

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*

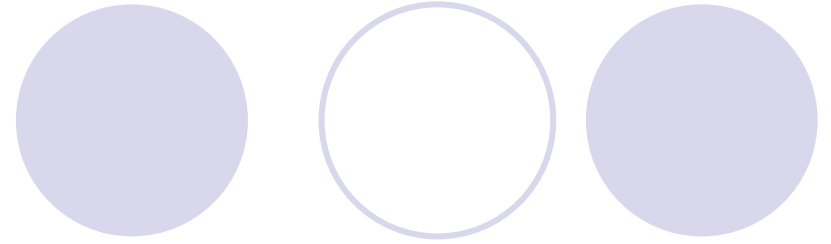
❑ *The most comprehensive source for 3D body measurement data*

❑ *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:

- Discriminating
- Quick to compute
- Concise to store
- Pose-independent
- Efficient to match



3D human



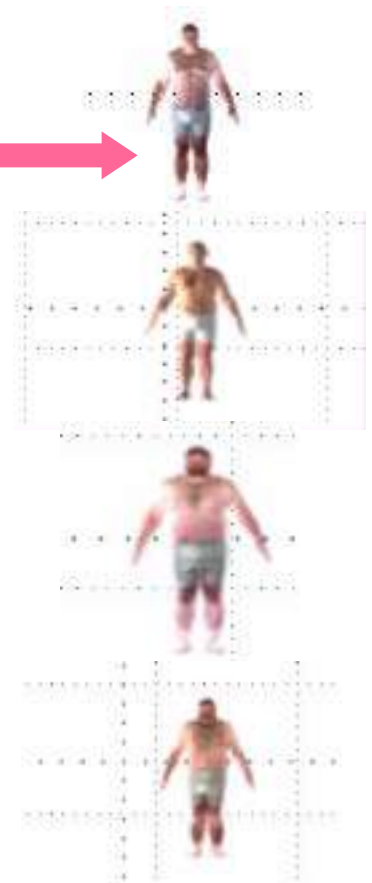
Shape descriptor



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

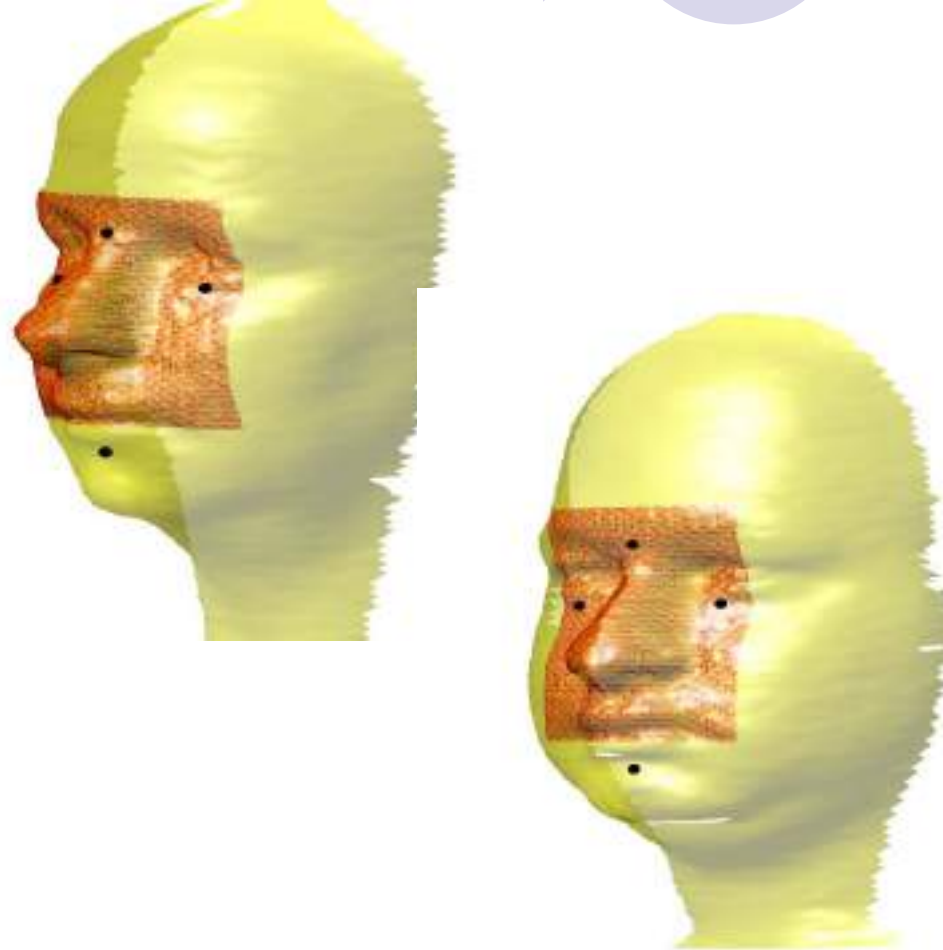
L2 distance

Mahalanobis distance

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

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

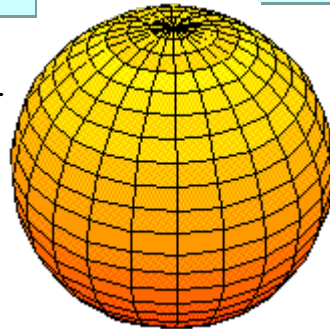
k th eigenvalue corresponding to the
th eigenvector



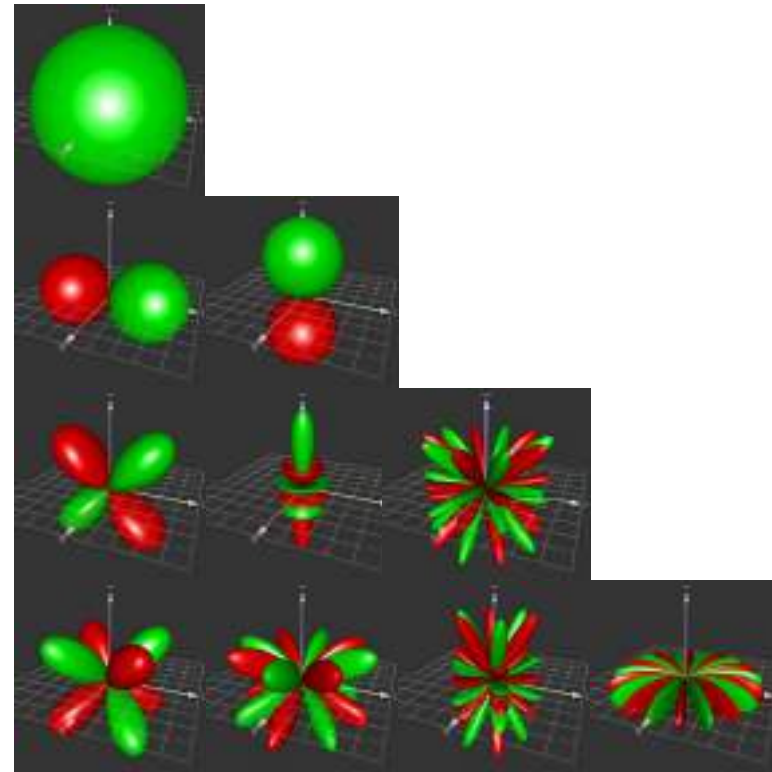
Facial grid for two subjects

Head Shape: Spherical harmonics based

Human head grid is mapped into a Sphere



Then 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

$$d = \{d_1, d_2, d_3, d_4 \dots\}$$

Distances:

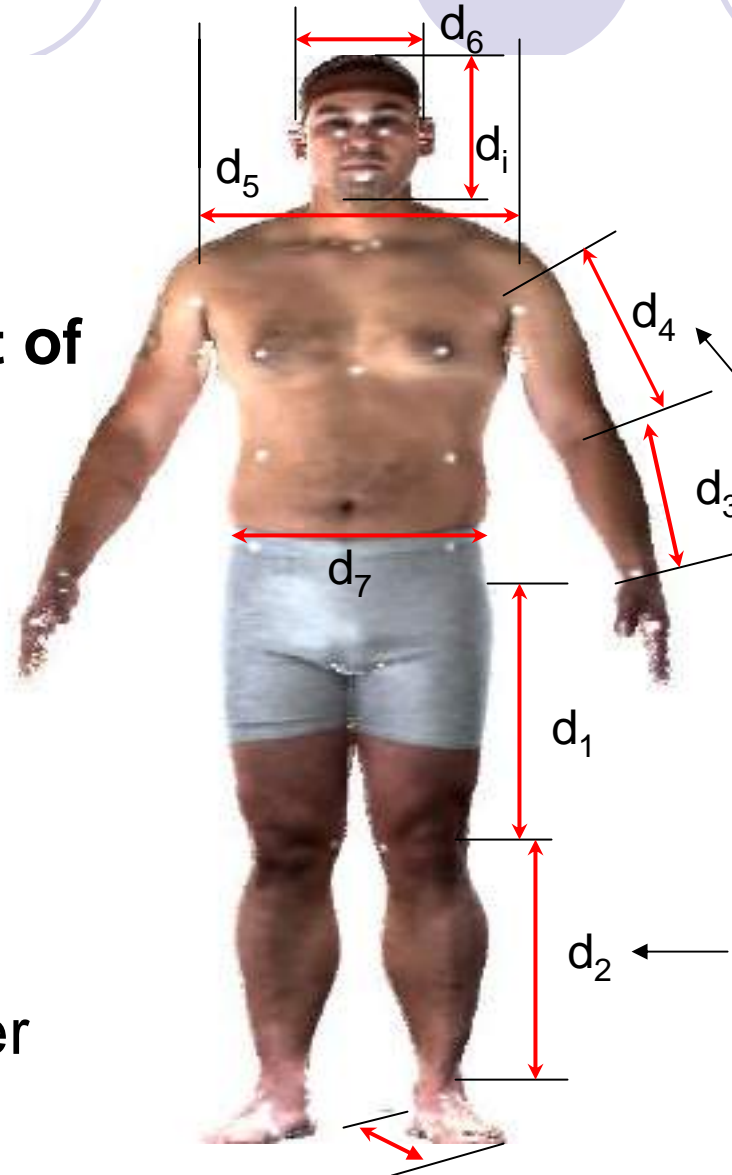
d_1 hip to knee

d_2 knee to ankle

d_3 wrist to elbow

d_4 elbow to shoulder

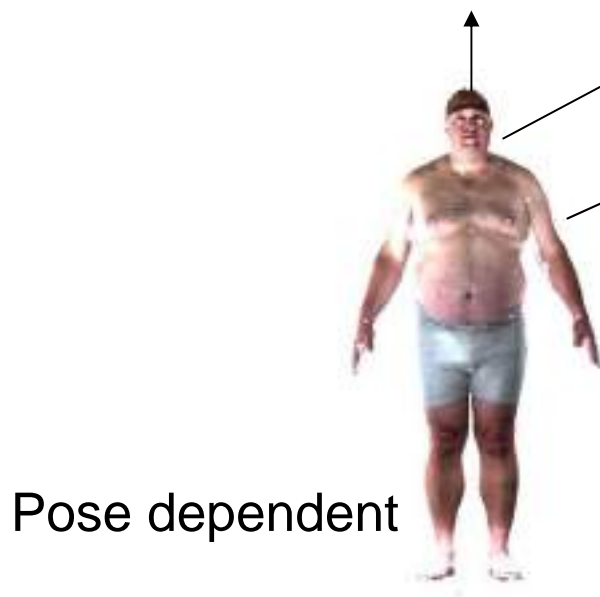
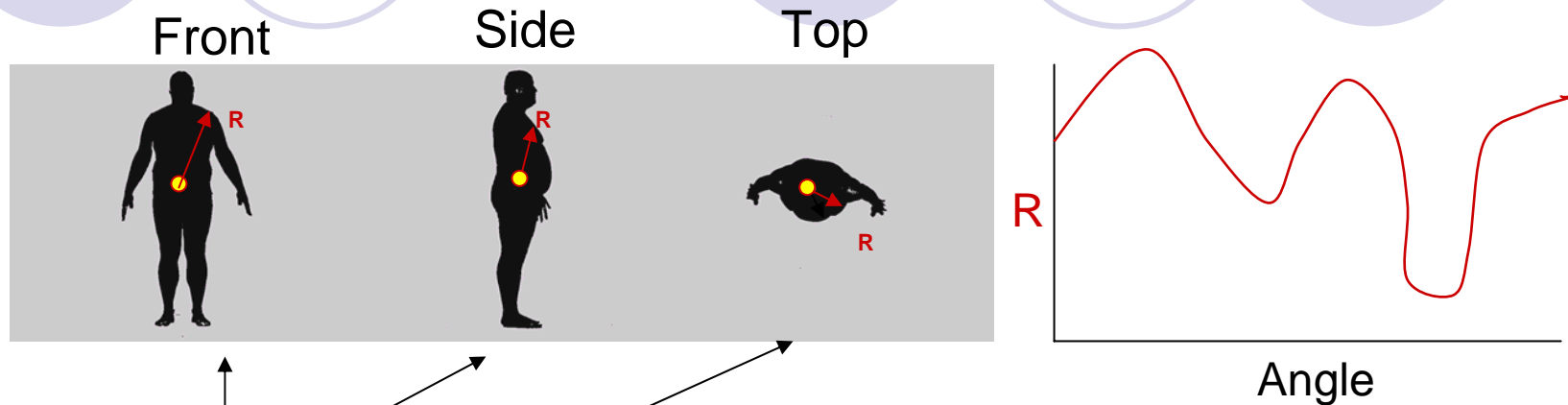
etc



Rigid Connections (Bones)

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

Body Shape: Silhouette Fourier descriptor



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

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

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 →

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



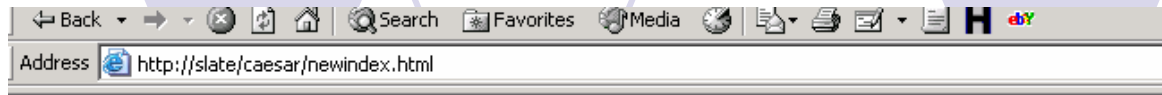
1.0	0.8	0.6	0.4	0.5
0.8	1.0	0.8	0.6	0.6
0.6	0.8	1.0	0.8	0.4
0.6	0.6	0.8	1.0	0.5

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 from a 3D Human Database


Subject Number

OR

Demographics

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 on body shape for 16270


















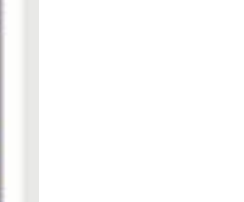





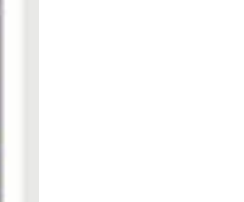






After the Image: subject of . gender, age (years), height (cm) . weight (kg) . [click on bodyface for similarity based on bodyface]

 16270 Female 20 1630 57 body face	 11175 Female 58 1674 60 body face	 11333 Female 55 1610 64 body face	 00327 Female 31 1536 63 body face
 00256 Female 43 1601 61 body face	 02113 Female 36 1671 60 body face	 15480 Female 56 1601 69 body face	 01721 Female 41 1574 61 body face
 00438 Female 27 1600 61 body face	 02632 Female 46 1625 77 body face	 02536 Female 41 1651 69 body face	 02090 Female 39 1651 72 body face
 12261 Female 31 1640 65 body face	 02974 Female 49 1625 66 body face	 01492 Female 19 1651 70 body face	 00094 Female 29 1600 74 body face

Similarity based retrieval for “00082”

Similarity based on body shape for 00082

After file (img): report id., gender, age (years), height (cm), weight (kg), I click on bodyfiles for similarity based on bodyfiles 1

 00081 Male 25 182 75 Body Sex	 00082 Male 25 182 75 Body Sex	 00083 Male 27 184 78 Body Sex	 00084 Male 40 170 134 Body Sex	 00085 Male 47 184 145 Body Sex	 00086 Male 40 175 135 Body Sex
 00087 Male 20 184 120 Body Sex	 00088 Male 47 183 138 Body Sex	 00089 Male 40 184 146 Body Sex	 00090 Male 40 184 146 Body Sex	 00091 Male 27 184 122 Body Sex	 00092 Male 37 180 130 Body Sex
 00093 Male 40 182 134 Body Sex	 00094 Male 20 180 138 Body Sex	 00095 Male 20 180 138 Body Sex	 00096 Male 20 179 131 Body Sex	 00097 Male 32 180 134 Body Sex	 00098 Male 30 180 138 Body Sex
 00099 Male 20 180 130 Body Sex	 00100 Male 18 180 120 Body Sex	 00101 Male 18 180 120 Body Sex	 00102 Male 25 180 138 Body Sex	 00103 Male 38 183 133 Body Sex	 00104 Male 40 180 145 Body Sex
 00105 Male 40 184 138 Body Sex	 00106 Male 40 180 138 Body Sex	 00107 Male 40 180 138 Body Sex	 00108 Male 40 180 138 Body Sex	 00109 Male 40 180 138 Body Sex	 00110 Male 40 180 138 Body Sex

Similarity based retrieval for 00068 based on PCA facial shape

Similar shape based on face3d for 00068

	00068		00172		00212		00010		00150
	00227		00043		00108		00016		00170
	00104		00219		00143		00121		00224
	00135		00247		00018		00145		00237

Each cell in the grid contains a small portrait of a face, a unique ID number, and a button labeled 'similar' with 'R' and 'E' options.

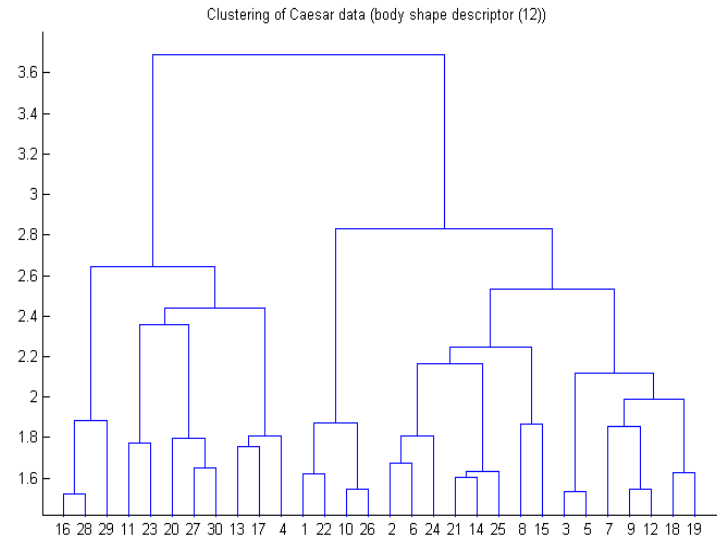
Similarity based retrieval for 00014 based on PCA facial shape

Similar shape based on face3d for 00014

	00014		00090		00095		00108		00206
	00189		00152		00104		00122		00170
	00106		00100		00115		00105		00175
	00205		00165		00055		00219		00192

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

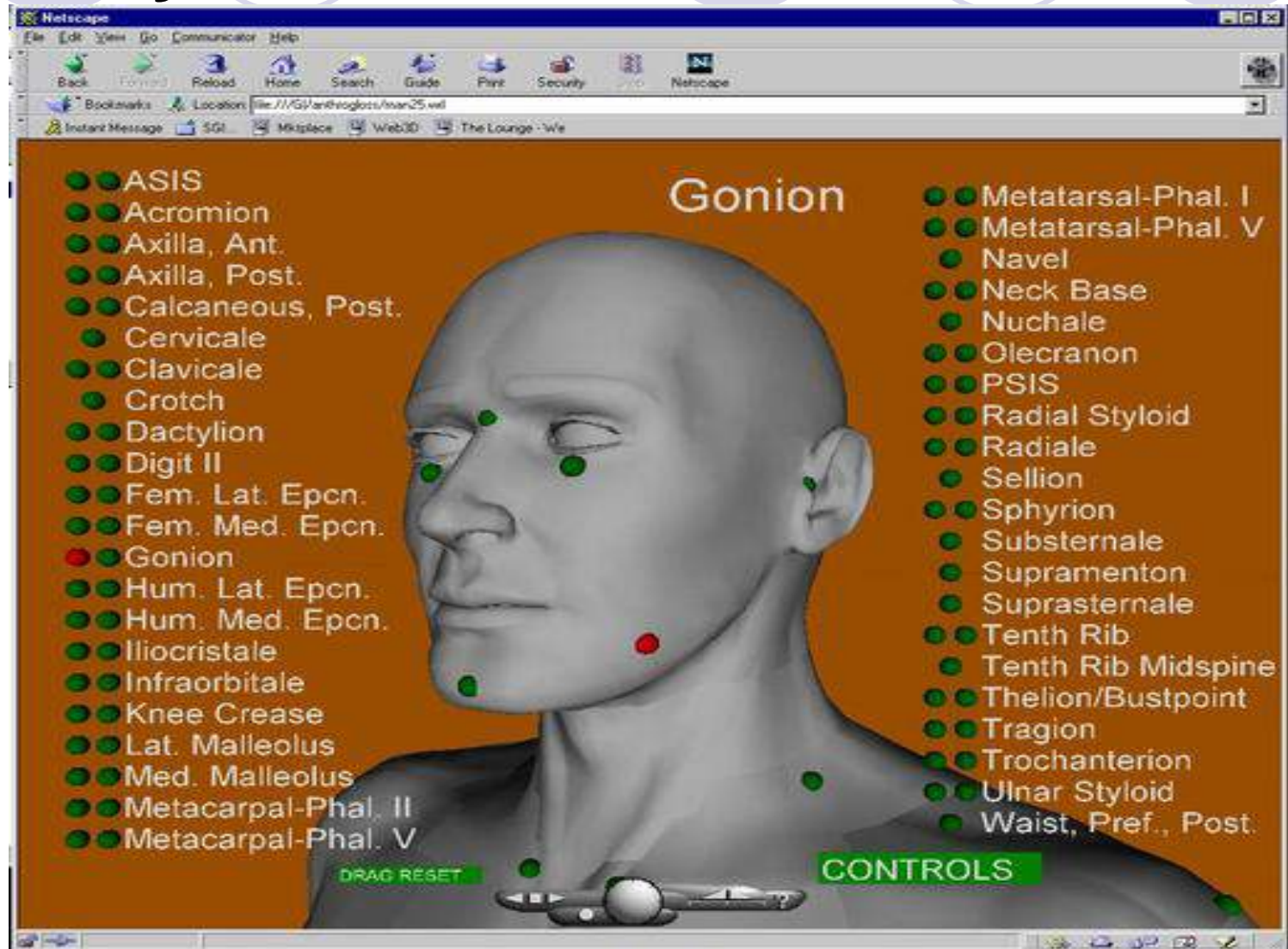
Ontologies generally consist of:

- 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

OWL Classes Properties Forms

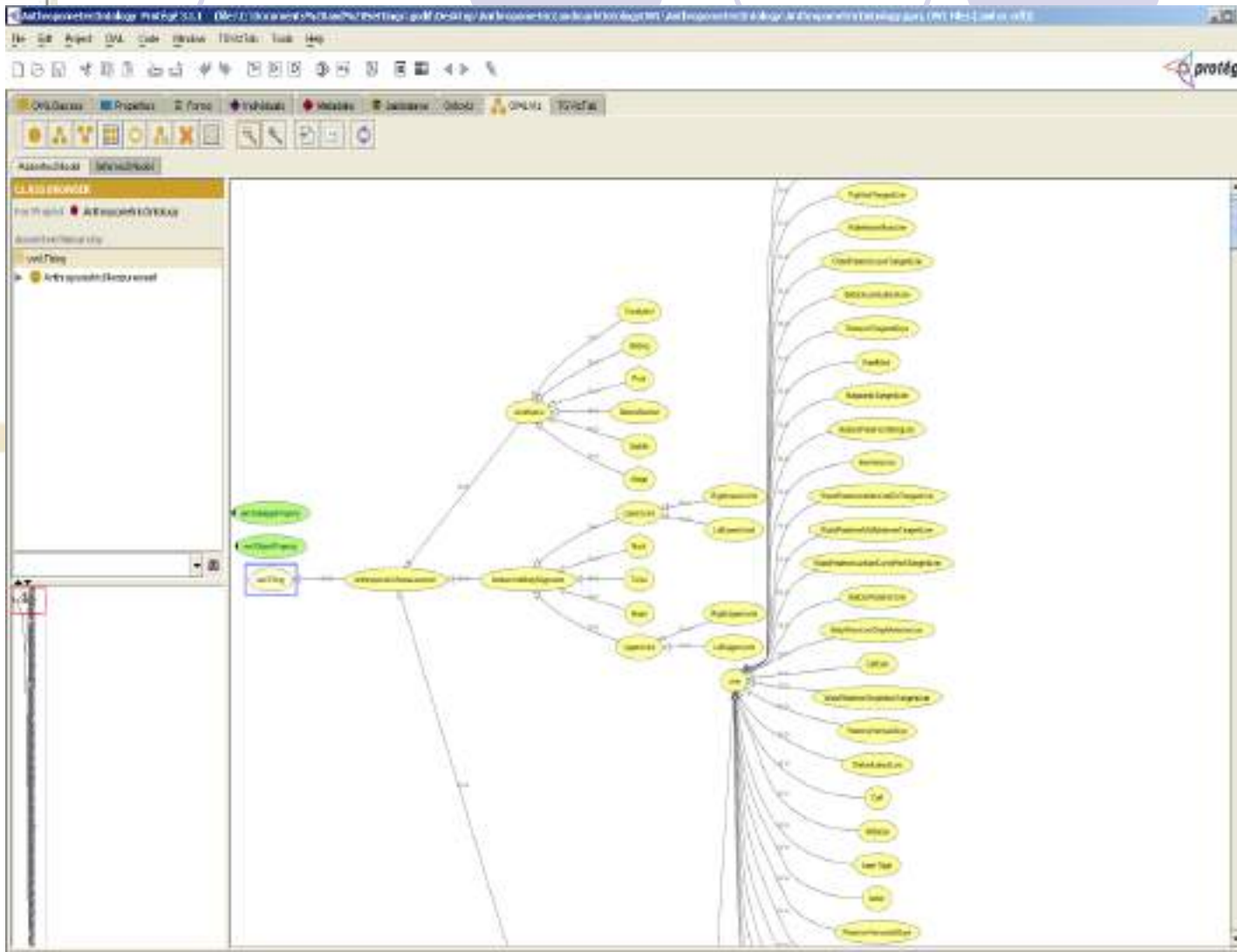
SUBCLASS RELATIONSHIP

For Project: AnthropometricOntology

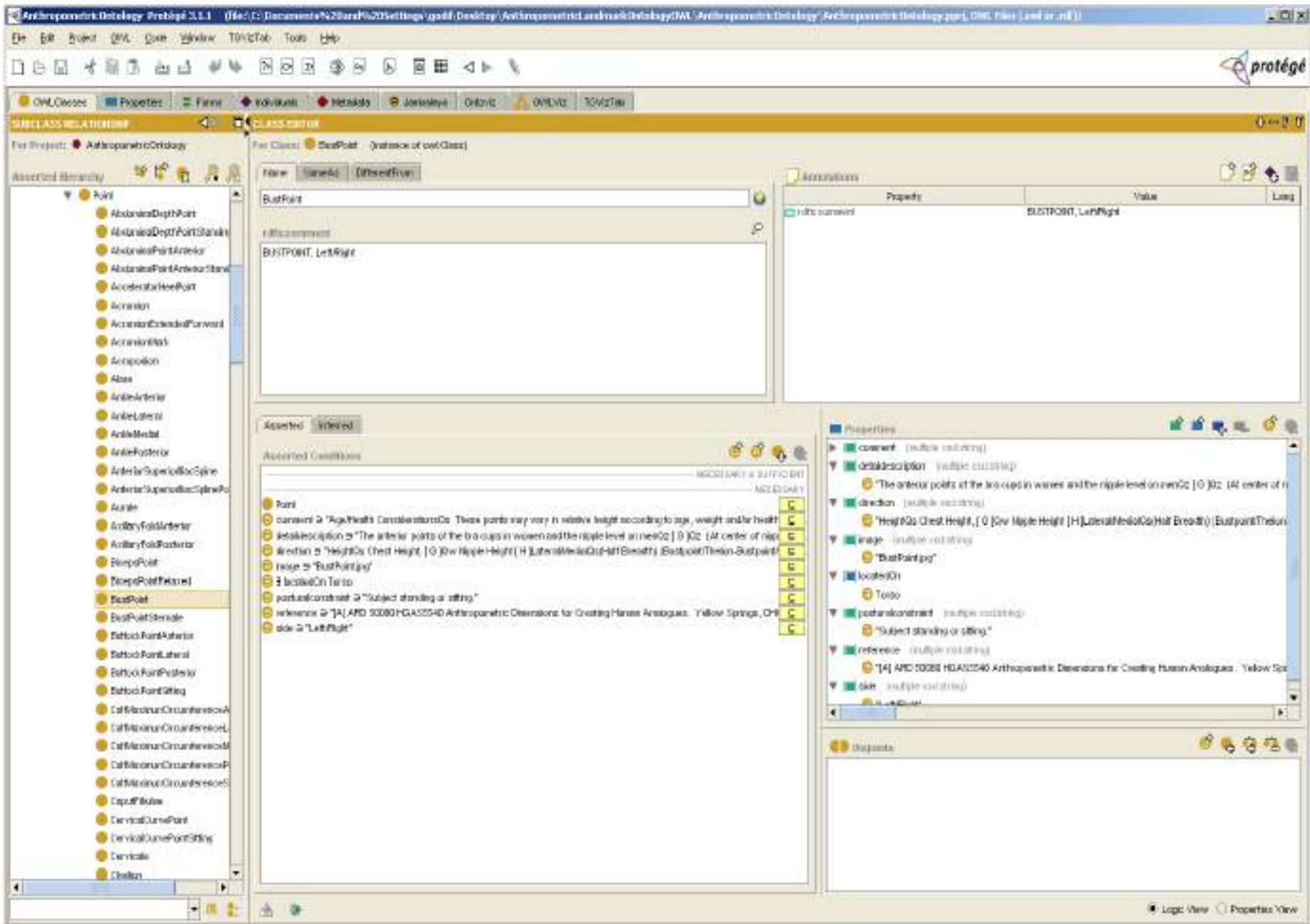
Asserted Hierarchy

- owl:Thing
 - AnthropometricMeasurement
 - AnatomicalBodySegments
 - Head
 - LowerLimb
 - LeftLowerLimb
 - RightLowerLimb
 - Neck
 - Torso
 - UpperLimb
 - LeftUpperLimb
 - RightUpperLimb
 - JointName
 - BallandSocket
 - Condyloid
 - Gliding
 - Hinge
 - Pivot
 - Saddle
 - Landmark
 - JohnRoehudi
 - Joint
 - AnkleJoint
 - ClaviscapularJoint
 - ElbowJoint
 - EyeBallJoint
 - GlenohumeralJoint
 - HeadNeckJoint
 - HipJoint
 - KneeJoint
 - L5S1Joint
 - LumbarJointSimple
 - NeckThoraxJoint
 - ShoulderJointSimple

Line
Plane
Point



Visualization of the tree structure of the ontology



Shows the ontology in the Protégé

Internet Explorer window showing the HTML view of an ontology class: **AnteriorScyeOnTheTorso**.

Address: <http://ontology.ncsl.nst.gov/~godf/Ontology/Anthropometrid.andmarkOntology/HTM>

Ontology

Class: AnteriorScyeOnTheTorso

Documentation: ANTERIOR SCYE ON THE TORSO, LEFT /RIGHT

Superclasses: Line

Subclasses: None

Types: STANDARD-CLASS

Instances (1)

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
defnDescription	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	<p>Right Side Shows, Left Side Opposite</p> <p>Illustration shows compression marks on upper arm at same height. See Anterior Scye On Upper Arm.</p>	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-88/044. Gordon, C. C., Churchill, T., Clauser, C. E., Bradmillar, B., McCormick, 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
RYE	Concrete

The html view of the ontology

TestNew Project: FrankfortPlane - Microsoft Internet Explorer

File Edit View Favorites Tools Help

Back Forward Stop Refresh Home Search Favorites Media Print Mail News RSS H

Address http://tiny.ncsl.net.gov/~god/ontology/Anthropometric/Landmark/Ontology.html

NIST
National Institute of Standards and Technology

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
dataDescription	A horizontal plane that is used to define certain constraints of the head posture for measurement purposes, in which the right TRACION 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): TRACION, RIGHT (r)R ? ORBITALE, LEFT (l)L (also called Infraorbitale, Left) ? ORBITALE, RIGHT (r)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 TRACION-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

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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