

S00-NS15 Automated Garment Development from Body Scan Data

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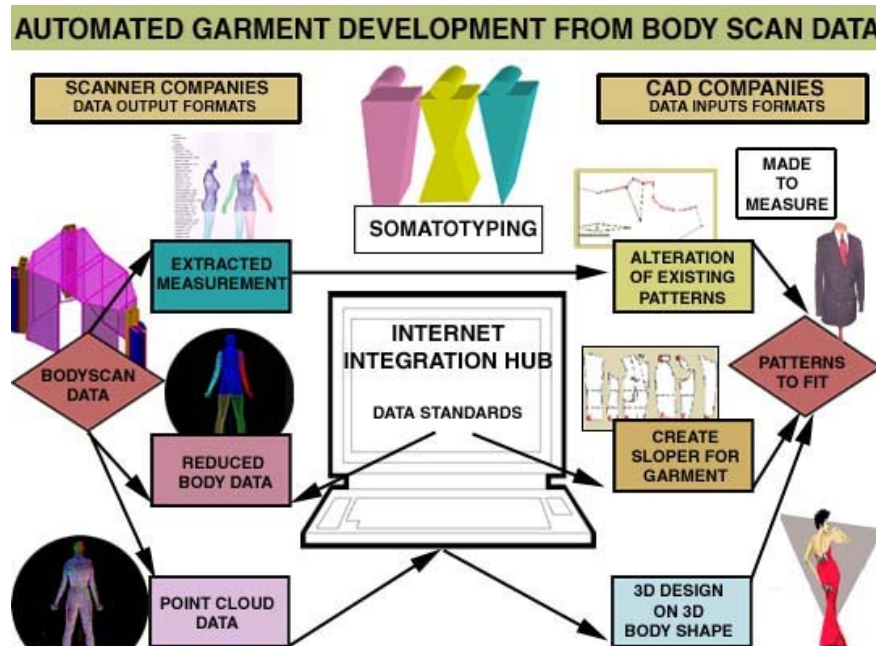
Abstract

We are creating a conceptual model to automatically integrate body scan data into commercial CAD/CAM software to facilitate garment design, pattern derivation and sizing. 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 is the third year of a three-year investigation. Our report presents a summation of our ‘learnings’ relative to this since project inception May 1, 2000. In the remainder of *Year 3* we will continue these research efforts and move toward activation and validation of our 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, pattern derivation, and sizing from body scan data, with a supporting research focus on standards for body scan data exchange in relation to the above. Our conceptualized Automated Garment Development process as shown in *Figure 1*:

Figure 1. Process Paths for Automated Garment Development from Body Scan Data.



Progress Overview

Standards Development

Members of our research team have also played primary roles in other areas of progress related to this project. We have been actively spearheading a new standards coordination initiative relative to data exchange between 3-D body scanners and CAD. We first surveyed all major apparel CAD/CAM vendors and body scanning manufacturers for their automated garment development strategies/solutions. We examined data formats of 3-D body scanners to learn

how various scanner vendors make their data available. We developed a website at <http://www.bodyscancentral.com> which links to other academic and commercial sites related to non-contact measurement, virtual apparel design and development, and to discussion forums for those on the cutting edge. We are now determining how 3-D body scanners interface with existing CAD systems. We have established some common definitions, or body landmarks, to describe pattern generation methods and later to match points (landmarks) when moving from 3-D body scanners to pattern generation/alteration on CAD Systems. Determining how needed 'critical' measurements would differ by body shape has proven both challenging and fruitful. We developed a syntax, *i.e.*, a standard set of identification codes, by compiling information on garment sizes and tolerance measurements in the manufacture of apparel, together with the minimum required critical measurements corresponding to points of garment alteration. Our current syntax is based on analysis of four patterning systems. Although other pattern development systems exist in the world, our basic point code list suffices as a starting point for any future automatic pattern generation. Our research has increased awareness of problem areas associated with 3-D body scanning, particularly in finding anthropometrically correct landmarks on the human body.

For three days in September 2002, we hosted a 3D Body Scanning Task Force meeting at the College of Textiles. All 3D Scanner developers, Apparel CAD system developers, Virtual Modeling & Avatar system developers, and industry users were invited to attend and present their interests in the technology integration process. The meeting was highly successful. Attendees committed to working toward a standard that would enable the integration of the technologies for the benefit of the industry. The basic model developed by NC State will be the foundation of this standardization process.

Year 3 Report: Continuing Research Progress

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

Some of the individual scanning systems have made alliances with a specific CAD system to provide information in a format that can be used by that CAD system. Tecmath has made an alliance with Lectra. Telmat SYMCAD worked with ScanVec for a while. [TC]² has provided data that can work with Gerber and ScanVec. While these alliances have allowed the made-to-measure process to occur more easily for individual companies, they have also limited use by others in the industry. Almost all of the systems provide 3D data in IGES or VRML formats, neither of which can be adequately used for current Made-to-Measure systems.

The Made-to-Measure part of all of the CAD systems requires a significant amount of effort to prepare patterns for alteration. Integral to this process is the selection of the most correctly shaped pattern to start with. This basically means that the customer must be evaluated and a garment in the correct size group must be chosen as the base. Towards this end, *we developed a program* that would allow us to determine the most correct sizing system for the subject from the systems currently set as "standard". The aim of the "**Best Fit**" software was to compare a woman's body-scanned data with different standard measurements and to identify the person's closest standard size. The software also reveals the number of measurements of the person that do not fall within the specification. The measurements are restricted to those measurements essential for determining the size or figure type of a person.

In our program, six formulas are used to identify the standard size closest to the person's body size. Women's size measurements are based on certain major dimensions like bust, waist, hip, and are given more weight than the other measurements. In making the size determination, a variable called the *Tolerance Difference* is calculated to find the number of standard measurements that do not coincide with the person's measurements. Hence, the standard size, which has the lowest *Tolerance Difference* value, is the closest size for the person. **Thus, our program identifies a person's closest standard size and determines the number of measurements that do not coincide with that size.**

The current sizing standard was significantly insufficient at describing the body shapes/sizes of most of the subjects compared in this study. Inconsistencies existed in almost 50% of the measurements compared within the one size that was determined to provide the "Best Fit" for each subject. Among the 254 subjects, 183 were between the age of 18 and 30, the age group best represented by the ASTM standards. These findings suggest that researchers could significantly impact consumer satisfaction with the fit of apparel by working to redevelop the sizing systems to more accurately reflect the shapes of today's consumers.

1. Written and visual (graphic) definition of common terms used between systems

Landmarking—An essential component

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) we first reviewed available measurements standards for both apparel and 3D Body Scanning.

In the process of integration with new technology, standardization between systems is a significant issue. We have discovered that from system to system or person to person, measurement terminology may be used quite differently. Without standardization of semantics and syntax of fundamental measurements between Body scan systems and CAD systems, successful integration between the systems will be impossible. Based on the need for standardization of measurement terminology and measurement method, important landmarks and points were analyzed from previous research (Hwang & Istook, 2001).

A new coding concept was also developed through “the metaphor matching process”(Hwang, 2001) that allows a more efficient communication of information and enables integration among systems. This coding system permits a structural way of defining essential body landmarks.

Three-dimensional body scanning allows for the extraction of body measurements in seconds. It also allows consistent measurements. However, *there are several problems* that exist with the adoption of this technology:

One such issue is the comparability of measuring techniques between the scanners. Among the growing number of scanners that are currently available, significant variance exists in how each scanner captures specific body measurements. Until the data capture process of these measurements can be standardized or, at the very least, communicated among the scanning systems, this technology cannot be utilized for its maximum benefit within the apparel industry.

A second problem is the unwillingness of some scanner companies to share information about their scanning process. Some companies will share how the data capture occurs, how and what landmarks are used, and general information about their measurement extraction. However, the real proprietary information is in the mathematic/algebraic algorithms that are used. Almost all scanning companies are keeping this secret, which is understandable since this might be their competitive advantage. When these scanning companies are questioned about their data capturing methods, they simply give a standard answer of “we follow the ISO standards” or a similar statement. These are the kinds of attitudes that create barriers that inhibit the growth of this technology. Research of the comparative nature undertaken in our investigation should enable 3D scanner companies to see the importance of their support in order to promote adoption of their technologies.

A third problem with body scanning technology is that there are no standards, published or unpublished, on the interpretation of measurements or measurement terms. Current standards for body and garment dimensions include those established by the American Society for Testing and Materials (ASTM) and the International Standards Organization (ISO). The predominant standard for measurements taken for the military today in their issue of clothing is the 1988 study of U.S. Army personnel by Gordon, Bradtmiller, Churchhill, Clouser, McConville, Tebbetts, and Walker (1989).

Comparing Scanning Systems Using Measurement Terms

Three-dimensional body scanning brings to the forefront issues concerning these current standards. Most current standards require palpitation, or touching of the human body, or the bending of body parts to find appropriate landmarks for the needed measurements. Most scanners are intended to be non-contact so that the privacy of the individual being scanned can be protected. If we were to use the current standards to define the measuring process in 3D scanning, they just will not work. New standards are needed that will work for 3D scanners on a global basis.

With the use of 3D body scanners, body measurement techniques can be non-contact, instant, and accurate. However, how each scanner establishes landmarks and takes the measurements needs to be established so that standardization of the data capture can be realized. A summary of traditional measurement terms compared to the selected scanner models is shown in *Table 4*. For development of this comparison our researchers chose seventeen measurements considered critical to the design of well fitting garments. On each of the seventeen measurements, the method of data capture was described for three different scanners, [TC]², Cyberware, and SYMCAD.

Of the seventeen measures in the study, [TC]² was the only scanner that had all of the measures. They were most closely in line with the current standards or with what the standards should be, depending on the measure.

SYMCAD is just now beginning to be used in apparel. They have a set of 60+ measurements that are defined according to ISO standards (so they say). These measures allow no revision or adjustment for users' needs. They also find it difficult to share information on anything that concerns their scanner. As mentioned previously, many of the traditional standards used by SYMCAD are inadequate for apparel fit needs and are imprecise.

Development of Semantics Model for New Integration Standard

The purpose of this study was to move toward standardization of body measurement terminology and methods for both apparel systems and 3D body scanning systems for mass customization. The Metaphor Matching Process (MMP) was developed for a constant variable-defining group using mapping metaphors and 'key coding' to show relationships and replace generic 'whole'/'aspects' terminology that symbolized a 'thing'.

The Metaphor Matching Process (MMP) has been well explained as a logic process. The MMP helped define further landmark definitions. This process also developed rules of creation and steps of matching metaphors for standardization, through the fundamental, key-coding, matching process of redeveloping terminology. The process of matching metaphors for "consensus of terminology" and "standardization" made it possible to connect people in different fields and integrate different systems, providing guidance for how to understand the metaphorical system in general. The Metaphor Matching Process (MMP) permitted a structural way of establishing a standard terminology and enabling integration between systems.

Application of the MMP in the creation of key codes minimized the number of landmarks that needed explicit definition and helped explain all of the other parts used for the critical measurements needed for development of basic patterns. From landmark points to lines in critical measurements, all definitions and methods were successfully well defined. In addition, redefined landmark terminology based on new body scanning technology provided a solution for the limitations of the 3D body scanning systems that can only recognize "body shapes" and not specific body parts. This system allowed a clear definition that worked for both 3D body scanning developers and apparel system developers. Therefore, standardization through the logical structural process of coding assisted efficiency in the work process, integration of 3D body scanning systems to apparel systems, and consistency of body measurement data.

As a solution, "Key Codes" were developed to show relationships and replace generic 'whole' or 'aspects' terminology that symbolize a 'thing'. These additional symbols are facades aimed at enhancing the 'raw' meaning and thus enabling a degree of differentiation. Hierarchy was created in that all additional facades are within the initial context ('whole' versus 'part') and each refinement is often within the context of a previous refinement. As we differentiate the whole and its aspects, each metaphor is developed to contain a pattern that is based on the way it is created in the mind. The following steps show how the process was developed to work.

Step 1. Develop codes for body measurement terminology as 'Parts':

Code	Terms
NK	Neck
BP	Bust point
BU	Bust
WS	Waist

Step 2. Develop the following syntax that describe the location of the body parts:

Syntax for Developing 3DBS Terminology

Body parts	_ =to	g=girth	b=back	0=center
		l=length	f=front	1=left
		W=width		2=right
		p=point		

The syntax has an order of description for each part. It starts with body part codes. The '_' indicates a linkage from a body part to a body part in order to describe lines such as length, width, or girth. The 'g' indicates girth, 'l' indicates

length, 'w' indicates width, and 'p' indicates point. The 'b' and 'f' indicates body position. The numbers in the last part of the syntax indicates the location of the points or lines.

Step 3. Input a “Whole” terminology from any different system.

Step 4. Analyze a “Whole” concept as “Parts” and match each “Part” to codes in the template.

Step 5. The output has the consensus of a “Whole” metaphor. The concept of the development for same terminology was based on the Metaphor Matching Process. The process shows how to develop the same terminology as a ‘whole’ by matching each ‘part’ to another ‘part.’

For an example of Body codes, the Back Waist Length gets result as WS1b0 (see Figure 1).

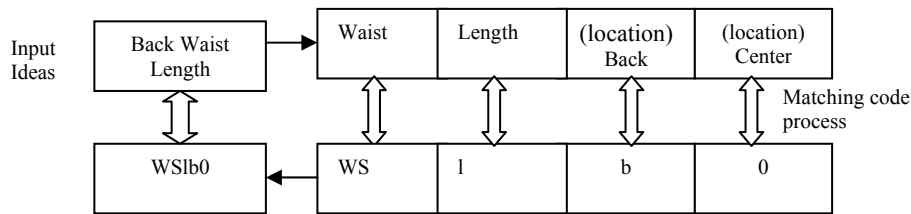


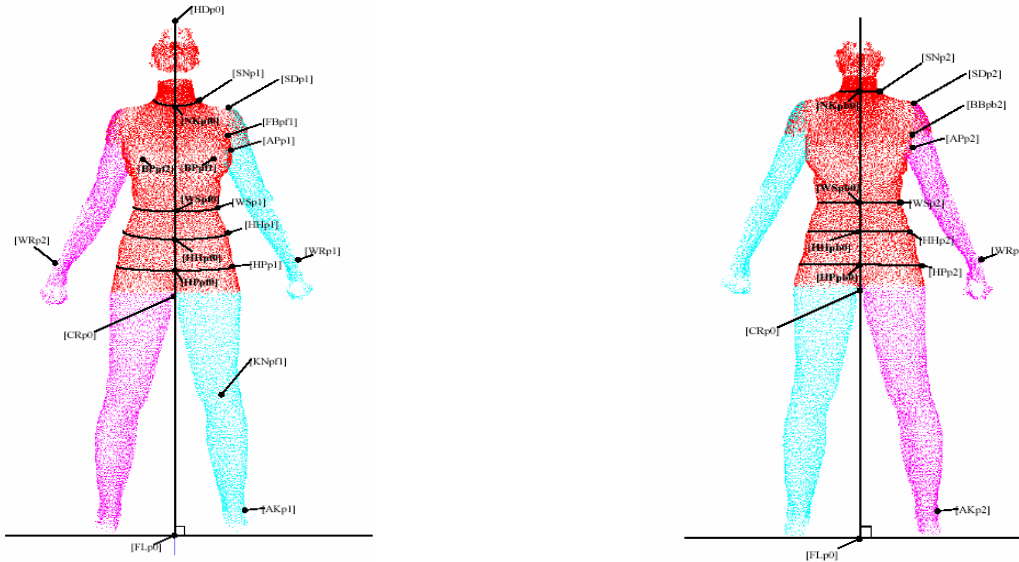
Figure 1. Metaphor Matching Process

As a result, each terminology as a semantic follows the same format for easy referencing and use. The process of matching metaphors for a consensus of terminology or standardization enables the connection of people in different field and integration between different systems. It provides an efficient working process. In the working process of integration within new technological areas, standardization between systems is an important issue. Without a consensus in semantics, integration might be impossible. Therefore, the metaphor matching process provides an efficient way of creating works and integrating new systems. It permits a structural way of finding a metaphor. It is simple to understand and can provide guidance to the concept of understanding the metaphorical system in general.

The 3D Body Scanning systems extract thousands of points within a point cloud, which represents the human body using x, y, z coordinates. All of the points within the point cloud are not necessary for all measurements. It would be inefficient to work with too many points. The selection of landmarks depends on the application or end use of the ultimate data. For example, the field of anthropometry requires very specific body part measurements, such as ‘Bimalleolar breadth’. However, the part may not be necessary for other applications. For our research, the selection of landmarks has the following forces that focus on apparel applications:

- ❑ Clear definitions. Landmarks have to be clearly understood.
- ❑ Link other parts to descriptions. All body measurements can be explained with the fundamental landmarks.
- ❑ Apparel applications. This focuses on apparel applications such as creation and alteration of garments using 3DBS. Some definitions might not be applied for other applications, such as medical uses and anthropometric research.
- ❑ Integrating 3DBS to apparel CAD systems. Points from the 3DBS can be delivered into apparel pattern systems.
- ❑ Minimize the number of landmarks. All of the points contained in a point cloud are not necessary for the determination of a measurement and can cause inefficiency.
- ❑ Select points, not lines. Critical measurements for apparel use are lines that consist of landmarks as end points.

Landmarks were selected based on the above forces. Each terminology had the underlying foundation of the ASTM and ISO standards but was modified for use with 3D Body Scanning systems. These landmarks were matched on the body picture obtained from 3D point cloud data from a 3D Body Scanning system. Figure 2 and Figure 3 show the specific location of each landmark point on the point cloud body image, with codes.



Shape Sorting and Figure Typing (Somatotyping)

A primary element of our integration model (see Figure 1) developed during the first year of this project was the understanding that technology integration alone would not enable successful customization efforts. Essential to the process was the requirement that human figures be sorted into appropriate shapes before a successful outcome could be enabled.

Mass customization methodologies appear to provide a “solution” by allowing customized fit of apparel. A significant underlying problem exists, however, when attempting to alter a garment for fit based on one standard shaped garment product. “Extreme” alterations seldom provide the desired fit in the final garment. This discovery has led us to understand that optimal customization can only occur if customization starts from the most correctly shaped garment for each customer’s “figure type”. Thus a system was developed to identify female figure types using 3D body scan data. Such categorization of body types will allow a more appropriate reorganization of sizing systems with more successful attempts at customization and mass customization. This information will allow researchers to analyze body scan data relative to target market sizing, develop new shape categories not possible with 2-dimensional systems, and characterize body types for today’s market. This process allows us to use the most “correctly shaped” garment for the customization procedure that will better ensure satisfactory fit of the final garment.

A comprehensive literature search was conducted to examine the elements or qualifiers for all of the pre-existing body shape classifications. The majority of methods used a simple visual process of classification with a vague list of descriptors to define the bodies that fell in each category. None of the methods used mathematical formulas, ratios, or descriptors to aid in the determination of body shapes. Through Visual Basic, a new shape sorting software was created. The elements for shape classification determined from the literature search were used as a starting point for the shapes. Once the basic shape categories were identified from literature, the relative visual and descriptive information was evaluated to help determine a mathematical logic that could successfully identify shapes. Using mathematical criteria and the tacit knowledge of experts in apparel design, development, and fit, code was written for the software.

In the first draft of the software, five shape categories were identified, “hourglass”, “oval”, “triangle”, “inverted triangle”, and “rectangle”. Each shape category was then given ranges of numerical values that corresponded to the body measurements that were significant for that shape. The “bust”, “waist”, “hip”, “stomach”, and “abdomen” circumferences were used in combination to describe each shape. Measurements such as shoulder width, rise, and others were not included because they can be more easily adjusted within each shape category for customized fit. After consideration of all of the available measurements that would describe the body, the basic ratios were essential circumferential measurements that are elemental for shape and for well fitting clothing.

The development of the shape sorting code required a stringent evaluation of all the variables that could potentially impact a person's shape and thus impact the fit of a garment. Combinations of variables were studied to determine their value in the development of new sizing systems or in the customization of clothing. We determined that the most benefit would be achieved by defining body shapes at the most elemental level.

Based on the premise that mass customization efforts will only be successful if customization starts from the most correctly shaped garment patterns, determining elemental, basic body shapes was vital. Any additional alterations that might be needed (based on other fit variables such as torso length, posture, bust development, knee skewedness, and others) could be fairly easily achieved using customization methods available in pattern development software. Inclusion of these additional variables in the definition of body shapes would have increased the number of body shapes exponentially and decreased the value of this research to the apparel industry and, ultimately, the consumer. The complication of the process would decrease its likelihood of adoption.

Why is the **FFIT for Apparel** software so important? In this study, we have proven that the basic sizing systems are not adequate. To further the effectiveness of this research, we ran all of the current and previous standards used in this pilot study (CS215-58, PS42-70, ASTM5585-95, and ASTM5586-95) through the **FFIT for Apparel** software to determine what shape categories the standards applied to. The CS215-58 measurements, found to provide the best fit for the majority of the subjects in this study, were almost 50% comprised of the Spoon category. The ASTM5586-95 (55+) measurements, found to provide the second best fit for the subjects in this study, were over 95% comprised of the Rectangle category. Through the **FFIT for Apparel** software, each standard, except the ASTM5585-95, consisted of differing shapes for its population. In this pilot study, the frequency of subjects in each category was the Bottom Hourglass (40%), Hourglass (21.6%), Spoon (17%), Rectangle (15.8%), Oval (3.6%), and Triangle (1.8%). ***This process allows us to use the most "correctly shaped" garment for the customization procedure that will better ensure satisfactory fit of the final garment.***

2. Developing the initial Body Scan/CAD Data Exchange & Garment Development Model

Creating a conceptual model that automatically integrates body-scanning data with CAD/CAM software to facilitate garment design, pattern derivation and sizing requires a specific focus on automated garment design, pattern derivation, and sizing from body scan data, with a supporting research focus on standards for body scan data exchange. Our conceptual model (*refer again to Figure 1*) describes the possible complexity of data exchanges emerging from body scans. The multiple paths and directionality of information flow stem from the need to extract and exchange this body scan 'point cloud' data with the sloper critical measurements and/or pattern stylizing and sizing functions. Our conceptualized Automated Garment Development process has three paths, two of current interest for this work. One path develops a garment from already existing patterns in CAD, and the second generates a pattern 'from scratch'. The third path, deriving the pattern shape in 3D, should be the focus of future research. The first and second paths are based upon relationships between garment topography, critical body scan measurements and 2-D 'flat pattern' alteration heuristics. The data flows through five major processes:

- 3-D body scanning,
- 3-D point cloud generation,
- Measurement extraction and output file creation,
- 2-D pattern alteration heuristics and marker generation, and
- 2-D to 3D garment generation.

The flow of data, and required file format conversions between three-dimensional body scanners and CAD are one-directional. The missing link between 3-D body scanners and 2-D pattern alteration represents a critical juncture at which integration is currently not automatic.

As demonstrated in our model (*refer again to Figure 1*), the translation/integration process is extremely complex when all parties and activities are considered. To make our efforts valuable, valid, and used, the industry players must be intimately involved. They have to "buy-in" to the process and be sold on its logic and fairness to all involved. This requirement makes the whole process much more difficult, but is essential to a successful outcome. We have spent a great deal of time trying to understand the "language" of each system so that we can accurately translate the information for a recipient system. Case in point: We did not anticipate that "waist" might not really mean "waist" to every participant. *The development of the semantic coding necessary for accurate communication between systems has been extremely time consuming and difficult and has delayed the development of our translation algorithms. The power of our Automated Garment Development model can only be made stronger as a result of this extra and unanticipated effort.*

Project URL: <http://www.bodyscancentral.com>

Publications, Conference, and Workshop Presentations:

- Istook, C., Simmons, K.P., & Devarajan, P. (2002, Nov). "Female Figure Identification Technique (FFIT) for Apparel," presented at the International Foundation of Fashion Technology Institutes (IFFTI) 4th International Conference in Hong Kong.
- Istook, C., & Parrillo Chapman, L. (2002, Nov). "Customized Product Development and Rapid Prototyping: Incorporating New Technologies in Education," presented at the International Foundation of Fashion Technology Institutes (IFFTI) 4th International Conference in Hong Kong.
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- Simmons, K.P & Istook, C. (2002, Nov). "3-D Body Scanning Measurement Procedures: Are they the Same as Traditional Physical Anthropometric Methods?" presented at the International Foundation of Fashion Technology Institutes (IFFTI) 4th International Conference in Hong Kong.
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Additional Graduate Student Work:

Su-Jeong Hwang A1 Paper " Three Dimensional Body Scanning Systems with Potential for Use in The Apparel Industry.." Presented at North Carolina State University, Raleigh, February, 2001. Paper presentation available at <http://www.bodyscancentral.com>
 Karla Peavy Simmons A1 Paper "Body Measurement Techniques: A Comparison of Three-Dimensional Body Scanning and Physical Anthropometric Methods" Presented at North Carolina State University, January, 2001. Powerpoint and paper presentation available at <http://www.bodyscancentral.com>

Award:

K. Simmons. (2001, February 17). Best Presentation. Graduate Student Presentation Contest. 9th Annual National Textile Center Forum, Myrtle Beach, SC.

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