Applications of 3D White Light Body Scanning

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1. The Body Scan process

[TC][2] researchers and developers have many years of experience with public deployments of 3D body scanners for a variety of purposes (Fig. 1). Approximately 250,000 3D body scans have been taken over the five venues illustrated in this Fig. Levi's, Brooks Brothers, and Land's End represent private company based scanner venues. SizeUK and SizeUSA are recent (2000~2003) automated 3D scan national sizing surveys of the United Kingdom and the United States of over 10,000 people each. Based on these experiences, indications are that the successful implementation of body scanners in public settings requires the following system characteristics:

- Private customer experience

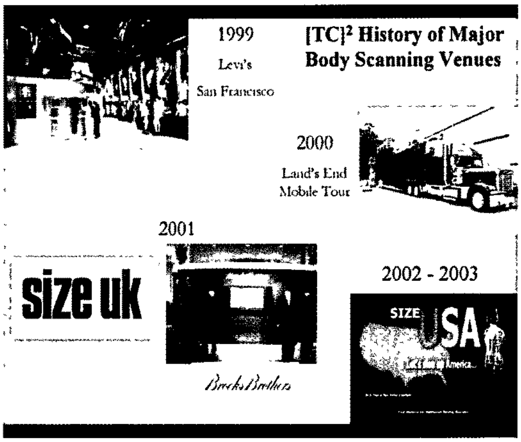

Fig. 1. Examples of public scanning venues

- Absolute perception of safety
- Fun, not sterile scan environment
- Accuracy level appropriate to the application
- Automation of scan and calibration processes (no skilled operators required)
- Robustness (high % up time)
- Automation of high value data output (size prediction, custom garment specification, measurement tracking, etc.)
- Low total cost of implementation and ownership

Body scanners rely on different base technologies to acquire 3D data and are generally categorized by the light or radiation used to illuminate the subject. The major categories today are laser, infrared, and white light. The basic output of 3D body scanners from any of these categories is a 3D point cloud (sometimes referred to as 3D range data) generated over the body surface. Additional differences arise between various systems in the way that the data is processed following the production of the 3D point cloud. For example, the process illustrated in [Fig. 2] is the [TC][2] sequence for body scan data processing from raw scan data into rich output data. Once the raw point cloud is computed the application (Body Measurement System) first detects major landmarks (crotch point, armpit points) in the point cloud and segments the body. In this process, the data is organized, smoothed, filled, filtered, and compressed to create a 3D body model (also shown in Fig. 2). Once the data is organized as a 3D body model, downstream tasks such as automatic mea-

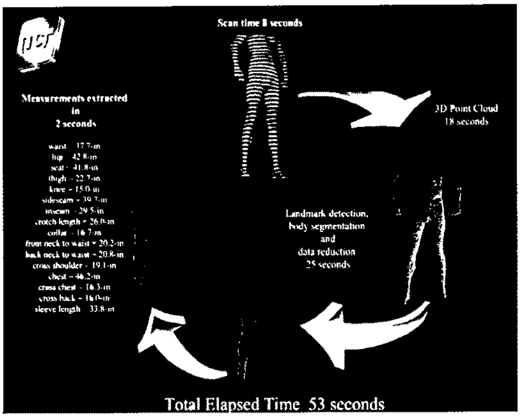

Fig. 2. [TC][2] Body scan data processing sequence

surement extraction, creation of a 3D surface model, or creating a customer or manufacturer printout is simplified.

2. Automatic user-customizable measurement extraction

When measuring bodies for general anthropometry it is typical that a standardized set of measurement definitions be used as a basis for the measuring. However, when measuring bodies for the additional purpose of utilizing the data for apparel applications, is more optimal to include the option to specify the measurement definition in the context of the garment for which the measurement data is to be used. The nature of the garment and the way it is intended to be placed on the body essentially becomes the measurement definition. A typical example of this is the waist definition. Typical anthropometric definitions of the body waist are of very little use when sizing a pant, slack, or jean. This limitation can be addressed through the incorporation of a methodology that allows a means for the garment reference in the specification of the measurement definition. A particular implementation of this is outlined in [Fig. 3 and 4] Without requiring programming skills, a user can create via a simple click selection interface a customized set of measurement definitions. Shown in [Fig. 3] is the top level selection panes which illustrate selection of a variety of waist measurements. The "parameters" or definition customization elements for the waist mea-

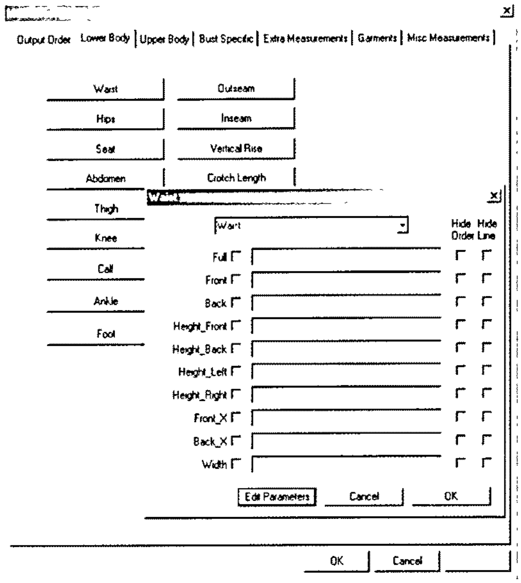

Fig. 3. Measurements selection dialog sample

surement are illustrated in [Fig. 4].

Having selected the parameters for the desired definition - this definition, along with hundreds of other parameterized measurement definitions, can be saved as a "measurement extraction profile" and can be called upon for a measurement extraction for any body scan. This process allows for the appropriate specification of the measurement definition and the efficient (automatic) subsequent utilization of those definitions. A similar technique

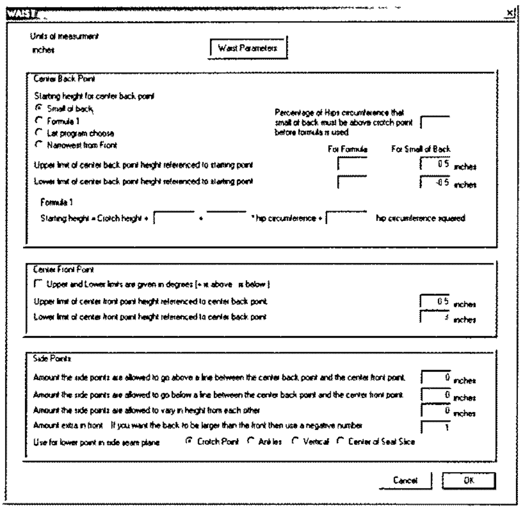

Fig 4. Customization parameters for the waist definition

can be used to not only create a customized definition, but to create a new definition altogether. [Fig. 5a] illustrates a technique (called "Extra Measurements") whereby a user can create a new definition through reference to known standard measurements or landmarks. [Fig. 5b] also shows a new measurement creation technique by which one can generate a new measurement as a "formula" or logical expression using constants or previously defined measurements as the elements in the expressions created. The particular example shown is a logical expression to determine a "Full Bust" shape extraction. [Fig. 6] illustrate the data process and extracted measurement graphics and output scalar values on a sample female and male body scan. In the case of the male scan in the lower right image of [Fig. 6], an illustration of internal joints approximate extraction is shown. All of the automatic measurement procedures can be processed in batch mode for large volumes of scan data sets as are common with large scale sizing surveys. Finally, if an individual manual assessment is desired, tools for the manual placement of slice planes for surface following or convex hull (tape equivalent) measures as well as local surface area and volume analysis are possible as shown in [Fig. 7].

3. Body Shape Extraction

Most characterizations of body shape used in either apparel or health/fitness industries are based on visual assessments that an expert makes from viewing the front and side profile of a subject. This task can be accomplished automatically via the body scanner and measurement extraction using the combination measurement editor. Some commonly used examples of some typical shape characterizations that can be automatically extracted using measurement formulas and logical expressions of combinations of measurements (see tool in Fig. 5) are:

Side profile shape assessments

- Full Chest/Bust (ratio of chest/bust to waist; circumference or thickness as viewed from the side)
- High/Low Bust (front neck height-bust height) /(front neck-waist height) ratio

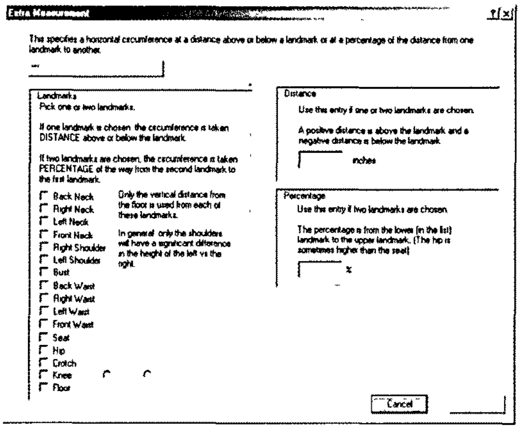

Fig. 5a Extra measurement definitions

- Full Waist - same technique as full chest
- Stout/Portly - (ratio of waist to chest; either circumference or thickness as viewed from the side)
- Extra Stout/Portly - (ratio of waist to chest; circumference or thickness as viewed from the side)
- Stooped Posture - (back neck X value - shoulder blade X)
- Erect Posture - same technique as stooped posture
- Sway Back Posture - comparison of blade, small of back, and seat X values

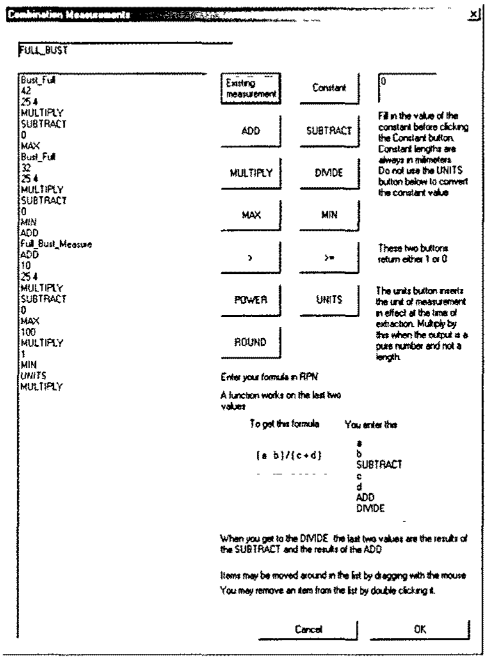

Fig 5b Measurement from formulas or combinations of other measurements

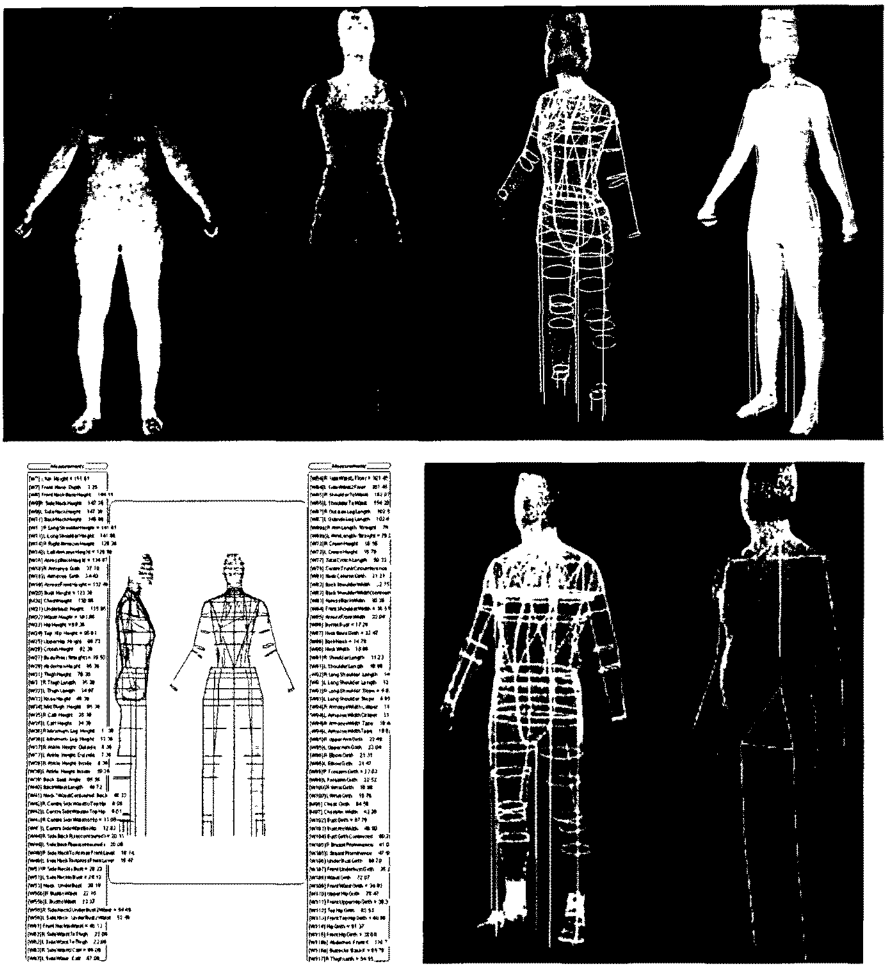

Fig 6 Sample extracted output

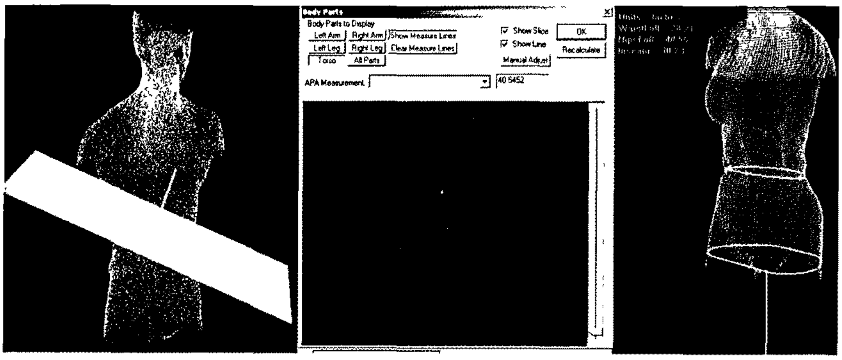

Fig. 7. Manual positioning for data extraction of measures, surface areas, volumes

- Head Forward - same as stooped posture
- Prominent Seat - Back of waist value compared to Rear Seat value
- Flat Seat - same as prominent seat technique
- Prominent Calves - back of seat value compared to back of calf
- Shoulder Back - relationship of shoulder point to back of neck point

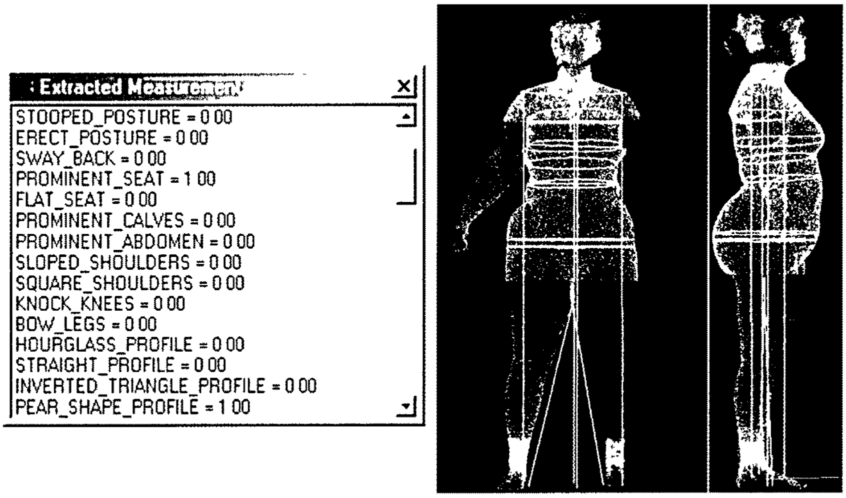

Fig 8 Shape extraction example

- Shoulder Forward - same as shoulder back technique

Examples of front profile shape assessments

- Sloped Shoulders - (shoulder slope or neck height vs. shoulder height)
- Square Shoulders - same as sloped shoulder technique
- Knock Knees - distance between knees versus hip width
- Bow Legs - same as knock knees technique
- Hourglass front profile - bust/waist/hip width ratios
- Straight front profile- same as hourglass profile technique
- Broad Shoulders/Small Hips front profile - same as hourglass profile technique
- Narrow Shoulders/Broad Hips front profile -same as hourglass profile technique

A sample application of shape extraction reduced to a yes=1.00 or no=0.00 indication of whether the shape characterization applies is shown in Fig. 8.

4. Size Prediction of Stock Garments and Specification of Made to Measure Garments

Using the automatic measurement and shape extraction tools, one can use straight-forward statistical and/or mathematical optimization correlation techniques to utilize the scanner as an "Expert System"

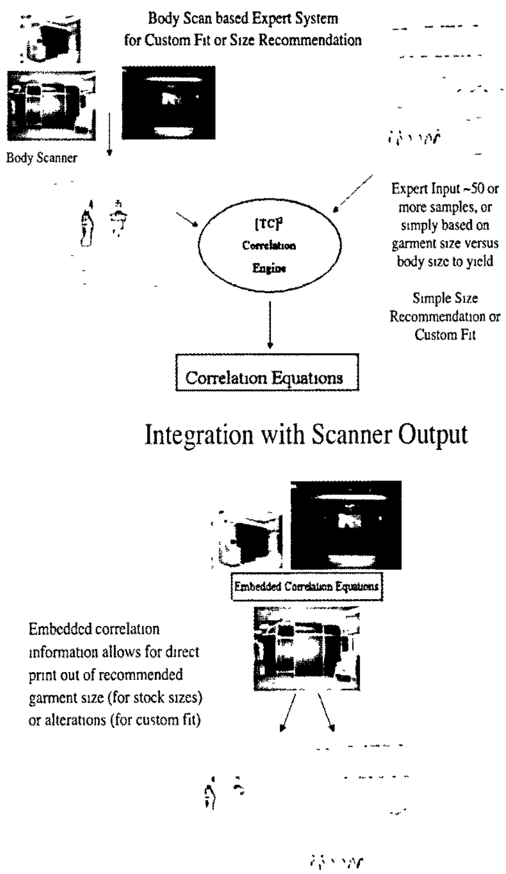

Fig. 9. Scanner output for size prediction and custom garment specification

which mimics the recommendations of an expert specialist in garment sizing or custom garment development. The images in [Fig. 9] graphically illustrate the process of correlating the expert assessment on a sample group of subjects to the body scanner extracted shapes and measures. Then, this correlation, compiled as a "formula" is re-introduced as a combination measurement (see lower Fig. 9) so that immediately and automatically the size prediction or custom garment specification is output from the scanner.

5. Application of Scanner Measurement Output to 2D Pattern Alteration Systems

A common mode of operation for the creation of custom garments is the export of body scan measurements directly into a 2D CAD system of apparel. Illustrated in [Fig. 10] is the export of measurement data in to the Optitex Modulate application. Other CAD systems actively in use with body scan output include Gerber MTM and others.

6. Direct Generation of Basic Blocks/Slopers and Finished Patterns directly from Scan data using Automatic Landmarking and 3D-to-2D Data Unwrapping

An idea developed in the 1980's was to directly utilize 3D scan data to directly generate garment patterns. Though conceptually elegant, it has defied

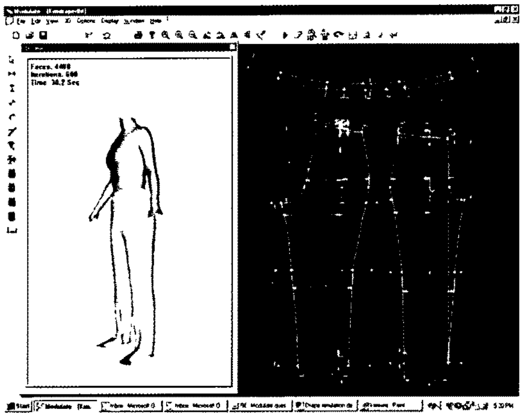

Fig. 10 Export of scan measures to 2D CAD systems

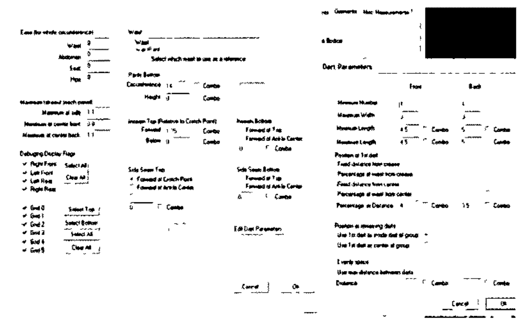

Fig 11 Extraction parameters for direct generation of pants/slack

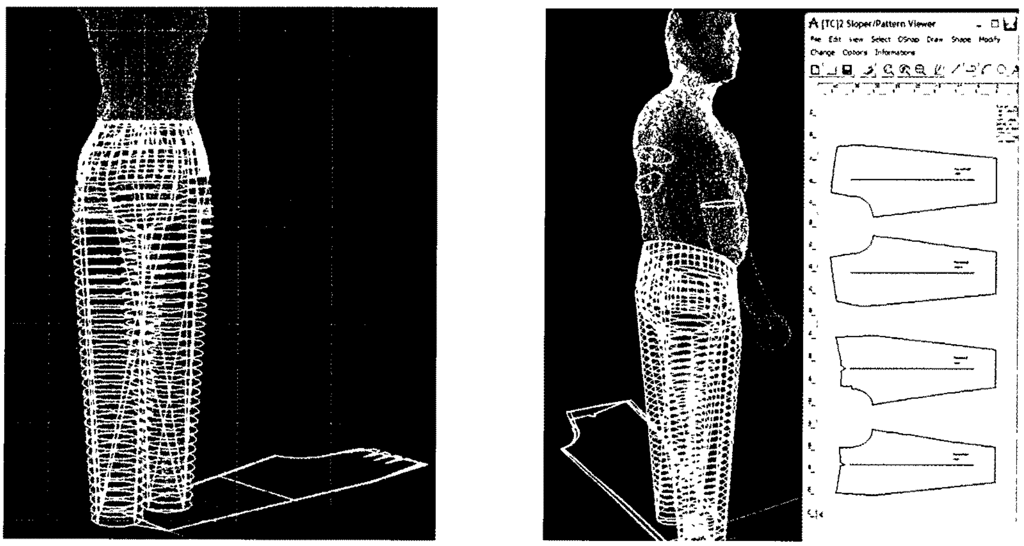

Fig 12 Sample output of women's and men's pants/slack

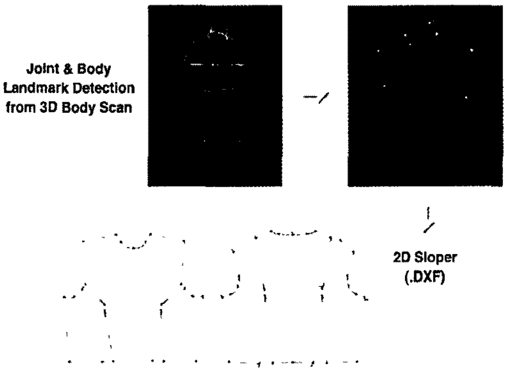

Fig 13 Direct generation of a basic block from 3D body scan

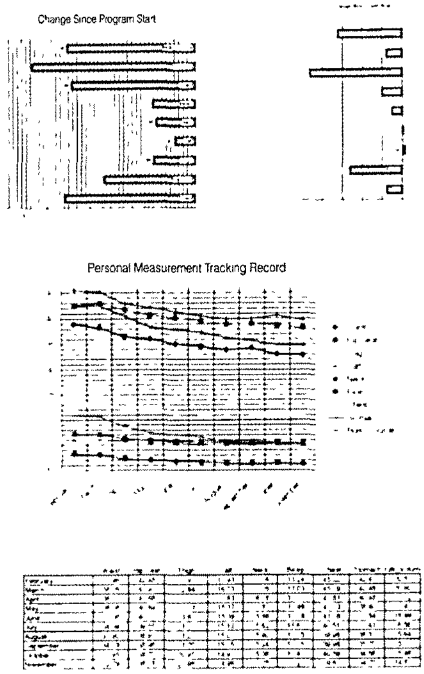

Fig. 14 Measurement tracking chart

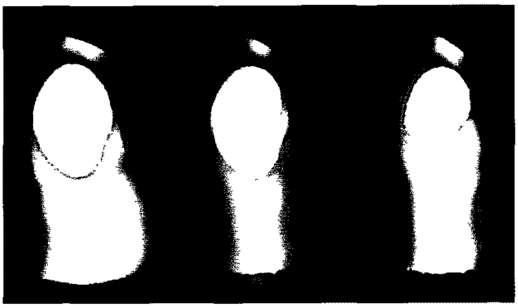

Fig. 15. 3D state transition - data morphing references

practical implementation. The difficulty in being successful with such a system lies not in the 3D- to- 2D data unwrapping, but rather in successfully automating the placement of seams, darts, and other key garment features with respect to the body. Additionally, issues of the garment style and design play a role in the determination of final geometric specifications of the output garment pattern. These issues are addressed in the [TC]² system via a parameter specification interface similar to the used for custom measurement parameters. In this interface (pants example in Fig. 11), items that are need to be determined by the designer in advance, and other items related to the pattern that do not stem from the 3D data (such as style and design issues) are specified here.

A sample automatic and direct extraction of a pants pattern using is illustrated in [Fig. 12]. The output mechanism is a .dxf format file - which can be imported into any 2D CAD system for further manipulation if desired, or direct output to a .dxf compatible cutter. Fig. 13 illustrates the use for a basic bodice block/sloper, instead of a finished pattern, which is of great interest for product development specialists working on new designs based on their fit model body scans or average scans from 3D scan surveys.

7. Measurement Tracking and 3D Data Morphing for Health/Fitness Applications

Given all the functionality developed to extract information from 3D body scans for apparel applications it is easy to imagine its possible use in health and fitness applications. Specifically, a common tracking mechanism employed in fitness salons is a regular evaluation of a person' s body measurements at key points on the body, such as waist, chest, stomach, bicep, etc. [Fig. 14] illustrates an actual example of the tracking of a person' s measurements over a six month period during a weight reduction program. [Fig. 15] illustrates the 3D data evolution (shown to the subject as a "morphing" from the beginning state of the weight reduction program to the final point of weight goal achievement). These tools provide both unambiguous feedback on the program progress and can also serve as a powerful motivational tool for meeting the health or fitness program goals. Coming future applications include "predictive" capabilities based on the subjects fitness goals and exercise and diet plan in concert with a 3D analysis of their current body shape and composition which will allow a subject to get an idea in advance of what effect a persons fitness program will have on their body.

References

[TC]2 - www.tc2.com
Brooks Brothers - www.brooksbrothers.com
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Size USA - www.sizeUSA.com
Land's End - www.landsend.com
Levi's - www.levis.com

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