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Automatic Pattern Generation Process for Made-to-Measure

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ABSTRACT

The objectives of this study are to analyze the automatic pattern generation process for making custom fit garment using the made-to-measure (MTM) CAD system, which produces apparel products based on individual body measurements, and to provide basic materials for the utilization of this technology in apparel manufacturing for mass customization. In order to make MTM patterns, basic patterns were digitized by using the Gerber CAD system, and designated critical alteration points based on body measurements important for pattern design. Then, grading rules and alteration rules based on the ASTM 5585 standard sizes were formulated, size tables for entering standard sizes and individual sizes were made, and MTM patterns were generated for custom fit garment according to individual body measurements. In the apparel manufacturing process, the computer-aided design (CAD) system for pattern design has been utilized merely for digitizing and grading patterns, and the application of individual size has usually been made through manual work on the patterns. The MTM CAD system in this study is expected to be utilized as a computer-aided manufacture system for the clothing industry in the age of mass customization and to play an important role in manufacturing custom fit garment reflecting individual customers' body measurements. Moreover, the MTM CAD system may be usable in the automated pattern generation reflecting individual body measurements.

Keywords: Mass customization, Made-to-measure (MTM) CAD, Automatic pattern, Custom fit, Alteration rule

I. Introduction

Today's apparel industry is evolving from the traditional mass production system to the mass customization system, which takes into account individual consumers' needs (Yang & Zhang, 2007). That is, people's interest is switching from conventional mass production (ready-to-wear), which has problems in size fitness and inventory control due to the manufacturing of limited designs and standardized sizes, to mass customization that can produce various designs and individual sizes (Fontana et al., 2005). For mass customization as such, advanced computer technology is being utilized extensively in the apparel industry from product planning to manufacturing and marketing. Particularly for fast and accurate production in the apparel manufacturing process, flexible computer-aided manufacturing systems are being applied to apparel manufacturing processes such as apparel pattern making, grading, and marker making (Ashdown & Dunne, 2006; Beazley & Bond, 2003). The MTM CAD system, which produces apparel products according to individual body measurements using such computer technologies, is playing an important role for mass customization in the apparel industry, and there are several different types of MTM CAD systems including Gerber, Lectra, Investronica, PAD, Optitex, and Assyst (Istook, 2002).

Research on the MTM pattern system is being made particularly for pattern making based on 2D and 3D CAD technologies. Individual patterns created by 2D CAD technology can be used as 2D basic patterns for generating MTM patterns by applying grading rules and alteration rules according to body measurements, so have a practical aspect to be utilized in the apparel industry. Previous studies in this area include Jeon and Kim (1998), Ashdown and Dunne (2006), Istook (2002). Individual patterns created by 3D CAD technology are 2D patterns that are flattened from a 3D body model, so they can reflect the human body type but have practical limitations including the need to build a new 3D CAD system on top of the existing apparel manufacturing process system. Among previous studies in this area, Kim and Park (2006), Petrak et al. (2006), Yang and Zhang (2007) researched on 2D pattern flattened from an individual 3D virtual dummy, and Jeong and Nam (2007), Kim and Park (2004), McCartney et al. (2000) researched on 2D patterns built from a 3D body model with 3D body scan data.

The objectives of this study were to analyze the automatic pattern generation process for making customized MTM patterns based on 2D CAD technology used currently in the apparel industry and to provide basic materials for the utilization of this technology in apparel manufacturing for mass customization.

II. Methods

In this study, Gerber CAD software for making made-to-measure (MTM) patterns was used and basic-style pants <Fig. 1> for experimental garment were chosen. As a pants pattern, the basic pattern of basic size 8 used by apparel manufacturers was digitized by using the Gerber Pattern Input Digitizer to AccuMark CAD software. Based on research by Istook (2002), a MTM pattern for producing custom fit garment was made from the digitized basic pattern. In the first step, critical alteration points based on body measurements that had an important effect on pattern composition were designated. In the second step, grading rule values were entered into the critical alteration points from the basic pattern of size 8 based on the ASTM 5585 size table. That is, grading rule tables were made by designating the grading points of pattern and entering grading rule values which indicate changes in axis X and Y into each grading point.

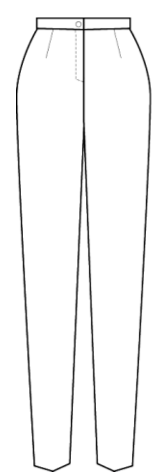


Fig. 1. Pants design

Table 1 shows the ASTM 5585 size table. In the third step, alteration rules were formulated in order to make a pattern adjusted by individual body measurements. Each alteration rule was produced by assigning a unique alteration number to each critical alteration point and entering algorithm that alters the critical alteration points of pattern according to body measurements. In the fourth step, size tables were made in order to enter standard basic size and individual size for making a MTM pattern that reflects an individual's size from the basic-size pattern. That is, a MTM size table was made for entering basic body measurements into each standard size of grading size 2-20 and entering individual body measurements into custom size. In the last step, a MTM pattern reflecting individual body measurement was created by selecting alteration rule from the 'Alteration Setup' window and the 'Altered Size' (AM) window and selecting a MTM size table, and then choosing an individual size entered in advance.

Table 1. ASTM 5585 size table: Standard table of body measurements for adult female misses figure type

Unit: inch

Measurement	2	4	6	8	10	12	14	16	18	20
GIRTH:										
Bust	32.00	33.00	34.00	35.00	36.00	37.50	39.00	40.50	42.50	44.50
Waist	24.00	25.00	26.00	27.00	28.00	29.50	31.00	32.50	34.50	36.50
High hip	31.50	32.50	33.50	34.50	35.50	37.00	38.50	40.00	42.00	44.00
Hip	34.50	35.50	36.50	37.50	38.50	40.00	41.50	43.00	45.00	47.00
Neck Base	13.50	13.75	14.00	14.25	14.50	14.88	15.25	15.63	16.13	16.63
Upper arm	10.00	10.25	10.50	10.75	11.00	11.38	11.75	12.13	12.75	13.38
Thigh, Max	19.50	20.25	21.00	21.75	22.50	23.50	24.50	25.50	26.75	28.00
Total Crotch	25.00	25.75	26.50	27.25	28.00	28.75	29.50	30.25	31.00	31.75
VERTICAL										
Cervical height	54.50	55.00	55.50	56.00	56.50	57.00	57.50	58.00	58.50	59.00
Waist height	39.25	39.50	39.75	40.00	40.25	40.50	40.75	41.00	41.25	41.50
Hip height	31.25	31.50	31.75	32.00	32.25	32.50	32.75	33.00	33.25	33.50
Crotch height	29.50	29.50	29.50	29.50	29.50	29.50	29.50	29.50	29.50	29.50
Ft waist length	13.50	13.75	14.00	14.25	14.50	14.75	15.00	15.25	15.50	15.75
Bk waist length (necktowaist)	15.50	15.75	16.00	16.25	16.50	16.75	17.00	17.25	17.50	17.75
Rise	9.75	10.00	10.25	10.50	10.75	11.00	11.25	11.50	11.75	12.00
WIDTH & LENGTH										
Across Schoulder	14.38	14.63	14.88	15.13	15.38	15.75	16.13	16.50	17.00	17.50
Cross-back width	13.88	14.13	14.38	14.63	14.88	15.25	15.63	16.00	16.50	17.00
Cross-chest width	12.88	13.13	13.38	13.63	13.88	14.25	14.63	15.00	15.50	16.00
Shoulder length	4.94	5.00	5.06	5.13	5.19	5.31	5.44	5.56	5.75	5.93
Shoulder slope (degrees)	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00	23.00
Arm length (shlder to wrist)	22.94	23.13	23.31	23.50	23.69	23.88	24.06	24.25	24.44	24.63
Bust point to bust point	7.00	7.25	7.50	7.75	8.00	8.25	8.50	8.75	9.00	9.25

III. Results

1. Basic pattern

The front, back and waist belt patterns of pants without seam allowance were used, and the outline, angle point, notch, dart point, dart notch, and grain line of the patterns were digitized. <Fig. 2> shows the basic pattern digitized by using a Gerber Pattern Input Digitizer.

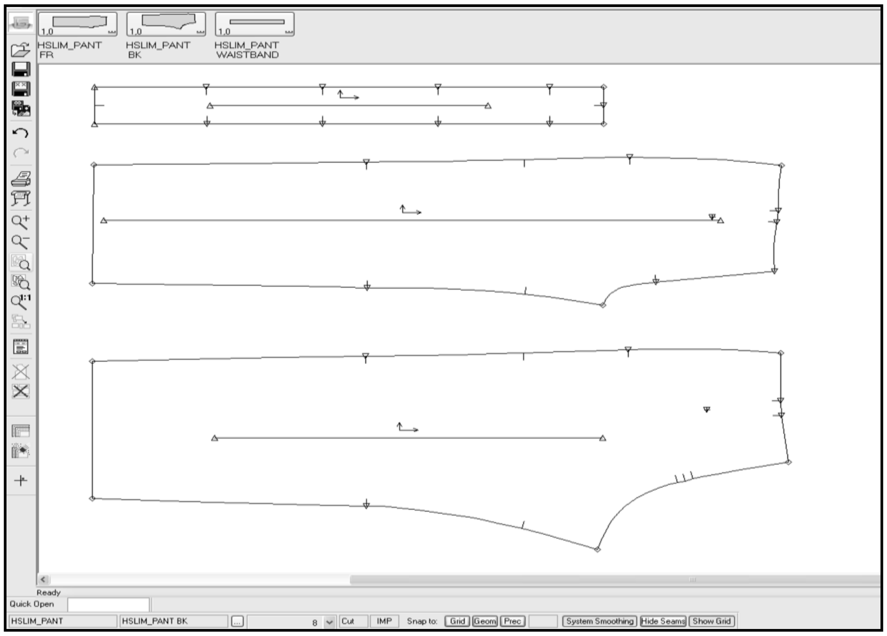


Fig. 2. Digitized basic pattern

2. Grading Rule

Body measurements for critical alteration points that have an important effect on pattern composition were designated. For example, in the human circumference measurements, critical alteration points are waist, hips (seat), thigh, knee, and ankle. In the length measurements, critical alteration points are inseam and body rise. <Fig. 3> shows the results of entering grading point numbers to the basic pattern based on the designated critical alteration points. In the grading rules, apparel items were designated in a 3-digit number (ex, tank top: 1##, skirt: 2##, pant: 3##), and the number to classify grading rule values (changes in axis X and Y) for each alteration point of pattern was designated in a 2-digit number. Through this principle, grading point numbers were entered into each point, and graded patterns were generated by entering the grading rule values into the grading points.

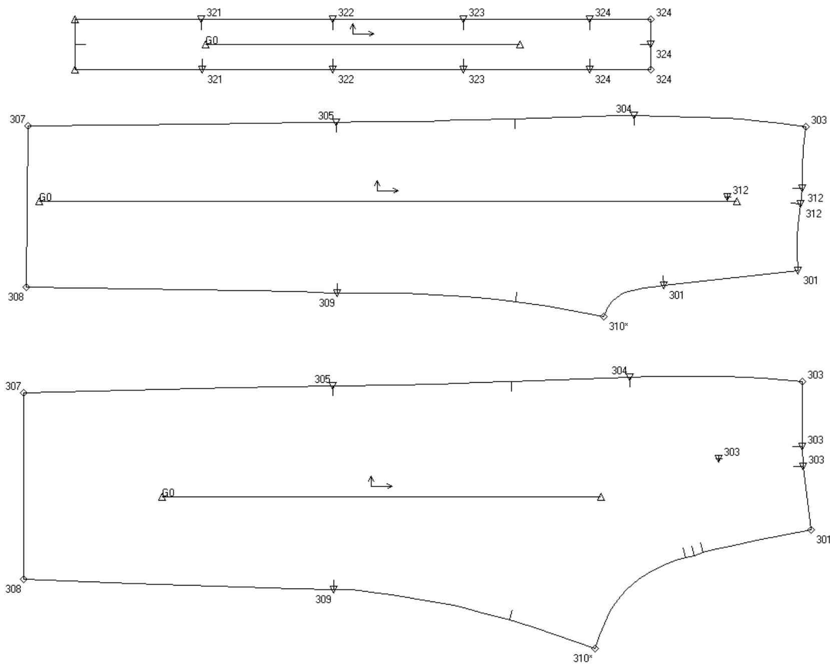


Fig. 3. Grade point numbers of pants' pattern

The patterns were graded by the grading rule values through increasing or decreasing the difference of each body measurement item between size breaks (ex, size 6-8, size 8-10, size10-12, etc.). <Fig. 4> shows the grading rule table of pants' pattern. In the circumference measurements, the difference (1 inch) of waist circumference between each size break was divided by 4 and then 0.25 (or 1/4) inch was entered into the grading value of axis Y for point 303 on the front and back patterns. For hip circumference also, 0.25 (or 1/4) inch was entered into one of axis Y for point 304. In addition, 0.25 or 1/4 inch, which was the difference of knee circumference and ankle circumference same as that for waist and hip circumferences ,was entered into the grading value of axis Y for points 305, 307, 308 and 309 on the front and back patterns.

In the length measurement, 0.25 inch, which was the difference of body rise, was entered into the grading values of axis X for points 301, 303 and 312 on the front and back patterns. In addition, 0.25 inch, the difference of inseam length, was entered as the grading values of axis X for points 307 and 308 on the front and back patterns. <Fig. 5> shows the graded nest of all size patterns through this process.

RuleTable - N:\MARE\MISSY - Imperial

File Edit View Rules Help

Grade Method: Small-Large Incremental

Grade Rules in Library: 55 Total Size Breaks: 13

		Rule		Rule		Rule		Rule		Rule		Rule		Rule		Rule	
	Number:	301		303		304		305		307		308		309		310	
	Comment:	C WAIST PT		SS WAIST PT		SS HIP PT		SS KNEE PT		SS ANKLE PT		C ANKLE PT		C KNEE PT		C CROTCH PT	
	Point Attribute:																
	Size Breaks	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y	X	Y
	0 - 2	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	2 - 4	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	4 - 6	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	6 - 8	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
*	8 - 10	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	10 - 12	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	12 - 14	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	14 - 16	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	16 - 18	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12
	18 - 20	0.25	0.00	0.25	0.25	0.00	0.25	-0.12	0.25	-0.25	0.25	-0.25	-0.25	-0.12	-0.25	0.00	-0.12

Fig. 4. Grading rule table of pants' pattern

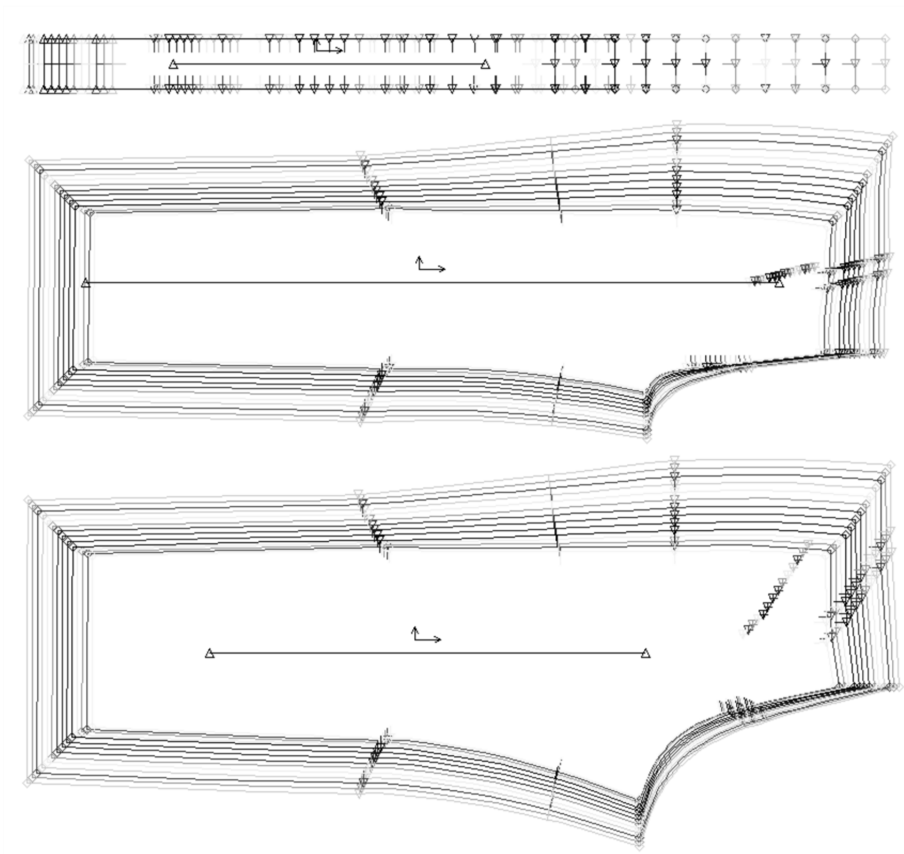


Fig. 5. Graded nest of pants' pattern

3. Alteration point numbering

In order to make an alteration rule table, first, a unique alteration point number was assigned to each critical alteration point. <Table 2> shows alteration point numbers for several garments. A 4-digit number is assigned to each apparel item. Tank top was given number 1### beginning with '1,' pants 2###, and jacket 3###. According to pattern piece, a 3-digit number was given. That is, front was given #1##, back #2##, sleeve #5##, and collar #6##. <Fig. 6> displays pattern of point numbers/names applied to the pattern piece of pants. All point numbers within a piece should be unique. For example, in the pants' front piece (31##), the ankle point of center front was numbered to 3110 and the waist point of center front was numbered to 3150 as shown in <Table2> and <Fig. 6>.

Table 2. Alteration point numbers

Category	Part	Point	Number
Pants	Front		31##
		CF Ankle	3110
		CF Knee	3120
		CF Waist	3150
		SF Waist	3160
	Back		32##
		CB Ankle	3210
		CB Knee	3220
		CB Waist	3250
		SB Waist	3260
	Belt		33##
Tops	Front		11##
	Back		12##
Jackets	Front		21##
	Back		22##
	Sleeve		25##
	Collar		26##

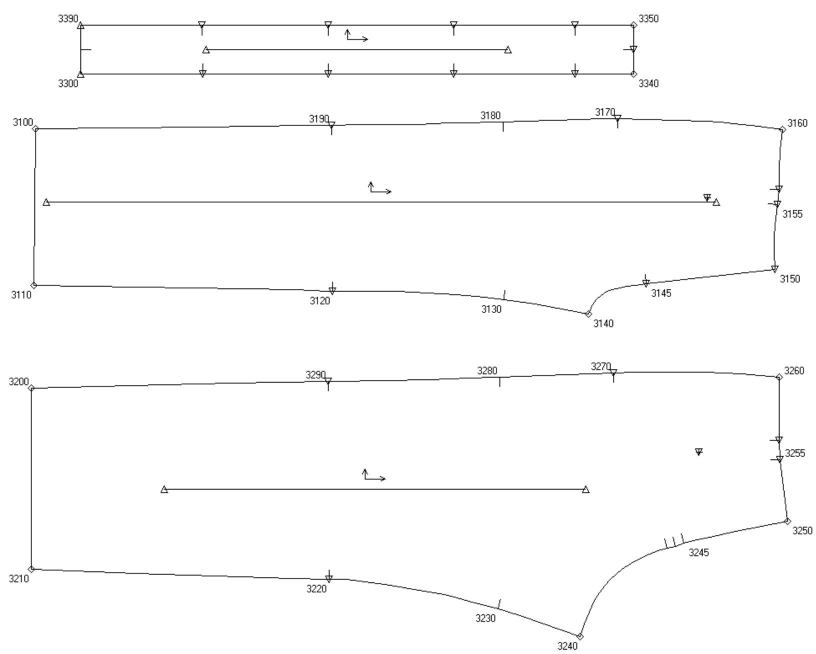


Fig. 6. Alteration points numbered in the pattern piece

4. Alteration Rule

The waist, ankle, knee, thigh, inseam, hip (seat) and rise measurements of critical alteration points which is important in the pattern composition of pants were included into the alteration rule table. Alteration rule values were given to the points on the pattern affected by these body measurements. There are 5 types of alteration movement for alteration rules: (1) counterclockwise, no extension, (2) counterclockwise, extension, (3) clockwise, no extension, (4) clockwise, extension, and

(5) X and Y move. In general, a hold point and a move point should be defined for these alteration movements. Thus, pivoting from the designated hold point (first point), the move point (second point) according to the alteration rule value was moved. That is, 'counter-clockwise, no extension' indicates a counter clockwise movement from the first point to the second point by the alteration rule value without change in the existing pattern line. 'Counter-clockwise, extension' indicates a counter clockwise movement by the alteration rule value so that the second point meets the extension of the existing pattern line.

'Clockwise, no extension' and 'clockwise, extension' indicate clockwise movements, and 'X and Y move' indicates the movement of the first and second points in the X and Y directions by the alteration rule value.

<Fig. 7> shows the alteration rule table of the pants pattern made in this study. In <Fig. 6>, alteration rule values were applied to the waistline dart points and side seam waist points of the front and back patterns according to waist circumference <Fig. 7>. To increase or decrease the waistline by any amount, the alteration value of waist circumference was allocated evenly (1/4 or 25%) to each side seam waist point (3160 and 3260) of the front and back patterns, which are half patterns. The position of the waistline darts of the front and back patterns was moved by 1/8 (12.5%) waist in proportion to the movement of the side seam waist point.

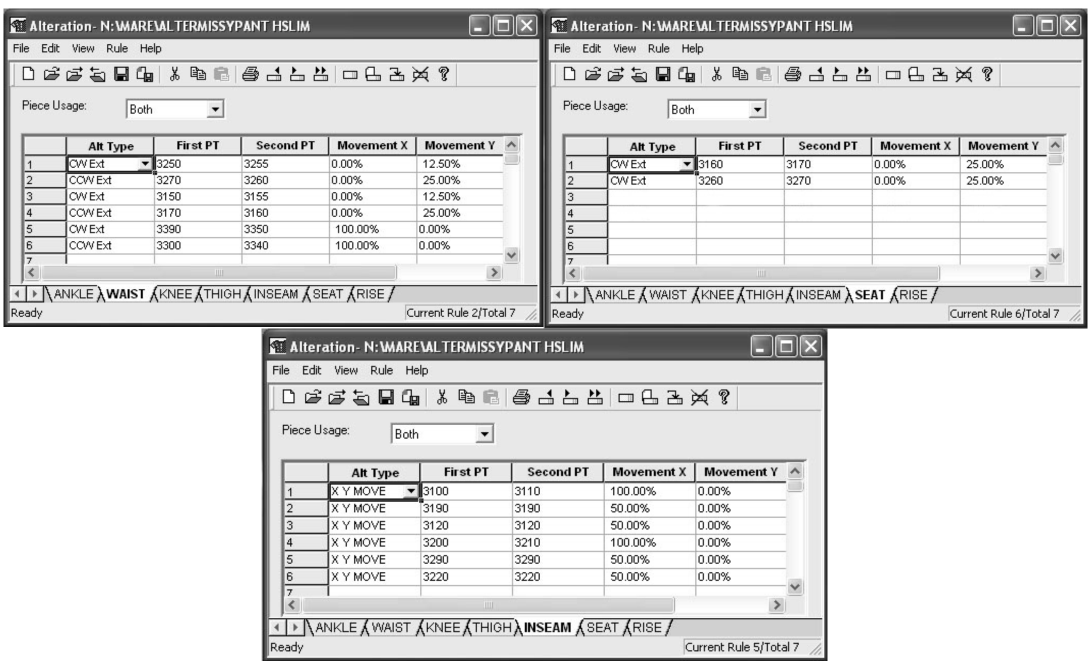


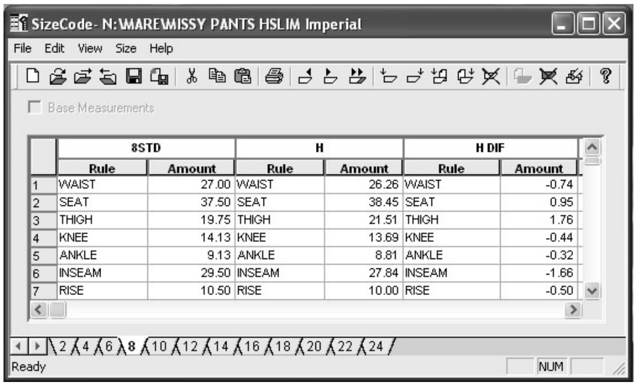
Fig. 7. Alteration rule table of pants

In the 'CCW Ext', the front side seam (SS) waist point (Second PT: 3160) moved as an amount of 25% waistline size toward counter-clockwise (CCW) on the pattern piece from the hold point (First PT: 3170) and the line were lengthened or shortened as necessary to meet the adjacent line. Also, the front dart point (Second PT: 3155) moved as an amount of 12.5% waistline size toward clockwise (CW) on the pattern piece from the hold point (First PT: 3150) and the line was lengthened or shortened as necessary to meet the adjacent line. In the inseam rule, both points of hemline (3100 and 3110) moved to the same amount of 100% inseam in X direction. The point of knee line (Second PT: 3190) located the half of inseam and moved to the amount of 50%

inseam in X direction from the hold point (First PT: 3190).

5. Size Table

To make fit patterns for individual body measurements, they were used to develop the size tables based on the specific difference between the individual measurements and the reference measurements. In this study, ASTM standard sizes (Standard table of body measurements for adult female misses figure type) were used to the reference measurement. <Fig. 8> shows the size table from 2 to 20 sizes and it contains the body measurements (unit: inch) including waist, seat (hips), thigh, knee, ankle, inseam, and rise. As shown in the size table, body measurements of a standard size (8STD) were entered into the reference measurements, and ones of a customer's size (H) were entered into the individual measurements. Difference values between the two sizes were entered in 'H DIF.'



	8STD		H		H DIF	
	Rule	Amount	Rule	Amount	Rule	Amount
1	WAIST	27.00	WAIST	26.26	WAIST	-0.74
2	SEAT	37.50	SEAT	38.45	SEAT	0.95
3	THIGH	19.75	THIGH	21.51	THIGH	1.76
4	KNEE	14.13	KNEE	13.69	KNEE	-0.44
5	ANKLE	9.13	ANKLE	8.81	ANKLE	-0.32
6	INSEAM	29.50	INSEAM	27.84	INSEAM	-1.66
7	RISE	10.50	RISE	10.00	RISE	-0.50

Fig. 8. Size table of pant

6. Individual MTM Pattern

In the last step for making an automatic made-to-measure (MTM) pattern, the alteration rule and the size table were combined, and <Fig. 9> shows the 'Alteration Setup' and 'Altered Size' windows for this process. As an alteration rule and a size table were selected and items with difference between the standard size and the individual size are selected, a MTM pattern applied the customer's size was generated automatically.

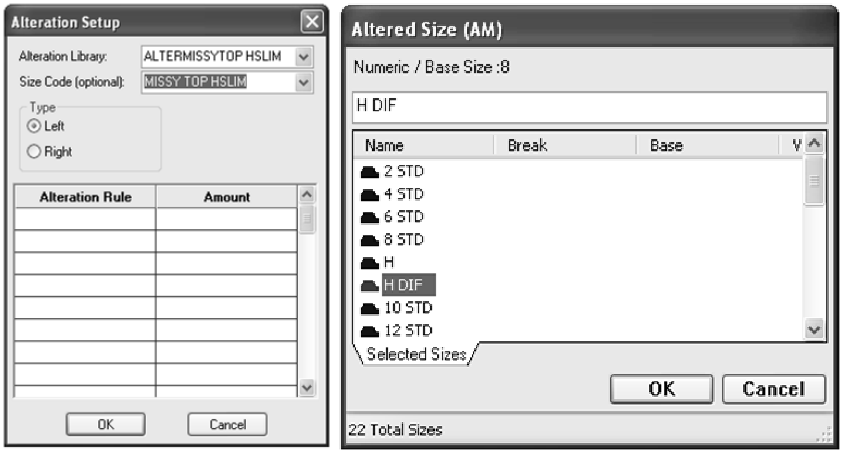


Fig. 9. Alteration setup and altered size

<Fig. 10> shows the MTM pattern generated through this process. In this figure, dark gray area indicates the MTM pattern and dot-pattern area indicates the basic pattern.

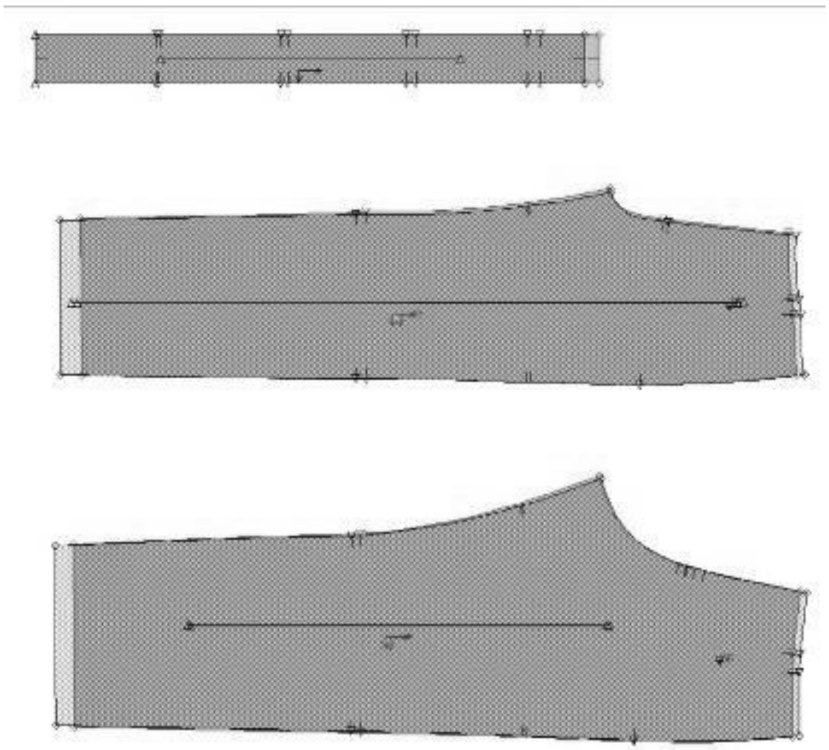


Fig. 10. Altered pattern of pant

IV. Conclusion

This study analyzed the process of making a MTM pattern fit for individual body measurements using the Gerber CAD system in order to produce mass customization apparel products. For this, a basic pattern of size 8 was digitized and graded according to the ASTM 5585 standard size. That is, critical alteration points were designated to points altered according to body measurement and a grading algorithm that enters changes in axis X and Y was implemented for each point.

Furthermore, in order to make a MTM pattern customized to individual body measurements, alteration rule values were entered by allocating the difference between the basic size and the individual size proportionally to relevant critical alteration points. Size tables were made for applying alteration values according to body measurements, and then entered the individual body measurements as well as the standard body measurements were entered into the size table. Through this process, a MTM pattern for custom fit garment, which reflected individual body measurements, could be generated from a standardized ready-made clothes pattern.

In the future mass customization age, the apparel industry should be equipped with systems that can manufacture products customized to individual body type and design preference for responding to consumers' needs quickly and maximizing customers' satisfaction. Thus, the MTM CAD system used in this study is expected to contribute to the manufacturing of mass customization clothes by using the existing ready-to-wear manufacturing process while reflecting individual customers' body characteristics and size as in custom-made clothes. For the active utilization of the MTM CAD system in the apparel industry, moreover, it is considered important to establish a comprehensive apparel manufacturing system including ordering, manufacturing and distribution systems for mass customization.

This study made a MTM pattern by applying the body measurements of individual size and standard basic size. Thus, future research needs to make MTM patterns applying various body sizes and basic patterns reflecting various standard basic sizes, and to evaluate the appearance and fit of these patterns.

References

Ashdown, S. P., & Dunne, L. (2006). A study of automated custom fit: Readiness of the technology for the apparel industry. *Clothing and Textiles Research Journal*, *24*(2), 121-136.

Beazley, A., & Bond, T. (2003). *Computer-aided pattern design and product development*. Oxford: Blackwell.

Fontana, M., Rizzi, C., & Cugini, U. (2005). 3D virtual apparel design for industrial applications. *Computer-Aided Design*, *37*, 609-622.

Istook, C. L. (2002). Enabling mass customization: Computer-driven alteration methods. *International Journal of Clothing Science and Technology, 14*(1), 61-76.

Jeon, E. K., & Kim, H. K. (1998). An automatic drafting of the apparel pattern for an easy order system. *Journal of the Korean Society of Clothing and Textiles, 22*(3), 303-311.

Jeong, M. E., & Nam, Y. J. (2007). A study on the automatic pattern development of adult male basic pattern using 3D body scan data. *Journal of Fashion Business*, *11*(3), 35-45.

Kim, S. M., & Park, C. K. (2004). Parametric body model generation for garment drape simulation. *Fibers and Polymers, 5*(1), 12-18.

Kim, S. M., & Park, C. K. (2006). Basic garment pattern generation using geometric modeling method. *International Journal of Clothing Science and Technology*, *19*(1), 7-17.

McCartney, J., Hinds, B., Seow, B., & Dong, G. (2000). An energy based model for the flattening of woven fabrics. *Journal of Materials Processing Technology, 107*(1), 312-318.

Petrak, S., Rogale, D., & Vinko, M. B. (2006). Systematic representation and application of a 3D computer-aided garment construction method-Part II: Spatial transformation of 3D garment cut segments. *International Journal of Clothing Science and Technology, 18*(3), 188-199.

Yang, Y., & Zhang, W. (2007). Prototype garment pattern flattening based on individual 3D virtual dummy. *International Journal of Clothing Science and Technology*, *19*(5), 334-348.