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# Machine Vision Analysis for Textile Texture Identification

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**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.*

## 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]:

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*:

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

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:

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

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

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

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

(typically $\chi = 2, \lambda = 1$)

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

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,

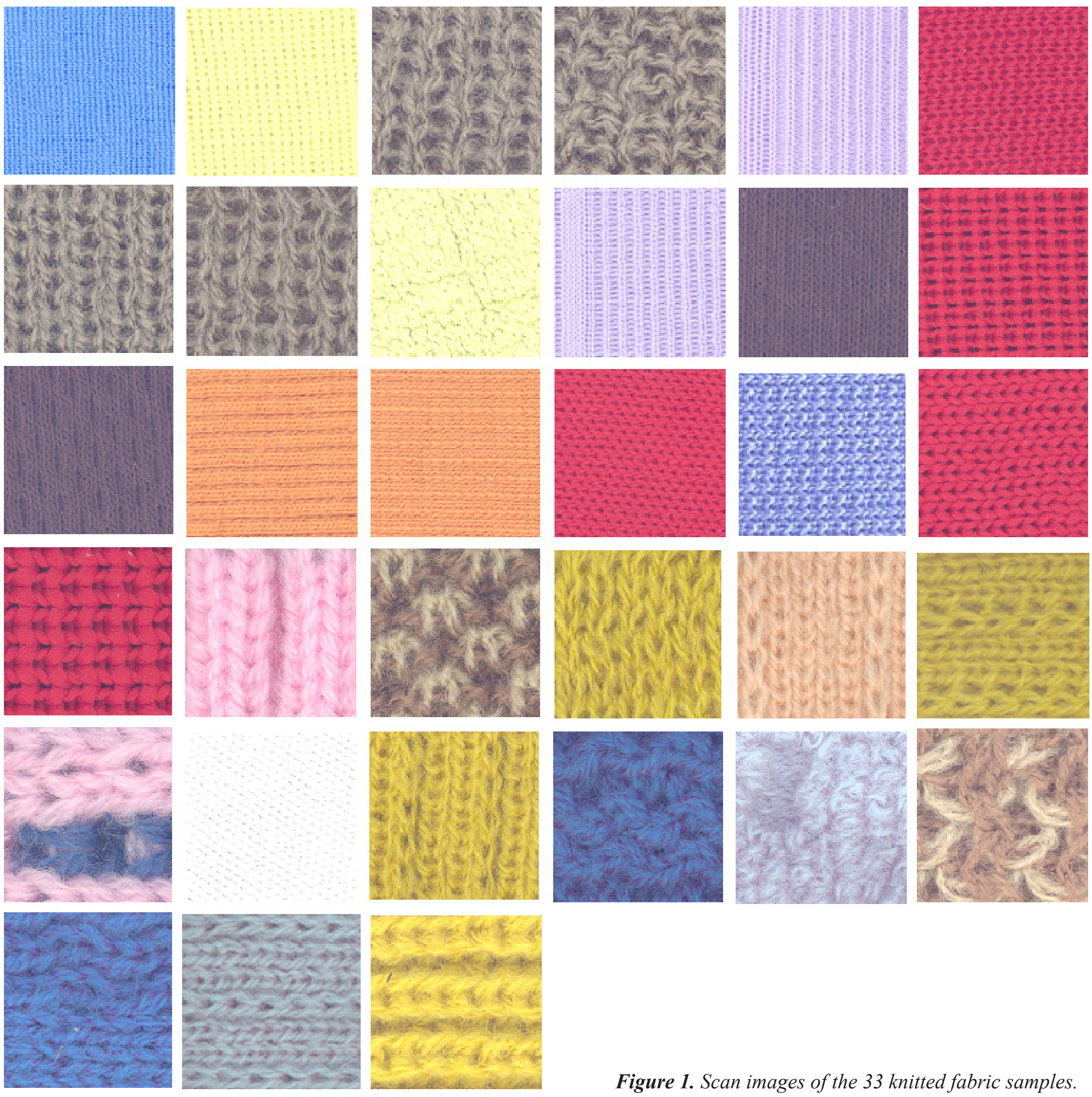

***Figure 1.*** *Scan images of the 33 knitted fabric samples.*

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, $TextureDiff_i$ indicates the texture difference between the sample and ith sample of the library.

$$TextureDiff_i = \sqrt{\sum_d \left(g(d) - g_i(d)\right)^2} \quad (4)$$

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,

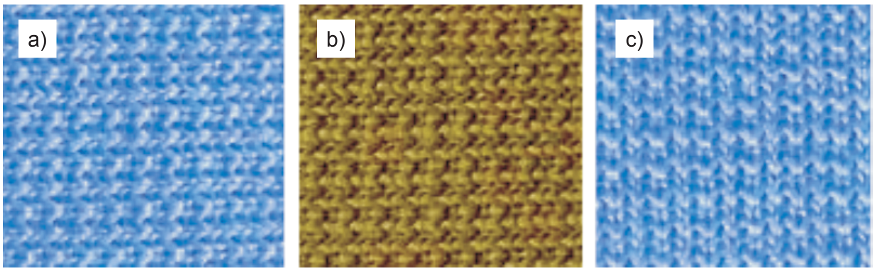


***Figure 2.*** *(a): One of the library textures, (b) sample with a similar texture to "a" but with a different colour, (c) sample with similar texture to "a" but in adifferent scanning direction.*

$TextureDiff_i$ 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 $TextureDiff_i$ is defined as the summation of results obtained for each angle.

$$TextureDiff_i = \sum_\varphi \sqrt{\sum_f \left(GLCM(f,\varphi) - GLCM_i(f,\varphi)\right)^2} \quad (5)$$

## Results and discussion

A library of the texture features of 33 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

***Table 1.*** *Edge frequency feature values for each sample.*

| 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 | 42872 | 10294 | 6916032 | 254 | 21 | 40190 | 9966 | 6812694 | 255 | 20 |
| 6 | 47204 | 10971 | 5162886 | 327 | 20 | 47476 | 10862 | 4773672 | 312 | 30 |
| 7 | 1643360 | 24743 | 1313856 | 1525 | 720 | 1596012 | 24772 | 1286280 | 1465 | 694 |
| 8 | 67630 | 12285 | 5918328 | 344 | 34 | 64048 | 11515 | 4822758 | 329 | 35 |
| 9 | 69470 | 12943 | 4391982 | 331 | 28 | 69560 | 13114 | 4556160 | 334 | 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 |
| 31 | 118730 | 15287 | 1495026 | 527 | 54 | 116670 | 15186 | 2080638 | 459 | 47 |
| 32 | 78252 | 13296 | 2533140 | 416 | 34 | 74300 | 13149 | 4534200 | 308 | 29 |
| 33 | 56290 | 11463 | 2196324 | 502 | 34 | 48516 | 10838 | 3823344 | 303 | 28 |
| | 90 degree | | | | | 135 degree | | | | |
| | Energy | Entropy | Contrast | Local Hom. | Max Freq. | Energy | Entropy | Contrast | Local Hom. | Max Freq. |
| 1 | 21995 | 4965 | 1208997 | 259 | 26 | 56476 | 11543 | 5460030 | 273 | 32 |
| 2 | 469619 | 10450 | 387000 | 919 | 472 | 1610456 | 23494 | 1277856 | 1398 | 908 |
| 3 | 12707 | 3756 | 2487357 | 153 | 13 | 44308 | 10745 | 5600970 | 250 | 19 |
| 4 | 10384 | 3259 | 3142611 | 124 | 11 | 37272 | 9849 | 6389784 | 278 | 20 |
| 5 | 11128 | 3338 | 2380032 | 168 | 12 | 38992 | 9632 | 6242490 | 244 | 18 |
| 6 | 12573 | 3687 | 2035665 | 162 | 14 | 44612 | 10557 | 4905180 | 301 | 22 |
| 7 | 362076 | 10498 | 727038 | 685 | 314 | 1504940 | 24553 | 1364490 | 1353 | 604 |
| 8 | 23507 | 4918 | 986850 | 280 | 27 | 74704 | 12473 | 4483332 | 391 | 46 |
| 9 | 29273 | 5816 | 787716 | 306 | 40 | 72862 | 13400 | 4663638 | 345 | 29 |
| 10 | 62562 | 7799 | 317610 | 400 | 53 | 228178 | 18622 | 682092 | 698 | 96 |
| 11 | 53568 | 7426 | 393939 | 335 | 46 | 183390 | 17305 | 980622 | 595 | 74 |
| 12 | 25089 | 5616 | 2200041 | 179 | 25 | 99078 | 15051 | 2982474 | 410 | 42 |
| 13 | 24806 | 5440 | 1808910 | 170 | 20 | 94516 | 14046 | 2435346 | 400 | 41 |
| 14 | 47587 | 7032 | 1130598 | 252 | 47 | 192226 | 17752 | 1888506 | 515 | 106 |
| 15 | 38623 | 6595 | 1214487 | 256 | 41 | 163614 | 16737 | 1761678 | 567 | 88 |
| 16 | 34131 | 6484 | 959967 | 254 | 31 | 129128 | 16087 | 2302200 | 369 | 50 |
| 17 | 27500 | 5635 | 1763703 | 170 | 32 | 105810 | 14692 | 3974832 | 324 | 48 |
| 18 | 48207 | 7131 | 1447857 | 251 | 54 | 171504 | 17406 | 2963106 | 400 | 82 |
| 19 | 46614 | 6711 | 1149660 | 262 | 58 | 165180 | 16154 | 2144790 | 539 | 112 |
| 20 | 28497 | 5642 | 760419 | 288 | 28 | 88884 | 13422 | 2593890 | 452 | 62 |
| 21 | 10766 | 3257 | 2283057 | 167 | 12 | 33446 | 8761 | 5060430 | 299 | 20 |
| 22 | 17640 | 4521 | 1420983 | 227 | 20 | 58570 | 12017 | 5055192 | 266 | 26 |
| 23 | 27520 | 5766 | 1029015 | 261 | 23 | 92366 | 14209 | 3232170 | 330 | 40 |
| 24 | 26274 | 5553 | 1551546 | 189 | 26 | 100034 | 14522 | 2611674 | 364 | 38 |
| 25 | 12130 | 3226 | 2308185 | 183 | 17 | 48156 | 9798 | 3875310 | 408 | 36 |
| 26 | 218328712 | 156789 | 1293129 | 14824 | 14761 | 990594490 | 350233 | 1876896 | 31592 | 31458 |
| 27 | 22113 | 5167 | 1393317 | 225 | 21 | 68170 | 12682 | 4317444 | 321 | 34 |
| 28 | 33850 | 6386 | 755424 | 270 | 28 | 124580 | 15983 | 1504296 | 530 | 50 |
| 29 | 19274 | 4642 | 1213236 | 216 | 24 | 66196 | 12258 | 2869110 | 382 | 38 |
| 30 | 11686 | 3288 | 2583567 | 151 | 16 | 39892 | 9344 | 5726034 | 321 | 24 |
| 31 | 30317 | 5966 | 1154799 | 224 | 26 | 112036 | 14910 | 2010474 | 467 | 46 |
| 32 | 20788 | 5053 | 2586141 | 147 | 17 | 74430 | 13485 | 4621572 | 287 | 29 |
| 33 | 13262 | 3762 | 2417526 | 149 | 15 | 50298 | 10964 | 3760650 | 325 | 28 |

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.

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