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Made-to-Measure

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CLOTHING THAT IS CUSTOM-MADE for a single individual is rare today due to the cost and the time it takes to manually measure, create patterns, and construct garments. The menswear tailor and couture fashion house are exclusive venues that offer high quality, custom clothing to a select few. Even sewing at home has become a leisure activity and creative outlet instead of a way to provide clothing for the family. In fact, it has become more economical to buy ready-to-wear (mass-produced) clothing than to make your own.

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A Historical Look at Custom Fit

CLOTHING THAT IS CUSTOM-MADE for a single individual is rare today due to the cost and the time it takes to manually measure, create patterns, and construct garments. The menswear tailor and couture fashion house are exclusive venues that offer high-quality, custom clothing to a select few. Even sewing at home has become a leisure activity and creative outlet instead of a way to provide clothing for the family. In fact, it has become more economical to buy ready-to-wear (mass-produced) clothing than to make your own.

Until the early 20th century, the majority of clothing was made one garment at a time for individuals. Women provided clothing for their families either by making it themselves or with the assistance of seamstresses. Men of the upper classes went to a tailor for individually fitted garments. Class distinctions were well defined by clothing as the garments made by professional seamstresses and tailors were fitted and styled differently from those made in the home. At the time, the

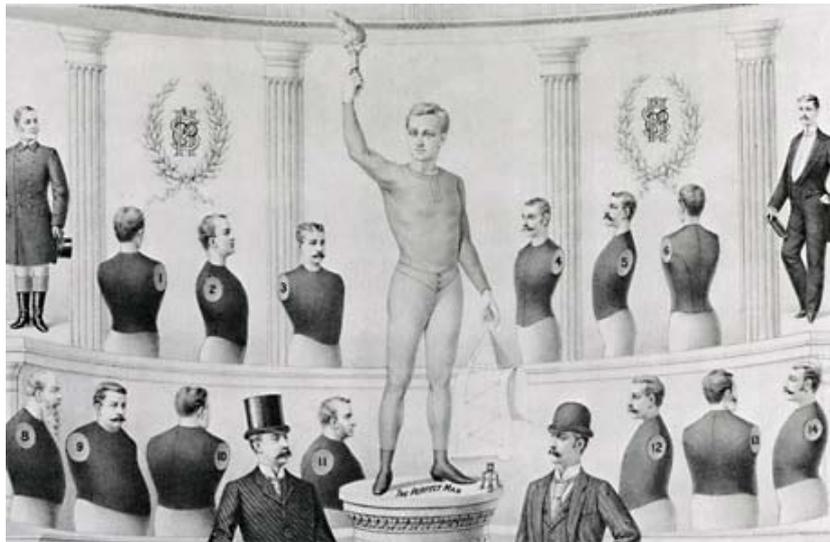


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Before the invention of tape measures, body dimensions were marked on strips of parchment. A tailor would have a parchment record of body dimensions for each client. (Images: parchment -- *Description des Arts et Metiers*, 1769; tailor -- *Encyclopedie Methodique*, 1789)

process of going to a shop to buy pre-made garments was limited to sailors, who purchased roughly constructed garments called slops.

Technological developments, patternmaking insights, and mass production changed how clothing was constructed by the early 1900s. Tailors recognized similarities between the garments they made for individual clients, and began to think in terms of proportionally scaled patterns for people of different sizes, known as "graded" sets of clothing sizes. The invention of power looms lowered the cost of fabrics, while sewing machines and industrialization decreased the overall costs of making clothing.



The identification of various body types occurred as tailors developed an understanding of the variation of body proportions in the population. The torch-bearing figure in the center is labeled "The Perfect Man." (Image: 1890 lithograph, Library of Congress)

By the 1920s most clothing was available as ready-to-wear products sold through catalogs such as Montgomery Ward or in the nascent urban department stores. The modern age of apparel production had begun. Historian Claudia Kidwell describes this evolution from custom-made to ready-to-wear clothing as the "democratization of clothing." Class distinctions based on clothing abated somewhat as relatively inexpensive ready-to-wear clothing, which often fit better than home-made, became readily available for purchase.

Custom Clothing Today

Twenty-first century technologies are defining a new era of customized and mass-customized clothing. Worldwide, apparel firms are experimenting with economical strategies that individualize clothing for each customer by offering a variety of design and fit options. Large and small, Internet as well as bricks-and-mortar companies are now making clothing "just for you."

Levi Strauss & Co. was the first large apparel company to offer mass customization when they introduced "Personal Pair" jeans, later



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Modern ready-to-wear sizing systems have their origins in the various drafting systems developed in the 19th century. (Image: advertisement, early 20th century)



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marketed under the name "Original Spin", in selected Levi's stores. Consumers could customize their jeans by choosing from a selection of styles, fabrics, finishes, colors, leg-opening sizes, and inseam lengths. Individual measurements were taken by a salesperson. Jeans fit was determined by inputting the individual's measurements and style selections into a computer program, and then trying on jeans that are kept in the store for that purpose. Thus, the customer could identify the exact fit that matches their preference. The jeans were individually manufactured and shipped to the customer's home. A record was kept of each customer's selections, so the next pair of jeans could be ordered without the try-on step. This program was discontinued in 2004 when Levi's closed the last of its domestic manufacturing plants.

Using a different strategy, Lands' End offers custom-made shirts, jeans, and chinos on their Web site. Customers type in their measurements, guided by instructions on how to take them properly. Style, fabric, and fit choices are made from a set of options on screen. An automated custom patternmaking process is used to create a pattern specific to each individual, then the garment is made and shipped to the customer's home. Lands' End keeps these measurements on file so customers can reorder.

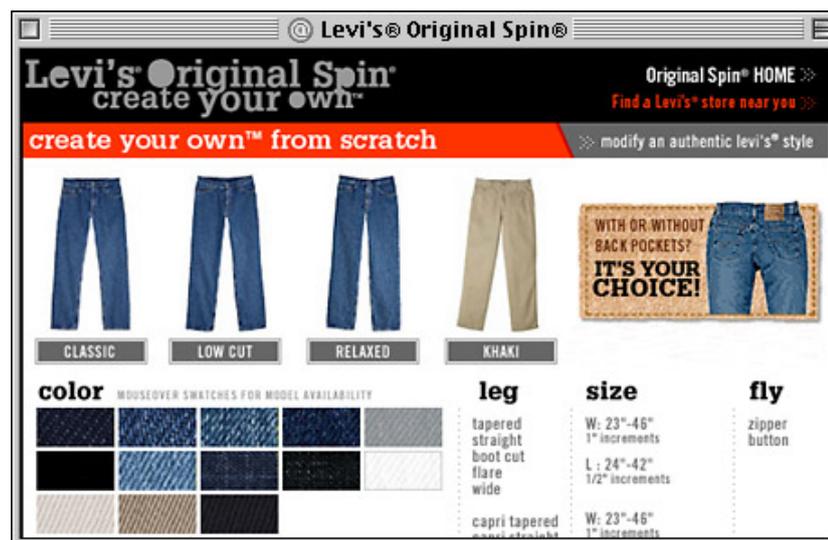
Brooks Brothers uses all of the new technologies, including the body scanner, seamlessly. They offer mass-customized suits at their New York City retail store using a 3D body scanner to collect customer measurements. Style, fabrics, and design features are selected from a computer screen in consultation with a trained sales professional, who facilitates the discussion of fit preferences, such as loose or form-fitted clothing. Brooks Brothers uses a proprietary custom patternmaking system to create an individual pattern based on the body measurements. The garment is manufactured and shipped to the store where a single fitting ensures customer satisfaction. Scan data and patterns for each customer are stored for reorders.

Brooks Brothers combines the newest technologies, including body scanning, with traditional knowledge from decades of tailoring experience to create affordable custom made clothing. (Image: Brooks Brothers)



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These custom-made blue jeans from IC3D were quick and easy to order, they fit well, and they have the desired style, fabric, and number of pockets -- all at a cost comparable to that of quality ready-to-wear jeans. (Image: Cornell Body Scan Research Group)



Customers are involved in the design process with Levi's Original Spin jeans, choosing from a selection of styles, fabrics, finishes, colors, leg-opening sizes, and inseam lengths. The jeans are custom-made for each customer's specific measurements and fit requirements. (Image: ©LS&CO)

Many smaller Internet-based companies offer a variety of custom

design and size choices for clothing products ranging from bridesmaid dresses to fleece jackets. Suppliers of military, school, and industrial uniforms are also offering style and size customizations. A tour of the Web will find companies offering mass-customized clothing such as IC3D (Interactive Custom Clothes Company Designs), American Fit, and BeyondFleece. Technology-enhanced made-to-measure (i.e., mass-customized) clothing is now affordable and easy to acquire from companies of all sizes.

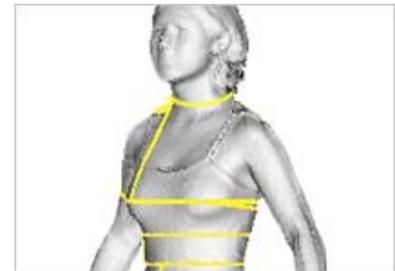
The Technologies

Mass customization strategies are driven by a host of enabling technologies ranging from bar codes to laser cutters, body scanners to Web applications. In the apparel industry, the critical technologies for mass-customized clothing are the body scanner for collecting body measurements; computer-aided design (CAD) systems for patternmaking; the Internet for communication between the customer and the customizer; and computerized processes that assist with accurate and rapid production and delivery.

One weak link in the Internet ordering process is self-measurement, which tends to be inaccurate. When it is more widely available, body scan technology will solve this problem. The 3D body scanner is a fast and reliable tool for collecting measurements. Once a scan is taken (a 12-second process), it is transferred to the computer and visualized on the screen (about 45 seconds). In the next step, software automatically locates body landmarks and generates measurements (about one minute depending on the number of measurements desired).

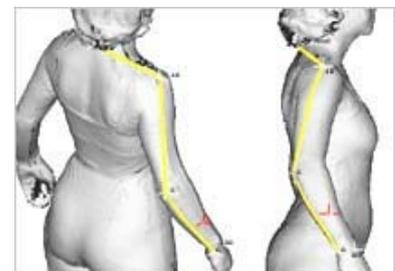
These measurements are very reliable but protocols for locating body landmarks still need to be perfected. Humans come in a very wide range of shapes. A human tailor can recognize the similarities in dissimilar bodies and make informed choices about how to make a body measurement, while a computer must be programmed for every eventuality. As new software is developed, the automated measurements generated by computers continually improve.

CAD technology is critical to the automated creation of custom-fitted apparel patterns. CAD is a generic term that covers pre-production design functions that are completed on the computer; this includes surface design, sketching, and patternmaking. CAD patternmaking systems use digital information about measurements and pattern shapes to create, modify, file, store, and reuse patterns. Scan data are saved in a special format to be read by CAD systems.



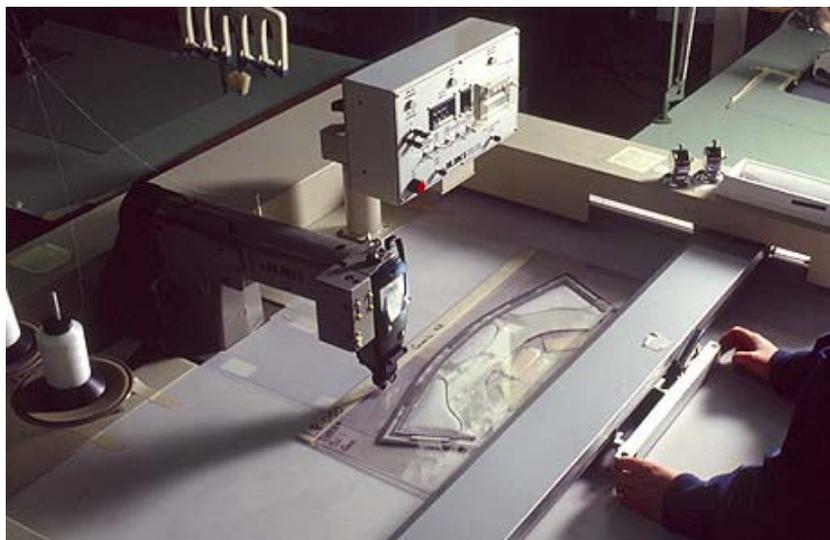
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The automated measurement feature from the body scan software generates measurements that can be used in automated pattern development for made-to-measure clothing. (Image: Cornell Body Scan Research Group)



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Software can be written to locate body landmarks using a combination of information about population norms and the location of body features on the scan. (Image: Cornell Body Scan Research Group)



Automatically generated custom patterns are sent in digital form to be cut and then used as part of an efficient mass customization process. Many aspects of garment construction can be automated, as with this machine that sews collar shapes. (Image: Cornell Body Scan Research Group)

Custom patterns can be generated in four basic ways:

- Traditional patternmaking and grading processes can be expanded by creating multiple sets of patterns that will fit a variety of different body proportions. For example, patterns can be generated for every possible combination of waist and hip measurement.
- Traditionally graded patterns can be used in another way by selecting the closest-fitting pattern and applying automated alterations to custom-fit the pattern.
- Traditional pattern drafting techniques can be used to automatically generate a pattern directly from a set of body measurements.
- New software programs are being developed that actually "unwrap" a 3D representation of a garment to make a 2D pattern shape.

Fitting the complex shape of a human body is a difficult task, even with body scanners and computer technology. The interactions between body shapes, pattern shapes, and fabric properties can create an exponential number of possible fitting issues to be resolved. The development and testing of these processes is still in its infancy, yet it is already possible to create a system that can provide well-designed custom-fitted garments.

Testing Made-to-Measure Systems at Cornell

Using technology available at Cornell University, students in an apparel design class tested the steps and technology needed to produce made-to-measure clothing.

CAD patternmaking software called FitNet (developed by Lectra, Inc.) was used in conjunction with the body scanner to generate patterns for a hooded rain jacket. The FitNet system begins with a standard graded pattern, provided by Log House Designs, a manufacturer of men's and women's outerwear which collaborated on the project.

Customized patterns were derived from the standard by making alterations based on body measurements. In planning the alterations, students had to make a variety of decisions based on the specific garment style, including:

1. which criteria are appropriate in choosing the base pattern size, e.g., choose a pattern with the closest hip measurement;
2. which alterations are critical to the fit of the style, e.g., jacket length, sleeve length, bust circumference, hip circumference, hood height, and wrist measurement;
3. which body measurement to relate to each alteration; and
4. which incremental and location changes need to be made to pattern pieces for each alteration.

The most important and difficult issue concerns the "ease" values -- extra fabric that allows for movement (wearing ease) and creates the desired silhouette (design ease). Charts that define this variable for each size and each body dimension were developed, tested, adjusted, and tested again. Then, Log House Designs made a set of 10 nylon custom-fitted jackets from the patterns generated by the class to test the fit on 10 clients.

A second critical issue arose in this custom clothing project: individuals have distinctive fit preferences. For example, several of the subjects preferred jacket or sleeve lengths that were longer or shorter than the standard lengths judged ideal for the jackets. Ultimately, fit preference issues must be resolved if mass customization systems are to be successful.

Results from the project were encouraging. Although the process of setting up and testing the system required many iterations, in the end a very good standard of fit was achieved. For seven of the ten subjects, the system created a jacket that fitted better than a standard ready-to-wear size, and for the other three the jacket fit just as well as the ready-to-wear size. Using advanced digital technologies, it was possible to create a working made-to-measure system in an acceptable amount of time.

Subsequent to the first project, Cornell students have experimented with several other made-to-measure products. Read about these projects in the [current research section](#) of the website.



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Many decisions must be made about the fit of each garment type in the development of an automated custom-fit operation. Cornell students discuss the jacket style from Log House Designs. (Image: Cornell Body Scan Research Group)



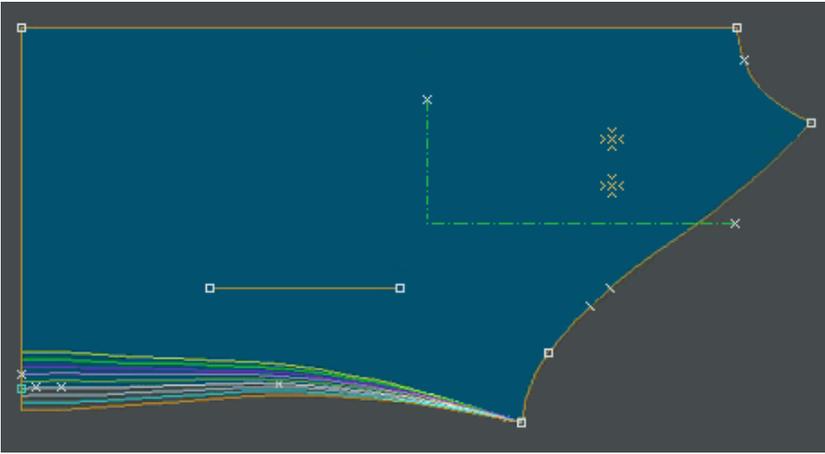
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Setting up the system required many iterations to refine the fit. Here a set of scaled patterns are compared to judge the effect of an adjustment to the system. (Image: Cornell Body Scan Research Group)



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Aleta is taller than average and usually cannot find jackets to fit well. Her made-to-measure jacket is a perfect fit. (Image: Gary Hodges, Jon Reis Photography)



The first step in the automated process is selection of the pattern closest to the individual's size. Alterations subsequently made to this pattern are driven by the individual's measurements. (Image: Cornell Body Scan Research Group)

Technologies exist to create cost-effective mass-customized clothing. Questions that require further research include: Can automated CAD patternmaking systems successfully create patterns for closely fitted garments? How many consumers will buy mass-customized clothing? Will they accept body scanning technology to take their measurements?

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