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Shape and Size Analysis and Standards

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14.1 Introduction

The field of anthropometry is the science of measurement of the human body from which comparisons and characterizations of the size and shape of the body in different postures can take place. The size and shape of human bodies are important in many applications, such as clothing design, machine design, transportation, in the medical/healthcare field, aircraft cockpit design, space suit design for astronauts, safety, biometrics, criminology, interface design for household/industrial products, and so on. The anthropometric data are some of the basic tools used for analysis and design requirements by human factors, ergonomics professionals, architects, interior designers, and industrial engineers. Anthropometry has its roots in physical anthropology, a discipline that focuses on how human body size and shape has varied with ethnic origins, gender, and with climatic and altitude variations. Most of the anthropometric measurement methods were first used by physical anthropologists. This study required the development of two sets of tools: (1) measurement techniques to obtain data from humans; and (2) statistical techniques to transform the measurement data into summary data.

Anthropometric data has been collected as scalar values (one-dimensional data) with a measuring tape, anthropometers, calipers, and so on. There are measurement errors because of error in location of landmarks, variation in posture, and instrument errors because of orientation and position location. There are also variations in measurements from one measurer to the other. The other problem with traditional measurements is that they lack shape and spatial relationship information. The work of Robinette (1992) was first to characterize the human body shape by contours. With the advancement in 3D scanning technology, it became possible to scan the entire human body in a reasonable amount of time. The first large-scale use of the 3D scanning anthropometric survey was the CAESAR project (Robinette, 2000). These sets of 3D anthropometric data are very effective to create highly accurate 3D human body surface models.

14.2 Anthropometric Surveys

The history of anthropometry dates back to the Renaissance. Dürer's (Durer, 1528) four books of human proportions illustrate the diversity of humans through different drawings. Most of the anthropometric measurements techniques, which are still used today, were developed by physical anthropologists. They figured out the different anatomical postures that would allow for repeatable measurements and locations of landmark points for measuring distances. They also developed different ways to summarize group data; the main concept was that of percentile, the number that is greater or equal to a given percentage of the population. The concept of percentile is first-order approximation. This methodology is followed in books by Tilley (2002) and Panero (1986) and is also used in many of the human modeling software. But no person is extreme and they differ in ways as shown by McConville and Robinette (1981). The other way is to use the boundary models, which represent actual people who are extreme in some respect, as opposed to the percentile person. This model involves the use of multivariate data analysis. One of the reasons given for the widespread use of percentile methodology is that they are easily listed in a tabular form.

14.3 Military Personnel Surveys

The study of man-machine relationships and interactions became important with the introduction of new types of war machines, like tanks, planes, submarines, and so on. Since then the U.S. Department of Defense has been interested in the field of anthropometry. The U.S. Defense Department has conducted over 40 anthropometric surveys of military personnel between 1945 and 1988, which also includes the ANSUR (1988) survey of men and women, with over 240 measurements. The number of individuals involved on these surveys is over 75,000 military personnel.

14.4 Civilian Surveys

There are a few civilian anthropometric surveys. The most complete survey of the U.S. population was the National Health Survey (1965) conducted by the Department of Health, Education and Welfare (HEW). This study involved over 7,500 civilians between 18 to 79 years of age.

14.5 CAESAR Database

The CAESAR (2006) (Civilian American and European Surface Anthropometry Resource) project has collected 3D scans, 73 anthropometry landmarks, demographics data, and traditional measurements data for each of 5,000 subjects. The objective of this study was to represent, in three-dimensions, the anthropometric variability of the civilian populations of Europe and North America and it was the first

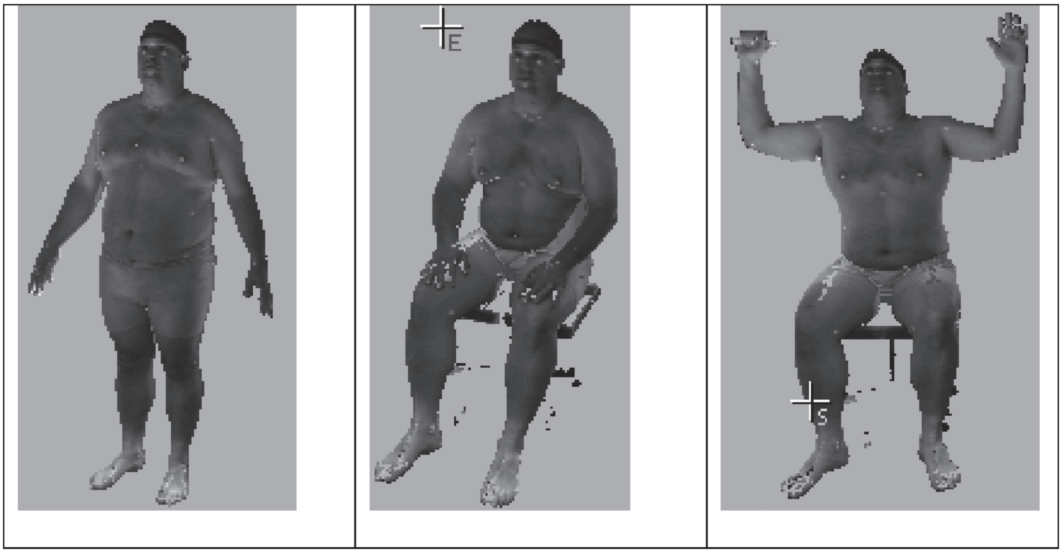

FIGURE 14.1 A CAESAR body with three postures (standing, sitting, and sitting with hands up).

successful anthropometric survey to use 3D scanning technology. The CAESAR project employs both 3D scanning and traditional tools for body measurements for people ages 18 to 65. A typical CAESAR body is shown in figure 14.1.

The 73 anthropometric landmark points were extracted from the scans as shown in figure 14.2. These landmark points are pre-marked by pasting small stickers on the body and are automatically extracted using landmark software. There are around 250,000 points in each surface grid on a body, and points are distributed uniformly.

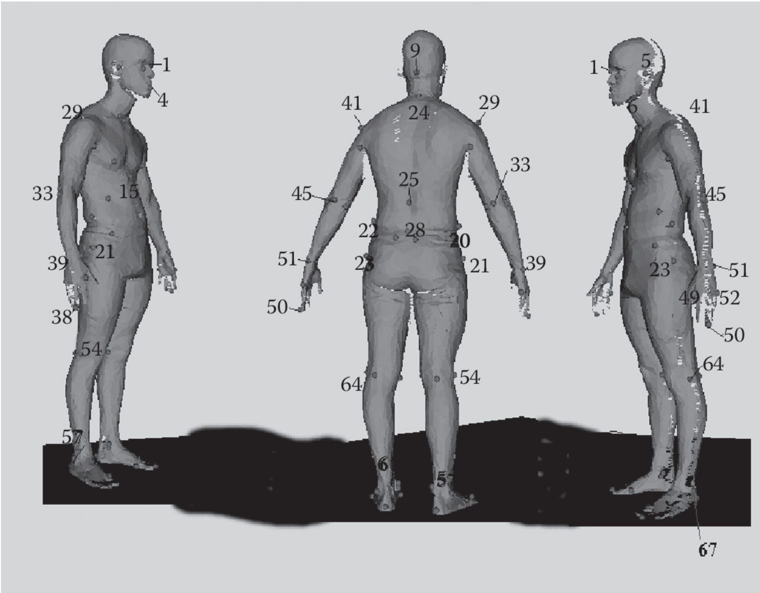

FIGURE 14.2 Shows a CAESAR body with the 73 landmark numbers and their positions.

14.6 SizeUK and Other

SizeUK (2006) is the U.K. National Sizing Survey, where they have 3D scanned 11,000 subjects and have extracted 130 body measurements from each subject using two postures: standing and seated. The survey took place between July 2001 and February 2002.

Similarly, SizeUSA (2006) is the U.S. National Sizing Survey, where they have 3D scanned 10,000 people and have extracted 130 measurements from each subject using two postures: standing and seated. The survey was completed in September 2003.

14.7 Tools for Size/Shape Analysis

14.7.1 Tools for Virtual Models of Humans

There are a number of tools that use information from anthropometry measurements to create virtual models of humans also called digital mannequins. These models, which can be added to any virtual environment or workspace, can be assigned tasks to analyze reach, comfort, and performance. They are also widely used for ergonomics studies, design, and analysis of automobile interior spaces, aircraft cockpits, and for workspace studies. Some of this information can also help them design safer products and achieve cost savings by having fewer redesigns. Some of the most widely used tools are RAMIS (2006), SAFEWORK (2006), JACK (2006), and ManneQuinPro (2006). All of these tools are based on anthropometric data based on a percentile person. SAFEWORK, however, departs from the percentile person by using the concept of boundary models, which are actual people who are extreme in some respect.

14.7.2 Visualization for Shape and Size Analysis

Visualization of the combined anthropometric data and the 3D scan data is also a powerful tool for data analysis. Figures 14.3, 14.4, and 14.5 show examples of the Visual Atlas developed at NIST by Ressler and Wang (2001, 2003). AnthroGloss is a visual 3D anthropometric landmark glossary usable over the web. Implemented using VRML, the virtual reality modeling language, users may easily locate and determine the names of these landmarks, which are visualized as small spheres located over the body. The goal is to create a 3D anthropometric glossary.

Two versions of the system have been implemented. Figure 14.3 illustrates a closeup of the head, and figure 14.4 illustrates the entire standing male. Landmark names are displayed simply by moving the cursor over the spheres; no selection is needed. The second version is functionally identical and illustrates the landmarks for a male in a wheelchair.

Figure 14.5 shows a CAESAR viewer implemented in VRML. These interactive bodies are the equivalent of AnthroGloss; however, they are now generated automatically for each CAESAR body rather than manually constructed for a particular synthetic body.

Our current version includes the ability to toggle on or off body textures, landmarks, and contours. It also provides the ability to select a color for the entire body. Labels for the control slider change as appropriate to match the particular functionality selected.

The controls currently available to the user allow for the display of multiple (up to 10) bodies. The control panel operates on the "current" body indicated by a box surrounding the body. The current body is selected by simply clicking the body. Contour lines associated with sagittal, coronal, and transverse cutting planes can be displayed. The user can measure distances on the contour display by selecting start and end points on the contour lines. The distances are in the same units as the original CAESAR data.

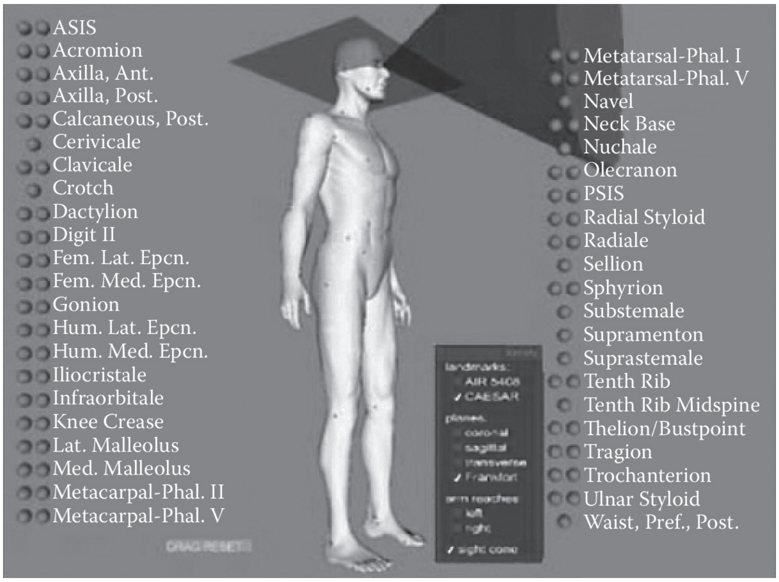

FIGURE 14.3 AnthroGloss screen layout with the Frankfort plane and sight cone indicators turned on.

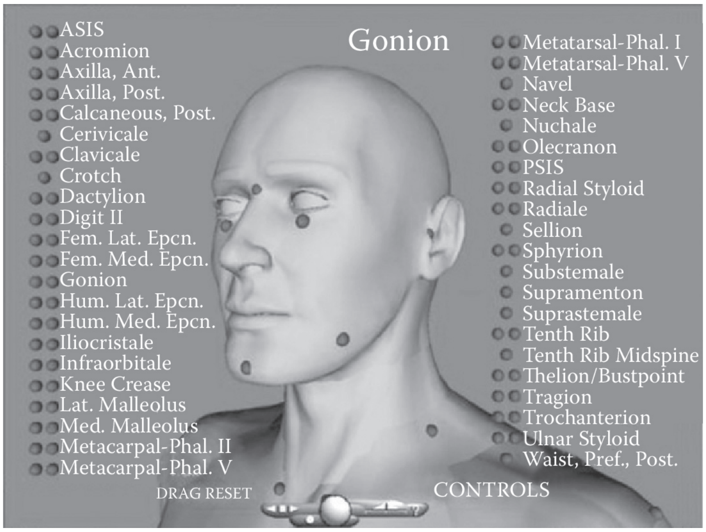

FIGURE 14.4 AnthroGloss screen with the Gonion landmark selected (head close up).

14.8 Compact Shape Descriptors of the 3D Human Body

The 3D scans of human bodies in the CAESAR human database contain over 250,000 grid points. To be used effectively for indexing, searching, clustering, and retrieval, this human body data requires a compact representation. Pioneering work in content-based retrieval was done by Paquet and Rioux (2002, 2004). We at NIST also have developed shape descriptors for a human body and head. The next subsection presents more details.

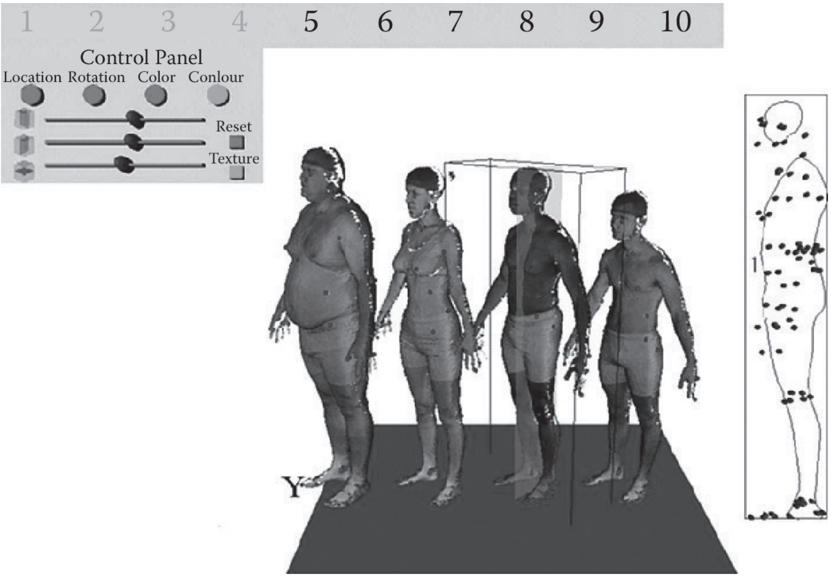

FIGURE 14.5 WEB3D version of AnthroGloss with multiple bodies.

14.9 Shape Descriptors for 3D Human Body

14.9.1 Shape Descriptors Based on CORD

The earliest work on creating a compact shape descriptor for human body representation for content-based retrieval was performed by Paquet and Rioux (2002, 2003). They performed content-based anthropometric data mining of 3D scans of humans by representing them with compact support feature vectors based on the concept of cords. A cord was defined as a vector from the center of the body to the center of a triangle grid on the surface. The distribution is then represented as a histogram. They also developed a virtual environment to perform visual data mining on the clusters and to characterize the population by defining archetypes. Paquet (2004) also introduced cluster analysis as a method to explore 3D body scans together with the relational anthropometric data as contained in the CAESAR anthropometric database.

14.9.2 PCA Based Volumetric Shape Descriptor

Ben Azouz et al. (2002, 2004) analyzed human shape variability using a volumetric representation of 3D human bodies and applied a principal components analysis (PCA) to the volumetric data to extract dominant components of shape variability for a target population. Through visualization, they also showed the main modes of human shape variation.

14.9.3 Distance-Based Shape Descriptor

The shape descriptor described by Godil et al. (2003, 2005) uses vector d based on lengths mostly between single large bones. For descriptor vector purposes, we require lengths only between landmark points where their separation distance is somewhat pose-independent. The reason it is not completely pose invariant is that distance is between landmark points which are on the surface body compared to

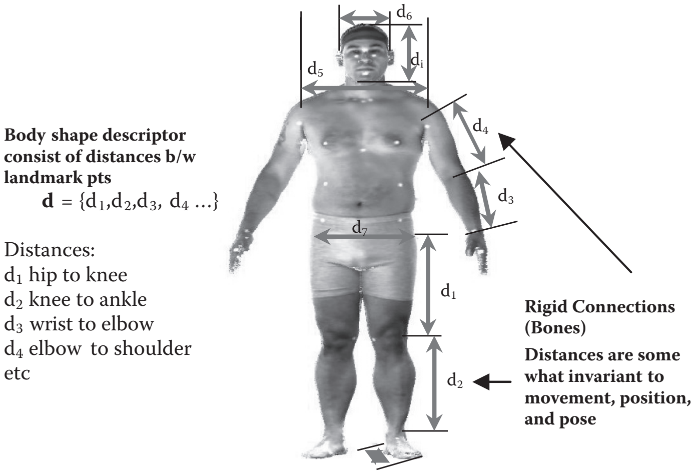

FIGURE 14.6 A distance-based body shape descriptor.

the distance between the center of the joint axis. This applies to points connected by a single large bone as shown in figure 14.6. Thus, we form a descriptor vector of 15 distances, d, with d_1 wrist to elbow, d_2 elbow to shoulder, d_3 hip to knee, and so on. More details and shortcomings about this descriptor were described in the paper by Godil et al. (2003, 2005).

To test how well the distance-based descriptor performs, we studied the identification rate of a subset of 200 subjects of the CAESAR database where the gallery set contains the standing and the probe set contains the sitting pose of each subject. In this discussion, the gallery is the group of enrolled descriptor vectors and the probe set refers to the group of unknown test descriptor vectors.

The measure of identification performance is the rank order statistic called the cumulative match characteristic (CMC). The rank order statistics indicates the probability that the gallery subject will be among the top r matches to a probe image of the same subject. This probability depends upon both gallery size and rank. The CMC at rank 1 for the study is 40%.

The partial results from body-shape-based similarity retrieval for subject number 16270 are shown in figure 14.7.

14.9.4 Fourier-Based Descriptor

The Fourier-based body shape descriptor, developed by Godil et al. (2003, 2005) is based on rendering the human body from the front, side, and top directions and creating three silhouettes of the human body as shown in figure 14.8. The theory is that 3D models are similar if they also look similar from different viewing angles. The silhouette is then represented as R(radius) of the outer contour from the center of origin of the area of the silhouettes. These three contours are then encoded as Fourier descriptors, which are used later as features for similarity-based retrieval. The number of Fourier modes used to describe each silhouette is 16; hence each human body is described by a vector of length 48. This method is pose dependent, so only bodies of the same pose can be compared. The Fourier-based descriptor is then used with the L1 and L2 norm to create a similarity matrix.

14.10 Shape Descriptors Head Shape

We now describe three methods for creating descriptors based on the shape of the human head.

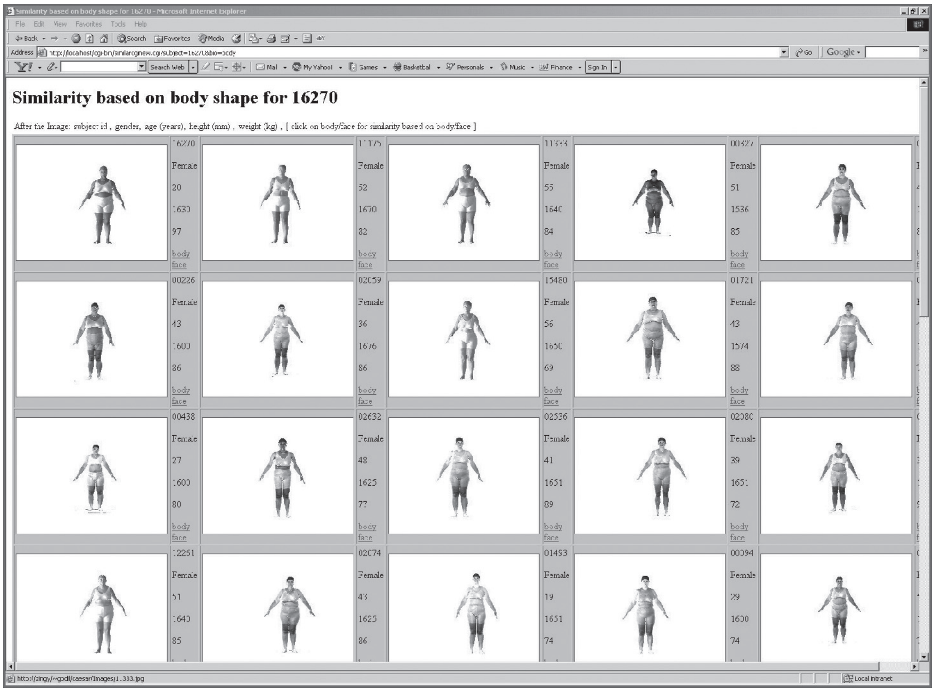

FIGURE 14.7 Similarity based retrieval for 16270 based on body shape.

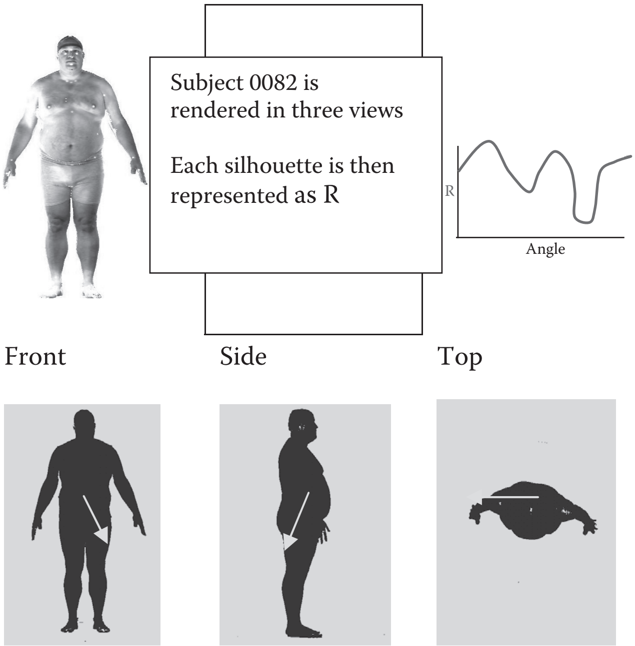

FIGURE 14.8 Subject 00082 is rendered in three silhouette views.

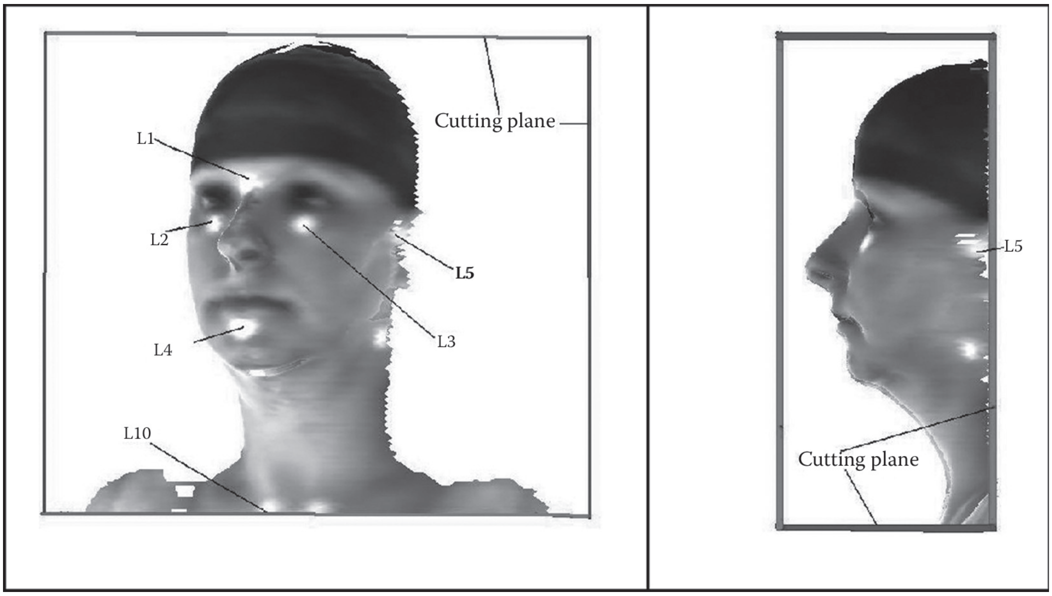

FIGURE 14.9 Landmark points 1, 2, 3, 4, 5, and 10. Vertical and horizontal lines are the cutting plane.

14.10.1 PCA Based Facial Shape

Godil et al. (2006, 2004) applied principal component analysis (PCA) on the 3D facial surface and creating PCA-based facial descriptors by cutting part of the facial grid from the whole CAESAR body grid using the landmark points 5 and 10 as shown in figure 14.9.

Then we interpolate the facial surface information and color map on a regular rectangular grid whose size is proportional to the distance between the landmark points L2 and L3 ($d = |L3 - L2|$) and whose grid size is 128 in both directions. For some of the subjects there are large voids in the facial surface grids. Figure 14.10 shows the facial surface and the new rectangular grid.

We properly positioned and aligned the facial surface and then interpolated the surface information on a regular rectangular grid. Next we perform principal component analysis (PCA) on the 3D surface

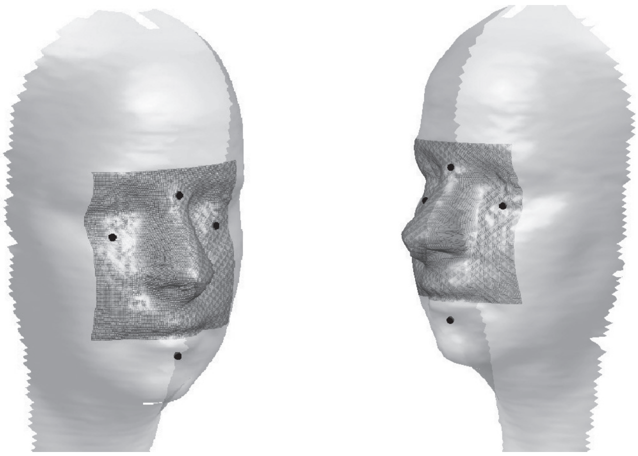

FIGURE 14.10 Shows the new facial rectangular grid for two subjects.

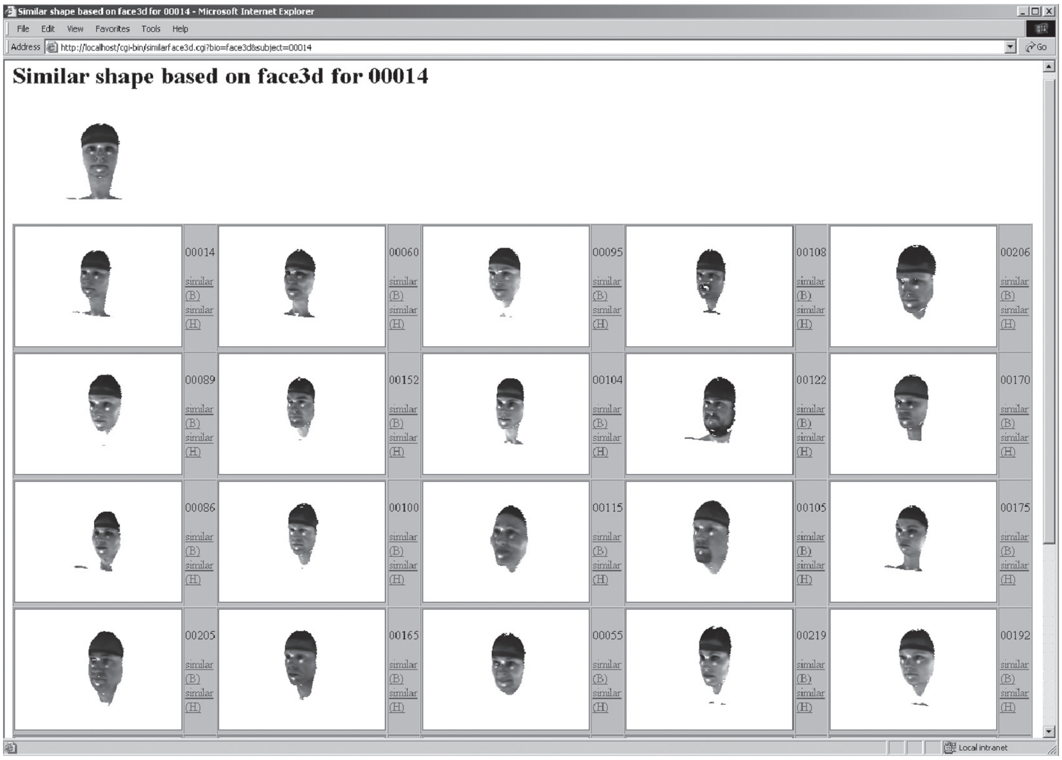

FIGURE 14.11 Similarity based retrieval for 00014 based on PCA facial shape.

and similarity-based descriptors are created. In this method the head descriptor is only based on the facial region. The PCA recognition method is a nearest neighbor classifier operating in the PCA subspace. The similarity measure in our study is based on L1 distance.

To test how well the PCA-based descriptor performs, we studied the identification between 200 standing and sitting subjects. The CMC at rank 1 for the study is 85%. More details about this descriptor are described in the paper by Godil et al. (2006, 2004).

The partial results from a head shape PCA-based similarity retrieval for subject number 00068 are shown in figure 14.11 and for subject number 00014 are shown in figure 14.12.

14.10.2 Spherical Harmonics Based

Godil and Ressler (2006) developed a spherical harmonic-based descriptor to represent a human head. The 3D triangular grid of the head is transformed to a spherical coordinate system by a least square approach and expanded in a spherical harmonic basis as shown in figure 14.12. Since the CAESAR head grid has large voids in the top and also because of cutting the grid at the neck there is a circular hole. Since these holes are not filled properly, we have a convergence problem with 10% of the head grids. The main advantage of the spherical harmonics-based head descriptor is that it is orientation and position independent. In the near future we plan to fix this problem using a method that fills voids. The spherical harmonics-based descriptor is then used with the L1 and L2 norm to create similarity measure.

To test how well the spherical harmonics-based head descriptor performs, we studied the identification of the human head between 220 standing and sitting subjects. The CMC at rank 1 for the study is 94%.

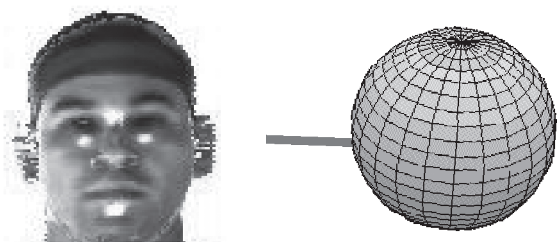

FIGURE 14.12 3D head grid is mapped into a sphere.

14.11 Extended Gaussian Images Descriptor

Retrieval based on head shape was performed by Ip and Wong (2002). Their similarity measure was based on extended Gaussian images of the polygon normal. They also compared it to an Eigenhead approach.

14.11.1 Clustering

Godil et al. (2006) have used the compact body and head descriptors for clustering. Clustering is the process of organizing a set of bodies/heads into groups in such a way that the bodies/heads within the group are more similar to each other than they are to other bodies belonging to different clusters. Many methods for clustering are found in various communities; we have tried a hierarchical clustering method. We then use dendrogram, which is a visual representation of hierarchical data to show the clusters. The dendrogram tree starts at the root, which is at the top for a vertical tree (the nodes represent clusters) and figure 14.13 shows the same with number of clusters at 30.

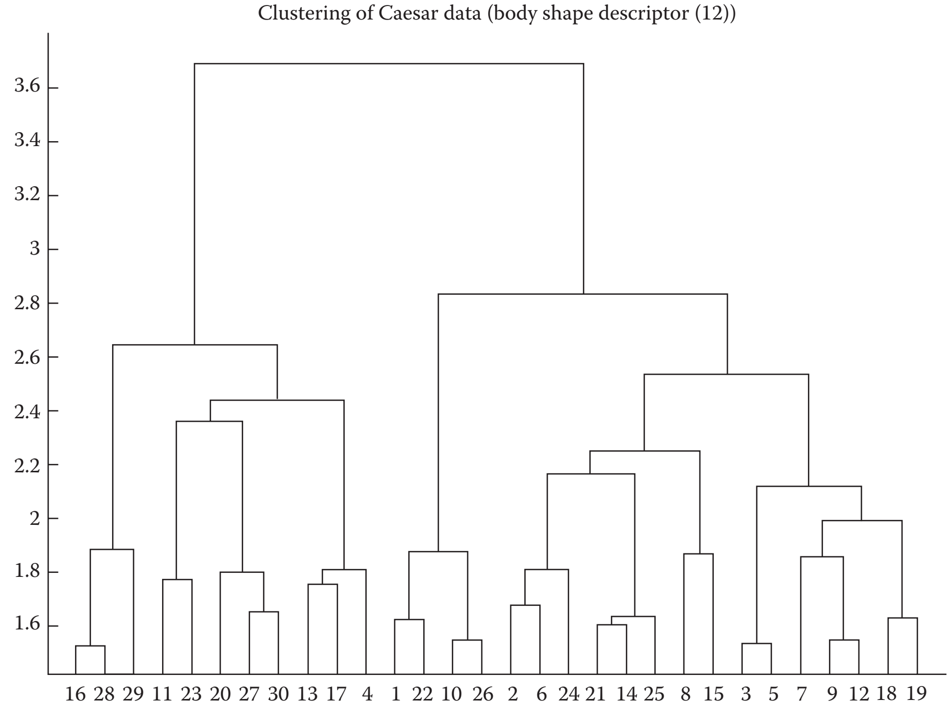

FIGURE 14.13 Clustering of body shape distances descriptor (number of clusters = 30).

14.12 Standards

In anthropometry, standard sets of measurements are needed to compare studies. However, anthropometric measurements differ from one application to another, depending on their intended use. Also, detailed standards are needed to define landmarks and provide traditional measurement naming in a standard way. There are, however, a few standards bodies that have tried to seek consensus on different naming conventions for landmark names and standard anthropometric database creation such as ISO, SAE 13, and WEAR.

Most countries have their own standards for ergonomics and garments/clothing and use different names and ways for classifying body shape, age and size. Most of these standards are created by their own standards organization, such as ANSI (American National Standard Institute); BSI (British Standard Institute); DIN (Deutscher Normeausschuss); JIS (Japanese Industrial Standard); AFNOR (Association French Norme); and others. But because of globalization there is an imperative to create international standards. ISO (International Organization for Standardization), a worldwide federation of standard organization, produces industrial and commercial standards, the so-called ISO standards. International standards are created by a technical committee. The anthropometry related standards are prepared by the technical committee ISO/TC 19, Ergonomics, Subcommittee SC 3, Anthropometry and Biomechanics. One such standard is ISO 7250:1996, “Basic human body measurements for technological design”—the standard provides descriptions of different anthropometric measurements and different guidelines. Some of the standards deal with definitions of measurements and landmarks, while some deal with ergonomics, safety, and mannequins. There are also standards for 3D scanning methodologies for anthropometry and a number of standards related to garment and clothing designs. Because of space limitation we are not going to discuss any of the standards in detail, but the standards related to anthropometry, garments, ergonomics, and safety are listed in table 14.1.

14.13 Conclusions and Future Trends

We believe that 3D human shape and size analysis will play a very import role in the field of digital human modeling, and in a number of applications such as clothing design, machine design, transportation, in the medical/healthcare field, interface design for household/industrial products, and so on. But there are still a number of important issues that need to be addressed:

The creation of a large publicly available Global Anthropometry database based on both 3D scanning and traditional tools for body measurements of people from around the world.

Developing shape descriptors that can efficiently represent the human body shape and size at different levels of detail and independent of the posture.

Developing techniques to locate different joint locations more precisely in the human body, such as in the hand, shoulder, neck, hip, and so on.

Developing techniques to locate the position of the different landmark locations on the body from the 3D scan of a person without pasting stickers on the body.

Developing better models to predict the range of motion for the different joints in the human body, which will have applications in reach analysis, comfort analysis, and so on.

Many of these topics described are receiving a lot of interest from researchers worldwide. We are optimistic that, because of this, there will be better digital human modeling tools that will help with the design, analysis, and ergonomics studies of different products. Some of this will also make these products more comfortable, safe, and cost efficient.

Finally, in spite of all the anthropometric (shape and size) tools, it is always critical to test the design or product with actual people. Human modeling software can be used for testing and design, but the results needs to be verified with actual user testing.

TABLE 14.1 Lists of ISO, ASTM Standards Related to Anthropometry, Garments, Ergonomics, Safety, etc.

	Organization and Standard Number	Title of Standards
1	AIRSTANDARD 61/83. Air Standardization Coordinating Committee. 1991	A Basis For Common Practices and Goals In The Conduct of Anthropometric Surveys
2	ASTM, Committee D-13.55	Standard Terminology Relating to Body Dimensions for Apparel Sizing. D 5219-97, West Conshohocken, PA: American Society for Testing and Materials (ASTM), Committee D-13.55 on Body Measurement for Apparel Sizing, October, 1997
3	ISO 7250:1996	Basic human body measurements for technological design
4	ISO/DIS 7250-1	Basic human body measurements for technological design—Part 1: Body measurement definitions and landmarks
5	ISO/NP 7250-2	Basic human body measurements for technological design—Part 2: Statistical summaries of body measurements from individual ISO populations
6	ISO 8559	Garments Construction and Anthropometric Surveys-Body Dimensions
7	ISO 3635	Size Designation of Clothes. Definition and Body Measurement Procedures
8	ISO 3636	Size Designation of Clothes-Men's and Boys' Outwear Garments
9	ISO 3637	Size Designation of Clothes-Women's and Girls' Outwear Garments
10	ASTM D 5586	Standard Tables of Body Measurements for Women
11	ASTM D 5219	Terminology Reverting to a Body Dimensions for Apparel Sizing
12	ASTM D4910	Standard Tables of Body Measurements for Infants
14	ISO 11226:2000	Ergonomics—Evaluation of static working postures
15	ISO 11226:2000/Cor 1:2006	
16	ISO 11228-1:2003	Ergonomics—Manual handling—Part 1: Lifting and carrying
17	ISO/FDIS 11228-2	Ergonomics—Manual handling—Part 2: Pushing and pulling
18	ISO/FDIS 11228-3	Ergonomics—Manual handling—Part 3: Handling of low loads at high frequency
19	ISO 14738:2002	Safety of machinery—Anthropometric requirements for the design of workstations at machinery
20	ISO 14738:2002/Cor 1:2003	
21	ISO 14738:2002/Cor 2:2005	
22	ISO 15534-1:2000	Ergonomic design for the safety of machinery—Part 1: Principles for determining the dimensions required for openings for whole-body access into machinery
23	ISO 15534-2:2000	Ergonomic design for the safety of machinery—Part 2: Principles for determining the dimensions required for access openings
24	ISO 15534-3:2000	Ergonomic design for the safety of machinery—Part 3: Anthropometric data
25	ISO 15535:2006	General requirements for establishing anthropometric databases
26	ISO 15536-1:2005	Ergonomics—Computer mannequins and body templates—Part 1: General requirements
27	ISO/FDIS 15536-2	Ergonomics—Computer mannequins and body templates—Part 2: Verification of functions and validation of dimensions for computer mannequin systems
28	ISO 15537:2004	Principles for selecting and using test persons for testing anthropometric aspects of industrial products and designs
29	ISO/TS 20646-1:2004	Ergonomic procedures for the improvement of local muscular workloads—Part 1: Guidelines for reducing local muscular workloads
30	ISO 20685:2005	3D scanning methodologies for internationally compatible anthropometric databases
31	ISO/IEC 19774:2006	Humanoid Animation (H-Anim)

References

Allen, B., Curless, B., Popovic, Z. Exploring the space of human body shapes: data-driven synthesis under anthropometric control. Proc. Digital Human Modeling for Design and Engineering Conference, Rochester, MI. SAE International, 2004.

Allen, B., Curless, B., Popović, Z. The space of human body shapes: reconstruction and parameterization from range scans. SIGGRAPH 2003, San Diego, California, July 2003.

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.

Anthropometric Source Book, Volume I. Anthropometry for Designers. Anthropology Research Project Staff, NASA Reference Publication 1024, Houston, TX, NASA, 1978.

Anthropometric Source Book, Volume II. A Handbook of Anthropometric Data. Anthropology Research Project Staff, NASA Reference Publication 1024, Houston, TX, NASA, 1978.

Anthropometric Standardization Reference Manual. Lohman, T. G., Roche, A. F., and Martorell, R., Champaign, IL, Human Kinetics Books, 1988.

ARD 50080 &AS5540 Anthropometric Dimensions for Creating Human Analogues. Yellow Springs, OH, Anthrotech, September 1999.

Ben Azouz, Z., Rioux, M., Lepage, R. 3D Description of the Human Body Shape: Application of Karhunen-Loève Expansion to the CAESAR Database. Proceedings of the 16th International Congress Exhibition of Computer Assisted Radiology Surgery, Paris, France, June 26–29, 2002.

Ben Azouz, Z., Rioux, M., Shu, C., Lepage, R. Analysis of Human Shape Variation using Volumetric Techniques, The 17th Annual Conference on Computer Animation and Social Agents (CASA2004). Geneva, Switzerland, July 7–9, 2004.

CAESAR: Civilian American and European Surface Anthropometry Resource web site: http://www.hec.afrl.af.mil/cardlab/CAESAR/index.html, Also at http://store.sae.org/caesar/, 2006.

Dürer. *Four Books on Human Proportions*, 1528.

Godil, A., Grother, P., Ressler, S. Human Identification from Body Shape. Proceedings of 4th IEEE International Conference on 3D Digital Imaging and Modeling, Banff, Canada, October 6-10, 2003.

Godil, A., Ressler, S. Retrieval and Clustering from a 3D Human Database Based on Body and Head Shape. SAE Digital Human Modeling Conference, Lyon, France, 2006.

Godil, A., Ressler, S. Similarity based Retrieval from a 3D Human Database. Poster Paper, SIGGRAPH 2005, Los Angeles, CA, 2005.

Godil, A., Ressler, S., Grother, P. Face Recognition Using 3D Surface and Color Map Information: Comparison and Combination, the SPIE's symposium on Biometrics Technology for Human Identification, Orlando, FL, 2004.

Ip, H.H.S., Wong, W. 3D Head Model Retrieval Based on Hierarchical Facial Region Similarity, Proceedings of 15th International Conference on Visual Interface (VI2002), Canada

JACK, http://www.ugs.com/products/tecnomatix/docs/fs_tecnomatix_jack.pdf, 2006

ManneQuinPro, http://www.nexgenergo.com/ergonomics/mqpro.html, 2006

McConville, J.T., Robinette, K.M., White, R.M. An Investigation of Integrated Sizing for U. S. Army Men and Women (Natick/TR-81/033), U.S. Army Natick Research and Development Command, Natick, MA, 1981.

National Health Survey, by National Center for Health Statistics, Weight, Height, and Selected Body Dimensions of Adults, United States 1960-1962, PHS pub no. 1000, series 11, no 8, June 1965.

Panero, J. Human Dimension and Interior Space: A Source Book of Design Reference Standards, 1986.

Paquet, E., Rioux, M. Anthropometric Visual Data Mining: A Content-Based Approach, Submitted to IEA 2003—International Ergonomics Association XVth Triennial Congress. Seoul, Korea. NRC 44977, 2003.

Paquet, E. Exploring Anthropometric Data Through Cluster Analysis. Digital Human Modeling for Design and Engineering (DHM). Oakland University, Rochester, Michigan. NRC 46564, June 2004.

Pheasant, S. Bodyspace: Anthropometry, Ergonomics and the Design of the Work, Second Edition, 1996.

RAMSIS, http://www.human-solutions.com/automotive_industry/ramsis_en.php, 2006.

Ressler S. A Web-based 3D Glossary for Anthropometric Landmarks in Proceedings of HCI International 2001, New Orleans, LA, August 2001.

Ressler, S., Wang, Q. Using Web3D Technologies to Visualize and Analyze Caesar Data in proceeding of XVth Triennial Congress International Ergonomics Association (IEA 2003), Seoul, Korea, August 2003.

Robinette, K.M. (1992). Anthropometry for HMD Design. Proceedings of the SPIE, Aerospace Sensing International Symposium and Exhibition.

Roebuck, J.A. Anthropometric Methods: Designing to Fit the Human Body, 1992, Human Factors and Ergonomics Society.

Roebuck, J.A., Kroemer, K.H.E., Thomson, W.G. Engineering Anthropometry Methods, New York, John Wiley & Sons, 1975.

SAFEWORK, http://www.safework.com, 2006.

SizeUK, UK National Sizing Survey (SizeUK), www.sizeuk.org, 2006.

SizeUSA, US National Sizing Survey (SizeUSA), http://www.tc2.com/what/sizeusa/index.html, 2006.

Tilley, A.R. The Measure of Man and Woman: Human Factors in Design, Henry Dreyfuss Associates, 2002.