I00-S15 Automated Garment Development from Body Scan Data

Investigators: C. Carrere (Leader); C. Istook; T. Little; H. Hong; T. Plumlee (NCSU)

Abstract

In order for body scanning to support automated garment development efforts, it is imperative that we first be able to automatically integrate measurement data into commercially available CAD/CAM software. To date, body scan data does not automatically integrate with any commercially available CAD/CAM system or measurement extraction algorithmic process. The lack of standard formats for transmission of body scan data further impedes the process, in that a recipient of body scan data cannot currently be assured that critical measurements needed by product design were appropriately extracted. This work is planned as a three-year investigation. This report presents a summation of our 'plans & learnings' relative to this since project inception May 1, 2000, presented within the context of our three-part *Year 1* goal of: 1) researching data and exchange formats of current body scanning devices, 2) compiling CAD garment sizing, pattern development and alteration processes, and 3) creating the conceptual model for body scan/CAD data exchange & garment development. In *Years 2 and 3* we will move toward development and activation of the model, culminating in creation of the integration linkage necessary for automated garment development.

Project Goal Statement

The goal of this project is to conduct fundamental research to link critical garment sizing measurements with critical anthropometric measurements extracted from body scans, either as 'point cloud' data, or as a yet-to-be-determined standard set of critical non-linear measurements. Our focus is upon automated garment design, derivation, and sizing from body scan data, with a supporting research focus on standards for body scan data exchange in relation to the above.

Progress Overview

Although this project was only partially funded, progress has been made in achieving this year's goals. Data formats of three-dimensional body scanners (3DBS) are being examined to learn how various scanner vendors are making their data available. Activities have included examination of our in-house $[TC]^2$ 2-tower/3-camera (2T3C) scanner with Gerber/MTM™ and Lectra/Fitnet™ CAD interfaces, participation in an ASTM task group concerning industry pattern data exchange formats, and surveys of all major CAD vendors and 3-D scanning vendors to determine their integration strategies for supporting automated garment development. Information has been compiled on foot scanners, macro methodologies employed by CAD vendors, anthropometry research, and ISO, NIST, ASTM, and AAMA data formats for pattern data exchange. Related studies at NCSU have provided validation of strengths and weaknesses of 3-D scanner system data relative to body position during scanning (McKinnon, 2000). Inquiries have been made of non-apparel 3D software vendors, such as GeoMagic, as to whether their systems produce "developable/ruled surface" approximation of surface patches (given as point clouds, polygons, NURBS). Work has been fruitful on locating a forum for discussing data exchange formats and proposing development of a working standard for integration of 3D body scanning output with CAD alteration processes. The American Society for Testing & Materials (ASTM) D13.66 Subcommittee on Apparel and Sewn Product Automation has extended an invitation to our NTC project to spearhead a new standards coordination initiative relative to data exchange *between 3 D body scanners and CAD*. We plan to act on this within ASTM in rapid fashion similar to the D13.66 Task Force initiative launched in July 2000 for revision of AAMA/ANSI 292 Pattern Data Exchange *between CAD systems*.

Our website, www.tx.ncsu.edu/3dbodyscan, is constantly evolving, and serves the fundamental function of informing viewers about this research project. We envision the site to ultimately serve as an information portal, linking to academic and commercial sites related to non-contact measurement and virtual apparel design and development. In that capacity, information available through the web site will range from fundamental introductions to the field, to links with discussion forums for those on the cutting edge of new development, such as www.techexchange.com. Currently, a synopsis of 3D body scanning technologies is provided, along with links to more detailed technical descriptions on scanner manufacturer web sites. The site is constantly updated through links to online news and events related to 3D imaging. Specific to the project, the site features a project synopsis, a link to our research proposal, and information about related graduate works taking place at NCSU. Links are provided to other research centers and universities as well. As the project progresses, we plan to implement our own discussion forum for qualified web site visitors. Eventually, we plan to add the ability to transfer 3D body scan data between scanner manufacturers, computer design and manufacturing companies, and the investigators on this project. This would allow us to test and refine the interfaces developed both as part of this project and through our standards development coordination initiative.

Part 1. Creating the Body Scan/CAD Data Exchange & Garment Development Model

Project group brainstorming has led to expansion of our initial conceptual model architecture, as shown by Figure 1.

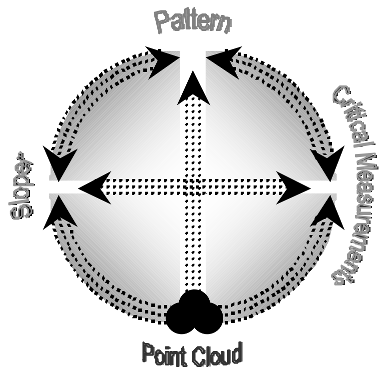

Figure 1

This model illustrates the possible complexity of data exchanges emerging from body scans. The multiple paths and directionality of information flow depicted stem from the need to extract and exchange this body scan 'point cloud' data with the sloper, critical measurement, and/or pattern stylizing and sizing functions during the conceptualized Automated Garment Development process. We initially envisioned that this model would have (2) development paths.

a) Path (1) would develop a garment from already existing patterns in CAD, based upon relationships to be created between garment topography and a point numbering system, critical body measurements extracted from body scan data, and 2-D 'flat pattern' alteration heuristics. [Note: The premise is that each garment topography/category has a complex set of alteration heuristics that are used to create a garment that will fit a unique human form.]

This path, as depicted by Figure 2, includes the following major processes through which data generally must flow and be converted:

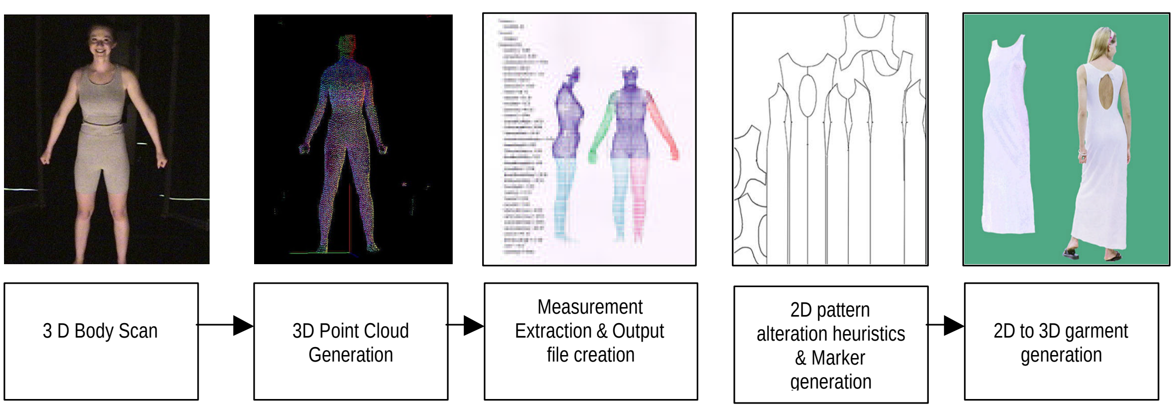

Figure 2

The flow of data, and required file format conversions between 3DBS and CAD are one-directional in this scenario. The missing link between 3DBS data measurement extraction and 2D pattern alteration represents a critical juncture at which integration is currently not automatic, and an immediate focal point for our model development research.

b) Path (2) would develop a garment directly from critical linear and non-linear body measurements extracted from body scan data, based upon 3-D 'draping' heuristics. [Note: Inclusion of non-linear body measurement algorithms would allow description of the arcs and complex curves inherent to 3-D (human) forms.]

After discussion at length, and given the current state of integration capabilities of the CAD industry, we have determined that for Year 1 of this project, Path 1 is the more immediately achievable of the two. To this end, we include our findings to date in Parts 2 and 3 of this report. Subsequent research during Years 2 and 3 would yield positive outcomes for achieving additional integration via Path 2.

Part 2. Exchange & Data formats of current 3D Body Scanning systems

The initial energy in this project has been applied to surveying all major apparel CAD vendors and body scanning manufacturers for their automated garment development strategies/solutions. Our approach was to compile our findings, organized by scanner product, hardware requirement(s), software(s) employed, scanner-to-CAD system integration capabilities and data file format(s) used.

Body Scanning Products surveyed

Our compilation to date includes surveys of the following 3D body scanning products: WB4 and WBX (Cyberware), BL Scanner (Hamamatsu), Voxelan (Hamano), 3T6C (the 3 Tower/6 Camera model by $[TC]^2$), 2T4C ($[TC]^2$), SYMCAD (TELMAT Industrie), TriForm BodyScanner (Wicks & Wilson), RAMSIS (TecMath), Contour (TecMath), Vitus & Vitus Smart (Vitronic), FASTSCAN (Polhemus), Micro Scribe 3DLX (Immersion), ModelMaker (London), and LASS (Loughborough).

Hardware requirements

As shown in Table 1, most 3D body scanning systems operate in SGI, Windows NT, or PC-based environments. For an example of operating system requirements, Model Maker runs on a PC based NT platform, and requires a minimum 200MHZ Pentium processor, 256 MB RAM, Windows NT4.0, a 2GB Hard disk, an 8X CD-ROM drive, a 4MB Graphics card, the Triton PCI chipset, and 3 Serial Ports.

Table 1. **Comparison of the Bodyscan Systems**

Products	Hardware	Software
WB4 (Cyberware)	SGI/ PC compatible	Cyscan (C++ and Tcl/Tk)
WBX (Cyberware)	SGI / PC compatible	Cyscan, CydirWB, DigiSize
BL Scanner (Hamamatsu)	Win32 PC/NT(98,95,2000)	BL Manager (Visual basic / C++)
Voxelan (Hamano)	Windows NT4.0/Windows95	VOXELAN (MS-DOS)
3T6 ([TC]²)	Windows NT (Intel)	Body Measurement System (Visual basic / C++/Open GL graphics)
2T4 ([TC]²)		
SYMCAD Turbo Flash/3D (Telmat Industrie)		SYMCAD, SYMCAD Body card
TriForm BodyScanner (Wicks & Wilson)	Windows NT4.0	BodyScanner
RAMSIS (TecMath)	Pentium PC/ minimum 100MHz Processor	RAMSIS
Contour (TecMath)	Windows 95/ Standard PC	Contour
Vitus Smart (Vitronic)	PC (Intel)	Vitronic (C++)
Vitus (Vitronic)		
FASTSCAN (Polhemus)	Windows NT/ PC or Workstation	Included
Micro Scribe 3DLX (Immersion)	PC Windows/ Mac/ SGI platform	3D Digitizing
ModelMaker (3D scanner in London)	PC based/ NT/ Windows NT4.0	
LASS (Loughborough)	Windows NT	Real time shadow- scanning

Commercially-developed Scanner & Measurement Extraction Software

Most of the 3D body scanning systems have developed their own software including: Cyscan, Cydir WB, Digisize (Cyberware), BL (Hamamatsu), Voxelan (Hamano), Body Measurement System ([TC]²), SYMCAD (Telmat), Body Scanner (Wicks and Wilson), RAMSIS, Contour (Tecmath), and Vitronic (Vitronic).

The Cyberware WB4 is controlled by Cyberware's Cyscan software that performs basic graphic displays. The software is written in C++ and Tcl/Tk. The scan data is convertible to VRML for web-based applications. Microscribe 3DLX by Immersion includes Digitizing Software for 3D model construction in data formats compatible with PC Windows, Macintosh, SGI and other platforms.

Related software

Still other measurement extraction-related software packages are available, having been developed in research centers. Examples of these include the ARN-SCAN software developed under the DLA-ARN program, DataSculpt by Laser Design, SHAPE ANALYSIS developed by Beecher Research Company, and 3DM developed by CAR (Clemson Apparel Research). Software such as SHAPE ANALYSIS (Beecher) and TECMATH-VITUS has been written to manually extract anthropometric measurements from pre-marked digitized images.

The 3DM (CAR) software package has been in development at Clemson University since 1991. It takes 3D whole body image files in text format and provides the user with a function to display, manipulate, segment, analyze, and measure the image. It is written in C++, uses OpenGL and X-Windows libraries, and runs on both an SGI workstation running Unix and on a PC running Windows NT (Pargas et al., 1998). 3DM reads image files generated by any scanner that generates points in the xyz format, where *x*, *y*, and *z* are the point coordinates in 3D. This includes files generated by both the Cyberware WB4 scanner and the [TC]^2 Body measurement system Scanner. 3DM allows a user to edit a 3D image, display and manipulate the image, manually identify, select and segment regions, manually select landmarks on the body and, using landmarks, extract anthropometric measurements specified by the user. In addition, Apparel Research Network (ARN) partners Cyberware, Ohio University, Clemson Apparel Research, Anthrotech, HAAS Tailoring Co., and Southern Polytechnic State University have jointly developed a derivative of Cyberware's Cyscan, ARNscan.

Body Scan-to-Apparel CAD Integration capabilities & data file formats

We are currently researching how 3D body scanners would interface with existing made to measure CAD systems. Many issues are involved including the file formats from 3DBS, the exchange of point cloud vs. critically-extracted measurement data, data exchange standards, and how to make the standards.

Part 3. Commercially available CAD garment sizing, pattern development, and alteration processes

Compilation of "measurement" information and how needed 'critical' measurements would differ by somatotype has proven both challenging and fruitful to date. The process has proven challenging in the sense that so much terminology coming from so many quarters is somewhat difficult to rectify with exact matches of human anthropometry and pattern generation/alteration. However, it has been fruitful in that there is opportunity for rectification through the research efforts of this project.

Critical measurements for integration of 3DBS into apparel CAD

We used a three-fold approach to address our objective of studying CAD garment sizing, pattern development, and alteration processes, and analyzing measurement information applicable to 3DBS and patterns development in current apparel CAD systems. First we defined measurement terms from available standards in order to clarify definitions that will be used in our experimental process. Next, we created and recommended 1) pattern codes and 2) landmark codes on critical body measurements to be used in defining measurement technical terms between 3DBS and CAD systems. Finally, to substantiate our proposed set of identification codes we compiled information on garment sizes in the United States and tolerance measurements for manufacture of apparel. Our recommendations were based primarily upon findings in the Fashiondex (1998), Solinger (1980) and ASTM (1999).

Measurement definitions

While immersed in the critical measurement definition process, it became apparent that simple coding is necessary to clarify and simplify technical discussion. Present forms are too limiting and incomplete for future integration of the professional terminology and integration of 3DBS and CAD systems. Measurements in apparel manufacture and in anthropometry differ by definition, method, and required sizing (body) parts. Matching terms synonymously between the fields is difficult, if not in some cases, impossible. Army (Natick) measurements are based on anthropometry methods (Clauser *et al*, 1986). Even within apparel, different measurement definitions and methods are used for pattern generation by different pattern making methods, *i.e.*, traditional (manual) flat pattern drafting vs. CAD. For our research, it is necessary to have common definitions or signs of body landmarks to describe pattern generation methods and later to match points (landmarks), or standard locations, when moving from 3DBS to pattern generation/alteration on CAD systems.

Pattern codes for critical measurements

Our own pattern codes are based on current available measurement and pattern development models, Istook *et al* (2000), Armstrong (1987), and Cooklin (1995). To arrive at our current set of codes, four different patterns were analyzed and compared. Although other patterns exist in the world, the basic pattern code list generated by this research will suffice as a starting point for any future automatic pattern generation.

Landmark codes for critical measurements

We found that measurements in Apparel and in Anthropometry had different definitions and measurement methods. Sizing parts requires analyzing and comparing terms in both apparel and anthropometry. Army (Natick), measurements are based on anthropometric measuring techniques (Clauser *et al*, 1986). Even in apparel, different definitions and methods are used in different pattern making methods, depending upon whether patterns are constructed by hand or in a CAD system, and whether developing men's or women's clothing. At this point, it is necessary to have common definitions or codes for the landmarks, or to describe measurement methods and later to match points (landmarks) or standard locations from 3DBS with patterns in the CAD systems. Landmarks are marks placed on a human body used to identify the origin, end-point, or location of a measurement.

Even though the measurement methods in anthropometry and apparel are different, both methods can be compared and adapted in order to create landmark codes since the concept of landmark used in both is primarily based on easily identified points on a human body. A coded landmark will assist in clarifying descriptions of different measurements and with matching pattern codes in order to alter patterns with 3D body scanning. Definitions that have been developed are based on the U.S. Army Anthropometric Measurer's Handbook (Clauser *et al*, 1986) and Fashiondex (1998).

Our research increased our awareness of two problem areas associated with 3D body scanning in finding landmarks on the human body. First, the definition of 'shoulder point' used in apparel is different from that used in 3D scanning. Traditional physical measurement methods in apparel are based on "feel" *i.e,* locating the landmark by hand, whereas body scanning systems read only based on a "body shape". Second, caution must be exercised when comparing results of different measurement methods that may vary in definition of 'arm length'; the length may be obtained with the arm in different positions such as bent, relaxed or straight, yielding a different sets of results, as documented in related scanner studies by McKinnon & Istook (2000).

Current available garment sizing in U.S.

In order to alter or to automatically grade patterns that already exist in CAD, it is necessary to collect information on current available garment sizing. We gathered information from ASTM, ISO, and British standards, Solinger (1980), Cooklin (1994), Fashiondex (1988), and Berke (1979), among others. Clothing size codes differ by markets and countries, and our collection continues. The current study is based on U.S. clothing size codes in which: Women's size measurements are based on five major female dimensions, *i.e,* height range, bust girth range, waist girth range, hip girth range, and bust point to bust point. Men's sizes are based on height, and weight, and grouped by height, chest, waist, seat, sleeve length, inside leg (inseam), and rise. Childrens'size groupings are based on approximated body size associated with age, *i.e.*, 2T-3T-4T-5-6-6X/7-8-10-12. Size ranges may also differ by body type, such as Juniors, Missy, Petites, Women's, and Half Sizes (Solinger, 1980). Sizing system inequities have been a chronic issue for the apparel industry as has been documented by Solinger, who reported that in 1954 that the Commodity Standards Division, Office of Technical Services, U.S. Department of Commerce, published bulletin TS-5200 recommending development of a number of size ranges.

Critical measurements for garment alteration

For each class, the minimum required critical measurements corresponding to points of alteration are:

1) Coats- coat, waist, seat, sleeve, shoulder, outseam, and inseam *lengths*, waist, bicep, and thigh *circumferences*.
2) Skirts- waist *length*, waist *circumference*
3) Slacks- outseam and inseam *length*, waist and thigh *circumferences*

Other critical measurement locations for specific garments remain, as yet, undocumented. These garments include: Bodice Block, Basic shirt w/Yoke, Pleasant blouse, A-line skirt, Peg skirt, Full or circle skirt, Long/Short skirts, Basic Pants, Culottes,Trousers, Slacks, Jeans, Pleated trousers, Baggy pants, High waist pants, Hip-Hugger pants, Pants with flared legs, Short shorts, Jamaica shorts, Shirt waist dresses, A-Line dresses, Princess line dresses, Jackets, Coats, Brassieres, Swimsuits, etc.

Outline of the alteration process:

Following outline stages were modified from an article on pattern design construction for ladies' made to measure (MTM) outerwear (Bond, T. *et.al*, 2000). This is an example of alteration process.

Stage 1. Measurements- matching points and points

Stage 2. Alteration to the balance of a garment (CFL and CBL)

Stage 3. Alteration amount of girth (Bust and hip), amount of length, and width

Stage 4. Alteration to the neck area

Stage 5. Alteration to the shoulder area

Stage 6. Alteration to the bust suppression

Stage 7. Alteration to the armhole area

Stage 8. Alteration to suppressions (bust and hip)

Stage 9. Alteration to the sleeve

Limitations and Suggestions:

In our view, the Bond *et.al*.study is limited in terms of measurement definition. Though the process described above may work in our initial tests with the $[TC]^2$ 2-Tower scanner, incongruities with measurement extraction definitions may present problems when working with other scanners. We have already encountered this in an experimental comparison test between the $[TC]^2$ 2T4C system and the $[TC]^2$ 3T6C system. Use of our proposed system of identification coding will help in our process of relating, and eventually integrating, 3DBS to specified CAD garment patterns. In addition, specific experimental garment styles and patterns need to be chosen, or at least specific basic patterns need to be selected.

Project URL: http://www.tx.ncsu.edu/3Dbodyscan

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ASTM D 5219-99 Standard Terminology Relating To Body Dimensions For Apparel Sizing

ASTM D 5585-95 Standard Of Body Measurements For Adult Female Missed Figure Type Sizes 2-20

ASTM D 5586-95 Standard Of Body Measurements For Women Aged 55 And Older (All Figure Types)

ASTM D 5826 Standard Of Body Measurements For Children Sizes 2 To 6x/7

ASTM D 6192 Standard Of Body Measurements For Girls, Sizes 7 To 16

ASTM D 6240 Standard Of Body Measurements For Men Sizes 34 To 60 Regular

ASTM D 6458 Standard Of Body Measurements For Boys, Sizes 8 To 14 Slim And 8 To 20 Regular

BS 3666-1982 Standard Specification For Size Designations Of Women's Wear

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	S. Hwang	Graduate Student
	L. McKinnon	Graduate Student
	K. Peavy-Simmons	Graduate Student
PAD	Bridgette Meunier	
	Olivier Cochaux	
	Joanne Laurendeau	
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