3D Shape Representation and Analysis of the Human Body and Ontology for Anthropometric Landmarks

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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

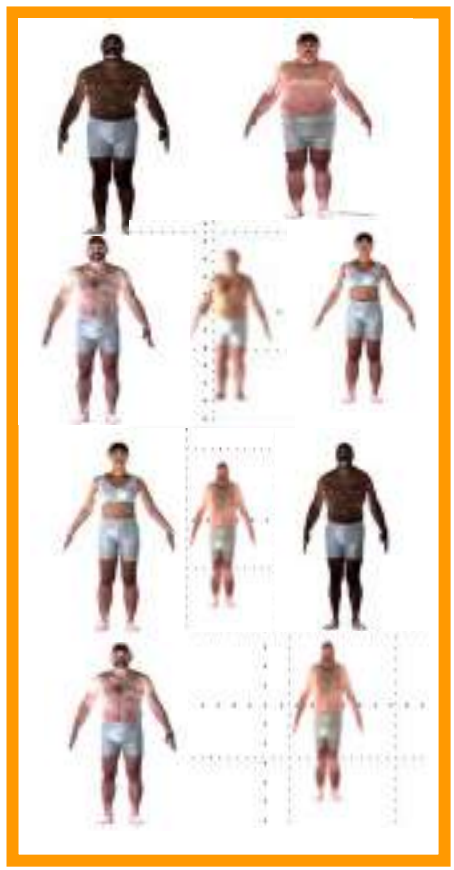
Research Challenge

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

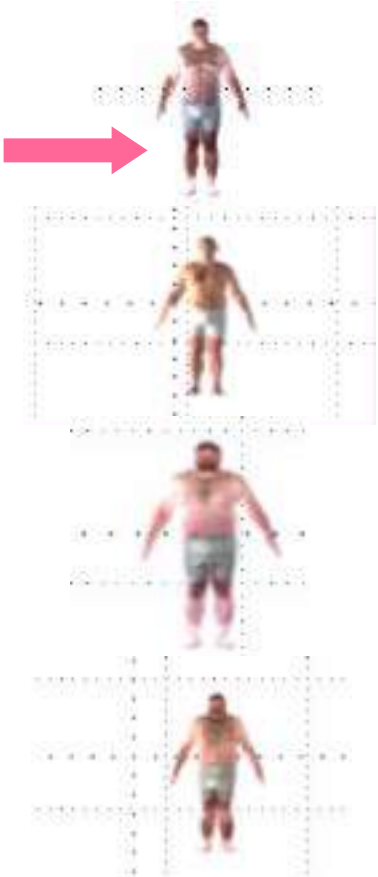
3D human

Shape descriptor

Caesar database



Rank List



Nearest Neighbor

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

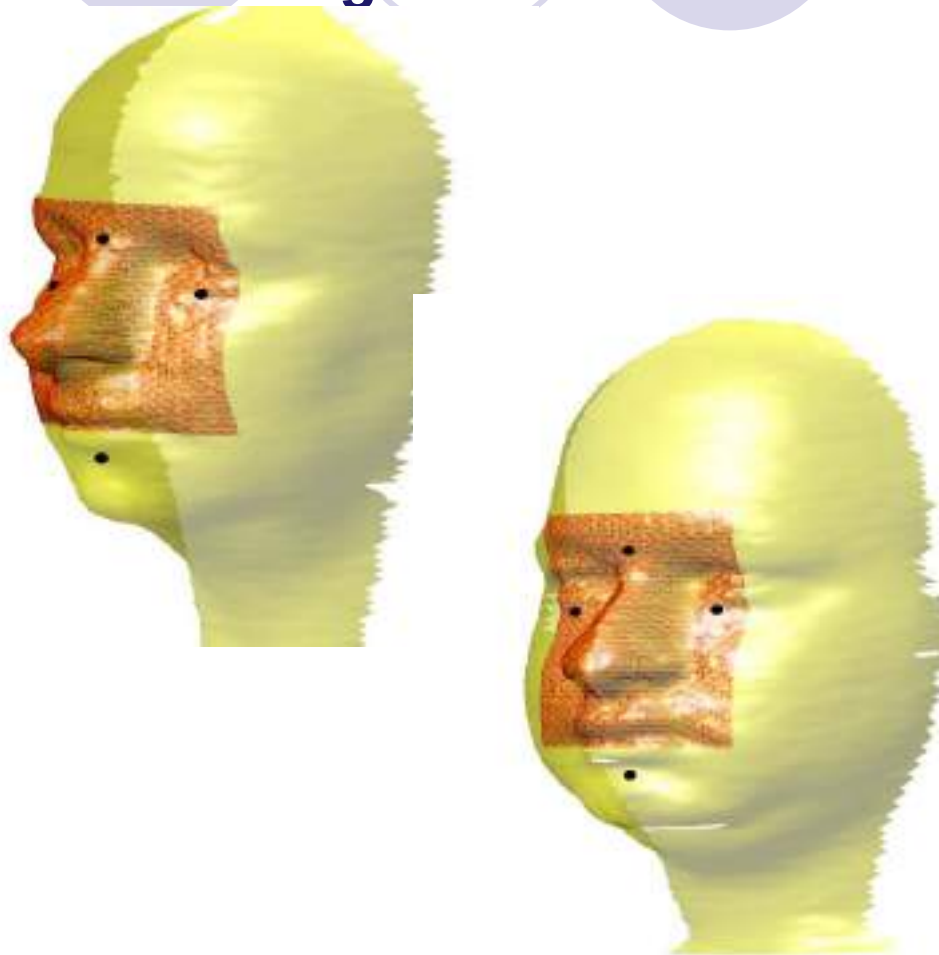
$$d(S_i, S_j) = \sum_{k=1}^{K} |S_i - S_j|$$

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

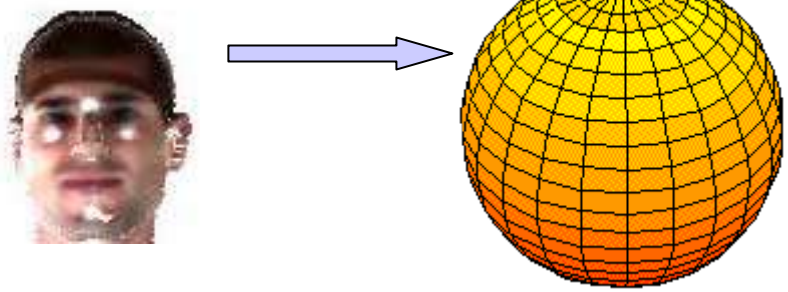


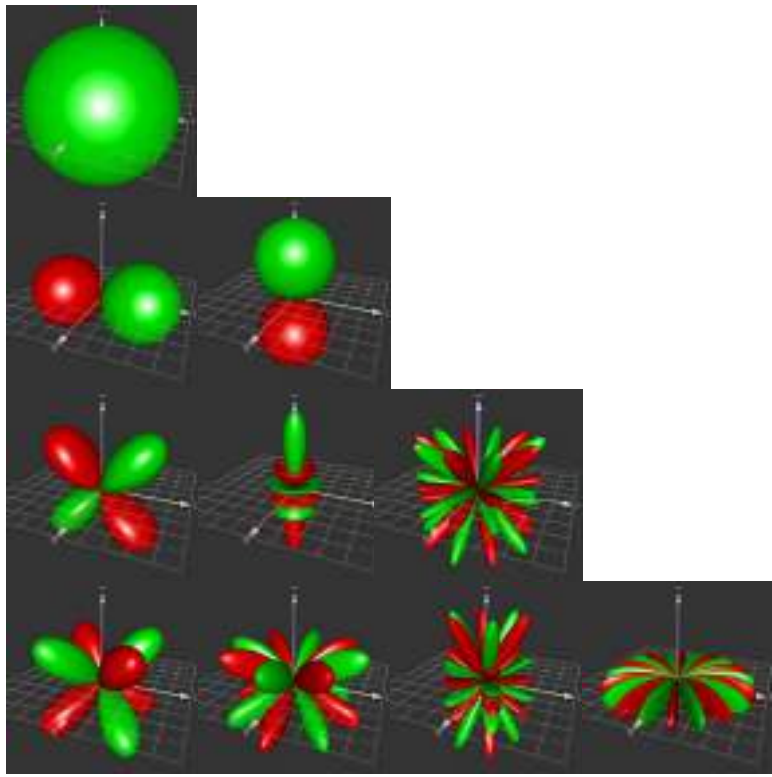
Facial grid for two subjects

Head Shape: Spherical harmonics based

Human head grid is mapped into a Sphere

Than expanded in the basis of spherical harmonics





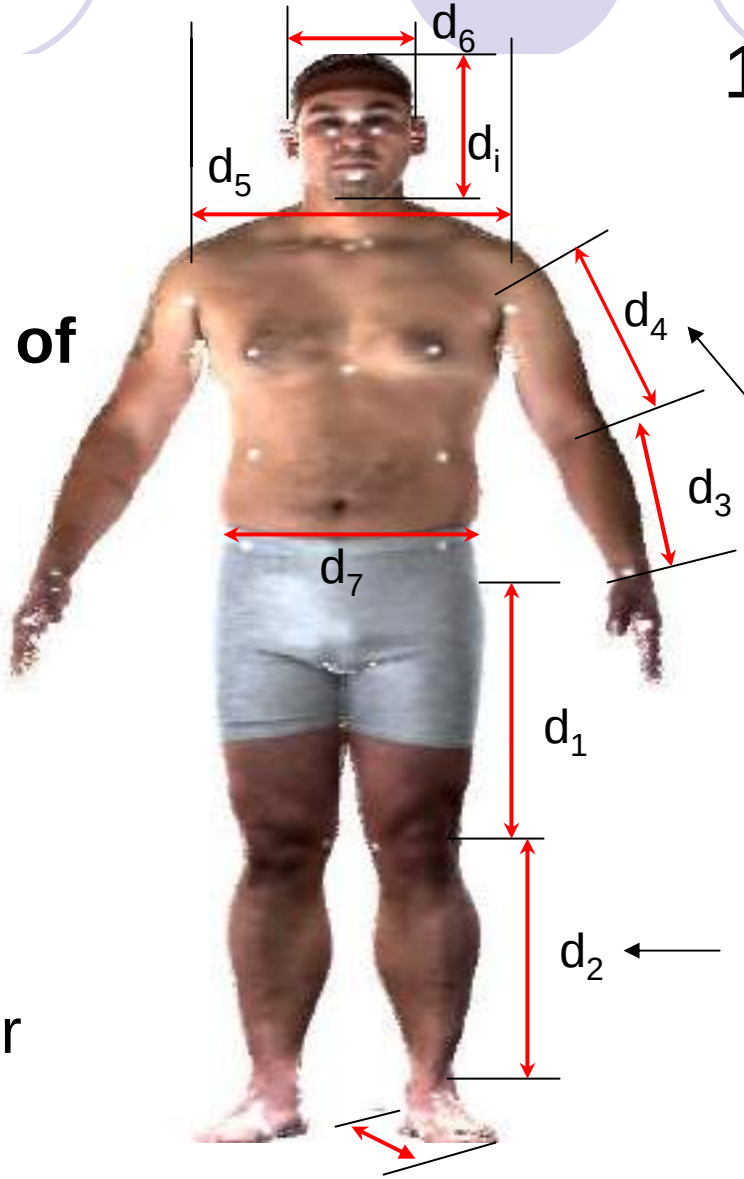
The 3D head grid is mapped into a sphere by a least square approach. [There is convergence problem for ~10% of head grids, maybe because of voids in the 3D grid]

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

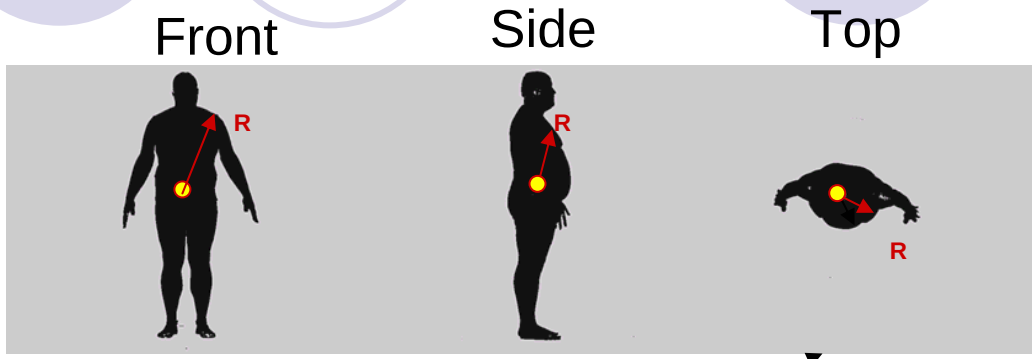
d_4 elbow to shoulder

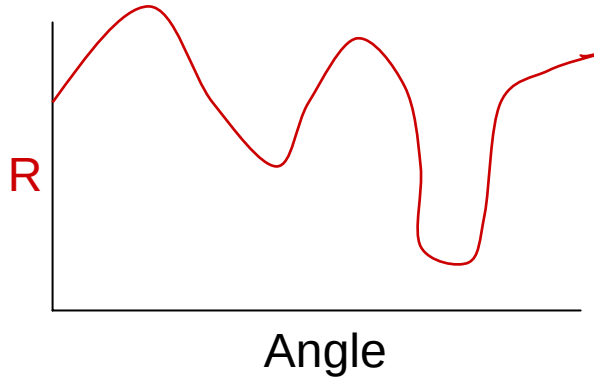
etc

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

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

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

Back Search Favorites Media

Address http://slate/caesar/newindex.html

Similarity based Retrieval from a 3D Human Database

Subject Number 00082 search

OR

Demographics

age Gt. 33 height Lt. 1833

search

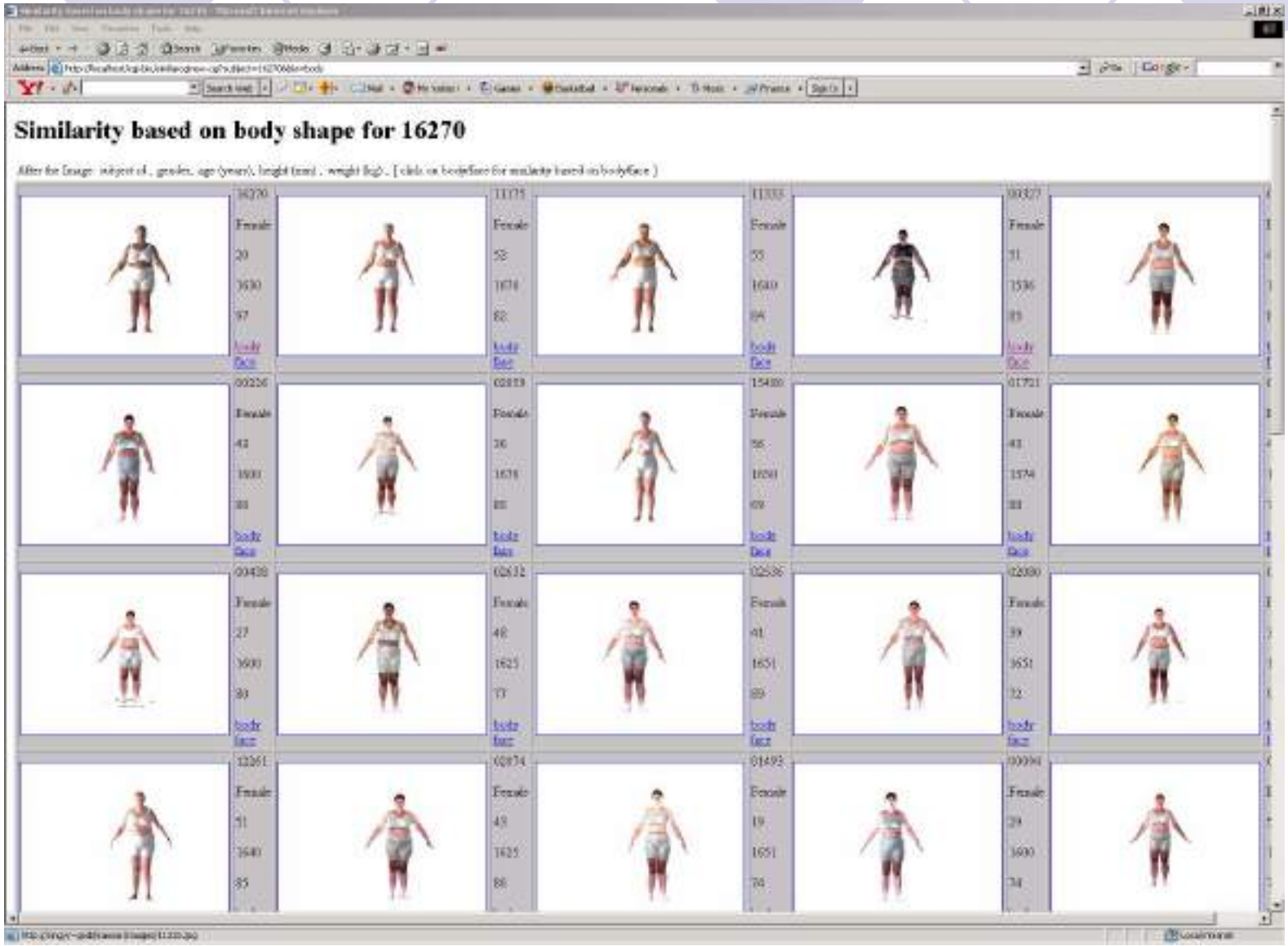
caesar web search results

SELECT subject_number,gender,age,reported_height,reported_weight,race FROM DemographicsU
subject_number = 00082

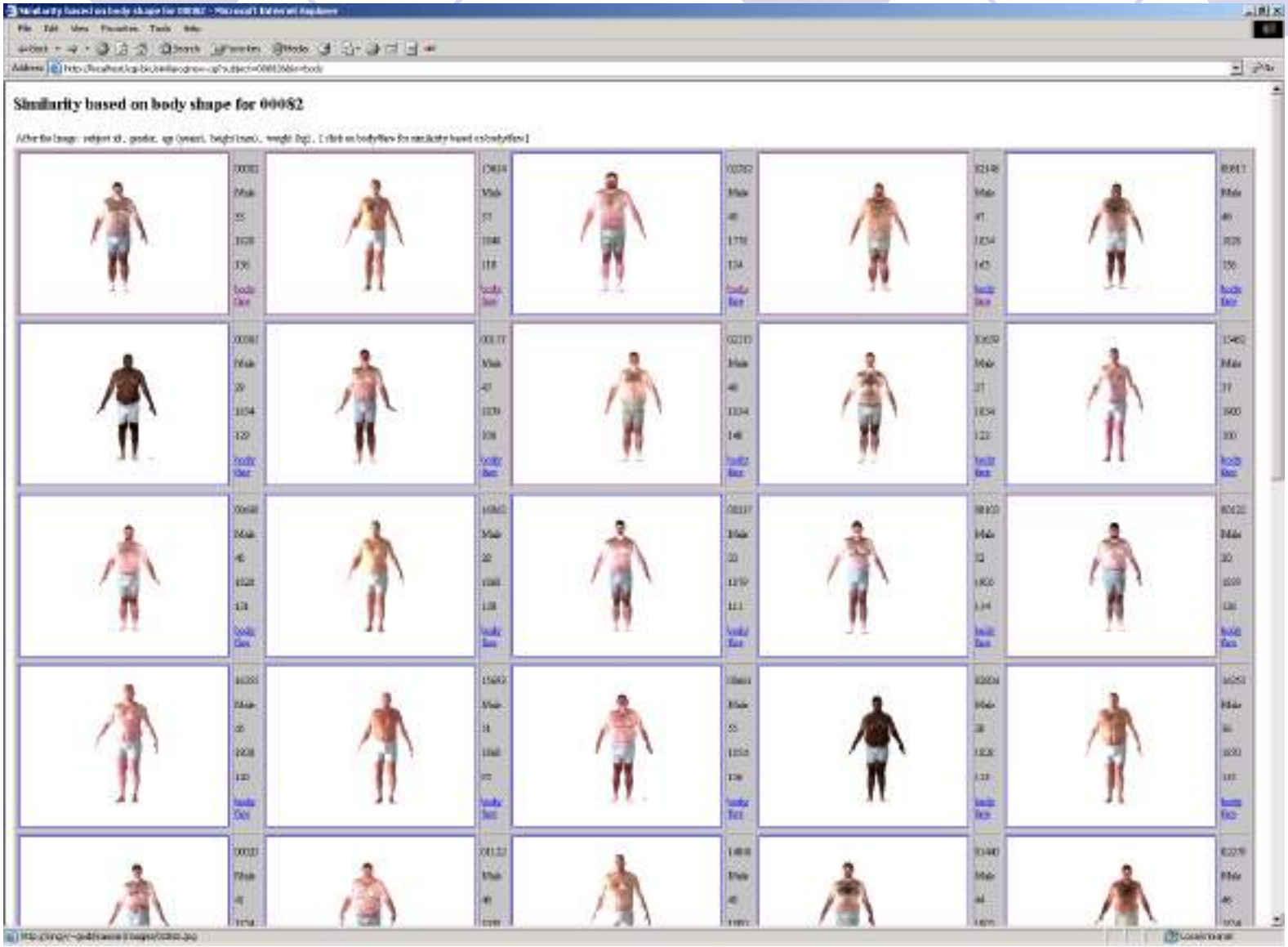
subject id	picture	gender	age	height (mm)	weight (kg)	race	similarity
00082		Male	33	1828	136	White	bodyshape face

And here is a list of the variables you entered...

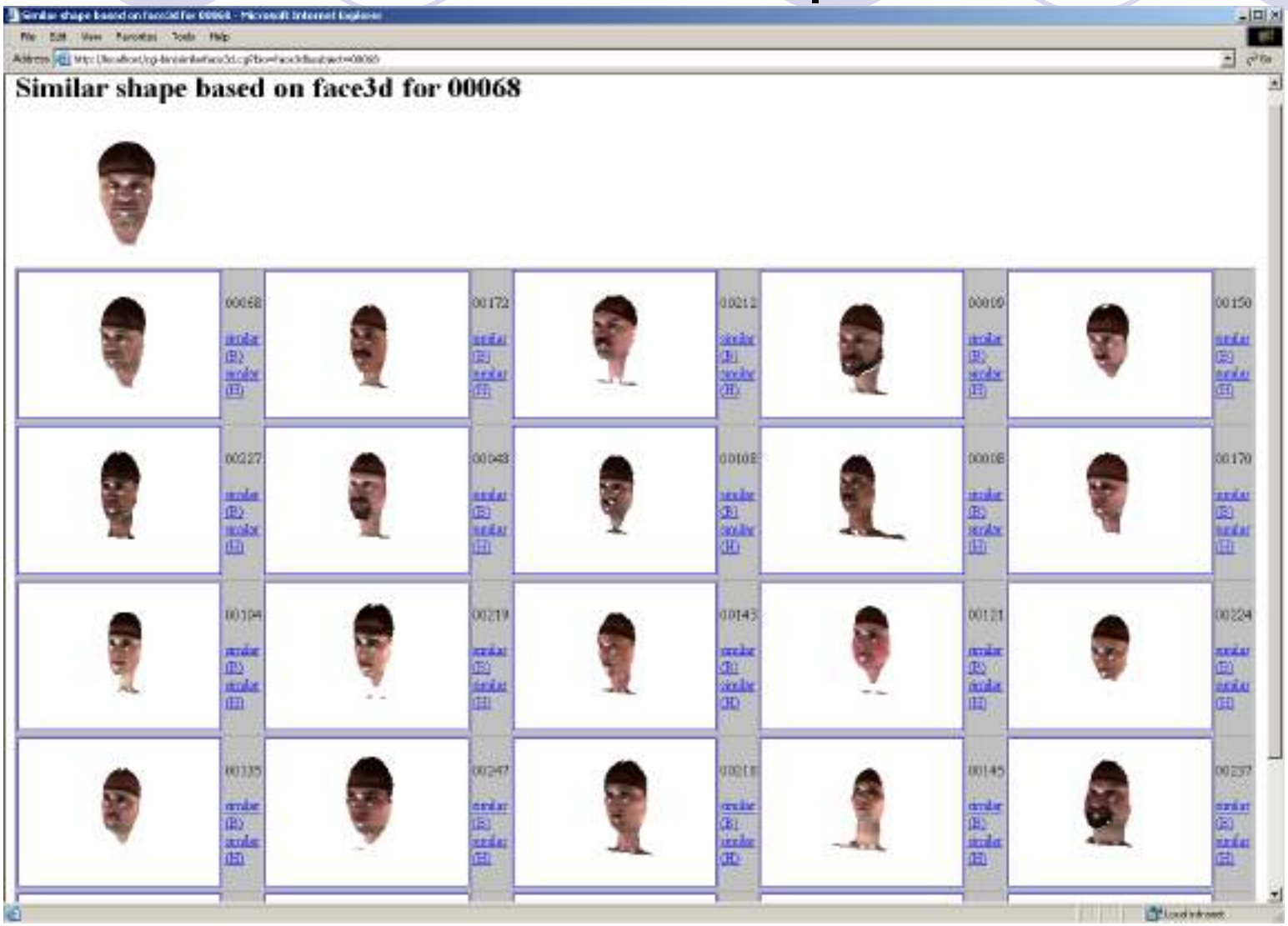
Similarity based retrieval for “16270”



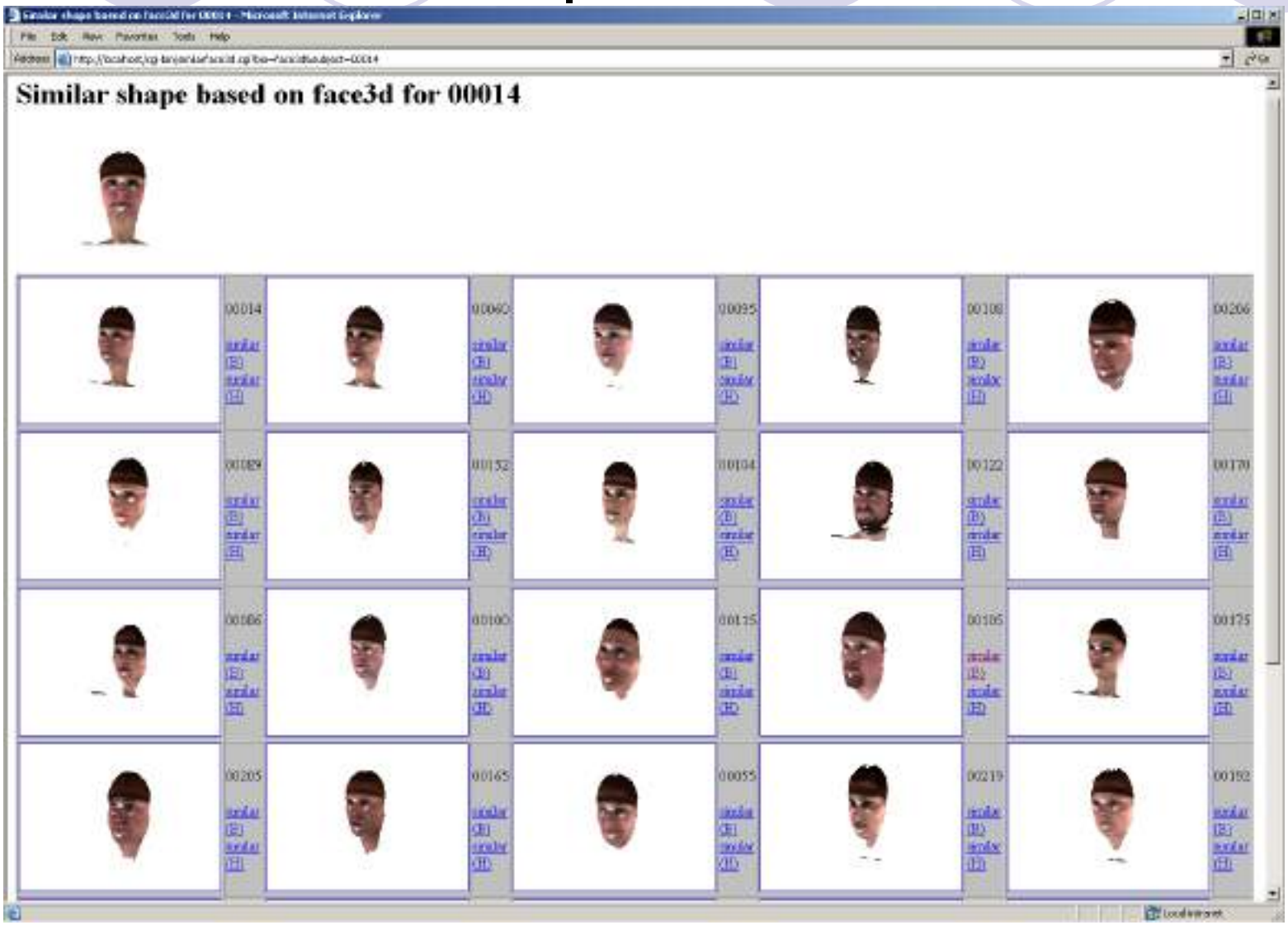
Similarity based retrieval for “00082”



Similarity based retrieval for 00068 based on PCA facial shape

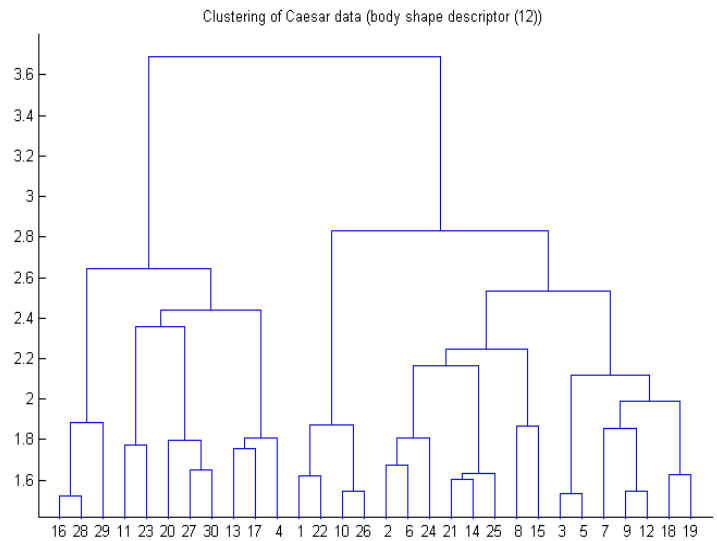


Similarity based retrieval for 00014 based on PCA facial shape



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.



Ontology for Anthropometric Landmarks

- Ontology is a formal way to describe knowledge in a particular domain
- An ontology defines a common set of vocabulary and definitions for researcher and engineers to share information in a particular domain or domains
- The ontology is both human understandable and machine interpretable statements of the basic definitions and relationships between them

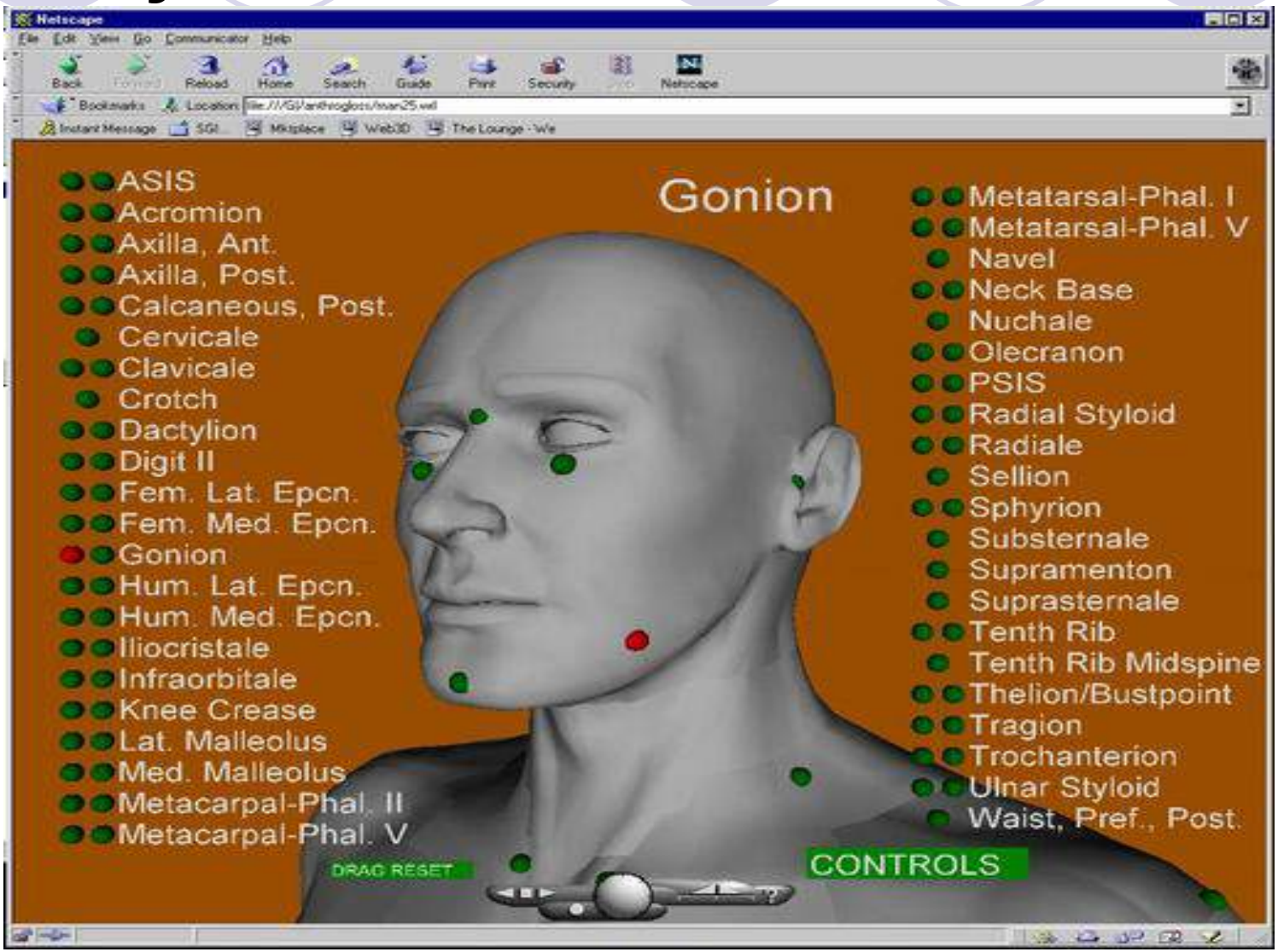
Ontologies generally consist of:

- Individuals: the basic or "ground level" objects
- Classes: collections, sets, or types of objects
- Attributes: properties, features, characteristics, or parameters that objects can have and share
- Relations: ways that objects can be related to one another

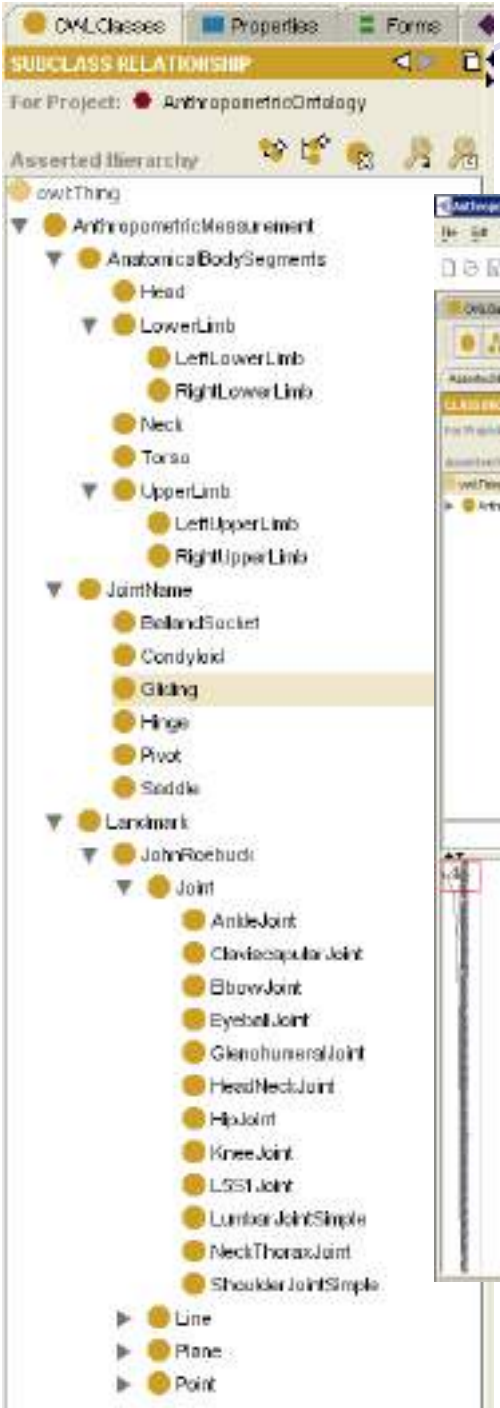
Reasons to Develop an Ontology

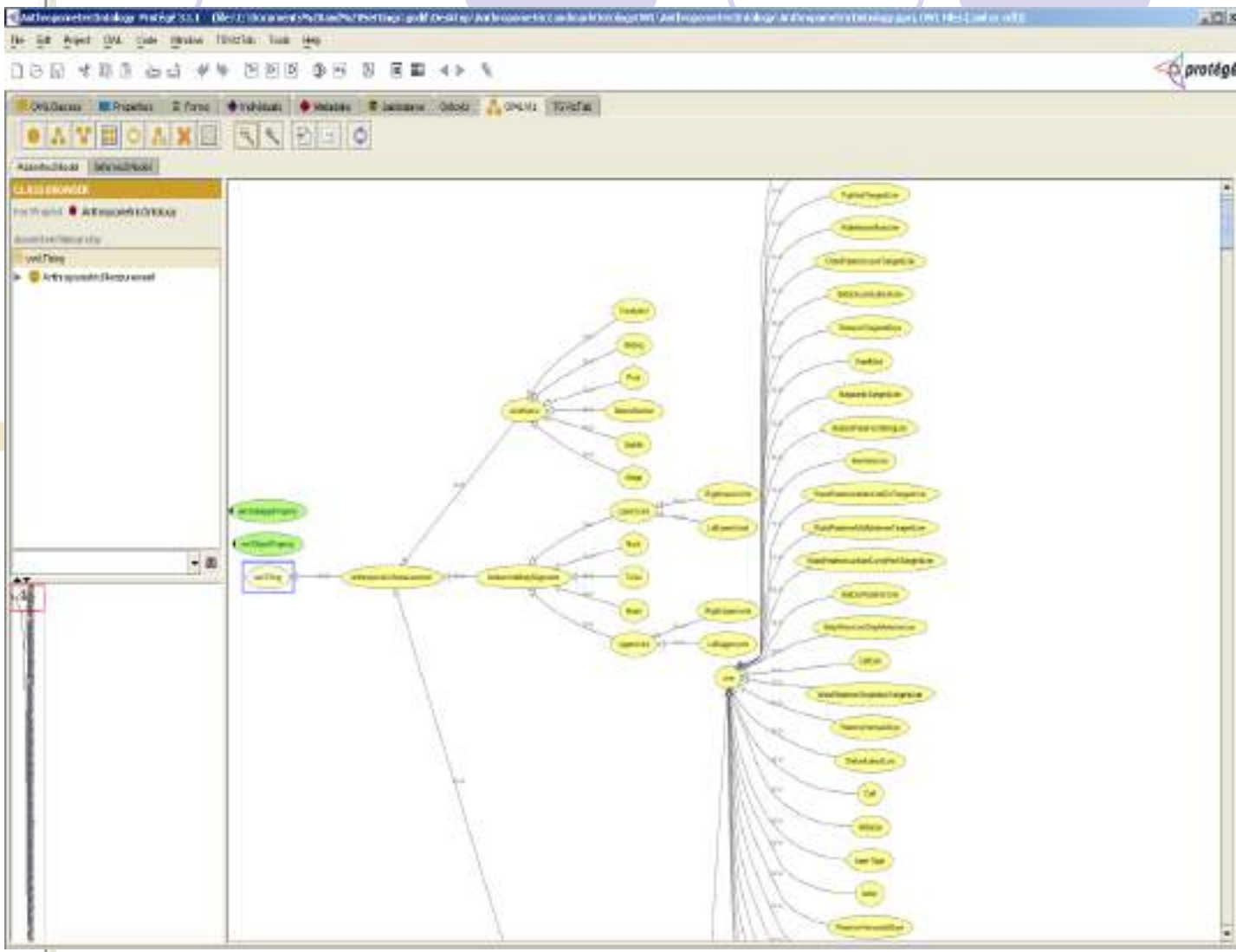
- To share a common understanding of the relationship, terminology and structure of the information in the domain
- To enable use and reuse of the information in the domain
- To make all the relationships and assumptions explicit

A 3D Visual Anthropometric Landmark Glossary

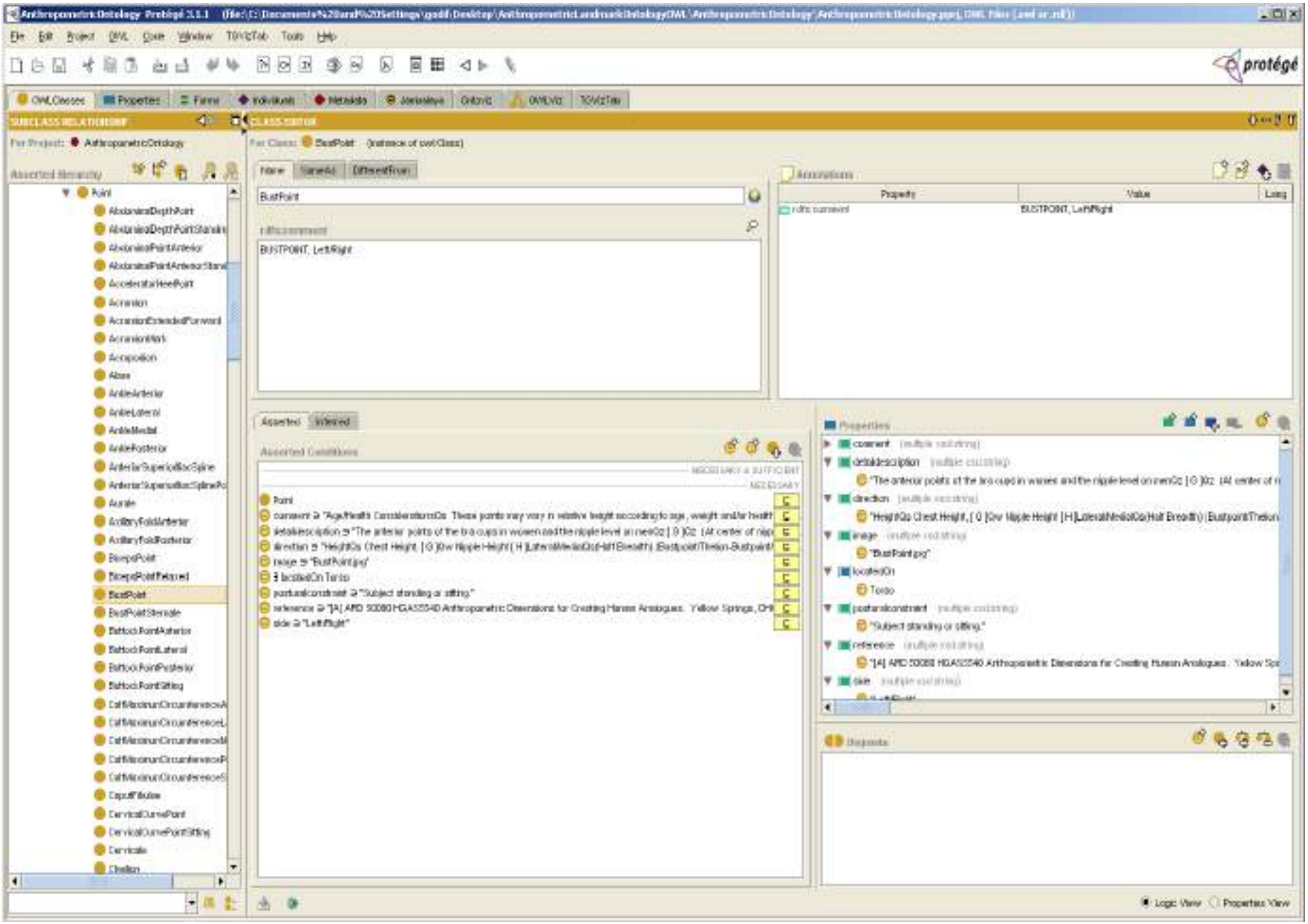


Structure of the ontology in Protégé





Visualization of the tree structure of the ontology



Shows the ontology in the Protégé

Ontology

Class: AnteriorScyeOnTheTorso

Documentation: ANTERIOR SCYE ON THE TORSO, LEFT /RIGHT

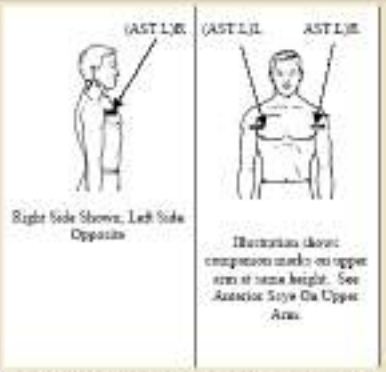
Superclasses
- Line

Subclasses
None

Types
- STANDARD-CLASS

Instances (1)

Template Slots

Slot Name	Documentation	Type	Cardinality
comment	These landmarks could also be considered as lines that define a portion of the intersection of the skin covering the pectoral muscles and a horizontal plane at the height of the Axillary Fold, Anterior, on the left and right side respectively.	String	0:1
detailDescription	These pointer marks (herein defined as LINES) help to define the height of the landmarks called AXILLARY FOLD, ANTERIOR (LEFT and RIGHT) or Axilla, Anterior, or Anterior Axilla Reference Point, Left and Right They are marked on the pectoral muscle region, just medial to the top of the fold [G]	String	0:1
direction		String	0:1
image	 Right Side Shown, Left Side Opposite. Illustration shows compression marks on upper arm at same height. See Anterior Scye On Upper Arm.	String	0:1
posturalConstraint	Subject standing or sitting upright, arms relaxed at side.	String	0:1
reference	[R]Unpublished briefing charts and papers by J. A. Roebuck Jr. [G]1988 Anthropometric Survey of US Army Personnel Summary Statistics Technical Report Natick/TR-89/044. Gordon, C. C., Churchill, T., Clauser, C. E., Bradtmiller, B., McConville, J. T., Tebbetts, I., and Walker, R. A., Natick, MA 01760-5000 United States Army Natick Research, Development and Engineering Center, (unclassified), 1989b	String	0:1
side	Left/Right	String	0:1

Own Slots

Slot Name	Value
R/V F	Concrete

The html view of the ontology

testNEW Project) FrankfortPlane - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Search Favorites Media

Address http://zingy.ncsl.nist.gov/~godi/Ontology/AnthropometricLandmarkOntology.HTML

Go Links Google

NIST

Ontology

Class: FrankfortPlane

Documentation: FRANKFORT PLANE

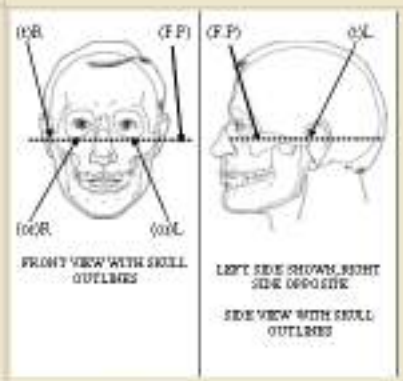
Superclasses
- Plane

Subclasses
None

Types
- STANDARD-CLASS

Instances (1)

Template Slots

	Slot Name	Documentation	Type	Cardinality
	comment		String	0:1
	detailDescription	A horizontal plane that is used to define certain constraints of the head posture for measurement purposes, in which the right TRAGION LANDMARK (approximate ear hole) and the lower edges of the two orbits (bony eye sockets, ORBITALE LANDMARKS) lie in this plane	String	0:1
	direction		String	0:1
	image		String	0:1
	posturalConstraint	When the head is properly oriented in the Frankfort Plane, the following landmarks lie in this plane and define the pitch and roll orientation of the head (but not its yaw orientation) ? TRAGION, RIGHT (r)R ? ORBITALE, LEFT (or)L (also called Infraorbitale, Left) ? ORBITALE, RIGHT (or)R (also called Infraorbitale) Note To refer to a plane passing through the same landmarks, but allowed to move in constant relationship to the head during simulations with a computer human model, see TRAGION-ORBITALE PLANE.	String	0:1
	reference	[R]Unpublished briefing charts and papers by J.A. Roebuck Jr.	String	0:1
	side		String	0:1

Own Slots

Internet

The html view of the ontology

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 developed an Ontology for Anthropometric Landmarks

Thank you for your attention!

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