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## Introduction

We recognise a texture when we see it, but it is very difficult to define [1]. Texture refers to properties that represent the surface or structure of an object; it is widely used and perhaps intuitively obvious, but it has no precise definition due to its wide variability [2].

Several authors have attempted to qualitatively define texture. Pickett states that "texture is used to describe two dimensional arrays of variations. The elements and rules of spacing or arrangement may be arbitrarily manipulated, provided a characteristic repetitiveness remains." Hawkins provided a more detailed description of texture: "The notion of texture appears to depend upon three ingredients: (1) some local ,order' is repeated over a region which is large in comparison to the order's size; (2) the order consists in a nonrandom arrangement of elementary parts, and (3) the parts are roughly uniform entities of approximately the same dimensions everywhere within the textured region." Although these descriptions of texture seem perceptually reasonable, they do not immediately lead to simple quantitative textural measures in the sense that the description of an edge discontinuity leads to a quantitative description of the edge in terms of its location, slope angle, and height [3].

A texture image has a number of perceived qualities which play an important role in describing texture [1]. Several methods have been introduced to identify and quantify different features of texture images, some of the most important of which are as follows [1, 2]:

# Machine Vision Analysis for Textile Texture Identification

#### Abstract

Texture identification and matching a sample fabric within a known collection of produced fabrics is a time-consuming and difficult process as a human activity. In this study, a computational method for textile texture identification is introduced using an image analysis technique. For this purpose, images of fabrics were captured by a digital flat scanner. Texture features were extracted using the Edge frequency and Gray Level Co-occurrence Matrix (GLCM) methods. In this way, a library of texture features was collected. To match a new texture with library samples, the closest texture feature based on Euclidian distance was identified as the fabric texture. Experimental results for 33 different textures showed the successful identification of textures with both methods. However, the edge frequency method is more feasible and acceptable due to its computational simplicity and lower processing time. In addition, it was shown that the edge frequency method is extremely insensitive to the colour and scanning direction of the fabric.

Key words: texture, textile, knitted, edge frequency, Gray Level Co-occurrence Matrix.

- 1. Statistical Methods, such as Co-occurrence Matrices, Autocorrelation Features and edge frequency
- 2. Geometrical Methods, such as Voronoi Tessellation Features and Structural Methods
- 3. Model Based Methods, such as Random Field Models and Fractals
- 4. Signal Processing Methods, such as Spatial Domain Filters, Fourier domain filtering and Gabor and Wavelet models.

Textile samples usually consist of several types of textures, thuse texture analysis techniques can be applied for different purposes in the textile industry [4 - 10]. The central point of some of these studies will be mentioned here. Different texture analysis methods have been used for automatic defect inspection of textile fabrics [4, 5]. In this way, the fabrics' defects are recognised using the changes in texture features. The texture characteristics of woven fabrics have already been implemented to recognise fabric structures automatically [6]. The method involved stabilising a Wiener filter adapted to the woven fabric texture. It was shown that the density of some woven fabrics, including plain, twill and satin can be calculated and the structure clearly identified [6]. Texture analysis has also been applied to recognise the fabric nature and type of main weaving texture [7]. To this end, the co-occurrence matrix was applied to extract the texture features and then the learning vector quantization network was adopted as a classifier. In another study, texture analysis was used for the identification of weave types in a fabric [8]. It was shown that this method can be used as a non-destructive method

to decrease human intervention in analysing fabric weave types, especially in the context of ancient textiles [8]. In another study a clustering algorithm based on Back-propagation Neural Network Fuzzy Clustering analysis was introduced to recognise the type of textile texture [9], in which it was shown that this method can identify accurately plain weave, twill weave and satin weave textures in woven fabric, single and double textures in knitted fabric, and non-woven texture in non-woven fabric. Texture analysis has also been proposed to evaluate mechanical abrasion based on the change in texture image properties [10]. It was shown that mechanical wear may result in a decrease in texture definition and a tendency toward randomness.

The aim of the present study was to introduce a suitable computational method for identifying textile fabrics from a library of samples according to their texture features.

#### Texture Metrics

#### **Edge frequency method**

In the edge frequency method, a gradient function is defined as the distance between the pixels used for identifying texture features [2]. The distance-dependent texture description function g(d) is computed for any subimage f defined in the neighborhood N for a variable distance d:

$$g(d) = |f(i, j) - f(i + d, j)| + + |f(i, j) - f(i - d, j)| + + |f(i, j) - f(i, j + d)| + + |f(i, j) - f(i, j - d)|$$
(1)

Function g(d) is similar to the negative autocorrelation function; its minimum corresponds to the maximum of the autocorrelation function, and its maximum corresponds to the autocorrelation minimum. In this equation, micro-edges can be detected using small-distance operators, and macro-edges need large-size edge detectors.

#### Gray level co-occurrence matrix

The Gray Level Co-occurrence Matrix (GLCM) estimates image properties related to second-order statistics based on the repeated occurrence of a certain gray level configuration in the texture [1, 2]. The occurrence of a gray level configuration may be described by a matrix of relative frequencies  $P_{\varphi,d}(a,b)$ , describing how frequently two pixels with gray levels *a* & *b* appear in the window separated by distance *d* in direction  $\varphi$ . Some texture features are defined based on  $P_{\varphi,d}$ data, such as Energy, Entropy, Maximum frequency, Contrast, Inverse difference moment and Correlation [2]. As an example, the energy is defined by the following equation:

$$Energy = \sum_{a,b} P_{\phi,d}^2(a,b)$$
(2)

$$Entropy = \sum_{a,b} P_{\phi,d}(a,b) \log_2 P_{\phi,d}(a,b)$$
(3)

Maximumy probability = 
$$\max_{a,b} P_{\phi,d}(a,b)$$
 (4)

$$Contrast = \sum_{a,b} |a-b|^{\chi} P_{\phi,d}^{\lambda}(a,b)$$
(5)  
(typically  $\chi = 2, \lambda = 1$ )

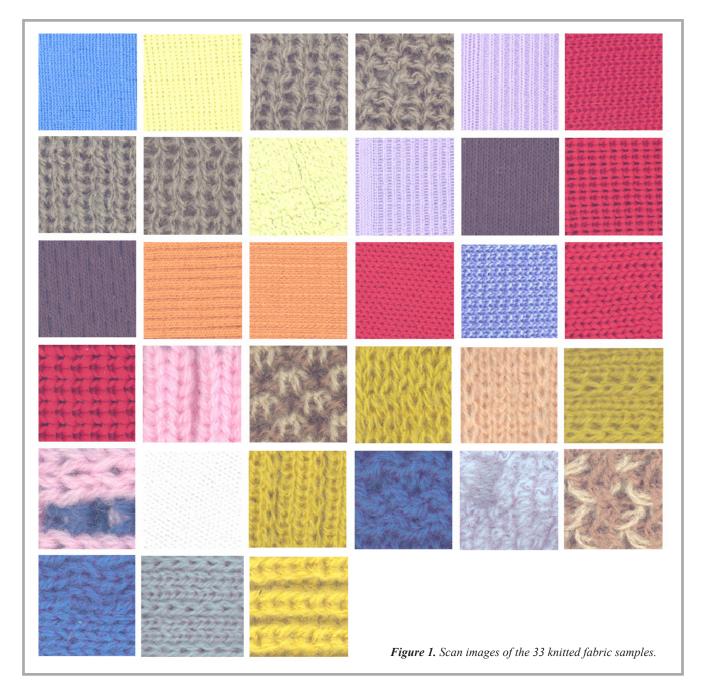
Inverse difference moment =  

$$= \sum_{a,b;a\neq b} \frac{P_{\phi,d}^{\lambda}(a,b)}{|a-b|^{\chi}}$$
(6)

In the above equation,  $\mu_x$  and  $\mu_y$  indicate means, and  $\sigma_x$  and  $\sigma_y$  are standard deviations.

## Experimental

To show the feasibility of the method for textile texture identification suggested, a library of texture features was collected,



which contains a set of 33 knitted fabric samples with different types of textures. An image of each sample was captured using a HP Scanjet 7400c scanner. *Figure 1* shows images of the fabrics applied. Then the colour images were converted to grey scale ones (luminance channel) according to the Federal Communication Commission's (FCC) colour space [11]:

$$I_{gray} = 0.2989R + 0.5870G + 0.1140B \quad (3)$$

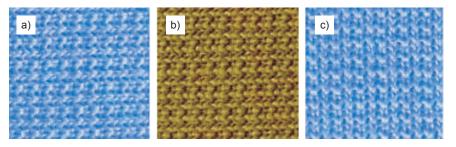
The texture features of each sample were computed by applying the edge frequency method. For this purpose, the gradient function in *Equation 1* was computed for distance values (d) of 1, 2, 3, 4, 5, ..., 10. This width range of d was chosen to support micro and macro features in the different kinds of textures.

To match a new texture with library samples, an image of the sample was first captured, and then its texture features were computed using *Equation 1* with specified values of d (as was done for the library set). Then the closest texture feature was identified based on the Euclidian distance between the features of the sample obtained, and each sample of the library was set as *Equation 4*. In this equation, *TextureDiff*<sub>i</sub> indicates the texture difference between the sample and ith sample of the library.

$$TextureDiff_{i} = \sqrt{\sum_{d} (g(d) - g_{i}(d))^{2}} \quad (4)$$

Therefore, if the library consists of n samples, then n texture differences are obtained for each one. The closest fabric texture with the minimum value of Euclidian distance calculated (*TextureDiff*) was reported as the sample texture. It should be mentioned that if the Euclidian distance was larger than the threshold value, the algorithm response was that "there is no matching texture in the library".

Furthermore, the GLCM method was applied in which six features were computed: Energy, Entropy, Maximum frequency, Contrast, Local Homogeneity and Correlation Coefficient. The correlation coefficient values were close to zero so they could be omitted. Again for a specified sample, these features were computed and then matched to the library based on the lowest Euclidian distance. The values of  $\varphi$  were selected as 0, 45, 90, 135 and *d* (distance between two gray levels) was set to 4. In this part,



*Figure 2.* (*a*): One of the library textures, (*b*) sample with a similar texture to "a" but with a different colour, (*c*) sample with similar texture to "a" but in adifferent scanning direction.

*TextureDiff*<sub>i</sub> is computed by *Equation 5*. According to this formula, the Euclidian distance between the GLCM features of the sample with each ith sample of the library is calculated for each angle. The *TextureDiff*<sub>i</sub> is defined as the summation of results obtained for each angle.

$$TextureDiff_i = (5)$$

$$= \sum_{\varphi} \sqrt{\sum_{f} \left( GLCM(f, \varphi) - GLCM_{i}(f, \varphi) \right)^{2}}$$

A library of the texture features of 33

Results and discussion

knitted fabric images was collected. *Table 1* shows the edge frequency features of each sample for 10 *d* values. Similarly *Table 2* indicates the GLCM feature measures of the 33 fabrics. The decimal parts of the values were negligible and omitted.

The test images were different to the library images to such an extent that they

d	1	2	3	4	5	6	7	8	9	10
1	0.3626	0.4027	0.3242	0.2469	0.3834	0.3905	0.3012	0.2869	0.4027	0.3769
2	0.0998	0.1411	0.1408	0.1220	0.1081	0.1024	0.1034	0.1278	0.1271	0.1277
3	0.2372	0.3137	0.3543	0.3831	0.4053	0.4220	0.4324	0.4372	0.4379	0.4350
4	0.2464	0.3298	0.3788	0.4124	0.4386	0.4576	0.4724	0.4822	0.4874	0.4868
5	0.2448	0.3284	0.3727	0.4029	0.4239	0.4359	0.4420	0.4407	0.4334	0.4234
6	0.2226	0.2920	0.3299	0.3578	0.3772	0.3917	0.4011	0.4078	0.4133	0.4126
7	0.1150	0.1442	0.1502	0.1494	0.1486	0.1502	0.1520	0.1516	0.1503	0.1477
8	0.2886	0.3510	0.2910	0.3106	0.3988	0.3737	0.2846	0.3247	0.3478	0.2552
9	0.2616	0.3262	0.2756	0.2662	0.3238	0.3160	0.2596	0.2916	0.3105	0.2611
10	0.1504	0.1742	0.1544	0.1575	0.1582	0.1327	0.1513	0.1801	0.1603	0.1470
11	0.1545	0.1805	0.1630	0.1683	0.1736	0.1644	0.1769	0.1817	0.1754	0.1787
12	0.2311	0.2635	0.2279	0.2621	0.2702	0.2316	0.2460	0.2589	0.2518	0.2607
13	0.2560	0.2819	0.2342	0.2617	0.2576	0.2284	0.2283	0.2371	0.2561	0.2865
14	0.1577	0.2067	0.2219	0.2312	0.2222	0.2077	0.1916	0.1868	0.2007	0.2101
15	0.1999	0.2441	0.2160	0.2330	0.2347	0.2000	0.2296	0.2267	0.1693	0.2020
16	0.1609	0.2247	0.2496	0.2515	0.2504	0.2400	0.2130	0.1843	0.1889	0.2223
17	0.1478	0.2165	0.2600	0.2764	0.2745	0.2574	0.2300	0.2106	0.2188	0.2361
18	0.1500	0.2105	0.2446	0.2589	0.2552	0.2407	0.2283	0.2194	0.2135	0.2135
19	0.1213	0.1629	0.1934	0.2155	0.2291	0.2361	0.2388	0.2378	0.2340	0.2262
20	0.1366	0.1813	0.2133	0.2398	0.2610	0.2789	0.2922	0.2994	0.3003	0.2956
21	0.2146	0.2788	0.3260	0.3647	0.3950	0.4187	0.4377	0.4529	0.4638	0.4710
22	0.1912	0.2625	0.3058	0.3361	0.3584	0.3692	0.3699	0.3645	0.3574	0.3510
23	0.1551	0.2154	0.2529	0.2732	0.2765	0.2693	0.2589	0.2519	0.2503	0.2545
24	0.1168	0.1903	0.2297	0.2519	0.2620	0.2632	0.2587	0.2534	0.2522	0.2558
25	0.1721	0.2221	0.2624	0.2976	0.3298	0.3584	0.3844	0.4067	0.4259	0.4428
26	0.0694	0.0916	0.0958	0.0969	0.0887	0.0786	0.0920	0.0954	0.0912	0.0911
27	0.1845	0.2503	0.2891	0.3144	0.3281	0.3293	0.3227	0.3147	0.3087	0.3078
28	0.1407	0.1702	0.1864	0.1988	0.2088	0.2168	0.2234	0.2281	0.2308	0.2324
29	0.1744	0.2194	0.2495	0.2692	0.2808	0.2893	0.2949	0.2992	0.3033	0.3051
30	0.2127	0.2856	0.3311	0.3681	0.3967	0.4186	0.4352	0.4475	0.4578	0.4663
31	0.1456	0.1943	0.2129	0.2267	0.2372	0.2445	0.2483	0.2488	0.2471	0.2425
32	0.1535	0.2483	0.2938	0.3148	0.3185	0.3078	0.2910	0.2774	0.2737	0.2819
33	0.1614	0.2197	0.2608	0.2967	0.3291	0.3587	0.3825	0.4006	0.4140	0.4218

Table 2. GLCM feature values for each sample.

		0 (	degree				45	degree		
	Energy	Entropy	Contrast	Local Hom.	Max Freq.	Energy	Entropy	Contrast	Local Hom.	Max Freq.
1	77430	13001	2533536	508	52	63462	12166	5177988	300	36
2	1424728	23999	1549962	1373	820	1596024	23057	1382022	1131	712
3	44498	10544	5623722	303	30	42594	10433	5631732	282	18
4	37562	9652	5744142	268	17	35558	9373	6249420	249	16
5 6	42872	10294	6916032	254 327	21	40190	9966	6812694	255	20
0 7	47204 1643360	10971 24743	5162886 1313856	1525	20 720	47476 1596012	10862 24772	4773672 1286280	312 1465	30 694
8	67630	12285	5918328	344	34	64048	11515	4822758	329	35
9	69470	12265	4391982	331	28	69560	13114	4556160	329	26
10	228660	19184	1211364	610	88	229472	18966	770634	718	89
11	203768	18209	1226790	546	82	199756	18157	996084	653	76
12	122664	15469	1358802	668	74	91606	14178	2609046	395	42
13	114008	15309	1694304	483	49	95170	14135	2619108	466	54
14	205006	17937	1827882	524	98	188038	17557	1986606	549	90
15	159542	16827	1670796	614	76	144908	15891	1578924	541	74
16	129676	16432	2491614	299	45	126022	15898	2444832	361	55
17	133482	15006	2002104	546	92	110324	15042	3912120	342	52
18	181184	17353	2272104	544	96	168804	16886	2716038	435	91
19	189828	16873	1518084	587	120	166460	16289	2094534	523	95
20	89550	13683	3062556	417	41	94842	13844	2553012	472	46
21	32376	8607	5897970	283	20	34420	8772	5175900	246	19
22	61814	12389	5585598	275	24	56172	11595	4602762	308	28
23	99120	14722	3726252	296	36	97040	14430	3197754	377	40
24	110596	14818	1619028	519	60	95442	14236	2716938	383	42
25	54780	10362	2454858	510	32	46944	9516	3562812	405	30
26	863485552	337005	2559276	29479	29354	897713116	338990	2319696	30063	29938
27	71460	13138	4659948	338	40	71910	12913	4225032	289	34
28	135508	16656	1397412	582	62	122416	15847	1488528	516	50
29	64548	12153	2738538	386	38	70390	12700	2556720	411	34
30	43728	10025	5341338	313	24	38784	9206	5297904	318	23
		45007	4405000	507	E 4	440070	15186	0000000	459	47
31	118730	15287	1495026	527	54	116670	12100	2080638	459	47
31 32	118730 78252	15287	1495026 2533140	527 416	54 34	74300	13149	4534200	308	29
		13296 11463	2533140 2196324				13149 10838	4534200 3823344		
32	78252 56290	13296 11463 <b>90</b>	2533140 2196324 degree	416 502	34 34	74300 48516	13149 10838 <b>135</b>	4534200 3823344 <b>degree</b>	308 303	29 28
32	78252	13296 11463	2533140 2196324	416 502 Local	34 34 <b>Max</b>	74300	13149 10838	4534200 3823344	308	29 28 <b>Max</b>
32	78252 56290	13296 11463 90 Entropy	2533140 2196324 degree	416 502	34 34	74300 48516	13149 10838 <b>135</b>	4534200 3823344 <b>degree</b>	308 303 Local	29 28
32 33	78252 56290 Energy	13296 11463 <b>90</b>	2533140 2196324 degree Contrast	416 502 Local Hom.	34 34 Max Freq.	74300 48516 Energy	13149 10838 <b>135</b> Entropy	4534200 3823344 degree Contrast	308 303 Local Hom.	29 28 Max Freq.
32 33	78252 56290 Energy 21995	13296 11463 <b>90</b> Entropy 4965	2533140 2196324 degree Contrast 1208997	416 502 Local Hom. 259	34 34 Max Freq. 26	74300 48516 Energy 56476	13149 10838 <b>135</b> Entropy 11543	4534200 3823344 degree Contrast 5460030	308 303 Local Hom. 273	29 28 Max Freq. 32
32 33 1 2 3 4	78252 56290 Energy 21995 469619 12707 10384	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000	416 502 Local Hom. 259 919 153 124	34 34 <b>Max</b> Freq. 26 472 13 11	74300 48516 Energy 56476 1610456	13149 10838 <b>135</b> Entropy 11543 23494	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784	308 303 Local Hom. 273 1398 250 278	29 28 <b>Max</b> Freq. 32 908 19 20
32 33 1 2 3 4 5	78252 56290 Energy 21995 469619 12707 10384 11128	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338	2533140 2196324 <b>degree</b> Contrast 1208997 387000 2487357 3142611 2380032	416 502 Local Hom. 259 919 153 124 168	34 34 <b>Max</b> Freq. 26 472 13 11 12	74300 48516 Energy 56476 1610456 44308 37272 38992	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632	4534200 3823344 <b>degree</b> <b>Contrast</b> 5460030 1277856 5600970 6389784 6242490	308 303 <b>Local</b> Hom. 273 1398 250 278 244	29 28 <b>Max</b> Freq. 32 908 19 20 18
32 33 1 2 3 4 5 6	78252 56290 Energy 21995 469619 12707 10384 11128 12573	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687	2533140 2196324 <b>degree</b> Contrast 1208997 387000 2487357 3142611 2380032 2035665	416 502 Local Hom. 259 919 153 124 168 162	34 34 <b>Max</b> Freq. 26 472 13 11 11 12	74300 48516 Energy 56476 1610456 44308 37272 38992 44612	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557	4534200 3823344 <b>degree</b> <b>Contrast</b> 5460030 1277856 5600970 6389784 6242490 4905180	308 303 Local Hom. 273 1398 250 278 244 301	29 28 <b>Max</b> Freq. 32 908 19 20 18 22
32 33 1 2 3 4 5 6 7	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038	416 502 Local Hom. 259 919 153 124 168 162 685	34 34 Max Freq. 26 472 13 11 12 14 314	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553	4534200 3823344 <b>degree</b> <b>Contrast</b> 5460030 1277856 5600970 6389784 6242490 4905180 1364490	308 303 Local Hom. 273 1398 250 278 244 301 1353	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604
32 33 1 2 3 4 5 6 7 8	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850	416 502 Local Hom. 259 919 153 124 168 162 685 280	34 34 <b>Max</b> Freq. 26 472 13 11 12 14 314 27	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332	308 303 Local Hom. 273 1398 250 278 244 301 1353 391	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46
32 33 1 2 3 4 5 6 7 8 9	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507 29273	13296 11463 <b>90</b> <b>Entropy</b> 4965 10450 3756 3259 3338 3687 10498 4918 5816	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716	416 502 Local Hom. 259 919 153 124 168 162 685 280 306	34 34 Freq. 26 472 13 11 12 14 314 27 40	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400	4534200 3823344 <b>degree</b> <b>Contrast</b> 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638	308 303 Local Hom. 273 1398 250 278 244 301 1353 391 345	29 28 Max Freq. 32 908 19 20 18 22 604 46 29
32 33 1 2 3 4 5 6 7 8 9 9 10	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610	416 502 <b>Local</b> Hom. 259 919 153 124 168 162 685 280 306 400	34 34 Freq. 26 472 13 11 12 14 314 27 40 53	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622	4534200 3823344 <b>degree</b> <b>Contrast</b> 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092	308 303 <b>Local</b> <b>Hom.</b> 273 1398 250 278 244 301 1353 391 345 698	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96
32 33 1 2 3 4 5 6 7 8 9 10 11	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939	416 502 259 919 153 124 168 162 685 280 306 400 335	34 34 <b>Max</b> Freq. 26 472 13 11 1 12 14 314 27 40 53 46	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305	4534200 3823344 <b>degree</b> <b>Contrast</b> 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622	308 303 <b>Local</b> <b>Hom.</b> 273 1398 250 278 244 301 1353 391 345 698 595	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74
32 33 1 2 3 4 5 6 7 8 9 10 11 12	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089	13296 11463 <b>90</b> <b>Entropy</b> 4965 10450 3756 3256 3338 3687 10498 4918 5816 7799 7426 5616	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041	416 502 259 919 153 124 168 162 685 280 306 400 335 179	34 34 <b>Max</b> Freq. 26 472 13 11 12 14 314 27 40 53 46 25	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051	4534200 3823344 <b>degree</b> <b>Contrast</b> 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74
32 33 1 2 3 4 5 6 7 8 9 10 11 11 2 13	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5440	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170	34 34 <b>Max</b> Freq. 26 472 13 11 12 14 314 27 40 53 46 25 20	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483322 4663638 682092 980622 2982474 2435346	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42
32 33 1 2 3 4 5 6 7 8 9 10 11 12 13 14	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5640 7032	2533140 2196324 degree Contrast 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 252	34 34 <b>Max</b> Freq. 26 472 13 11 12 14 314 27 40 53 46 25 20 47	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 122473 13400 18622 17305 15051 14046 17752	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483322 4663638 682092 980622 2982474 2435346 1888506	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42 41
32 33 1 2 3 4 5 6 7 8 9 10 11 11 2 13	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5440	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170	34 34 <b>Max</b> Freq. 26 472 13 11 12 14 314 27 40 53 46 25 20	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483322 4663638 682092 980622 2982474 2435346	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42
32 33 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15	78252 56290 Energy 21995 469619 12707 10384 11128 12573 3362076 23507 29273 62562 53568 25089 24806 47587 38623	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 55460 5646	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 252 256	34 34 <b>Max</b> Freq. 26 472 13 11 12 14 314 27 40 53 46 25 20 47 41	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 122473 13400 18622 17305 15051 14046 17752 16737	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1888506 1761678	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42 41 106 88
32 33 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5646 5640 7032 6595 6484	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 959967	416 502 259 919 153 153 168 162 685 280 306 400 335 179 170 252 256 254	34 34 34 7req. 26 472 13 11 12 14 314 27 40 53 46 25 20 47 41 31	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614 129128	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 122473 13400 18622 17305 15051 14046 17752 16737 16087	4534200 3823344 degree Contrast 54600300 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1888506 1761678 2302200	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 46 29 96 74 41 106 88 50
32 33 4 5 6 7 8 9 10 11 12 13 14 15 16 17	78252 56290 Energy 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131 27500	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 55416 5646 5646 56440 7032 6595 6484	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 959967 1763703	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 252 256 254 170	34 34 34 7req. 26 472 13 11 12 14 314 31 40 53 46 25 20 47 41 31 32	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614 129128 105810	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051 14046 17752 16737 16087	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1888506 1761678 2302200 3974832	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369 324	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 46 29 96 74 42 41 106 88 50 48
32           33           1           2           34           5           6           7           8           9           10           11           12           13           14           15           16           17           18	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131 27500 48207	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5646 5640 7032 6595 6484 5635 7131	2533140 2196324 <b>degree</b> <b>Contrast</b> 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 959967 1763703 1447857	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 252 256 254 170 255	34 34 34 26 472 13 11 12 14 314 27 40 53 46 25 20 41 41 31 32 54 58 28	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614 129128 105810 171504	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051 14046 17752 16737 16087 14692 17406 16154	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1888506 1761678 2302200 3974832 2963106	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369 324 400	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 46 29 96 74 46 29 96 74 46 29 96 74 48 88 50 48
$\begin{array}{c} 32\\ 33\\ 1\\ 2\\ 3\\ 4\\ 5\\ 6\\ 7\\ 8\\ 9\\ 10\\ 11\\ 12\\ 13\\ 14\\ 15\\ 16\\ 17\\ 18\\ 19\\ 20\\ 21\\ \end{array}$	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131 27500 48207 46614 28497 10766	13296 11463 <b>90</b> Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5440 7032 6595 6484 5635 7131 6711 5642 3257	2533140 2196324 degree Contrast 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 959967 1763703 1447857 1149660 760419 2283057	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 255 256 254 170 2554 254 170 2554 254 170	34 34 34 26 472 13 11 12 14 314 27 40 53 46 25 20 41 31 31 32 54 54 58 28 28 28 212	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192266 163614 129128 105810 171504 165180 88884 33446	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051 14046 17752 16037 16087 14692 17406 16154 13422 8761	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1761678 2302200 3974832 2963106 2144790 2593890 5060430	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369 324 400 539 324	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42 42 41 106 888 50 48 82 2112 62 20
32           33           1           2           3           4           5           6           7           8           9           10           11           12           13           14           15           16           17           18           19           20           21           22	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131 27500 48207 46614 28497 10766	13296 11463 90 Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5440 7032 6585 6484 5635 6484 5635 7131 6711 5642 3257	2533140 2196324 degree Contrast 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 959967 1763703 1447857 1149660 760419 2283057	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 255 256 254 170 255 256 254 170 251 262 288 167 227	34 34 34 26 472 13 11 12 14 314 27 40 53 46 25 20 47 47 41 32 54 54 58 28 28 220	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614 129128 105810 171504 165180 88884 33446 58570	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051 14046 17752 16037 16087 14692 17406 16154 13422 8761	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1761678 230200 3974832 2963106 2144790 2593890 5060430	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369 324 400 539 324	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42 41 106 888 50 048 82 2112 62 20 26
32           33           1           2           3           4           5           6           7           8           9           10           11           12           13           14           15           16           17           18           19           20           21           22           23	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131 27500 48207 46614 28497 10766 17640 27520	13296 11463 90 Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5440 7032 6595 6484 5635 6484 5635 7131 6711 5642 3257 4521 5766	2533140 2196324 degree Contrast 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 1763703 1447857 1149660 760419 2283057 1420983 1029015	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 252 256 254 170 255 254 170 251 262 254 170 251 262	34 34 34 26 472 13 11 12 14 314 27 40 53 46 25 20 47 41 31 32 54 54 58 28 20 47 20 20 23	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614 192226 163614 129128 105810 1771504 165180 88884 33446 58570 92366	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051 14046 17752 16737 16687 14692 17406 16154 13422 8761 12017	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1761678 2302200 3974832 2963106 2144790 2593890 5060430 5055192 3232170	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369 324 400 539 324 400 539 324	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42 41 106 888 50 048 82 112 62 20 26 40
$\begin{array}{c} 32\\ 33\\ \hline \\ 1\\ 2\\ 3\\ 4\\ 5\\ 6\\ 7\\ 8\\ 9\\ 10\\ 11\\ 12\\ 13\\ 14\\ 15\\ 16\\ 17\\ 18\\ 19\\ 20\\ 21\\ 22\\ 23\\ 24\\ \end{array}$	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131 27500 48207 46614 28497 10766 17640 27520 26274	13296 11463 90 Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5540 7032 6595 6484 5635 7131 6711 5642 3257 4521 5766	2533140 2196324 degree Contrast 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 1763703 1447857 1149660 760419 2283057 1420983 1029015 1551546	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 252 256 254 170 251 254 170 251 268 8167 227 261	34 34 34 26 472 13 11 12 14 314 27 40 53 46 25 20 47 41 31 31 32 54 58 28 28 220 20 25 20 20 22 32 26	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614 192226 163614 105810 1771504 165180 88884 33446 58570 92366	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051 14046 17752 16737 16087 14692 17406 16154 13422 8761 12017 14209 14522	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1761678 2302200 3974832 2963106 2144790 2593890 5060430 5055192 3232170	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369 324 400 539 324 400 539 324 400 539 324 330	29 28 Freq. 32 908 19 20 18 22 604 46 29 96 74 42 41 106 88 50 48 88 50 48 82 112 62 20 26 40 38
$\begin{array}{c} 32\\ 33\\ \hline \\ 1\\ 2\\ 3\\ 4\\ 5\\ 6\\ 7\\ 8\\ 9\\ 10\\ 11\\ 12\\ 13\\ 14\\ 15\\ 16\\ 17\\ 18\\ 19\\ 20\\ 21\\ 22\\ 23\\ 24\\ 25\\ \end{array}$	78252 56290 21995 469619 12707 10384 11128 12573 362076 23507 29273 62562 53568 25089 24806 47587 38623 34131 27500 48207 46614 28497 10766 17640 27520 26274 12130	13296 11463 90 Entropy 4965 10450 3756 3259 3338 3687 10498 4918 5816 7799 7426 5616 5540 7032 6595 6484 5635 7131 6711 5642 3257 4521 5766 5553 3226	2533140 2196324 degree Contrast 1208997 387000 2487357 3142611 2380032 2035665 727038 986850 787716 317610 393939 2200041 1808910 1130598 1214487 1763703 1447857 1763703 1447857 1149660 760419 2283057 1420983 1029015 1551546 2308185	416 502 259 919 153 124 168 162 685 280 306 400 335 179 170 252 256 254 170 251 265 254 170 251 268 8167 227 261 189	34 34 34 26 472 13 11 12 14 314 27 40 53 46 25 20 47 41 31 31 32 54 58 28 28 225 47 41 31 225 47 71 11 12 12 14 20 14 14 27 14 20 20 14 20 20 14 20 20 20 20 20 20 20 20 20 20 20 20 20	74300 48516 Energy 56476 1610456 44308 37272 38992 44612 1504940 74704 72862 228178 183390 99078 94516 192226 163614 192226 163614 105810 171504 105810 88884 33446 58570 92366 100034 48156	13149 10838 <b>135</b> Entropy 11543 23494 10745 9849 9632 10557 24553 12473 13400 18622 17305 15051 14046 17752 16737 16087 14692 17406 16154 143422 8761 12017 14209 14522 9798	4534200 3823344 degree Contrast 5460030 1277856 5600970 6389784 6242490 4905180 1364490 4483332 4663638 682092 980622 2982474 2435346 1888506 1761678 2302200 3974832 2963106 2144790 2593890 2506430 5060430 5055192 3232170 2611674 3875310	308 303 273 1398 250 278 244 301 1353 391 345 698 595 410 400 515 567 369 324 400 539 324 400 539 324 400 539 324 400 539 324 400 539 369 324 400 539 369 369 369 369 369 369 369 369 369 3	29 28 <b>Max</b> Freq. 32 908 19 20 18 22 604 46 29 96 74 42 41 106 88 50 48 88 50 48 22 20 26 40 38 36
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were scanned from another part of those 33 fabrics.

The experimental results show the successful identification of textures using the edge frequency method with the parameters proposed. In addition, the GLCM method performed well. However, it is so time consuming and more computationally complicated than the edge frequency method.

Moreover, it was shown that the method proposed based on the edge frequency is insensitive to the sample colour and scanning direction (rotating the sample) of fabric, which is an important and ideal advantage. For instance, the fabric shown with (a) in *Figure 1* might have a different colour from (b) or scanned in a perpendicular direction as in (c). The method applied can successfully identify texture (a) for both image (b) and (c).

It addition, although the GLCM method is almost insensitive to the scanning direction and colour of fabrics, it is not as effective as the edge frequency method. For instance, for the first fabric in the third rows of *Figure 1*, when both the colour and direction were changed, GLCM did not give the correct answer. However, the edge frequency method gave good results.

Consequently, it seems that the edge frequency method is a feasible and acceptable method for identifying fabric textures, performing better than some well-known methods, such as GLCM, especially considering the length of the process time and some other factors mentioned like insensitivity to fabric colour and scanning direction.

# Conclusions

In this study, a computational method for textile texture identification was introduced using the Edge frequency method, in which a gradient for all pixels of the texture is computed, and the texture features are defined as average values of the gradient at a specified distance. The method proposed was evaluated for fabric images of 33 knitted samples. The experimental results showed the successful identification of textures. In addition, as an ideal and desirable advantage, the method proposed is insensitive to the color and scanning direction (rotating the sample) of the fabric. Furthermore, GLCM was applied and compared with the edge frequency method. Although this method performs well, it is more computationally complicated and time consuming than the edge frequency method. Moreover, the sensitivity of the edge frequency method to the scanning direction and colour of the sample is lower than for GLCM.

#### References

 Tuceryan M., Jain A. K.; The Handbook of Pattern Recognition and Computer Vision (2<sup>nd</sup> Edition), by C. H. Chen, L. F. Pau, P. S. P. Wang (eds.), Chapter 2.1, pp. 207-248, 1998, World Scientific Publishing Co.

- Sonka M., Hlavac V., Boyle R.; Image Processing: Analysis and Machine Vision, 1993, 1<sup>st</sup> edition published by Chapman and Hall.
- 3. Pratt W. K., Digital Image Processing, 3<sup>rd</sup> ed., John Wiley & Sons, New York, 2001.
- Ibarra Pico F., Cuenca Asensi S., García Crespi F., Lorenzo Quintanilla J. J., Morales Benavente J. L.; "A comparative study of texture analysis algorithms in textile inspection applications". In: Proceedings of the 12<sup>th</sup> Scandinavian Conference on Image Analysis, Bergen 11<sup>th</sup> - 14<sup>th</sup> June, 2001 / editor: Ivar Austevoll. Stavanger : NOBIM, 2001.
- Brad R., Brad R.; "Automated Fabric Defect Inspection for Quality Assurance Systems", The 83rd Textile Institute World Conference, Shanghai, China, 23 - 27 May 2004, pp. 1261-1264.
- Liqing L., Tingting J., Xia Ch., "Automatic recognition of fabric structures based on digital image decomposition", Indian Journal of Fiber & Textile Research, Vol. 33, 2008, pp. 388-391.
- Kuo Ch. J., Tsai Ch., "Automatic Recognition of Fabric Nature by Using the Approach of Texture Analysis, Textile Research Journal, Vol. 76(5), 2006, pp. 375-382.
- Lachkar A., Benslimane R., D'Orazio L., Martuscelli E.; "Textile woven fabric recognition using Fourier image analysis techniques: Part II - texture analysis for crossed-states detection", Journal of the Textile Institute, Vol. 96(3), 2005, pp. 179-183.
- Su T., Kung F., Kuo Y.; "Application of back-propagation Neural Network Fuzzy Clustering in textile texture automatic recognition system", International Conference on Wavelet Analysis and Pattern Recognition. ICWAPR, 08., Hong Kong, 30-31 Aug. 2008, pp. 46-49.
- Berkalp O. B., Pourdeyhimi B., Seyam A., Holmers R.; "Texture Retention after Fabric-to-Fabric Abrasion", Textile Research Journal, Vol. 73(4), 2003, pp. 316-321.
- Sangwine S. J., Horne R. E.N, The color image processing handbook, pp. 67-92, 1998 London: Chapman & Hall.

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# the 9<sup>th</sup> International Scientific-Technical Conference



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