A STRUCTURED FRAMEWORK FOR VIRTUAL DRAPE ANALYSIS

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ABSTRACT

Virtual technologies, including three dimensional virtual draping of apparel, have impacted apparel processes considerably and will continue to influence future developments. Accurate analysis of drape in the virtual environment is challenging due to the complexity of capturing, processing, and evaluating three dimensional deformation of apparel. Further, drape depends on numerous factors such as fiber type, fabrics used to construct garments, yarn and fabric properties, and fabric finishing. Hence, a mechanism to bridge various components of drape analysis in the three dimensional virtual environment is needed.

The goal of this paper was to develop a framework for analysis of three dimensional virtual drape and to provide a route map for capturing, evaluating and characterizing drape in a virtual environment. The framework was based on a series of investigative steps and their contributions to virtual drape evaluation. The framework is divided into six categories and five segments signifying various components of drape analysis. The six categories are research segments, sample preparation, fabric objective testing, drape capture, drape parameters, and comparison and evaluation. The five segments are fabric drape, fabric drape with body scanner, garment drape with body scanner, fabric drape simulation, and garment drape simulation. The developed framework demonstrates the applicability of drape simulation, virtual prototyping, and virtual product development for apparel products.

The framework could be utilized as a business tool for decision making on aspects related to fabric and apparel drape. The framework can also assist the user in future development by examining the current tools and techniques used to characterize apparel drape in the virtual environment. Eventually, the use of virtual drape analysis to understand fabric/apparel drape could lead towards completely designing, developing, and demonstrating apparel products in the virtual environment.

1. INTRODUCTION

Simulating drape of fabric and garments has captured the interest of researchers in computer graphics, textile and apparel industries. However, accurate three dimensional representation of drape in a virtual environment is very challenging. This is due in part to the complexity of recording, analyzing and evaluating the three dimensional deformation of cloth objects. Further, garment drape lacks defining terminology and instrumentation, and the relationship between fabric mechanical properties and garment drape is difficult to quantify.

In the computer graphics community, there is a limited understanding of the construction, nature, and characterization of cloth. Drape simulation software is built largely on the “if it looks right, it is right” philosophy, where “right” means “a fabric”. Pioneering work by

Breen, House & Getto (1992) developed a non-continuum particle model that attempted to directly capture the underlying fine grained mechanical structure of cloth. However, the textile and apparel industries need improved accuracy of the simulation output for implementation into practical applications in apparel processes. Specifically, a garment that is developed in a virtual environment should represent its actual counterpart to the greatest possible extent, including draping differently when simulated in different fabrics. In this paper, a framework is developed documenting the contributing elements of virtual drape and identifying the methodological and substantive segments responsible for significant contributions to the investigation of virtual drape. The framework was based on the understanding of investigative steps and their contributions to 3D drape visualization research. The framework will be useful as a platform for future work in this area of research.

2. DEVELOPMENT OF FRAMEWORK FOR VIRTUAL DRAPE ANALYSIS

One way that a conceptual research framework can assist in future development is by benchmarking the tools and techniques currently used to characterize drape in the virtual environment. The framework developed in this paper is divided into six categories and five segments. The six categories are research segments, sample preparation, fabric objective testing, drape capture, drape parameters, and comparison and evaluation. The five segments are fabric drape, fabric drape-body scanner, garment drape-body scanner, fabric drape-simulation, garment drape-simulation. The six categories are represented by colored blocks, and each segment is shown with rectangular box representing the complete process for each segment.

2.1 Segment One: Fabric Drape

In the flowchart for fabric drape analysis, Figure 1, various instruments available for fabric drape measurement, and the parameters used to characterize fabric drape for circular fabric samples are illustrated. The first instrument developed to evaluate drape was the FRL Drapemeter which used the ratio of the draped area of the circular fabric sample with the undraped area of the sample to quantify fabric drape (Chu, Cummings, & Teixeira, 1950). Measurement of drape using the FRL Drapemeter was very tedious and was prone to manual errors, so in the early 60s, Cusick designed and developed the much simpler to use Cusick Drapemeter (Cusick, 1968). Measurement of drape using the Cusick Drapemeter was easier, but was still prone to manual errors. Researchers developed methods to improve the instrument with the addition of image analysis processes (Vangheluwe & Kiekens, 1993). One of the limitations of image analysis is that it requires specialized software to process the captured drape image. Kenkare & May-Plumlee (2005) developed a method to overcome the limitation of specialized software using a digital camera and *Photoshop*^{TM} software to capture and evaluate drape. The results show that the digital method is compatible with the conventional technique and has advantages in terms of time, quality of data and ease of use. In recent years, researchers in Kanazawa University, Japan, developed the Dynamic Drapemeter to characterize both dynamic drape and static drape using one instrument (Yang, & Matsudaira, 2000, 2001).

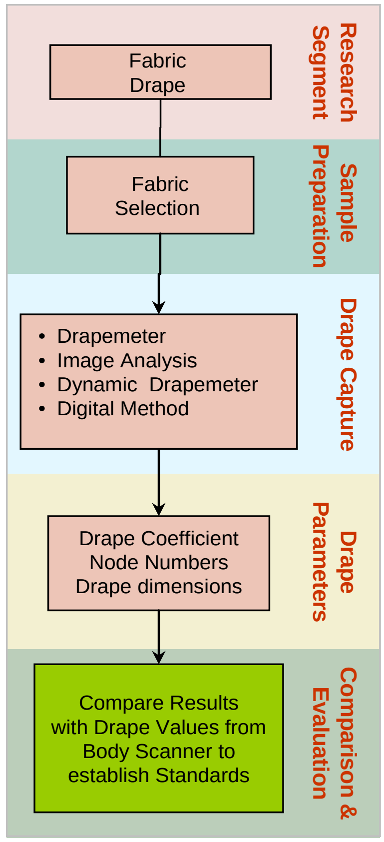

Figure 1: Flowchart of fabric drape analysis

For decades, Drape Coefficient was the most widely used parameter for evaluating drape. Stylios & Wan (1999) point out the possibility of identical Drape Coefficients being associated with entirely different fabrics. It was demonstrated in May-Plumlee, Eischen, Kenkare & Pandurangan (2003) that the additional parameters of node number and node dimensions were capable of discriminating the drape to a greater extent than Drape Coefficient alone.

One more important result obtained during the development of this framework was an understanding of drape variability in fabrics. The anisotropic nature of fabrics contributes to variation in properties such as bending and weight, which in turn influence draped configuration. So, when a fabric is draped repeatedly, it drapes slightly different each time. Documenting variability of fabric drape provided insight into the behavior of a particular fabric and provided the range of values used for assessing simulation accuracy, as discussed in segment four.

2.2 Segment two: Fabric Drape-3D Body Scanner

Generation of a Drape Coefficient attempts to characterize the 3D phenomenon of drape using a 2D measurement. Even with the addition of node characteristics, an incomplete picture of fabric drape is obtained. Three dimensional measurement of fabric drape overcomes the limitations of two dimensional measurement by capturing and characterizing drape of a three dimensional image of draped fabric.

In building this framework, a white light based three dimensional body scanner was used to capture images of draped fabrics (Figure 2) for evaluation of fabric drape. 3D scanners capture information about objects in three dimensions using white lights, lasers or low frequency radio waves [for more information see Istook and Hwang (2001) and Hwang (2004)]. Any scanner available in the market could be used for scanning draped fabric provided the image data is in 3D form and the file is in a format such as VRML that can be read by processing software. The body scanner takes around 10 seconds to capture data in a proprietary file format that can then be converted into 'VRML' and read by 'point cloud processing' software (in this case, *Raindrop-Geomagic*™).

To capture fabric drape using a 3D body scanner, a fixture was built to mimic the mounting disc on a traditional Cusick Drapemeter. The fixture held the circular specimen and allowed it to drape as in the Cusick Drapemeter. A fabric sample of 36 cm in diameter was used to capture fabric drape values using both the Cusik Drapemeter and the 3D body scanner. The reason for maintaining the same dimensions in both methods was to compare and verify the compatibility of the drape values from the body scanner with the drape values from the conventional method.

The raw point cloud data captured in the body scanner was processed using `point cloud editing' software to generate a 3D model of the draped specimen. Then the 3D model was used to capture Drape Coefficient, Number of Nodes and Node Dimensions (For more information refer to May-Plumlee et al., 2003). These values not only provide a detailed traditional representation of fabric drape, the model can also be used to visually compare drape of different fabrics in three dimensions.

2.3 Segment three: Garment Drape-Body Scanner

After establishing the framework for evaluating drape for circular fabric samples, the approach was extended to garments (Figure 2). A flared skirt that fit on the waist line and draped over the body with minimal contact was selected for examining garment drape. The skirt provided sufficient space for the garment to deform in its own characteristic manner depending on the fabric with which it was made.

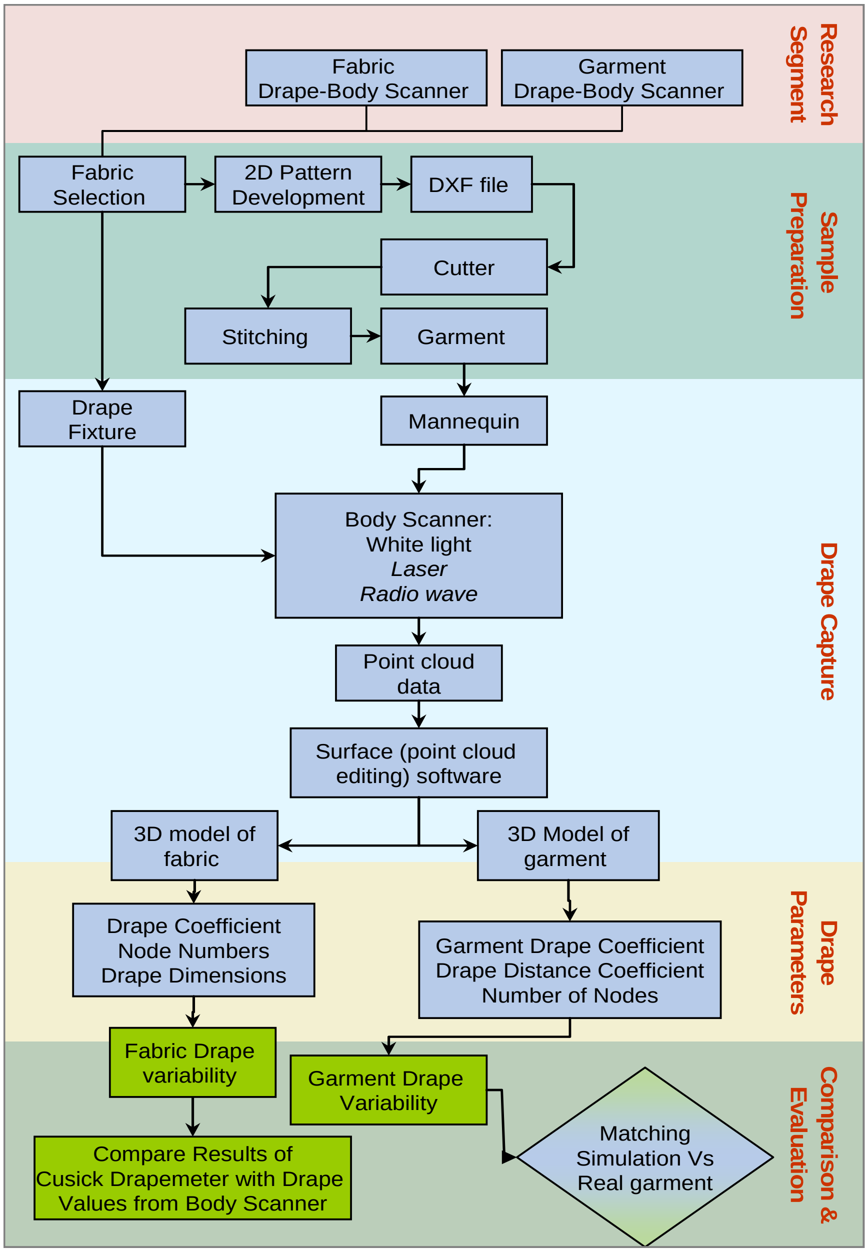

Figure 2: Framework for fabric and garment drape analysis using a 3D body scanner

Two specific skirt styles were developed for investigation. Skirt patterns were developed on a 2D CAD package and transferred to the *Gerber*™ cutter for precise cutting of the garment pieces. Each skirt was stitched, fitted on a mannequin and placed in the 3D body scanner. The captured point cloud images were processed to develop 3D polygonal models. These models of draped skirts were used in creating virtual 3D representations of physical products (skirts in this case). As there were no standard parameters used in the industry to evaluate three dimensional garment drape, developing garment drape parameters was an important step towards objective evaluation of garment drape and framework development. Garment Drape Coefficient (GDC), Number of Nodes (NoN) and Drape Distance Coefficient (DDC) were defined as parameters for garment drape evaluation (more information on deriving these parameters is found in Kenkare, 2005). In this work, these parameters were used to objectively evaluate garment drape and compare simulated garment drape with actual draped skirts. These parameters are the first of their kind and are likely to impact future 3D research in the area of garment drape.

Studying variability of garment drape provided insight into the behavior of a particular garment for repeated drape values and provided the target range for simulation, as discussed in segment five. In evaluating drape simulation, it is important to accommodate the variability in garments for repeated drape by draping each garment three times and tabulating the garment drape parameters. Use of three readings to calculate garment drape values were similar to the number of readings used in fabric drape measurement (for the face side of the fabric). Finding that the garments had a certain configuration memory making them fall in a very specific range each time they were draped provided confidence in a target range of simulation values.

2.4 Segment four: Fabric Drape-Simulation

Simulation is the process of imitating actual phenomenon (in this case cloth drape) with a set of mathematical formulas. In practice, cloth simulation is very challenging because cloth drape is subject to an infinite number of influences. One important aspect of developing a useful framework is to determine the most important factors influencing fabric drape. Figure 3 (grey area in the figure), lists the factors influencing fabric drape including both fabric characteristics and other factors. Further, fabric characteristics are classified into parameters measurable by KESF, parameters measurable by FAST, yarn parameters and fabric parameters. Other factors include wind factor, atmospheric condition and the placement of cloth for simulation. From previous research, and statistical analysis of KESF and FAST parameters and fabric Drape Coefficient, it is known that bending, shear, friction, and weight are the primary factors influencing drape.

A cloth simulation system is used to reproduce virtually the mechanical behavior of cloth. The cloth object exists only in computer memory and must be modeled with a given accuracy through ‘geometric representation’. Further, geometric representation of the cloth requires implementation of any one of several available simulation schemes, or ‘numerical integration’ set-ups for computing the evolving simulation of the cloth.

For virtual assessment of fabric drape, an avatar (cylinder in this case) with dimensions similar to the Cusick Drapemeter `disc' was constructed. Then, a circular virtual fabric sample with associated technical characteristics such as type of fabric and physical and mechanical properties was mounted close to the top of the cylinder to simulate drape using a commercially available apparel simulation package. The material properties were captured by testing the fabric on KESF instruments and translated to simulation input parameters using a relationship curve built through a series of simulation experiments. The user interface options allow simulation parameter values to be input, and a built-in simulation engine renders the pattern pieces to give a realistic output. Like the scanned fabrics, the simulated drapes were processed on `point cloud editing' software to capture the drape values (Drape Coefficient, Node number, and Node dimensions). The fabric drape simulation provides a foundation for garment simulation in the framework.

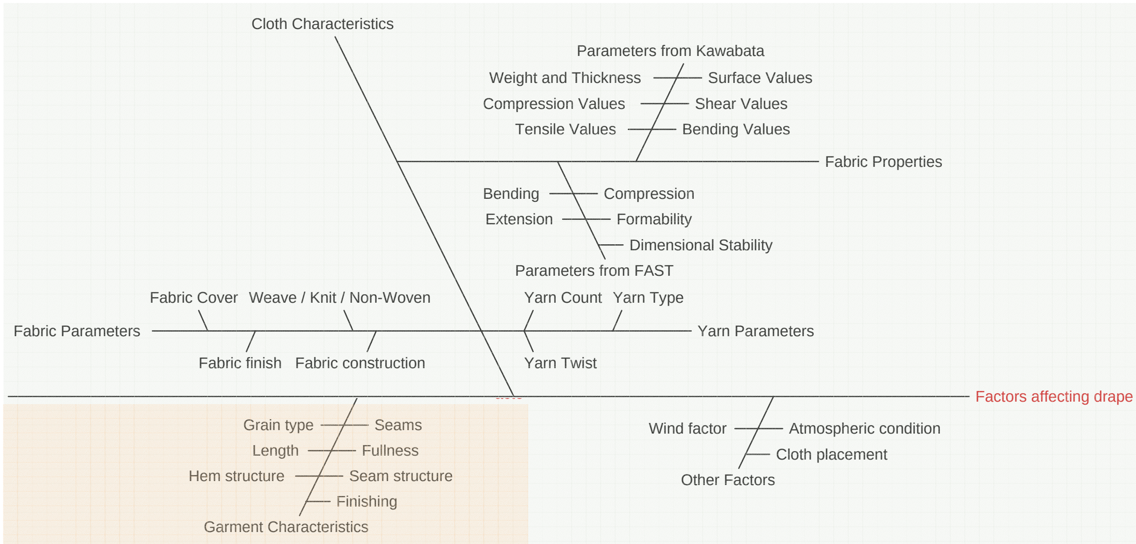

Figure 3: Factors influencing fabric drape (grey area in the figure) and garment drape simulation (whole figure).

2.5 Segment five: Garment Drape – Simulation

Figure 3 identifies a few of the factors influencing drape of garments. Garment drape is affected by factors such as grain orientation, garment length, seams, garment fullness, hem structure, seam structure, and garment finishing in addition to the factors explained earlier for fabric drape. In addition to these factors, successful garment drape simulation requires understanding of the instruments to capture, parameters to evaluate and compare, methods to process and tools used in drape simulation. One of the main contributions of this framework is to demonstrate the complex nature of garment drape simulation in an easy to understand flow diagram. Figure 4, shows the framework for a complete analysis of drape simulation of fabrics and garments in the virtual environment.

To simulate garments, an avatar (virtual mannequin) with necessary measurements was built by converting the mannequin used to drape actual skirts in the body scanner into a virtual three dimensional mannequin. This step is essential to maintain uniformity in actual and virtual garment drape readings. Then, a garment pattern can associated with a virtual fabric, the garment ``parts" can be stitched with virtual seams then aligned around the avatar, and the garment rendered with a built-in simulation engine. To capture garment drape parameters the simulation was processed using the `point cloud editing' software. The captured garment drape values (Garment Drape Coefficient, Number of Nodes, and Drape Distance Coefficient) from the simulation were compared with the actual garment drape values. A relationship curve was built to provide compatible input to the garment drape simulation using KESF test results useful for generating additional simulations.

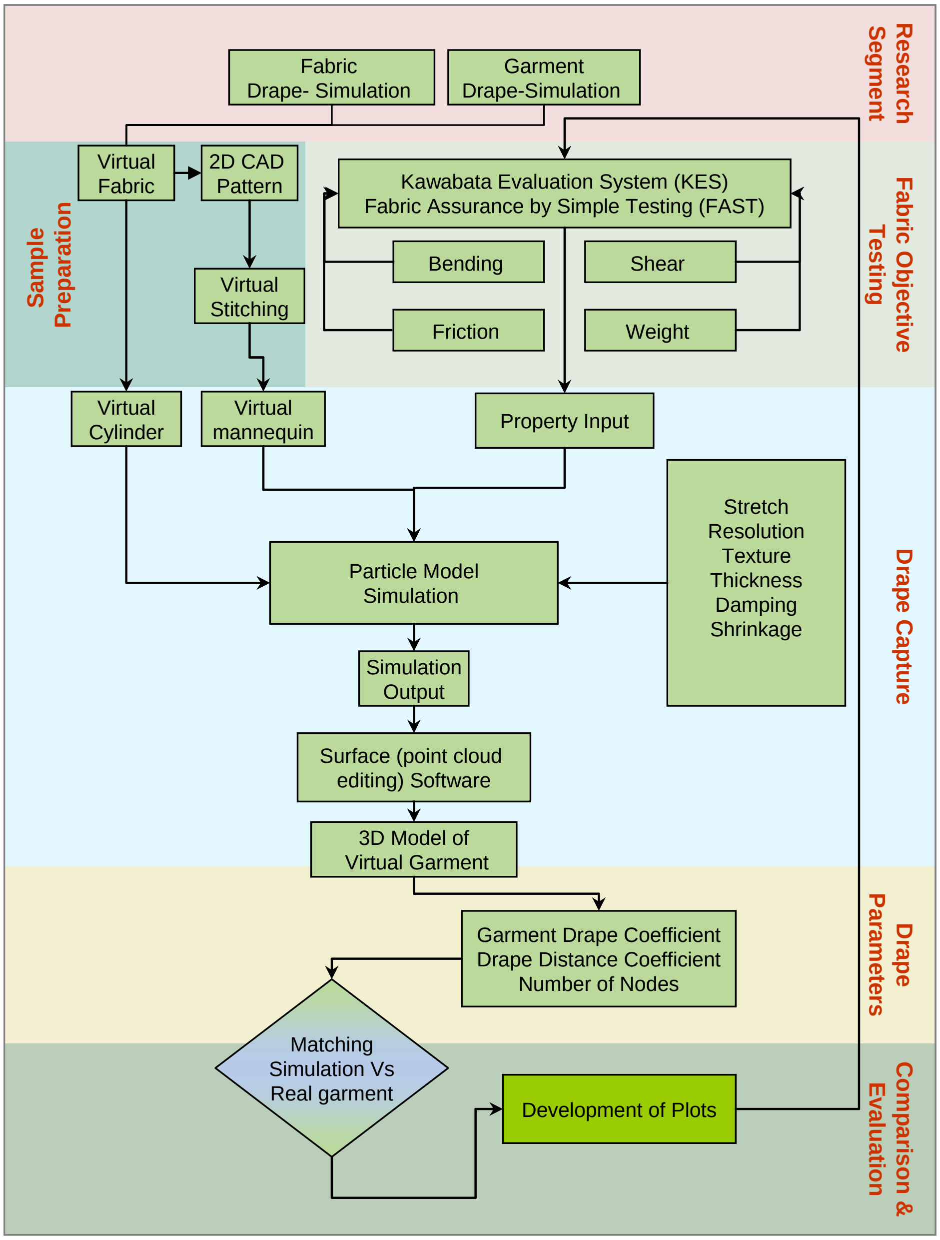

Figure 4: Framework for virtual simulation of fabrics and garments.

3. APPLICABILITY OF THE FRAMEWORK TO BUSINESS DECISIONS

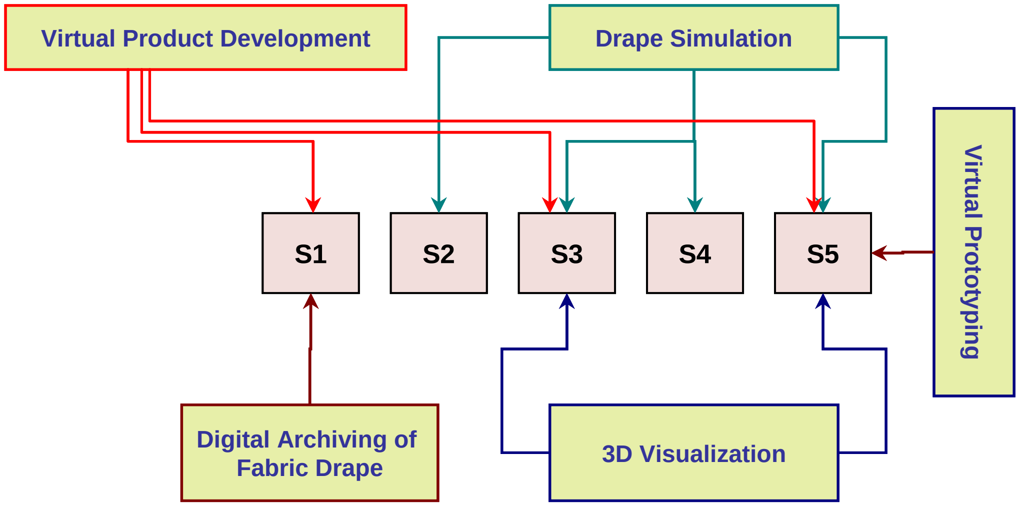

Figure 5: Framework of Drape in Three Dimensional Virtual Environment to guide decision making process for a specific application.

Figure 5 shows the applicability of the framework in making business decisions related to virtual product development, drape simulation, digital archiving of fabric drape and 3D visualization and virtual prototyping. In the figure, S1 to S5 represent the segments of the framework. The connections between segments and specific applications demonstrate the process involved in making decisions. As an example, the applicability of the framework in virtual prototyping is demonstrated in the following paragraphs.

An important contribution of this framework is that it provides a complete overview of how to simulate garments for a specific fabric. The user who wants to visualize a garment constructed in a particular fabric needs to obtain the KESF results for bending, shear, friction, and weight. The results can be transformed into simulation input values using relationship plots. With the help of appropriate input values to the simulation from relationship plots, a three dimensional garment drape can be simulated effectively in a virtual environment. This will provide the user accurate visualization of garment drape from a specific fabric, before garment construction.

When considering other garment types, the relationship plots provide a limited understanding of their drape. The user could decide either to use the relationship plot for limited understanding of the simulated garment drape or to follow the steps shown in segment five of the framework to determine a different set of relationship plots for the required garment type.

In a conventional setup, the prototyping process consumes time, material, money and labor, making it one of the key elements in the development process. By adopting a cloth modeling tool and following the developed framework for analyzing the results, companies could develop samples virtually in different color ways and texture map them before constructing a final sample.

Figure 6: (a) Simulation with default input properties (b) Simulation with accurate input properties (c-d) Simulation with textured mapped designs

Figure 6 shows how accurate 3D visualization could be used to assist in product development decisions. As illustrated, the default simulation of the skirt (6a) lacks the authentic look of a draped skirt. Figure 6b, is the output of the simulation with the input values derived using the framework. This, along with the texture mapping of various designs and patterns (Figure c and d), will provide a 360 degree visualization of a garment and also provide quantifiable values that help in decision making.

4. CONCLUSIONS

The goal of this paper was to develop a framework for analysis of three dimensional virtual drape and to provide a route map for capturing, evaluating and characterizing drape in a virtual environment. The results from this research could potentially be used in computer graphics as well as in the textile and apparel industries. The research would benefit the apparel industry in simulating, quantifying and comparing drape of apparel virtually, and could eventually lead to improved products, higher product success rates; reduced quantities of incorrect product produced and enhanced business processes. In computer graphics, the results could be used in comparing simulation output and in devising a comparative standard for an acceptable simulation.

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