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A Method for the Classification of Fabric Hand Based on it Drape

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Abstract- In this paper fabric hand was objectively evaluated through the exploration of three-dimensional drape. Four Windows Kinect sensors were arranged to capture the point cloud data of the draped fabric. To extract the actual drape features, a new algorithm was designed and implemented in Matlab technical computing environment. Thirty seven woven fabrics were clustered in accordance with subjective hand preferences of softness and stiffness collectively as ground truth. The performance of the objectively clustered data was evaluated against the ground truth. The results revealed that the objective classification of the fabrics using 3D drape data correlated to the fabric hand preferences with 86 % matching accuracy when applied on same fabrics. The evaluation of hand from fabric drape in a non-touch manner will be a better reference for online shopping and computer simulation.

Keywords- Fabric hand, Fabric classification, 3D Drape model, Principal Component Analysis, Drape.

I. INTRODUCTION

In recent years, online business is booming due to its convenience and economy. Contrarily, online sale and purchase of fabrics are restricted due to virtual environment of the e-business. The real-time fabric hand sensation is considered to be more satisfactory as compared to virtual assessment. For online-shopping, evaluation of fabric hand is still a looming problem as the fabrics and garments cannot be touched. The non-availability of any acceptable and viable method to classify fabrics based on its hand requires a robust and acceptable solution.

Drape is an important and complex phenomenon of fabric appearance. Drape Coefficient (DC) i.e. the two dimensional area under the draped fabric, peaks, their intensity and shapes are considered to be the most important parameters that define the fabric drape [1, 2]. Over the years, efforts have been made to classify fabrics using drape parameters obtained by Cusick drape tester [3]. Though from 1950 to 2013, almost thirty six drape indicators have been described in the literature, DC still continues to be the most widely used and acceptable drape parameter [4]. A new drape coefficient, dependent upon draped fabric shape and drape angle was presented and correlated with fabric flexural rigidity by the scientists elsewhere [5]. However, DC's inadequacy to completely account for drape-shape requires exploring more drape-related parameters that may correlate better with the complex phenomenon of fabric hand.

The fabric drape has long been realized a 3D phenomenon. Therefore, in recent years emerging technologies have been taken advantage in determining 3D drape of fabrics [6]. For instance, 3D scanned images have been used to measure the drape parameters for fabric [7]. However, due to the older measuring principle of drape, non-significant results were obtained. A new measuring principle in which force of gravity acts perpendicular to fabric plane was proposed along with new characterizing parameters [8]. These parameters were claimed to be more conforming with actual aesthetics of fabric drape.

On the other hand, physical instruments like PhabrOmeter along with fabric linear density was proposed as an alternate test to fabric drape measurement [9]. Physical involvement of instruments for the evaluation of fabric hand is the hindrance to accept these methods for online customers. Therefore, there is a need to delve deep into vision perspective (3D drape) for the objective classification of fabric samples based on hand attributes.

In the research work there has been suggested a new approach derived from 3D drape for the classification of fabrics based on hand. Three dimensional drape-images were captured by Kinect depth sensors. The numerical data obtained from depth sensors were processed in software to reconstruct the 3D surface. Drape models were analyzed with newly developed algorithms to extract drape indicators. The objectively acquired drape data were classified using Hierarchical clustering technique and validated with the ground truth.

II. MATERIALS AND METHODS

Thirty seven commercially available woven fabrics were collected from the market. The circular fabric samples having diameters of 240 mm were hung freely in umbrella shape under gravitational force on the disk (diameter 120 mm) placed on a tripod. The 3D fabric-drape positional numerical data was generated by special arrangement of Windows Kinect sensors. The 3D images of fabrics were processed in Geomagic software (3D Systems, USA) to get refined polygonal mesh. The main steps of the current study are shown in Fig. 1.

A. Scanning of 3D drape

Windows Kinect sensors were arranged to capture point cloud data from the actual shape of 3D drape. The computer-controlled sensors use infrared-waves to capture the image-depth. Kinect sensors require scanning the image at different locations to capture 3D view. Therefore, four Kinect sensors placed at corners of the square table were used to scan 3D drape of the fabric.

B. Registration

Kinect sensors use RGB and infrared sensors to capture 3D image. Coordinates of these sensors need to be unified for better image quality. Therefore, registration using Smisek et al.'s algorithm was performed to align both the images (RGB & IR) [10].

C. De-noising and 3D Surface Reconstruction

The captured 3D drape cloud data were processed in different software packages. First, the data were imported into the Geomagic software (3D Systems, USA) for noise removal and polygonal mesh refinement as shown in the Fig. 2 a & b.

D. Slicing and Feature Extraction

An algorithm was designed and implemented in the Matlab software (MathWorks, USA) for the processing of 3D drape images. Slices were drawn automatically on the surface of 3D drape model as shown in Fig. 2a. Drape indicators were then derived for the further analysis of the data. To understand the multidimensionality of the drape data, principal component analysis (PCA) was performed to increase the perception of data with minimum loss of information [11, 12].

E. Subjective and Objective Assessment

Samples measuring 300×300 mm were taken for the subjective assessment of fabric subjective softness and stiffness [13]. A training session was organized to help the assessors become familiar with the descriptors as well as the methods of handling the samples for the required subjective hand preferences [14-16]. On the other hand, to assess samples objectively, four drape variables i.e., drape coefficient, minimum drape, average trough and drape height were assessed through Hierarchical clustering.

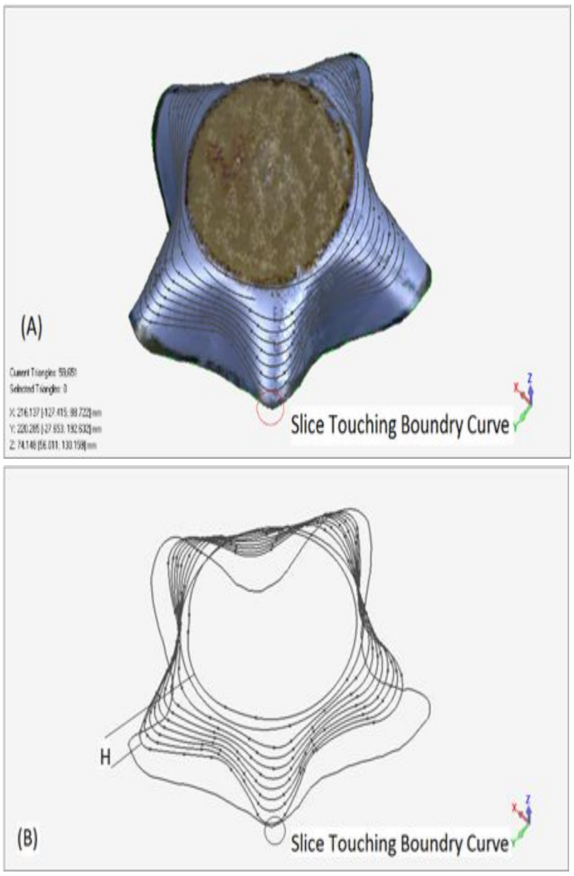

Fig. 2: Slicing of three dimensional drape model, (A) 3D drape model with slice curves, (B) slice curves and boundary curves.

F. Cluster Analysis

Polythetic Aglomerative Hierarchical Clustering (PAHC) technique was chosen to classify the 3D drape data objectively. In principle, the algorithm starts from singleton-clusters and merge those clusters with minimal distances until all objects are included in one cluster. The

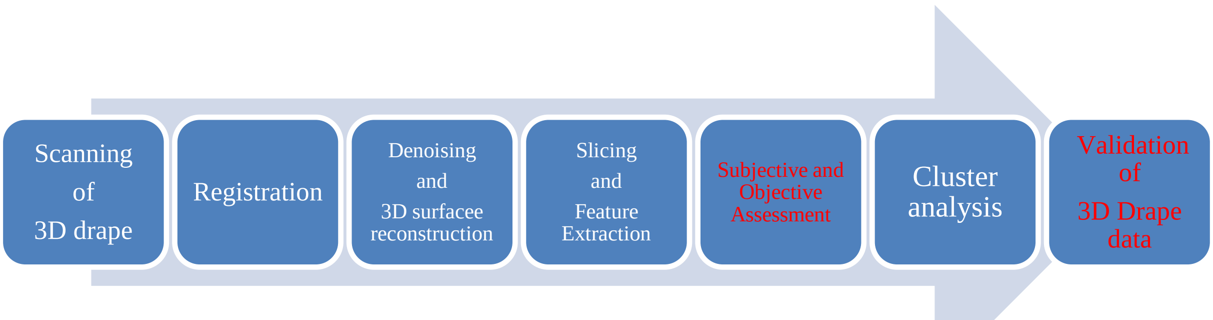

Fig. 1: Main Stages involved in the determination of fabric objective hand

average linkage (L) is defined below mathematically in (1),

$$L = \frac{1}{|A||B|} \sum_{a \in A} \sum_{b \in B} d(a, b) \quad (1)$$

where *d* selected as metric (Euclidian distance); $d(a, b)$ is the distance between two elements of clusters A and B.

The clustering procedure is completed in an n-dimensional space (*n* is the number of variables); this means during clustering the difference of every parameter between samples is considered, so the results are much more realistic and definite, this being a unique advantage of clustering compared to other statistical approaches [17].

Requirements of data and sphericity (homogeneity of variances) for further processing of data through principal component analysis was checked with Kaiser-Mayer-Olkin test and Bartlett's test respectively, as shown in Table I.

TABLE I. KMO AND BARTLETT'S TEST OF 3D DRAPE DATA

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Sampling Adequacy		0.83
Bartlett's Test of Sphericity	Sig.	0.000

G. *Validation of 3D-Drape Data*

For the validation of results, an external criterion was adopted which measured the performance of the PAHC technique in terms of matching accuracy. Let x_i denotes the number of objects correctly matched to the i^{th} cluster C_i; *f* is matching accuracy, mathematically is described as follows,

$$f = \frac{1}{n} \sum_{i=1}^{k} x_i \quad (2)$$

where *k* is the number of clusters and *n* is the total number of samples assessed.

III. Results and Discussions

PCA was applied on drape parameters to classify fabrics objectively with the fabric hand preferences in terms of softness and stiffness. Two principle components explaining 95.54% data variability were selected.

Samples requiremnet and data sphericity (homogeneity of variances) results were validated with Kaiser-Meyer-Olkin Sampling Adequacy test and Bartlett's Test of Sphericity. The value of Kaiser-Mayer-Olkin sampling adequacy test was observed 0.83 (more than 0.5) proved that the selected number of samples (37) are statistically large enough for further processing of the data with PCA. Results of the subjective hand preferences of fabric softness and stiffness classified the samples into three clusters, representing the classes of fabrics viz., class 1(soft), class 3 (moderately stiff) and class 2 (stiff) as shown in column 2 of the Table II.

To match fabric preferences objectively with subjective hand preferences, drape data were processed through PCA and clustered. Interestingly, the objective data were also classified into three classes as was the case with fabric hand preferences as shown in Table II.

TABLE II. CLUSTER VALIDATION FOR FABRIC HAND AND DRAPE

Sample No.	Cluster Numbers	
	Fabric Hand	Fabric Drape
1	**1**	**1**
2	**1**	**1**
3	**2**	**2**
4	**2**	**3**
5	**3**	**3**
6	**3**	**3**
7	**3**	**3**
8	**3**	**3**
9	**3**	**3**
10	**3**	**3**
11	**2**	**2**
12	**1**	**1**
13	**1**	**1**
14	**3**	**3**
15	**3**	**2**
16	**2**	**2**
17	**2**	**2**
18	**2**	**2**
19	**2**	**2**
20	**2**	**2**
21	**2**	**2**
22	**3**	**2**

23	**2**	**2**
24	**2**	**3**
25	**2**	**2**
26	**3**	**2**
27	**2**	**2**
28	**2**	**2**
29	**2**	**2**
30	**2**	**2**
31	**3**	**3**
32	**2**	**2**
33	**1**	**1**
34	**1**	**1**
35	**1**	**1**
36	**1**	**1**
37	**1**	**1**
Matching Accuracy	**32 / 37 = 86%**	

To validate the clustered data (subjective hand preferences and 3D drape) matching accuracy of the objective (PCA) classification with subjective hand preferences of fabric softness and stiffness combined was examined. The overall matching accuracy using (2) was observed f = 86% i.e. 32 out of 37 samples matched correctly with the objective clustering of 3D drape in respective clusters. The entire sample was divided into three hierarchical clusters objectively, as was the case of ground truth, shown in Fig. 3 and Table II. Cluster 1 represented the soft, cluster 2 represented the stiff and cluster 3 represented the moderately stiff fabrics. Overall, five out of thirty seven specimens were miss classified in different clusters as shown in Fig. 3 and Table II. It means fabric hand from 3D drape was successfully classified based on the customer subjective preference.

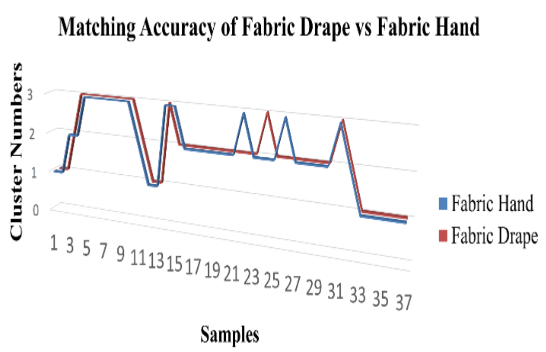

Fig. 3. Pairwise matching accuracy of clustered values of fabric hand and 3D drape.

IV. Conclusions

This paper presented efficaciously an objective method for the classification of fabric-hand derived from 3D numerical datasets of fabric drape. The fabrics were scanned to get 3D drape models using a method developed in our earlier research with the low-cost devices. Objective classification of fabrics based on 3D drape significantly matched with subjective hand assessments. Fabrics were represented by three classes. In future, more 3D drape indicators need to be explored to enhance the matching accuracy of fabric drape with its hand.

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