Similarity Matrix

$$1/S_{ij} = [\sum_{k=1,M} (|d_i^k - d_j^k|)^n]^{1/n}$$

For i , j = 1 to NB

M = Size of descriptor vector

NB = Number of Bodies/Heads

n=1 → L1 norm

n=2 → L2 norm

What does Similarity mean?

Compare all bodies/head with all bodies/head based on the descriptor
And report a number indicating sameness or similarity of body/head

Similarity Matrix

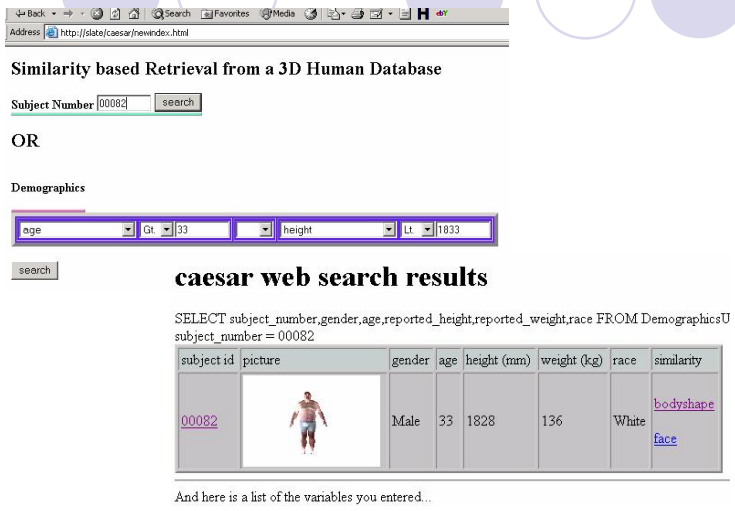
1.0	0.8	0.6	0.4	0.5
0.8	1.0	0.8	0.6	0.6
0.6	0.8	1.0	0.8	0.4
0.6	0.6	0.8	1.0	0.5

The similarity Matrix can also be used for **clustering similar** bodies

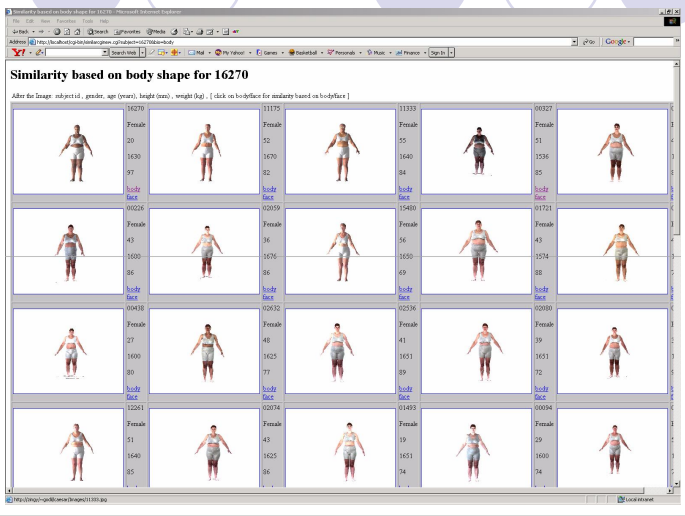
Results

- To test how well shape descriptor represent the bodies, we studied identification rate of 200 subjects sitting vs. standing
- The measure of identification performance is the “rank order statistic” called the Cumulative Match Characteristic (CMC).
- CMC at rank 1, for 200 people sitting vs. standing:
  - Facial PCA =85%
  - Spherical harmonics for head = 94%
  - Body shape: distance descriptor =40%

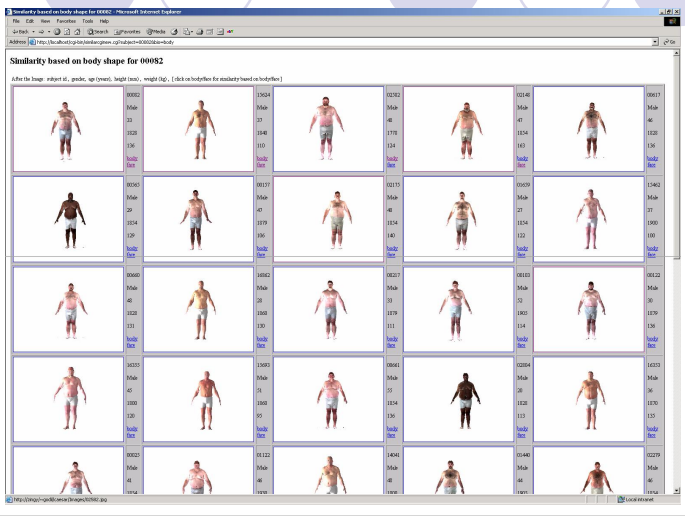
Results



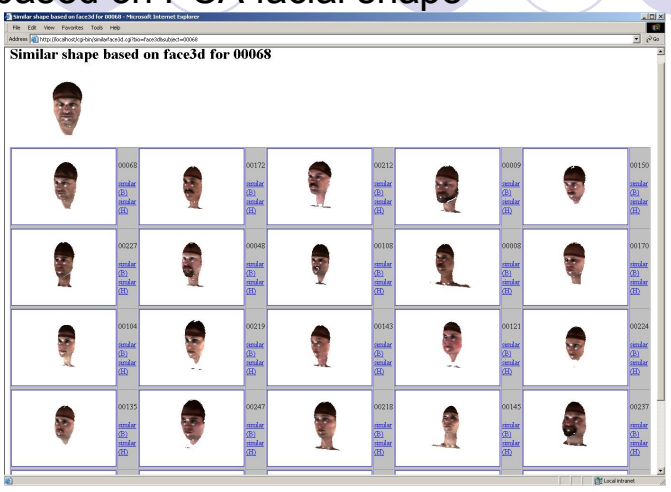
Similarity based retrieval for “16270”



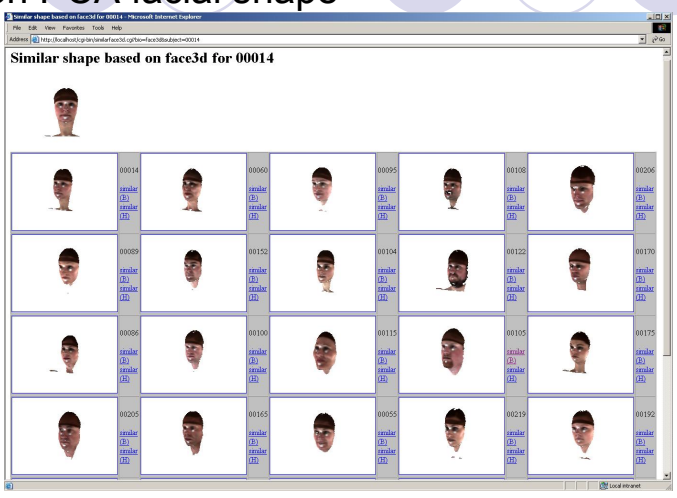
Similarity based retrieval for “00082”



Similarity based retrieval for 00068 based on PCA facial shape

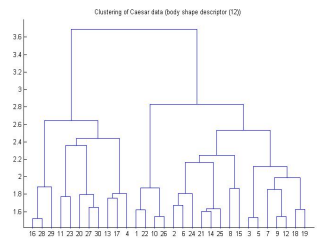


Similarity based retrieval for 00014 based on PCA facial shape



Clustering Results

- Clustering is the process of organizing a set of bodies into groups in such a way that the bodies within the group are more similar to each other than they are to other bodies belonging to different clusters.
- Hierarchical clustering method.
- Dendrogram which is a visual representation of hierarchical data to show the clusters.



Applications

- The tool is used for retrieval and clustering of human bodies based on body shape or head shape
- This tool will provide better understanding of the human body and head shape variation (statistical analysis)
- Might result in better design of various products (helmet, mask, eye glasses, etc)

Conclusions

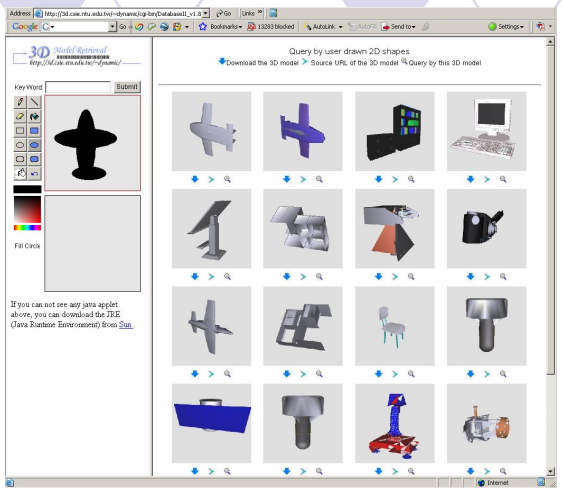
- We have developed a similarity based retrieval and clustering system for a 3D human database based on both human body and head shape
- In the future we plan to use the body and head shape descriptor for design of various products

3D Retrieval Interfaces

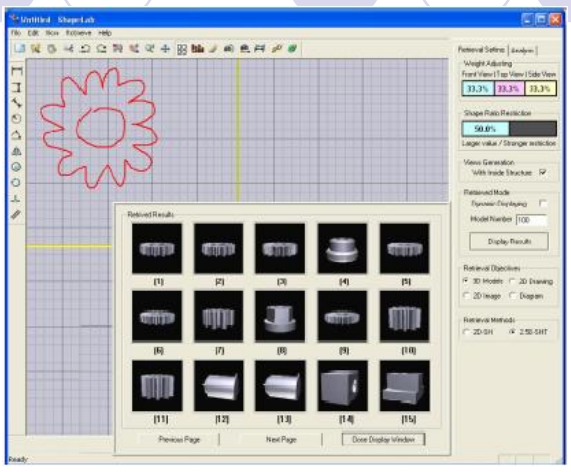
- 2D Sketches
- Physical Objects (Tangibles)
- Others

2D sketches (Princeton)

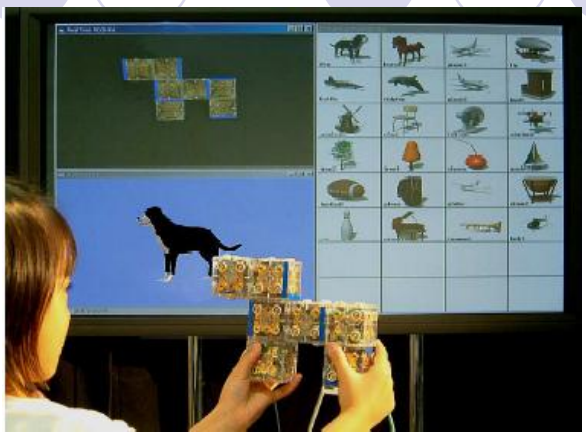
2D sketches (Taiwan)



2D sketches (Purdue)

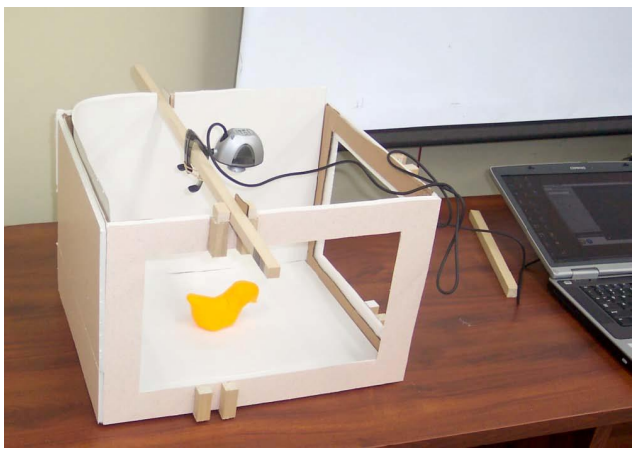


Using Physical objects

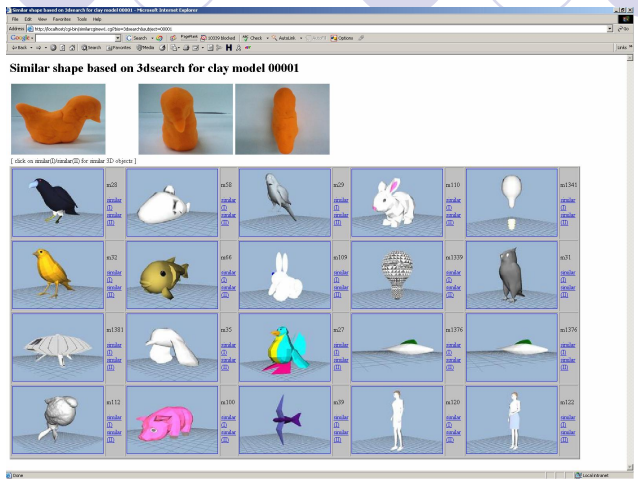


Interactive retrieval of **3D shape** models using **physical objects ...** Tsuyoshi Takei

Tangible 3D Shape Searching



Tangible 3D Shape Searching



Conclusions

- We have developed a similarity based retrieval and clustering system for a 3D human database based on both human body and head shape
- We also have done work in 3D Retrieval Interfaces (Tangible 3D Shape Searching)

Thank you for your attention!

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