Unidirectional Fabric Drape Testing Method

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Abstract

In most cases, fabrics such as curtains, skirts, suit pants and so on are draped under their own gravity parallel to fabric plane while the gravity is perpendicular to fabric plane in traditional drape testing method. As a result, it does not conform to actual situation and the test data is not convincing enough. To overcome this problem, this paper presents a novel method which simulates the real mechanical conditions and ensures the gravity is parallel to the fabric plane. This method applied a low-cost Kinect Sensor device to capture the 3-dimensional (3D) drape profile, thus we obtained the drape degree parameters and aesthetic parameters by 3D reconstruction and image processing and analysis techniques. The experiment was conducted on our self-devised drape-testing instrument by choosing different kinds of weave structure fabrics as our testing samples and the results were compared with those of traditional method and subjective evaluation. Through regression and correlation analysis we found that this novel testing method was significantly correlated with the traditional and subjective evaluation method. We achieved a new, non-contact 3D measurement method for drape testing, namely unidirectional fabric drape testing method. This method is more suitable for evaluating drape behavior because it is more in line with actual mechanical conditions of draped fabrics and has a well consistency with the requirements of visual and aesthetic style of fabrics.

Introduction

As an important aesthetic indicator of textiles, drape refers to the 3D deformation of fabrics arising from their own weight [1–2] and affects garment appearance quality profoundly [3–4]. Measuring and predicting the behavior of draped fabrics has been one of the most significant things in the field of fabric computer simulation which helps to clothing design and production [5–8].

Normally, drape is subjectively evaluated by textile and apparel workers in the design and manufacturing industry [9], but the result of this method varies greatly with different individuals and lacks of reproducibility. To find an efficient, accurate and reliable method to reflect the drape property, lots of effort and improvements have been made to interpret drape quantitatively. The progress of evaluating fabric drape was first begun by Peirce in 1930 [10].
developed an instrument and defined two parameters, bending length and flexural rigidity, to quantize draping quality of a fabric instead of judging handle or feel. This is an indirect method to reflect drape. Although this method is supposed to be feasible to measure drape, using two-dimensional distortions measurement and only two parameters to describe 3D complex fabrics is not convincing enough. A modified method was later proposed by Chu et al in 1950 [11–12]. He designed the standard Fabric Research Liberating (F.R.L) drape meter which was capable of distorting the fabric in all three dimensions and proposed the drape coefficient for the first time to analyze drape. The F.R.L drape meter is an optical instrument that traces the draped pattern of the circular sample sandwiched between two circular plates on a thin piece of paper, and then the draped pattern is cut and weighed to obtain the drape coefficient. The principle of F.R.L drape meter becomes the basis of most of further developed devices, however it is very time consuming and needs skills [13]. The most commonly applied testing device for fabric drape is the Cusick Drape Meter [14] which is also designed based on the principle of F.R.L drape meter. The Cusick drape meter obtained more accurate drape coefficient with less tedious and costly procedures, but on the other hand, it could not completely describe drape behavior with two-dimensional fabric projection image and only one parameter.

With the development of photography techniques and computer, researchers began investigating the use of image processing technology [13, 15–17] in studying fabric drape on the basis of Cusick drape meter. This method involved a camera and a beam of parallel light to capture the projection of draped fabric and a set of software to process the projection image. By means of image analysis the detailed data of drape property such as drape shape parameters and statistical information including drape wave amplitude, wave length and number of nodes were developed and computed from drape profile image [9]. Image analysis method takes less time, independent of operator, and has a better repeatability with more parameters and makes it possible to investigate time dependence of drape coefficient [18].

In view of previous work, we can notice that both the cut and weigh devices (F.R.L drape meter and Cusick drape meter) and image analysis equipments are based on umbrella projection method, namely traditional method, which makes the sample draped on a circular plate and captures its contour to evaluate drape. This method predicts and evaluates drape using a two-dimensional projection image, but fabric drape is a 3D deformation property [19] and different samples may have the same projection contour. More important, it also ignores a key aspect that the fabric is subjected to gravity perpendicular to its plane, which is contrary to most actual cases that the fabrics such as curtains, skirt, suit pants etc. are normally draped under their gravity parallel to the plane. So the traditional method is not appropriate and accurate enough, and a novel method is necessary.

Some researchers made attempt to test fabric drape with the method of 3D reconstruction, but they still use umbrella model to capture 3D contour of fabric [20–21]. Although the commercial 3D scanners can capture the 3D fabric model, they are normally expensive and not suitable for drape testing.

This paper proposed a new, low-cost and more reasonable method, the unidirectional drape testing method, which imitates the actual mechanical conditions of draped fabric to analyze drape performance. In this study, we designed a corresponding drape meter and established unidirectional fabric drape evaluation system from the real 3D draped contour. To verify the feasibility of our new method, we compared the accuracy of measurements from unidirectional method with those of the conventional method. In addition, a comparison was made with subjective evaluation to further prove the feasibility of this method.
Experimental Details

Equipment

The test work was carried out by a self-designed drape meter. This is a new, computer-controlled and 3D scanning based equipment. It consists of three parts: a clamp, a Kinect Sensor and a computer. The schematic diagram of the drape meter is shown in Fig 1. The sample is clamped in a manner at one end and hangs free at the other, as shown in Fig 2(A), which is the so called unidirectional fabric drape. The Kinect Sensor was mounted on slide guide and it can be driven by step motors to move side-to-side and up-to-down. The fabric sample can move forwards and backwards to adjust scanning distance. To capture clear image, the Kinect Sensor should scan the sample from different spatial locations repeatedly. Fig 2(B) shows a typical drape profile model captured by this method. The 3D model was then saved to the computer and processed by the image-analysis software to calculate unidirectional drape parameters.

The Kinect Sensor is actually a depth camera developed by Microsoft and it can enable us to capture 3D depth images. With the help of KinectFusion [22–23], a 3D point cloud splicing technology, the clear 3D model of the sample is obtained by fusing multiple depth images together in the same coordinate system.

To check the precision and repeatability of our equipment, a regular geometrical object cuboid of 562mm × 391mm × 112mm was chosen as the scanning object. Table 1 recorded the test data of 10 times measurements. It can be clearly seen that the relative error is about 0.3% and the maximum deviation is less than 2mm. Both the stability and reproducibility are very good. As for our test work, the relative error within 1% is acceptable. So the accuracy meets our test requirements.
Materials
For this study 20 pure polyester woven fabric samples with different weave structures were used. All the samples were conditioned at 65±2% relative humidity and 20±2°C temperature for 24 hours before measuring to relieve localized stresses caused by handling during preparation. We selected these samples because they are common in clothing fabrics and commercially available and less affected by temperature and humidity. The detailed physical properties of the samples are listed in Table 2.

Method
In this study, we chose the projective wave curve (as the red curve shown in Fig 2(B)) which was obtained by intercepting the 3D model with a horizontal plane from the bottom of the fabric as our evaluating object for the following reason: the closer the horizontal plane was to the holder, the stronger clamping effect to the sample would be, which meant that the fabric drape was not in a free hanging state and the result would not be accurate. Fig 3 is the projective wave curve we extracted. Through recognizing the peaks and the troughs (the blue and red points in Fig 3) of the wave curve, we can calculate unidirectional drape parameters such as unidirectional drape coefficient (UDC), wave numbers, bending index, peak height and peak width.
Here the UDC is a new parameter defined by Eq (1). It is created for the description of drape degree, which indicates that the smaller the value of UDC, the better the drape of the fabric.

\[ UDC = \frac{L_0 - L_1}{L_0} \times 100\% \] (1)

Table 1. Accuracy test of the equipment.

| No. | length/mm | width/mm | height/mm |
|-----|-----------|----------|-----------|
| 1   | 559       | 388.3    | 113.7     |
| 2   | 554.1     | 391.9    | 114       |
| 3   | 554.4     | 386.6    | 110.5     |
| 4   | 568.5     | 391.1    | 111.3     |
| 5   | 564       | 392.8    | 113       |
| 6   | 562.8     | 387.4    | 112.2     |
| 7   | 558.6     | 390      | 110.9     |
| 8   | 560.2     | 389.9    | 113       |
| 9   | 555.6     | 392.4    | 113.1     |
| 10  | 567.2     | 391.2    | 111.2     |

Average value 560.44 390.4 112.29

Actual value 562 391 112

Absolute error 1.56 0.6 0.29

Relative error 0.28% 0.15% 0.26%

Standard deviation 5.105 2.15 1.242

Relative standard deviation 0.91% 0.55% 1.11%

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Table 2. Basic properties of sample fabrics.

| Fabric | Weave structure | Thickness (mm) | Weight(g/m²) | Density (picks/inch) | Bending stiffness (cN.cm) |
|--------|----------------|----------------|--------------|----------------------|-------------------------|
|        |                |                |              | Warp     | Weft    | Warp | Weft |
| 1      | Plain          | 0.8            | 215          | 96       | 84      | 0.078| 0.088|
| 2      | Plain          | 4.542          | 321          | 120      | 100     | 0.23 | 0.226|
| 3      | Plain          | 0.722          | 65           | 105      | 77      | 0.006| 0.014|
| 4      | Plain          | 2.264          | 232          | 53       | 65      | 0.071| 0.045|
| 5      | Plain          | 0.324          | 78           | 121      | 99      | 0.058| 0.019|
| 6      | Plain          | 0.516          | 195          | 96       | 80      | 0.005| 0.007|
| 7      | Plain          | 0.496          | 166          | 119      | 102     | 0.178| 0.065|
| 8      | Plain          | 0.73           | 120          | 99       | 84      | 0.098| 0.034|
| 9      | 1/2 twill      | 1.238          | 167          | 112      | 85      | 0.119| 0.037|
| 10     | 1/2 twill      | 0.98           | 168          | 118      | 78      | 0.268| 0.037|
| 11     | 1/2 twill      | 1.5            | 262          | 101      | 101     | 0.216| 0.109|
| 12     | 1/2 twill      | 0.68           | 53           | 118      | 76      | 0.051| 0.081|
| 13     | 1/4 twill      | 0.506          | 133          | 111      | 95      | 0.066| 0.067|
| 14     | 1/4 twill      | 0.962          | 72           | 96       | 73      | 0.014| 0.013|
| 15     | 1/4 twill      | 0.704          | 81           | 66       | 80      | 0.046| 0.027|
| 16     | Satin          | 1.424          | 268          | 122      | 84      | 0.079| 0.076|
| 17     | Satin          | 0.658          | 104          | 124      | 102     | 0.089| 0.038|
| 18     | Satin          | 0.16           | 71           | 147      | 158     | 0.017| 0.018|
| 19     | Satin          | 0.472          | 103          | 113      | 91      | 0.1  | 0.051|
| 20     | Satin          | 0.134          | 78           | 89       | 105     | 0.012| 0.041|

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Where $L_0$ is the length of the specimen, $L_1$ is the folding width and $L_2$ is the draping width, as shown in Fig 4.

The bending index refers to the ratio of the curve length between two adjacent troughs (such as point 2 and point 3 in Fig 4) and their horizontal distance, which is used for describing the degree of the drapability. The wave numbers, peak height and peak width are also draping degree parameters and their definitions have no difference with the conventional draping parameters.

Fabric Height

It is obvious that the shape of fabric will be distinctly different when the fabric height changes. As the fabric height decreases, the clamping effect will be increasingly strong. But on the other hand, fabric shapes will be very random and the bottom crinkle tends to be a straight line if the height is too large. In order to choose the most proper height value, we made a comparison
among projective wave curves of the 20 fabrics at the height of 30cm, 40cm, 50cm and 60cm and selected 3 fabrics (see Fig 5) whose drape shape changed the most significantly.

As shown in Fig 5, with the decrease of fabric height, the projective wave curves tend to be similar. The wavenumbers are the fewest at the height of 60cm and the uniformity is the worst. The curve shapes of three fabrics change not very obviously at the height of 30cm and 40cm, which makes it difficult to discriminate good from bad drape performance among different samples. And when the height is set as 50cm, it is clear that the distinctions among three fabrics are the most obvious. Through above analysis, the sample height was selected 50cm finally. As for the fabric width, it correlates with unidirectional drape not very closely and in this study we set it as 87cm considering our equipment size.

### Clamping Manner

The clamping manner involves two aspects including clamping depth and width (Fig 6) and it has a significant effect on the unidirectional drape performance. It is difficult to form wave

![Clamping depth and width (top-view).](https://doi.org/10.1371/journal.pone.0143648.g006)
curve if the clamping depth is too small because of short wave amplitude, but on the contrary, too large clamping depth will reduce wavenumbers and form more regular wave curve, which means that the differences of curve shapes among fabrics will be less obvious. With the increase of clamping width, the wavenumbers will be fewer and fewer; the wave curve will overlap if the clamping width becomes too narrow, which makes it difficult for Kinect to capture the complete fabric contour.

In order to select an appropriate value of clamping depth and width, we set the clamping depth and width as 3cm, 4cm and 5cm respectively considering the fabric width. We captured

![Fig 7. Different unidirectional drape projection wave curves at different clamping depth.](doi:10.1371/journal.pone.0143648.g007)

![Fig 8. Different unidirectional drape projection wave curves at different clamping width.](doi:10.1371/journal.pone.0143648.g008)
### Table 3. Experimental results of fabrics drape by conventional method.

| Fabric | Drape coefficient (%) | Angle irregularity (%) | Peak height irregularity | Peak width irregularity (%) |
|--------|-----------------------|------------------------|--------------------------|----------------------------|
| 1      | 47.3                  | 9.255                  | 10.471                   | 9.726                      |
| 2      | 90.8                  | 8.977                  | 11.096                   | 11.404                     |
| 3      | 26.8                  | 10.051                 | 7.507                    | 6.695                      |
| 4      | 58.3                  | 7.051                  | 6.048                    | 4.245                      |
| 5      | 48.9                  | 10.794                 | 4.942                    | 7.428                      |
| 6      | 12.4                  | 2.187                  | 7.985                    | 7.3                        |
| 7      | 79.6                  | 5.347                  | 7.327                    | 8.684                      |
| 8      | 76.2                  | 11.173                 | 1.789                    | 3.427                      |
| 9      | 32.2                  | 5.753                  | 7.229                    | 3.566                      |
| 10     | 85.6                  | 6.618                  | 3.388                    | 3.812                      |
| 11     | 77.2                  | 6.168                  | 10.116                   | 10.518                     |
| 12     | 63.5                  | 5.377                  | 6.301                    | 8.007                      |
| 13     | 72.6                  | 3.816                  | 6.341                    | 6.579                      |
| 14     | 64.4                  | 10.08                  | 4.92                     | 4.4                        |
| 15     | 71.4                  | 7.667                  | 6.4                      | 1.693                      |
| 16     | 54                    | 9.953                  | 1.481                    | 1.2                        |
| 17     | 78.6                  | 11.77                  | 6.716                    | 5.751                      |
| 18     | 69.4                  | 9.514                  | 1.582                    | 2.105                      |
| 19     | 74.4                  | 6.618                  | 4.134                    | 7.659                      |
| 20     | 42.3                  | 6.632                  | 2.094                    | 5.171                      |

### Table 4. Experimental results of fabrics drape by unidirectional method.

| Fabric | UDC (%) | Peak numbers | Avg. bending index | Bending variation index (%) | Avg. peak height(mm) | Peak height variation index (%) | Avg. peak width (mm) | Peak width variation index (%) |
|--------|---------|--------------|--------------------|-----------------------------|----------------------|-------------------------------|----------------------|-------------------------------|
| 1      | 76.45   | 6            | 2.077              | 7.39                        | 40.126               | 8.073                         | 40.256               | 5.922                         |
| 2      | 44.84   | 4            | 7.901              | 17.861                      | 63.326               | 12.996                        | 57.027               | 6.62                          |
| 3      | 89.7    | 6            | 2.577              | 3.823                       | 45.716               | 14.627                        | 49.082               | 8.125                         |
| 4      | 75.6    | 6            | 2.684              | 6.419                       | 50.709               | 6.002                         | 46.061               | 6.265                         |
| 5      | 80.27   | 7            | 2.594              | 5.474                       | 44.889               | 4.155                         | 52.939               | 5.651                         |
| 6      | 92.78   | 7            | 2.387              | 2.668                       | 40.115               | 6.657                         | 55.764               | 7.513                         |
| 7      | 48.87   | 5            | 1.811              | 12.179                      | 43.628               | 11.083                        | 43.096               | 12.532                        |
| 8      | 59.31   | 6            | 2.124              | 12.95                       | 41.789               | 10.013                        | 57.331               | 8.652                         |
| 9      | 87.83   | 7            | 2.193              | 4.622                       | 42.692               | 7.015                         | 49.032               | 7.201                         |
| 10     | 56.52   | 5            | 2.222              | 11.608                      | 47.591               | 10.564                        | 48.64                | 9.562                         |
| 11     | 54.3    | 5            | 2.148              | 8.001                       | 50.058               | 11.688                        | 49.18                | 9.628                         |
| 12     | 69.57   | 5            | 2.263              | 13.022                      | 47.391               | 7.877                         | 51.315               | 11.526                        |
| 13     | 60.87   | 5            | 2.385              | 12.722                      | 45.051               | 9.233                         | 60.281               | 7.654                         |
| 14     | 72.91   | 7            | 2.263              | 8.975                       | 39.924               | 4.444                         | 47.908               | 9.854                         |
| 15     | 66.45   | 7            | 2.265              | 10.816                      | 41.352               | 7.85                          | 52.5                 | 7.485                         |
| 16     | 77.36   | 7            | 2.743              | 11.884                      | 50.413               | 5.077                         | 46.261               | 5.598                         |
| 17     | 57.68   | 6            | 2.317              | 10.651                      | 42.783               | 10.498                        | 57.755               | 8.486                         |
| 18     | 64.77   | 6            | 2.397              | 10.822                      | 45.359               | 6.139                         | 43.143               | 3.634                         |
| 19     | 63.26   | 6            | 2.656              | 10.179                      | 45.924               | 8.187                         | 54.166               | 7.233                         |
| 20     | 84.52   | 7            | 2.748              | 7.881                       | 42.506               | 5.211                         | 51.351               | 10.621                        |
the projective wave curve of three fabrics mentioned above at the clamping depth and width of 3cm, 4cm, and 5cm respectively and the results are listed in Figs 7 and 8. We can see that larger clamping depth and width value give more regular shapes and smaller differences among fabrics. The wavenumbers are the fewest and the wave shapes are not obvious especially in Fabric 8 and 2 at the clamping depth of 3cm and the clamping width of 3cm. As for clamping depth and width of 4cm and 5cm, the latter is more difficult to compare unidirectional drape
differences among three fabrics than the former. So clamping depth and width of 4cm is better recommended value for the unidirectional draping measurements.

**Results and Analysis**

This study employed CNS (Chinese National Standard) GB/T23329-2009 *Textiles. Determination of drapability of fabrics* to represent the conventional method and performed comparisons with the novel method proposed in this paper. Tables 3 and 4 showed the drape parameters of 20 fabrics of both methods. We only listed the main drape degree and aesthetics parameters that determine drape performance to a large extent according to previous researches.

Here, the angle irregularity refers to the variation coefficient of the angle between two adjacent peaks and it is calculated as the following formula.

\[
\hat{\theta} = \frac{1}{\bar{\theta}} \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (\theta_i - \bar{\theta})^2} \times 100\%
\]
Where $\bar{\theta}$ is the angle irregularity, $\bar{\theta}$ is the average value of peak angle, $\theta_i$ is the angle value between neighboring fold peaks (see Fig 9).

We cannot compare these two methods straightly since the testing principles of these two methods are completely different. So a comprehensive index describing fabric drape is needed. In this research, we calculated the weighting coefficients of each drape parameters with the main-factor analysis of SPSS 17 software and a comprehensive index, namely aesthetic coefficient, was obtained and given as Eqs (3) and (4), respectively.

\[
B_1 = 0.461f + 0.109\bar{\theta} + 0.14\bar{h} + 0.207\bar{d}
\]

(3)

Where $B_1$ is the aesthetic coefficient of conventional method, $f$ is the drape coefficient, $\bar{\theta}$ is the angle irregularity, $\bar{h}$ is peak height irregularity, and $\bar{d}$ is peak width irregularity;

\[
B_2 = 0.553f_u + 0.243\theta + 0.168h
\]

(4)

Where $B_2$ is the aesthetic coefficient of unidirectional method, $f_u$ is the unidirectional drape coefficient, $\theta$ is the bending variation index, and $h$ is the peak height variation index.

Linear regression analysis was used to evaluate correlations between $B_1$ and $B_2$ and the result was shown in Fig 10. The correlation coefficient at the 1% level of significance was 0.964 which showed a highly correlated linear relationship between $B_1$ and $B_2$. In another words, the unidirectional method is quite consistent with conventional method in drape parameters given by these two methods. So the unidirectional method is acceptable and equivalent to the conventional method in describing fabric drape performance.

Drape is a subjective property and results produced by drape meters should correlate with subjective evaluation [14]. In this research, we invited 10 professionals and 10 non-professionals to evaluate drape performance. The drape performance was divided into 5 grades from bad
The scores range from 1 to 20 where 20 represents the best of drape performance and 1 is the worst. The evaluators graded each sample through judging the drape degree and aesthetic feeling of drape shapes using their visual sense. The final score is calculated as this formulation: \((\text{professionals} \times 60\% + \text{non-professionals} \times 40\%) / 10\). We sorted the final score and \(B_2\) calculated above and listed the ranking results in Table 5. In order to determine the relationships between subjective evaluation and unidirectional method, we made a linear regression analysis of score rank and \(B_2\) rank as shown in Fig 11. The correlation coefficient at the 1% level of significance was 0.967 and it can be clearly seen that unidirectional method correlates strongly with subjective method in evaluation of fabric drape. So there is no significant difference between these two methods in describing fabric drape.

**Conclusion**

A new fabric drape testing method was presented and corresponding drape meter with automatic measuring system was devised. This is a new, low-cost, non-contact scanning and 3D measurement method.
A new parameter, unidirectional drape coefficient (UDC), which is used to describe drape degree, was created in our work. And the other unidirectional parameters such as peak height, peak width, bending index and wavenumbers were obtained from the 3D fabric contour.

In order to investigate the feasibility of the unidirectional testing method, we compared the result of unidirectional method with those of conventional method and subjective evaluation method respectively. It confirmed that the unidirectional method was quite consistent with conventional method and subjective evaluation. Thus unidirectional fabric drape testing method can be implemented on a rapid and automatic basis to enable full characterization of the drape profile of fabrics.

Unidirectional fabric drape testing method has some advantages over conventional method. First, this method simulates the mechanical conditions of fabric drape in actual situation where the gravity is parallel not vertical to fabric plane, so the results of unidirectional drape testing method is closer to that of real. Second, this is a 3D measurement and it can reflect drape performance more completely. Third, the fabric drape is not influenced by fabric transmittance. But this method only uses polyester material and woven fabrics as our testing materials. We will test unidirectional drape of different materials and fabric structures to further confirm the feasibility of this new method. And we do not discuss which factors and how they influence unidirectional drape performance because of limited time. The subsequent study will put emphasis up on discussing factors influencing unidirectional drape to find relationships between these factors and unidirectional drape.

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Author Contributions
Conceived and designed the experiments: HZ ZM WS. Performed the experiments: ZM WS JY TZ YW. Analyzed the data: ZM. Contributed reagents/materials/analysis tools: ZM WS. Wrote the paper: ZM.

References
1. Agrawal S.A. Study Of Height Dependency Of Drape Parameters. International Journal of Engineering Research and Application. 2013; 3: 261–265.
2. Mizutani C., Amano T., Sakaguchi Y. A. New Apparatus for the Study of Fabric Drape. Textile Research Journal. 2005; 75(1): 81–87.
3. Geršak J. Investigation of the Impact of Fabric Mechanical Properties on Garment Appearance. Tekstil. 2003; 52:368–378.
4. Geršak J. Study of Relationship Between Fabric Elastic Potential and Garment Appearance Quality. International Journal of Clothing Science and Technology. 2004; 16: 238–251.
5. Agrawal S.A., Patel D.P., Vasavada D.A. Numerical Simulation of Three Dimensional Drape. Man-Made Textiles in India. 2011; 39: 363–366.
6. Collier B.J. Measurement of Fabric Drape and Its Relation to Fabric Mechanical Properties and Subjective Evaluation. Clothing and Textiles Research Journal. 1991; 10: 46–52.
7. Lim H., Istook C.L. Drape Simulation of Three-Dimensional Virtual Garment Enabling Fabric Properties. Fibers and Polymers. 2011; 12: 1077–1082.
8. Lojen D.Z., Jevsnik S. Some Aspects of Fabric Drape. FIBRES & TEXTILES in Eastern Europe. 2007; 15: 39–45.
9. Sanad R., Cassidy T., Cheung V. Fabric and Garment Drape Measurement-Part 1. Journal of Fiber Bioengineering & Informatics. 2012; 5: 341–358.
10. Peirce F.T., B.Sc., F.Inst.P., F.T.I. THE “HANDLE” OF CLOTH AS A MEASURABLE QUANTITY. Journal of the Textile Institute Transactions. 1930; 21: 377–416.
11. Chu C.C., Cummings C.L., Teixeira N.A. Mechanics of Elastic Performance of Textile Materials: Part V: A Study of the Factors Affecting the Drape of Fabrics -The Development of a Drape Meter. Textile Research Journal. 1950; 20: 539–548.

12. Chu C.C., Platt M.M., Hamburger W.J. Investigation of the Factors Affecting the Drapeability of Fabrics. Textile Research Journal. 1960; 30: 66–67.

13. Jeong Y.J. A Study of Fabric-Drape Behaviour with Image Analysis Part I: Measurement, Characterisation, and Instability. The Journal of The Textile Institute. 1998; 89: 59–69.

14. Cusick G.E. THE DEPENDENCE OF FABRIC DRAPE ON BENDING AND SHEAR STIFFNESS. Journal of the Textile Institute Transactions. 1965; 56: 596–606.

15. Behera B. K., Mishra R. Objective measurement of fabric appearance using digital image processing. The Journal of The Textile Institute. 2006; 97: 147–153.

16. Kenkare N., May-Plumlee T. Fabric Drape Measurement: A Modified Method Using Digital Image Processing. Journal of Textile and Apparel, Technology and Management. 2005; 4: 1–8.

17. Tsai K-H., Tsai M-C., Wang P-N., Shyr T-W. New Approach to Directly Acquiring the Drape Contours of Various Fabrics. FIBRES & TEXTILES in Eastern Europe. 2009; 17: 54–59.

18. Vangheluwe L., Kiekens P. Time Dependence of the Drape Coefficient of Fabrics. International Journal of Clothing Science and Technology. 1993; 5: 5–8.

19. Thilagavathi G., Natarajan V. Development of a method for measurement of fabric three-dimensional drape and studies on influencing factors. Indian Journal of Fibre & Textile Research. 2003; 28: 41–49.

20. Yi S., Hua Z., Hongyuan Y. Model ZYF-3 fabric-drape three-dimensional tester. Journal of Textile Research. 2008; 29: 118–122.

21. Thilagavathi G., & Natarajan V. 3-D measurement of fabric drapeability. The Indian Textile Journal. 2003; 113: 27–31.

22. Richard A., Izadi S., Hilliges O., Molyneaux D., Kim D. KinectFusion: Real-Time Dense Surface Mapping and Tracking. 10th IEEE International Symposium on; 2011 Oct 26–29; Basel, Switzerland: Mixed and Augmented Reality (ISMAR); 2011. p. 127–136.

23. Izadi S., Kim D., Hilliges O., Molyneaux D., Newcombe R., Kohli P., et al. KinectFusion: Real-Time 3D Reconstruction and Interaction Using a Moving Depth Camera. Proceedings of the 24th annual ACM symposium on User interface software and technology; 2011 Oct 16–19; Santa Barbara, CA, USA: UIST'11; 2011. p. 559–568.