From 3D Scans to Haptic Models: Apparel Design with Half Scale Dress Forms

Susan P. ASHDOWN*[1], Arzu VURUSKAN[2]
[1] Dept. of FSAD, Cornell University, Ithaca NY, USA;
[2] Izmir University of Economics, Izmir, Turkey

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Abstract

Any design process requires prototype development to test properties and perfect proportional or functional relationships before committing to production. Prototypes are also used to communicate concepts or solutions using limited materials and at an affordable cost. Architects have communicated their ideas using scaled models beginning as far back as medieval times. These models demonstrate their design ideas and help address functional issues in 3D. Scaled down dress forms used in fashion design are a more recent concept. One of the first uses of 3D body scanning for apparel in the early 2000s was to make dress forms based on body scans. In 2007, in a collaborative effort between Cornell University and Alvanon, a half scale form from body scan data was developed for educational use. This form is an exact reduction of a full scale form made from a body scan, and allows students to develop their designs with limited fabric, time commitment, and studio space. Students digitize the patterns they develop into a patternmaking CAD program and then scale them up to full scale. These forms have been used very effectively in product development and patternmaking classes at Cornell, and are now popular in schools around the world.

Further uses of half scale forms are being investigated for apparel research, creative pattern making, and pattern development for different body types. Half scale forms can be made in-house from body scans easily and economically. By using 3D body scan technology and transferring 3D digital data to sliced foam models or 3D printed models, custom half scale forms are developed. These forms have the potential to benefit both academia and industry.

Keywords: half scale dress forms, 3D body scanning, apparel design, education, creativity

1. Introduction

Whether an object created by a designer is a building, a cell phone, a mouse trap, or an article of clothing, the design process is the same. Architects, engineers, product designers and apparel designers all go through similar steps in creating their particular product. Many different descriptions of the creative design process are available in the literature; for example Aspelund (2014) in his introduction to design defines the seven stages of the process as inspiration, identification, conceptualization, exploration/refinement, definition/modeling, communication, and production [1]. However, this linear list does not characterize the process well. A critical aspect of the design process is its iterative nature. Repeated iterations foster the development of a variety of ideas, experimentation with different combinations, exploration of material properties, and refining of proportions and functionality. According to Leiberman (1977) the process of combining and re-combining knowledge into different groupings, "the way a kaleidoscope shifts objects" is important to creative development [2]. Kelley and Kelley (2013) describe this as a process of exploration, engaging in many 'experiential learning loops' to 'adapt, iterate, and pivot our way to human-centered, compelling, workable solutions' [3]. Christian Lacroix characterized the design process as a "complex alchemy of rich oppositions," in which one creates by "combining things that are normally contrasted" [4]. Each iteration keeps some aspect of the last one, adding and morphing until the final form is perfected. LaBat and Sokolowski (1999) characterize the apparel design process and creativity, defining the important stage of iterative creative exploration and ideation which should occur after problem identification [5]. There are many methods of creating iterative prototypes in the design development process, both virtual and physical, and both 2D and 3D. The use of half scale dress forms in academia for creative patternmaking, development of final patterns, and research is fairly recent, and dependent on the ability to create correct body forms from 3D body scans. In this paper we explore both the history of prototyping and the use of scaled models in many design fields, and the development and use of modern half scaled forms in apparel design.

* spa4@cornell.edu; 001- 607-255-1929; http://www.bodyscan.human.cornell.edu

2. Prototyping for apparel design in academia and the industry

The apparel industry has historically used sketching as a way of testing and refining multiple iterations of a design. The method is rapid and can be used to experiment with the proportional relationship of the garment to the body in two dimensions, as well as making some initial explorations of scale, line, texture, and surface design. The sketch is often used to convey the creative concept behind the garment, or the unique artistic focus of the company, rather than an accurate representation of the final garment. Also, the full dimensionality of the piece cannot be expressed in a sketch, although front and back views are common. Even the proportions of an apparel illustration are generally only an approximation. The almost universal graphic convention that has developed for apparel sketching that utilizes elongated body proportions that are freed from the constraints of the actual proportions of the majority of the population can limit its usefulness in creating the final product [6]. Although designers are adept at sketching proportional relationships to this elongated body that can then be reproduced to some extent on a normally proportioned body, this process does not model the direct relationship between the garment and the body.

Aspelund in his discussion of three-dimensional thinking as it is contrasted to 2D work characterizes 3D as introducing structure, gravity, and motion. He also speaks of spatial differences in perception that occur in the shift from 2D to 3D, and the fact that the move to 3D also brings the reality of the inside-to-outside of the product to the fore. In the case of apparel the structural supports inside the garment and the outside aesthetics are related but distinct. And finally Aspelund introduces the 4th dimension of time, and movement through space as concepts related to the 3D object and not as easily accessible in a 2D sketch [1].

According to fashion designer Galliano "The most exciting discoveries, the marvelous moments aren't with the sketchbook, but in the making" [7]. Many creative apparel designers from Charles James to John Galliano have worked extensively in 3D. The introduction of material properties in direct relationship to the 3D body expands both the creative possibilities and the complexities of the design.

Tools for virtual prototyping in 3D are also under development for the apparel designer. To date these virtual programs are used to replace some of the iterations needed to test garment design and fit. These tools can represent the relationship of the 2D pattern shapes to the body in three dimensions, along with some very basic representations of fabric properties and reactions of the fabric to gravity [8]. However in their present stage of development the virtual representation is not very highly refined and is best suited to gross refinements in fit, motif placement on the body, and some experimentation with garment proportions.

Prototype development for apparel in 3D is done in different ways in academia and in the industry, largely due to cost and time issues. In academia students are taught both draping (creating pattern shapes in 3D on a dress form with muslin) and flat pattern design (either drafting a pattern from measurements or manipulating basic pattern shapes to modify the design). The patterns developed using these methods are then typically made in muslin and fitted on a live fit model to adjust fit, silhouette, and proportions. When necessary, additional muslins are made and fitted to perfect the fit of the garment before the pattern is finalized. All of these methods are time consuming, and require ample studio space for dress forms and large tables for drafting patterns and cutting materials. The actual fabric to be used for the design is introduced late in the process, as fabric must be purchased retail and is generally too expensive for use in prototype development.

In the industry, the technique of draping in 3D for pattern development is rarely used. Often new patterns are created from flat patterns of garments that were successful from a previous season, or from base patterns developed to represent the target market of the company. Once patterns are developed they are immediately made up in the fabric intended for the design, and fitted to a fit model or dress form. More iterations of the garment are made from the fabric and fitted as needed to perfect the fit. The fabric used for industry designs is purchased wholesale in large volumes, so the amount used for prototype development is less significant. Companies either have a sample shop, with employees dedicated to creating fitting prototypes, or the work is sourced to the factory that will produce the final garment [9].

Both academia and the industry would benefit from more effective ways of creating and testing 3D apparel prototypes in a timely and cost effective manner. In academia, students who are able to develop their designs iteratively can learn their craft more quickly, experiencing a greater variety of garment shapes and learning more about the relationships among body shapes, pattern shapes and fabric properties. They can also experience the creative power of iterative 3D prototypes, in which they can investigate and create all the way around the body. As Kelley and Kelley describe the process, design thinking relies on feeling, intuition, and inspiration, but these qualities require the pairing of empathy and prototyping in order to 'dive into the problem and find new insights'. Their design process makes use of 'iterative rounds of rapid prototypes – early rough representations of ideas'. They warn against becoming too invested in a single solution too early in the process, which can occur if students put too much effort into any one prototype [3].

In industry, designers work within very tight deadlines imposed by the need to rapidly produce garments, and are often reduced to making modifications to styles that have succeeded in previous seasons. Raymond Loewy, a prolific industrial and graphic designer of the 20th century describes the dangers of this type of design cycle and how it can be effectively addressed as follows:

> "Style for the sake of style alone will have less meaning to the consumer than value. An interruption of the spiral created by boosting sales from year to year with false inducements of style, bulk, and flash gives design a new lease on life."
>
> Raymond Loewy, https://www.raymondloewy.com/about/quotes

Finding a tool that would make it possible (without introducing higher costs) to interrupt this spiral of garment design that incorporates small changes season to season, and lacks creative energy, can benefit the industry by helping to infuse the full design process back into the work of the industry designer.

3. Modeling for design

3.1. Models in architecture

Scaled models have been used in the design of buildings from as early as the middle ages. Although the exact purpose of earlier architectural models is not known, by the 15th century Leon Battista described the model both as a tool in the design process (allowing the architect to continually modify the design), as a tool to solicit feedback, and as a tool to estimate the materials and cost of the building [10]. Architectural models were not commonly used in education until the 20th century. Before this time drawings were considered to be more appropriate expressions of the architect's 'art' as it was then easier to classify the architect along with artists, on a higher plane than the model builder, or the carpenter and masons who actually built the resulting structures. 'Craft' and 'art' were considered separate and unequal [10]. In modern architecture schools, the physical model is again giving way in some programs to the digital model with virtual walkthroughs. Electronic entries are more convenient for competitions, and for storage and archiving of projects, as physical models are difficult to store. However, the model is still used to express complex structures in 3D space. Building of architectural models is made more accessible today by the use of laser cutting, removing some of the craft skills initially needed in model building.

Of course the scale of architectural models is the essence of its usefulness. A scaled model allows the building to be visualized in 3D at very little cost, with limited time and effort [10]. The model allows the project to be comprehended as a whole structure, and can express the full idea or concept as a real, solid object that can be viewed, rotated, peered into, and stepped back from in a unique way [11]. The model can be much more accessible to the lay person than even the most sophisticated digital walkthrough.

3.2. Models in other design fields

Scaled models are also used in other areas of design. The clay model in automobile design is a good example of this process. Hand sculpted scaled models are created early in the design process, eventually moving to a full scale version of half the car in clay. Once this half model is refined, it can be scanned and the other half can be milled for a perfect symmetrical model. Again, the purpose is to create many iterations in the development phase. The final version in malleable and inexpensive clay can continue to be modified, and when the other half is milled the car can be tested in a wind tunnel.

Model making of full sized consumer products is a key part of the development of all types of products sold on the market. Hallgrimsson discusses the various types of models made as prototypes for testing, or to persuade an investor of the value of a product. He distinguishes the early stage of model building as 'prototyping', in which the key idea is to reduce cost and time of each iteration in order to experiment with more versions, sometimes even using found objects, and the later stages of model making in which the goal is to test a more finished object, still produced in cheaper or more malleable materials but made to convey the look or capture the function of the final product. Many different materials are used for making models for consumer products including paper, cardboard, foams, thermoplastic materials, Polyurethane foam board, wood, and clay. When a negative mold can be made easily and inexpensively, various casting materials are used as well [12].

4. Half scale body forms in the apparel industry

As apparel's primary function is to clothe the body, the complex, organic, highly variable body form is a necessary template for apparel design. The half scale body form has the potential to bridge the gap between rough sketching and final pattern refinement; to allow multiple iterations in the development of the patterns. It must be kept in mind that whatever tools are developed for apparel designers, fitting on live fit models who can demonstrate the actual fit of the garment on a real body and give their kinesthetic response to the comfort and balance of the garment in motion is an essential part of the process. However, reducing the number of these fit sessions and the expense of multiple prototypes at this late point in the process can both reduce the product development time and expense.

4.1. Traditional half scale dress forms

Academic programs in apparel use half scale dress forms in two ways: to teach flat patternmaking and to create the early, fast prototypes described by Hallgrimsson [12]. The designer Madeline Vionnet is credited with the first use of a scaled form in the 1930s. She adopted an 80cm artist's articulated human form to drape scaled models as a first step in creating her designs. She then used the knowledge gained in this process to create the actual pattern shape on a full scale dress form [13]. The half scale form was an essential tool in the development of her innovative bias cut gowns, but it was not an accurate representation of the human body, and only made possible a rough approximation of the shape of the final pattern.

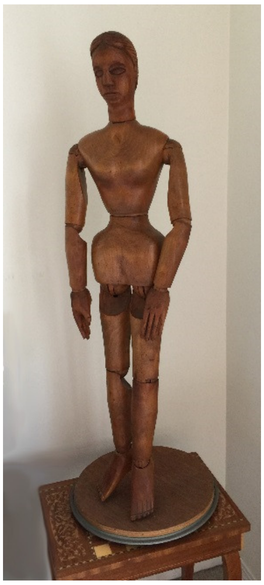

Fig.1 Wooden artist's model used by Madeline Vionnet. Image: Anne Bissonnette

It is not known when half scale dress forms became common in academic apparel programs, but they were often seen in classrooms by the 1930s. In the United States, the most popular dress form used in apparel classes was manufactured by Wolf forms. These forms, like the majority of full sized forms of the time, were not body shapes, but rather the shape of the clothing, with a gradual slope under the bust, a flat plane over the buttocks, and a simplified cylindrical waist and upper hip shape. The only dress forms that were shaped like the body were lingerie forms. Although these less organic forms could be used for initial explorations of pattern shapes, they did not relate directly to fit model's bodies, or even, in most cases, to the full scale dress forms of this time period.

Fig. 2. Cornell University apparel design students using half scale forms, 1950; Standard Wolf half scale forms

4.2. Development and use of modern half scale dress forms from body scans

The first modern half scale forms for apparel were developed in 2007, in a collaborative project between Cornell University and Alvanon, a manufacturer of dress forms and consultant to the apparel industry. These forms were created from body scan data of current consumers in various demographics used by Alvanon in developing their full size dress forms. They are therefore accurately shaped like the human body. Unlike earlier forms they are designed with legs instead of in a skirt form, and can be used to create patterns for anything from swimwear to outerwear.

Fig.3. Cornell University apparel design students using half scale forms, 2014; Alvanon half scale form developed from a body scan

These Alvanon forms were developed for use in a product development class, for which there was limited studio space. The forms allowed the students to create patterns and half scale models in the appropriate fabrics for a full line of garments in a limited amount of time, using less materials and space than would be required for more traditional projects in full scale. Because the form is the shape of the body, students in the product development class can work with a variety of apparel categories in their line development project; activewear, lingerie, as well as eveningwear, daywear, and outerwear. Students have created everything from swimwear to winter coat lines in this class. A second set of male forms were also purchased so students can design menswear lines.

Once the patterns for the line have been developed, students can then digitize patterns for one of the outfits, scale it up to full scale, and assemble it to be displayed on the full scale dress form, with perfect fit as both dress forms are developed from the same scan. The use of the half scale forms for the majority of their line makes it possible for the students to address every aspect of the development of a full line of 6 to 10 garments, from pattern development for each item, to the design of logos and hang tags, to a full set of tech packs including flats and construction details, all within the time frame of a single semester. Without the half scale forms, the full semester would be dedicated to cutting and constructing the set of garments. Making one garment in full scale is generally enough to address most construction issues. The half scale models for the rest of the line are also made in the final fabric, but generally the edges are not finished and some areas that would be difficult to sew in the smaller scale, such as set-in sleeves, are pinned or basted only. These Alvanon half scale forms have been subsequently introduced into other classes, and are used for a creative draping project and, for pattern manipulation exercises in both a beginning and advanced flat pattern class.

4.3. Development and use of custom half scale dress forms from body scans

4.3.1. Classroom projects

We began to develop half scale dress forms from scans generated in our own body scanner in the spring of 2013. A team of students in a class wanted to develop a line of garments for a plus size target market. The dress forms available for use for plus sized garments are generally very unrealistic. These forms ignore the body shape of a larger woman, and merely increase the size of the forms made for smaller women to match the hip, waist, and bust measurements for plus size. For this first half scale form we used a scan of a plus size woman that we had created in our Vitus XL Human Solutions scanner. A water-tight triangle mesh model was created using the automatic merging and patching function in ScanWorX. The file was then exported as a binary STL file to Geomagic, and trimmed at the neck, upper arm, and thigh.

Nobody is completely bilaterally symmetrical, but most clothing is developed symmetrically in order to reduce patternmaking time, to simplify cutting and construction, and to develop clothing that does not emphasize body asymmetries. The model was therefore divided on the sagittal plane, separating the left and right sides of the scan. Two choices were then tested, first making a copy of the right side, flipping it, and joining it to the original for a symmetrical model. This process was repeated with the left side. Then each side was measured. Comparing the measurements of these two models, it was determined that the model made from the left side was a better representation dimensionally to the original scan.

The model was then scaled down to half scale, and three ¼" (64mm) holes were created vertically through the model, one at the central axis, and one on each side from the middle of the shoulder through the middle of the leg. The model was then divided into ½" (127mm) cross sections. These cross sections were imported into Illustrator, and cut from ½" open celled foam on a laser cutter. The holes through each slice were used to maintain the correct relationship of the slices to one another in the x-y direction (if z is through the central axis), by threading the foam slices onto dowels.

The dress form was then covered in a knit fabric, and style lines were added at the neck, armscye, under bust, and waist. This form was very popular, and was eventually used by the students to develop several plus size lines. Several other forms were subsequently made for students for individual projects using this method.

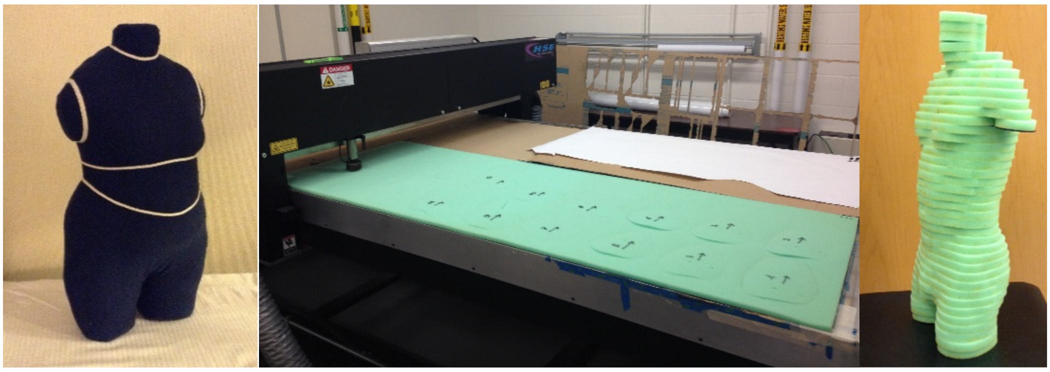

Fig. 4. The initial plus size half scale form made from a body scan; slices being cut on the laser cutter; a male form showing the slices stacked on dowels before covering with a knit fabric .

In 2015, a full set of half scale forms were developed from a body scan for a patternmaking class, with the goal of introducing the students to an ideal body shape from a different era, and to explore patternmaking techniques from this time period. These forms were made from a scan of a slender student with a long torso, who exemplified the 'boyish' figure of the late teens and early 1920s. Because the forms are made of a compressible open celled foam, the bust area of the form could be flattened with a bandeau, a form of body shaper from the period. Another student took advantage of this property of the forms, when she developed period corset shapes using small steel corset bones. These corsets compress the body and create the new body shape.

Fig. 5. Projects on historical silhouettes with the 20s form with a bandeau in the background; 1901 half scale corset.

4.3.2. Extracurricular projects – Cornell Fashion Collective

In 2016 we offered to create half scale 'kits' for freshman who brought in their model for the annual fashion show to be scanned (freshmen can show one garment in the show). We ended up processing files for seven custom torso forms for the students. We prepared the files and cut the foam, but the students assembled the numbered slices on the dowels and covered the forms. At this stage we had introduced some improvements to the design of the forms. As the shoulders are so important to the fit of the garment, and as the foam slice method results in an uneven 'stepped' line at the shoulder (see Figure 4), we added a stiff felt yoke around the neck and over the shoulder. We also added layered tagboard 'caps' at the neck, armscyes, and neck that hold the knit cover in tension and finish off these areas very effectively.

Once students made their forms, they added style lines, and draped their patterns. As these students were not yet trained in CAD the teaching assistant helped them digitize, scale, and true their patterns. They then fitted these patterns, and went ahead to create their designs from the fitted patterns. This was ultimately a highly successful project, resulting in very good fit of the designs even though the freshman designers lacked experience in patternmaking and fitting.

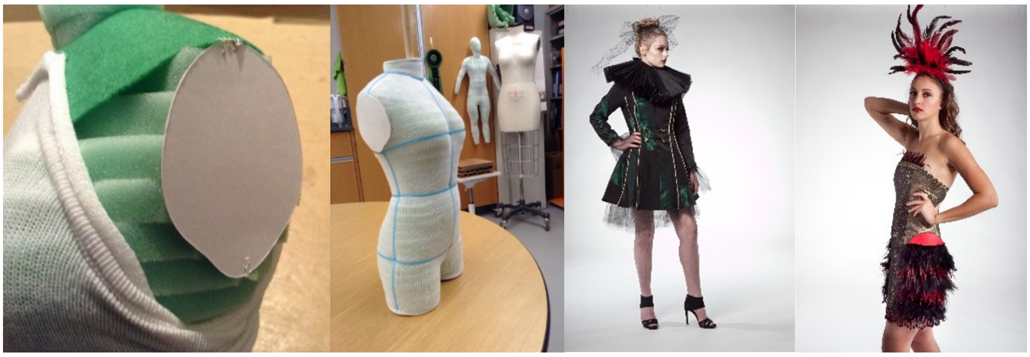

Fig. 6. Felt collar at neck and tagboard cap at armscye; a finished form; designs developed on half scale forms by freshmen designers Stephanie Laginestra and Jillian R. Lawler (Photographs of student designs by Shai Eynav)

4.3.3. Extracurricular projects – styleengineers.org

Another type of form was developed for a project in which we created activities designed to interest middle school girls in science, technology, engineering and mathematics through their interest in fashion. As this program is posted on the internet, and is designed for after school programs and other venues where dress forms are not available, we created patterns and instructions to make a torso form from a body scan of a middle school girl out of cardstock, fabric, and polyester stuffing. Once the final edits are made, these instructions and patterns will be posted on the website for the project, styleengineers.org. Because we wanted the form to be made out of readily available materials, we designed a frame by taking slices on the sagittal and frontal planes, at 45˚ angles to these planes, as well as a horizontal plane at the waist, and created patterns that can be cut from cardboard and slotted together. We then created patterns for the outer 'skin' of the form. These forms can be cut, sewn, and stuffed by the middle school girls themselves, and then used for several of the activities on the website.

Fig. 7. Cardstock frame for the middle school girl form, with finished form in the background; middle school girls using the forms for a Style Engineers activity

4.3.4. Half scale forms for research on for different body types

In the fall of 2015 a technology start-up for blue jeans contacted us to discover if we would do some pattern development to explore novel pattern shapes for two categories of women; plus sized women, and athletic women with well-developed thigh or calf muscles. A team of students in a graduate class took on this challenge, and decided to use custom half scale forms in order to minimize the time and materials used in the project. Two plus sized women and two athletic women were scanned for the project. The plus size forms were made from the waist down to the ankle, using the same stacked foam method described. The students explored other methods of making half scale forms for the athletic women. One scan of an athletic participant was used to create a 3D printed negative mold. A latex form was then made in this mold. This was not a successful attempt as the latex was too unstable to drape patterns easily, and the form was very heavy to handle. The second athletic form was 3D printed in PLA, a hard plastic. Although the 3D printed form had a better surface resolution, the plastic was hard and lacked friction with the fabric being draped, making pattern development difficult. Ultimately the soft, pinable surface of the stacked foam forms was the best material for draping patterns. These forms were also less expensive to manufacture.

Once the forms were constructed, patterns were developed on each half scale form. The patterns were then scaled up and sent to a jeans manufacturer for production. The final garments were fit tested on the original participants who were scanned for the study. Some promising patternmaking techniques for the non-standard bodies were identified in this study.

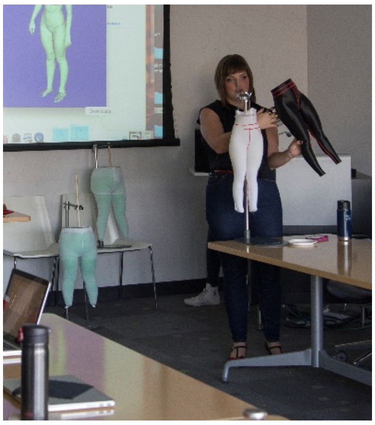

Fig. 8. Student presenting results of the study to the client. The two half scale forms are under the screen; the student is holding the 3D printed form. The latex form is on the stand.

4.3.5. Half scale forms for research in patternmaking for the active body

The custom half scale form is ideal for the development and testing of designs for active body positions. Several studies are underway at the Cornell Body Scan Research Group exploring the issues relating to change in body shapes and dimensions when in active positions, and appropriate methods for patternmaking for these positions.

As part of a study for testing bicycle shorts for the active position, experiments were made with a variety of materials and methods for creating the active half scale forms. Three different materials for 3D printing and various foam materials of differing densities and thicknesses were tested. Use of a parging material to equalize the stepped surfaces of the stacked foam forms was also tested. As the active position sometimes puts limb surfaces almost parallel to the ground, these stepped shapes are more frequently seen in the active forms. Although the 3D printed forms from PLA plastic provided a reliable surface for pressure testing and were easier to dress in the tight, power stretch bike shorts, the stacked foam forms using ½" open cell foam and covered with a knit fabric proved to be the best for developing patterns. On the other hand, when covered with a layer of felt and a custom fitted linen layer, the 3D printed forms were better suited to draping. However, this is a time consuming process, and adds to the already considerable expense of the 3D printed forms.

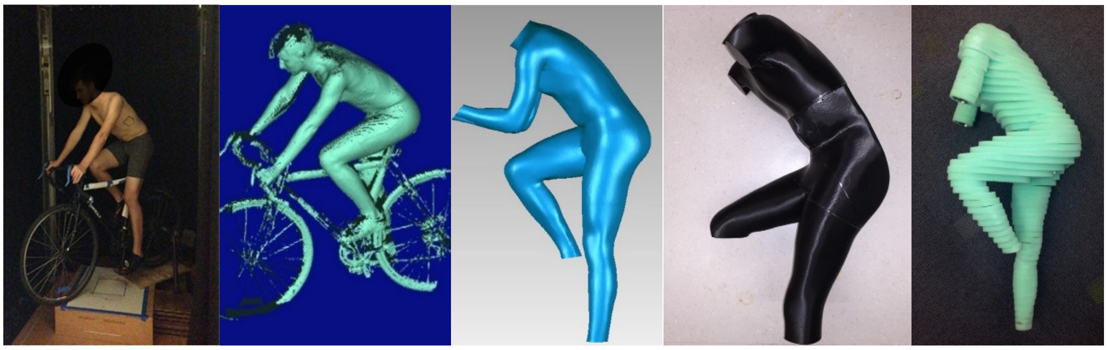

Fig. 9. Active half scale form creation: Scanning participant on bicycle; unprocessed scan; processed scan; 3D printed half scale model; stacked foam 3D model without knit cover.

4.3.6. Half scale forms for custom clothing for individuals

Another area of inquiry that has not been fully developed is the possible use of half scale forms for the creation of custom made clothing. Although it is the common practice of some couture shops to create a personal dress form for their most active clients, this is not a technique that has been used by custom tailors or dressmakers. One pilot test has been conducted, in which a professor created a jacket using only the custom half scale form for a client on her half scale custom dress form, with no intermediate muslin fitting or shell fitting of the garment in the final fabric before finishing. Results are promising, particularly when considering the balance of the jacket, as it is fitted over shoulders that roll forward, a common occurrence as one ages. Plans to continue to test this use of the custom half scale form are underway.

4.4. Benefits and Drawbacks of half scale dress forms

The benefits of working with half scale dress forms were repeatedly seen in the projects discussed here. Time for pattern creation is much less with half scale forms. Only one quarter of the materials are needed in half scale, resulting in reduced costs. Handling the smaller pieces of fabric is significantly easier. It is easier to work with the small forms as they can be picked up, laid on their side, held in the lap, and oriented to give access to whatever part of the figure is being addressed.

Student comments on working with half scale reiterate these benefits. When questioned about working with the forms, students comment on both the economic use of fabric and the ease of making changes. This ease of reworking a pattern is key to the development of creative patterns, as the multiple iterations help the students to test and re-test their concepts until they arrive at the best solution.

Another advantage of the forms is the ease of seeing proportions; as one student said she could 'hold the form and really be able to engage with the proportions while looking at it all at once'. The smaller scale allows the designer to see the proportions related to the body continually while working. When working with a full scale form, the designer would need to repeatedly step back from the work to get the same perspective. The blurring of some details in the half scale form could also be an advantage, allowing the designer/patternmaker to focus on the more impactful overall shape of the figure.

Many students who work with the forms comment negatively on the need for greater precision, though one student said she liked the requisite precision. One student summed up the half scale experience as 'fun, but not as easy as expected. It forced me to work slower and pay attention to details.' Of course these can be seen as effective ways to help students develop the attention to detail and quality appropriate for apparel design.

In the freshman fashion show project the advantage of the reduced time and ability to create quick iterations, along with the ability to work in 3D directly on the form which has the exact (scaled) size, proportions, shape, and posture of their model were very clear. Despite their lack of training, the first 6 out of 7 of the first muslins fit with minor shoulder adjustments. Students were not distracted by fitting alterations, and spent more time looking at the proportions and silhouettes of their muslins, resulting in great improvements in the designs.

Because of the difference in scale, the fabric (which is 'full' scale on a half scale form) does react to gravity differently that it will in full scale. However, these differences have been less problematic than expected. We are accustomed to looking at a muslin prototype and making the adjustments needed to accommodate the drape and movement of the actual fabric. Perhaps the difference in scale can just as easily be accommodated.

A quarter of the space is needed for storage of the forms. The reduced space needed for storage is a definite plus. Students can keep the forms in their lockers, professors can assemble all the projects from a class on a tabletop for grading, and storage of the forms when not in use is much easier. We have generated as many as 40 half scale forms for various projects; an equal number of full sized forms would fill all the research and teaching space available.

Fig. 10. Graphic showing need for only a quarter of the fabric used in full scale work; half scale dress form storage in the studio; half scale forms in the research space

4.5. Future of half scale dress forms

The amount of creative thought designers are able to infuse into the process of creating clothing may be dependent in some ways on the tools they use. The ability to create quick 3D prototypes allows iterative prototyping of patterns perfectly suited to the exact size, shape, proportions and postures of the user of the apparel being developed; this tool has the potential to jump start the creative process in new ways.

The development of effective scanning procedures using inexpensive handheld scanners makes it more possible to easily create half scale dress forms of students and their models, of fit models in industry, of participants in research projects, of home sewers, and of actors for theatrical costuming. This tool can be introduced and used by anyone who creates fitted clothing.

The apparel industry has often been limited by time and cost considerations to modifications of styles from prior seasons, rather than engaging in creative patternmaking. If apparel designers can create in 3D on a half scale dress form of their fit model, perhaps more creative designs can be developed in the same limited time. The overdependence of apparel practitioners on flat pattern manipulation separates them from both the 3D figure and the active manipulation of the fabric in creating designs that optimize interactions among the body size and shape, material properties, and the garment silhouette. Re-introducing the haptic process of draping in an affordable way will ultimately impact the industry favorably overall.

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