DEVELOPMENT OF THE METHOD OF SCALING PATTERNS AND VIRTUAL GARMENTS FORMS

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Abstract: *In the paper a method of non-uniform scaling was applied to scale separate horizontal sections of the virtual mannequin and to scale garments patterns of the bodice blocks. A connection between features of the garments forms and eases was determined as regressions between body measurements, amount of ease and scale factors. It was proposed to calculate the scale factors by using values of eases, which were obtained with formulas based on measured projection parameters by using specified conditional units. It allows recreating and studying any form of garment with its geometrical symbol only. Several algorithms of calculating the scale factors in different processes of design and study of virtual garments forms were the basis for the computer program "Scale factor". "Shape scale" is the part of the program which includes all cases of the scale factors calculation for the 3D-scaling. "Pattern scale" is the part that is recommended for different processes of 2D garment design. User can choose the method of the calculation according to the available input data.*

Keywords: *non-uniform scaling, virtual model, scale factor, amount of ease, patterns.*

1 INTRODUCTION

Nowadays the garment industry is quickly becoming a high-tech industry, which uses 2D and 3D CAD tools. If designers use 2D CAD tools, they often need the instructions for the basic blocks. Instructions are given for a wide range of basic garments (for example, in [1] author represents women's outerwear, in [2] and [3] women's and men's garments designs were described). The instructions must be used in every given circumstances in order to obtain the garment blocks with different values of eases. Furthermore, even if designers use pattern design system (PSD), it takes relatively a long time nonetheless. That is why many researchers try to find new methods to obtain the garments blocks and make it faster with the same level of quality.

Method of silhouette transformation of the garment's parts was proposed in [4]. Transformation of the base design of the skirt into the base design of trousers that was described in [5] is the logical extension of the method of silhouette transformation. Both methods are similar to the grading process. A method of grading patterns by scaling was advanced in [6]. Hence, that provides the ability to accomplish the silhouette transformation of the garment parts by scaling their patterns.

Some of the PSD have specific tools to scale patterns (for example, PSD "Julivi" has a tool "Scale", and another PSD "Gracia" has a tool "Stretch", which is corresponded to the scale process). However, these tools are supposed to be used only for making experimental garments samples or for taking into account the fabric properties. At present there is no enough knowledge about the scaling process in garment industry, especially about a determination the scale factors in specific design situation.

Besides that, scaling is one of many methods that are used in order to obtain a virtual garment. Group of authors proposed to apply a uniform scaling to scale separate horizontal sections of the virtual mannequin [7]. However, a garment form is not the same as the human body form. Flat bodice blocks mostly take into account this fact by using different eases for the different garment parts. Obviously, a ratio of values of the eases in scaled garment form must be the same as in the flat bodice blocks, which were obtained by classic instructions. Probably it could be achieved by non-uniform scaling with a separate scale factor for each axis direction. Such method was proposed in [8] where non-uniform scaling was applied to scaling the horizontal sections of the virtual mannequin. Authors described the regression relationships between body measurements, amount of ease (on bust line, waistline, and hipline) and the scale factors. The regressions ensure that the ratio of different parts of eases in the virtual garment form will be the same as in a standard form of the real garment. Therefore, they can be used to calculate the scale factors in order to create the virtual form of the garment.

The main purpose of current work is to develop a computer program for calculating the scale factors to be used in processes of apparel design. In order to achieve such a goal we need to obtain detailed information about determining the scale factor for each axis direction in any possible case of 2D and 3D garment design.

2 SCALING PATTERNS OF BODICE BLOCKS

2.1 Determination of scaling center for the experiment

Usually the scaling is performed with basic point that called a center of scaling. Until now, we have no information about scale factors for each axis direction in the case of scaling patterns of bodice blocks. Therefore if the scale factors are different for both directions of the same axis then the location of the scaling center must be clearly defined.

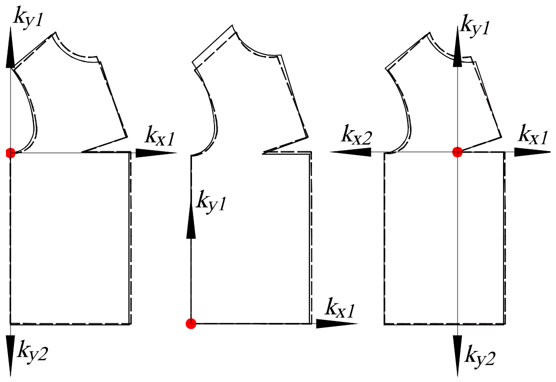


Figure 1 Variants of scaling with various scaling centers

The center of scaling was determined as the result of the follows operations. Few separate cases of scaling the bodice blocks of women's garments were performed with various centers of scaling (Figure 1).

Constructions of the woman's suit jacket and coat were designed within two pattern design systems: "Gracia" and "Julivi". Constructions were designed for the same body size and with the same instructions of the design that were described in [3]. For the suit jacket an amount of ease on the bust line is a minimal value of the recommended range in the selected instruction, and for the coat the amount of ease is a maximal value. Coordinates of constructive points were measured with PDS options. The scale factors were obtained for each axis as a ratio of coordinates of the corresponding points (Table 1).

According to the data in the Table 1 Fisher test confirmed that any of constructive points could be used as a center of scaling. However, as a result of visual observations of the scaled constructions on the Figure 1 the point on the top of the side line was selected as recommended center of scaling. The areas of the garments parts, which were designed by various instructions, and the areas of the scaled garments parts were compared (Table 2).

The analysis confirmed that non-uniform scaling with the selected center of scaling could be used to obtain the bodice blocks of various garments types.

Table 1 Scale factors and Fisher test results

Parameter		Scaling center					
		top of the side line		bottom of the side line		center of the dart	
name	symbol	*coat → suit jacket*	*suit jacket → coat*	*coat → suit jacket*	*suit jacket → coat*	*coat → suit jacket*	*suit jacket → coat*
Scale factors	k_{x1}	0.934	1.071	0.934	1.071	0.956	1.046
	k_{x2}	–	–	–	–	0.906	1.111
	k_{y1}	0.912	1.098	0.995	1.005	0.907	1.105
	k_{y2}	1.020	0.980	–	–	1.021	0.969
Unexplained variance	D_X	0.132	0.099	0.091	0.099	0.099	0.140
	D_Y	0.225	0.275	0.746	0.579	0.216	0.301
Explained variance	Da_X	0.141	0.206	0.101	0.206	0.110	0.237
	Da_Y	0.227	0.284	0.748	0.589	0.218	0.309
Fisher test (experimental)	F_X	1.069	2.077	1.099	2.077	1.106	1.692
	F_Y	1.011	1.031	1.003	1.016	1.011	1.026
Fisher test	F_t	3.020	3.020	3.020	3.020	3.020	3.020

Table 2 Comparing the areas of the garments parts

Parameter	Areas of the garment parts [cm^2]			
	suit jacket		coat	
	front	*back*	*front*	*back*
draft in "Julivi"	1513.84	1638.05	1631.33	1739.45
draft in "Gracia"	1508.22	1639.80	1615.08	1761.18
average value for drafts in PSD	1511.03	1638.93	1623.21	1750.31
scaled construction	1500.44	1653.54	1623.54	1717.39
difference	10.59	14.61	0.33	32.92
relative difference [%]	0.70	0.89	0.02	1.88

2.2 Experimental part

Theoretical scale factors for the scaling patterns were obtained by mathematical model of calculating scale factors. Each scale factor is an average value of the results of division the length between two points of the garment block by the length between the same points of the basic block of other garment type. The lengths were computed according to the instructions which have been proposed by few different authors (Figure 2). Thus, the list includes three instructions: I – described in [2], II – described in [1], and III – in [3]. The lengths depend on the body measurements, on the eases, and on features of the selected instructions.

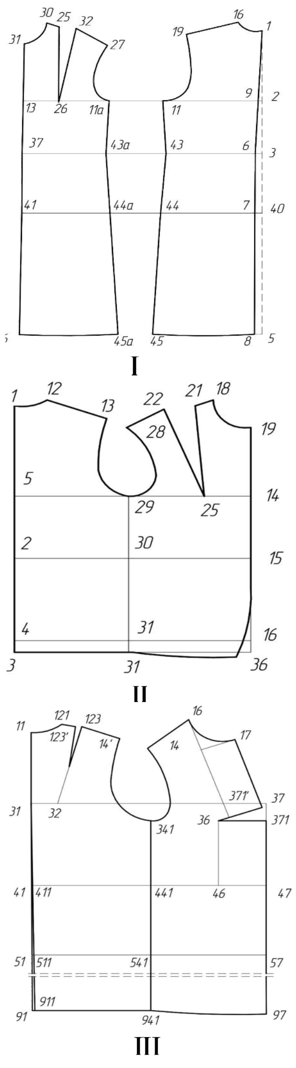


Figure 2 Bodice blocks for the research

Each instruction includes different number of the constructive points, different names of points, and different graphic methods. Thus, coordinates of each constructive point can be calculated by few various formulas accordingly to each instruction. In order to be able to compare the coordinates the same points in the various constructions were named identically (Table 3).

Table 3 Corresponding constructive points in various instructions

Part of bodice blocks	Point	Point in the instruction		
		I	*II*	*III*
Front	1f	31	19	17
	2f	13	14	371
	3f	37	15	47
	4f	47	16	57
	5f	44a	31	541
	6f	43a	30	441
	7f	11a	29	341
	8f	27	28	14
	9f	32	22	-
	10f	26	25	36
	11f	25	21	-
	12f	30	18	16
Back	1b	1	1	11
	2b	9	5	31
	3b	6	2	41
	4b	7	4	51
	5b	44	31	541
	6b	43	30	441
	7b	11	29	341
	8b	19	13	14”
	9b	16	12	121

Thus, the formulas of the calculation the coordinates were obtained for each point in the Table 3. For example, for the point 2f the formulas are follows:

$$X_{2fI} = 0.5\,(S_{gIII} – S_{gII} + S_{gI} – B – F + P_g – P_f + 0.9) \quad (1)$$

where X_{2fI} – abscissa of the constructive point 2f, computed according to [1]; S_{gIII}, B, F, S_{gI}, S_{gII} – measurements of the body [cm]; P_g, P_f – amount of eases [cm].

$$X_{2fII}=0.25(O_{gII}+10.25–B+F+0.25Wa) \quad (2)$$

where X_{2fII} – abscissa of the constructive point 2f, computed according to [2]; O_{gII}, B, F – measurements of the body [cm]; Wa – width of the armhole [cm].

$$X_{2fIII}= –0.24(T_{57}+P_{35})+0.5(T_{45}+T_{15}–1.2–T_{14})+P_{37}–a_{17} \quad (3)$$

where X_{2fIII} – abscissa of the constructive point 2f, calculated according to [3]; T_{57}, T_{45}, T_{15}, T_{14} – measurements of the body [cm]; P_{35}, P_{37} – amount of eases [cm]; a_{17} – constant.

Each scale factor is average value of the results of division the coordinates of the corresponded points, which were calculated by the same formulas but with the different amount of eases. The scale factors were calculated according to the plan of the experiment (Table 4).

The results of calculation were used as a basis to obtain the regression relationships between the body measurements, amount of ease and the scale factors for the patterns scaling (Table 5).

Similar experiments were conducted for the bodice blocks of the four woman’s garments types (a suit jacket, a jacket, a coat, and a raincoat) taking into account all possible directions of scaling between them.

Table 4 The main characteristics of the experiment

Characteristic	Height H [cm]	Bust B [cm]	Hips Hs [cm]	Amount of ease on the bust line E [cm]	
				garment 1	*garment 2*
middle	161	92	100	7.9	9.2
range	15	4	4	1.4	1.6
maximal	176	96	104	7.2	8.4
minimal	146	88	96	8.6	10.0

Table 5 Results of regression analysis

Direction of scaling	Scale factor	Formula	R^2
suit jacket → coat	k_{xf}	$1.477–0.02E_{BJ}+0.022\ E_{BC}\ –0.0015B$	0.892
	k_{y1}	$1.267–0.01(0.138H–0.1\ B\ +0.1Hs)$	0.608
	k_{xb}	$1.007–0.023\ E_{BJ}\ +0.021\ E_{BC}$	0.998
coat → suit jacket	k_{xf}	$0.961+0.021\ E_{BJ}\ –0.019\ E_{BC}$	0.988
	k_{y1}	$0.826+0.01(0,118H–0.044Hs)$	0.770
	k_{xb}	$0.995+0.018\ E_{BJ}\ –0.015\ E_{BC}$	0.977

where E_{BJ} (E_{BC}) – amount of eases on the bust line for the suit jacket (coat) [cm].

Table 6 Comparing the areas of bodice blocks

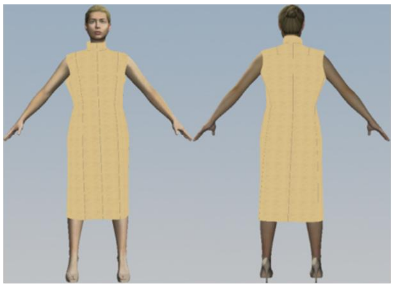
Initial garment type	Areas of the garment parts [cm²]				Differences [%]			
	suit jacket	*raincoat*	*coat*	*jacket*	*suit jacket*	*raincoat*	*coat*	*jacket*
–	3219	3342	3352	3875	–	–	–	–
coat	3138	3356	–	3777	-2.50	0.42	–	-2.54
suit jacket	–	3392	3606	3848	–	1.50	7.57	-0.71
raincoat	3087	–	3337	3778	-4.10	–	-0.47	-2.51
jacket	3379	3572	3427	–	4.99	6.88	2.23	–

2.3 *Results and discussion*

The areas of bodice blocks of various garments types were measured with tools of PSD "Julivi" (Table 6). The differences in areas between blocks that were scaled and that were designed with standard instructions mostly lie in the range from 0 to 5%. Scaling directions "suit jacket-coat" and "jacket-raincoat" are characterized with differences that excess 5% mark that recommended in garment industry. Such bodice blocks need minor improvement with tools of 2D garment design in order to achieve a high level of fitting quality.

In order to evaluate fitting quality of garments that obtained with scaling method, virtual garments were designed (Figure 3). Ten experts evaluated parameters of fitting quality (the scale from 0 to 5) that were described in [9]. Complex indexes for the virtual garments samples are shown in the Table 7.

Complex indexes of fitting quality of virtual garments samples are no lower than four that confirms the possible application of developed method into garment design and manufacturing. The pair "raincoat-coat" gets the lowest values of complex indexes of fitting quality while the differences in areas of the garment parts for this pair are minimal (Table 6). Thus, the patterns, which are obtained by scaling, provide the same level of fitting quality as constructed ones and the lowest value of complex index is not due to the scaling.



bodice blocks obtained by scaling method

bodice blocks obtained by instructions [3]

Figure 3 Virtual garment samples (fragment)

Table 7 Complex indexes of fitting quality

Initial garment type	Q			
	suit jacket	*raincoat*	*coat*	*jacket*
coat	4.632	4.469	–	4.725
suit jacket	–	4.879	4.721	4.731
raincoat	4.650	–	4.407	4.577
jacket	4.812	4.521	4.787	–

Although the fitting quality of garments samples corresponds to a high level, no one of them gets the highest mark. That is because the amount of eases, which is one of the main factors for scale factor calculating, is considered only at the bust line. Furthermore, it is impossible to take into account the amounts of eases at other constructive lines such as hips and waist simultaneously with described one.

That is why in order to achieve desired level of fitting quality, the bodice blocks of garments samples must be scaled as it was described above and after that, the bodice blocks are to be improved by simple moving the constructive points on the hips and waist level. In such a way, the garment silhouette will correspond to the garment type, which is must be designed, with required level of accuracy.

Thus, the scaling of the bodice blocks might be used in apparel design when designer has previously developed patterns of one of above-mentioned garments.

3 SCALING BASED ON PROJECTIONS PARAMETERS OF GARMENT SHAPE

All described calculations could be used as a basis for the scaling when information about values of eases is available. However, in some cases there is no such information. For example, we have only a sketch or geometrical image of the garment's shape. The shapes of different garments were analyzed in [10]. Geometrical images of the garments shapes were represented on the female figure. It is possible to measure only projections parameters of the shapes (as it shown on the Figure 4). The values of the projections parameters for different garment shapes are represented in the Table 8.

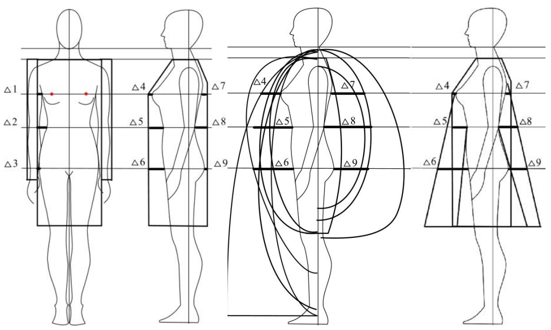


Figure 4 Projections parameters of the garments shapes

Projections parameters were measured on geometrical images of the garments shapes on the female figure (height 170 cm, bust 88 cm, hips 92 cm). According to [11] this female figure is harmonious. Thus, values of the projections parameters can be computed for any other female figure by using the specific ratio coefficient and conditional units.

Table 8 Projections parameters values

Shape	Parameter	Value	
		cm	***conditional units***
Shape 1 (Rectangle)	Δ_1	0.25	0.11
	Δ_2	5.53	2.47
	Δ_3	0÷0.14	0÷0.06
	Δ_4	0÷0.18	0÷0.08
	Δ_5	0.78	0.35
	Δ_6	0.88	0.39
	Δ_7	0.18	0.08
	Δ_8	0.63	0.28
	Δ_9	0÷0.11	0÷0.05
Shape 2 (Trapezium)	Δ_1	0÷0.85	0÷0.38
	Δ_2	0÷1.27	0÷0.57
	Δ_3	0.19÷1.09	0.08÷0.49
	Δ_4	0÷0.14	0÷0.06
	Δ_5	0÷1.12	0÷0.50
	Δ_6	0.27÷1.76	0.12÷0.79
	Δ_7	0÷0.20	0÷0.09
	Δ_8	0÷1.67	0÷0.75
	Δ_9	0.11÷1.04	0.05÷0.46
Shape 3 (Ellipse)	Δ_1	0.13÷2.46	0.06÷1.10
	Δ_2	0.73÷3.48	0.33÷1.55
	Δ_3	0.33÷3.35	0.15÷1.50
	Δ_4	0.00÷1.14	0.00÷0.51
	Δ_5	1.05÷2.25	0.47÷1.00
	Δ_6	1.19÷2.37	0.53÷1.06
	Δ_7	0.20÷1.91	0.09÷0.85
	Δ_8	0.94÷2.78	0.42÷1.24
	Δ_9	0.36÷2.00	0.16÷0.89

where Δ_1, Δ_2… Δ_9 are projection parameters (Figure 2)

If there is a need to study features of the garment forms, which are represented by their geometrical images, information about relationship between the projections parameters and the eases is mandatory. In [12] author proposed to calculate amount of ease by formulas, which we have transformed according to our purpose (taking into account the ratio coefficient for the specific body shape):

$$E_B = -1.004+0.013T_1(0.976\Delta_4+0.214\Delta_1-0.008\Delta_7) \quad (4)$$

$$E_W = -4.14-0.013T_1(0.1\Delta_5+0.82\Delta_2-0.12\Delta_8) \quad (5)$$

$$E_{HS} = 10.84+0.013T_1(0.06\Delta_6-0.66\Delta_3+0.1\Delta_9) \quad (6)$$

where E_B (E_W, E_{HS}) – amount of ease on bust line (waistline, hipline), [cm];

Δ_1, Δ_2… Δ_9 – projection parameters of the garment's silhouette, conditional units;

T_1 – figure height, [cm].

Projection parameters of the garment's silhouette supposed to be measured or selected from the Table 8 (as it shown on the Figure 4) using conditional units. Thus, the scale factors can be calculated by use values of eases, which were obtained with (4)-(6) and measured (or selected) projection parameters. Therefore it would be possible to recreate and study garment form even if only its image is available.

4 DEVELOPING THE COMPUTER PROGRAM

All design processes in garment industry are characterized by rapid technology development that has to be maintained by using the appropriate software. That is why obtained information was used to develop a computer program for scale factors calculating. Computer program "Scale factor" includes several simple algorithms. Each of them could be called from the main window by clicking on the appropriate button (Figure 5).

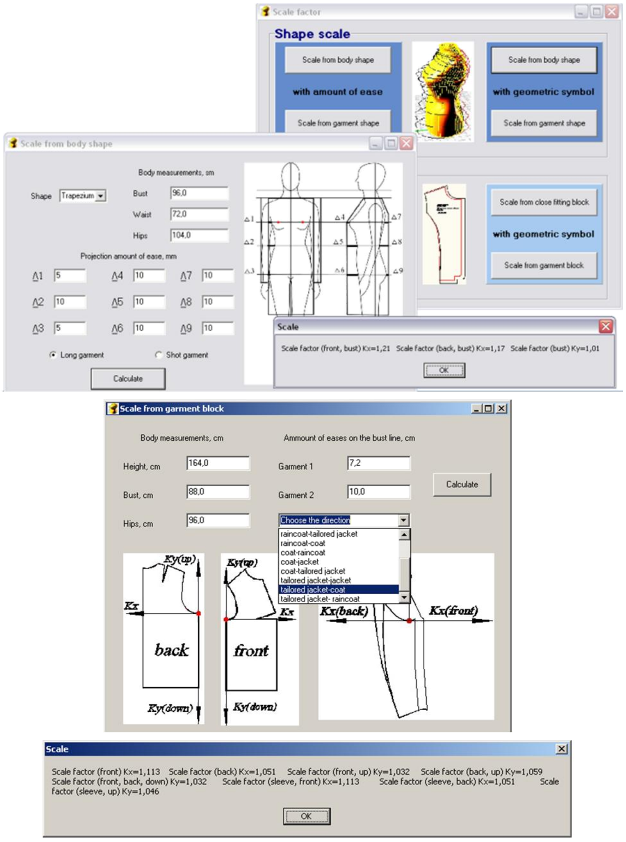


Figure 5 Computer program "Scale factor": examples of usage

"Shape scale" is a part of the program, which includes all cases of the scale factors calculation for the 3D-scaling. The text of the program units includes regression relationships between the body measurements, the amount of ease (on the bust line, waistline, and hipline) and the scale factors. The regressions were described in previously published work [8]. The formulas must be applied in a case when garment form is obtained by scaling the horizontal sections of virtual human body form. If there is no virtual human body form and there is a garment form, then the scale factors must be obtained as a ratio of two scale factors: the first one is using in scaling process from body form to garment form, that is designed, and the second one is using in scaling process from body to actual garment.

"Pattern scale is the part that is recommended for the different processes of 2D garment design. Program units of this part include results of the current research. Both parts include two panels: "with amount of ease" and "with geometric symbol".

Thus, user can choose the method of the calculation according to the available input data. A click on each button calls the next window. Clicking on the button "Calculate" begins the computing process. User gets the output data as a sequence of message boxes.

5 CONCLUSION

The main result of the work is that it gives further progress in study of adaptations of the blocks or previous patterns by using the pattern design system. Thus, the scaling method for designing patterns and developed computer program could be useful in a case of the rapid change in production of women's outerwear.

Computer program "Scale factor" can be also used in study of garment shape features and its transformation within time span. Besides that, it would be possible to research relationship between the body measurements and proportional characteristics of the form to achieve garment aesthetic quality.

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