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Derivation of Shape Descriptors on Uniform Local Binary Patterns for Classification of Textures

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Abstract

The Local Binary Pattern (LBP) measures effectively local characteristics of the texture. The uniform LBP (ULBP) derived from LBP contains the fundamental properties of texture. The Uniform LBP (ULBP) contains 0 or 2 transitions from 0 to 1 or 1 to 0. There are 59 ULBP's on a 3×3 neighborhood LBP. The present paper sub divided the ULBP into micro-level shape descriptors by combining several different ULBP codes into one. These shape descriptors also contains fundamental features because the ULBP represents them. Based on these ULBP shapes the present paper classified the textures. The present paper further investigated how the derived shape feature varies by considering rotational invariant ULBP's (formed by considering min/max of ULBP code). The present paper computed the histogram of the derived ULBP shape features on different textures and subsequently evaluated the prominent shape features which classify the stone group textures with sand textures. The results are compared with histograms of ULBP and Non-ULBP (N-ULBP).

Keywords: *Shape Features, Rotational Invariant, Histogram, Local Characteristics, Fundamental Properties.*

1. Introduction

Description and representation of shapes is one of the fundamental issues in image processing, computer vision, graphics and pattern recognition. The associated shape features such as size, shape, profile, roughness, randomness, orientation etc. have drawn extensive attention in scientific studies. In past decades researchers have shown tremendous interest in estimating shape descriptors and also proposed various methods for studying and categorizing shape characteristics [1-5]. Despite of utilizing multi-resolution based texture representation [6–10], Ojala et.al.[11] represented texture features by observing the statistical distributions of local binary patterns [12]. Uniform and rotation-invariant uniform LBP descriptors are extended from original LBP to extract the uniform and rotation stable local binary patterns [23,24]. The LBP operator is a gray scale invariant texture primitive which is theoretically simple and effective. The LBP measures the characteristics of the local structure effectively and accurately. Therefore the features derived based on LBP are used by many researchers in wide spread of applications like texture classification, face recognition[22,25], facial expression recognition, age classification, medical image processing... etc. [13-21].

The section two of the present paper gives a brief description about LBP and ULBP. The section three derives the shape features from ULBP i.e. the methodology. The section four, five gives results and discussions and conclusions respectively.

2. Basic Concepts on LBP and ULBP

The objective of this section is to describe briefly about the basic concepts of LBP and ULBP.

2.1 Local Binary Pattern (LBP)

The LBP operator is initially defined on a 3×3 neighborhood or second order neighborhood [11, 12]. Later it is also extended to third order neighborhood. The basic form of an LBP operator on a 3×3 square second order neighborhood labels the each pixel into some value (usually binary) by comparing it with some threshold value. An illustration of the basic LBP operator is shown in Fig.1 and the threshold is measured as the gray value of centre pixel. If the neighboring pixels gray value is greater than or equal to centre pixel value then it made as 1 otherwise 0.

12	10	9	1	1	0	2^0	2^1	2^2	
15	10	7	1		0	2^7		2^3	195
12	5	6	1	0	0	2^6	2^5	2^4	

a) 3×3 neighborhood b) LBP c)LBP weights d)LBP code

Fig 1: Calculation of LBP code from 3×3 neighborhood.

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One of the major limitations of the basic LBP operator is that the 8 neighboring pixels are not forming exactly circular shape with respect to centre pixel i.e. the unequal distance between the centre pixel and its neighbors.

2.2 Uniform LBP (ULBP)

A LBP generates 8 bit code ranging from 0 to $2^8 - 1$ i.e. 0 to 255. These are called LBP codes or units in the literature. Considering such a huge number of LBP units (0 to 255) is a tedious and complex task for any type of image processing, pattern recognition, and other applications. LBP patterns are divided into Uniform LBP (ULBP) and Non-Uniform LBP (N-ULBP) based on the number of transitions from 0 to 1 or 1 to 0. Initially Ojala et al. [11] observed that certain patterns of LBP forms fundamentals properties and these patterns are named as uniform LBP. The uniform LBP contains 0 or 2 transitions from 0 to 1 or 1 to 0. For example the LBP code 0 (00000000) and 255 (11111111) will have exactly 0 transitions. The LBP codes 16 (00010000) and 64 (01000000) will have exactly 2 transitions from 0 to 1 or 1 to 0. Ojala et.al [11] treated the remaining LBP patterns (which are not uniform) as non-uniform LBP. The non-uniform will have more than 2 transitions. No LBP code forms an odd number of transitions.

The total number of ULBP codes is 59. That means ULBP represent only 23.04% of total LBP codes. The total number of N-ULBP codes are 197 (i.e. 256-59) and falls into a large category of total LBP which represents 79.96% of total LBP codes. Ojala et al. [21] proved that majority of texture features can be categorized by ULBP. Many researchers derived methods based on ULBP for various applications. Based on this assumption the present paper further divided ULBP based on their shapes. The 59 different ULBP forms a total of 12 shapes. These shapes are called fundamental shape descriptors because they are derived from ULBP's. The present paper derived various shapes on ULBP based on the pattern formation.

3. Derivation of Shapes from ULBP

The ULBP code values 1, 2, 4, 8, 16, 32, 64 and 128 contains only one pixel value as 1 and the remaining seven pixel values as zeros as shown in Fig.2. These ULBP codes form a shape of Dot.

	1	0	0	0	1	0	0	0	1	0	0	0
	0		0	0		0	0		0	0		1
	0	0	0	0	0	0	0	0	0	0	0	0
ULBP	0000000			0000001			0000010			0000100		
ULBP Code	1			2			4			8		

	0	0	0	0	0	0	0	0	0	0	0	0
	0		0	0		0	0		0	1		0
	0	0	1	0	1	0	1	0	0	0	0	0
ULBP	0001000			0010000			0100000			1000000		
ULBP Code	16			32			64			128		

Fig.2: Dot shape of ULBP.

The ULBP code values 3, 6, 12, 24, 48, 96, 129 and 192 contains two adjacent ones and they form a shape of Small Line (S Line) and shown in Fig.3.

	1	1	0	0	1	1	0	0	1	0	0	0
	0		0	0		0	0		1	0		1
	0	0	0	0	0	0	0	0	0	0	0	1
ULBP	0000001			0000011			0000110			0001100		
ULBP Code	3			6			12			24		

	0	0	0	0	0	0	1	0	0	0	0	0
	0		0	0		0	1		0	1		0
	0	1	1	1	1	0	0	0	0	1	0	0
ULBP	0011000			0110000			1000000			1100000		
ULBP Code	48			96			129			192		

Fig.3: Small Line (S Line) shape of ULBP.

The decimal value of ULBP i.e. 7, 28, 112 and 193 contains three adjacent ones horizontally or vertically and they form a shape of Line (Line), as shown in Fig.4.

1	1	1	0	0	1	0	0	0	1	0	0
0		0	0		1	0		0	1		0
0	0	0	0	0	1	1	1	1	1	0	0

ULBP	0000011	0001110	0111000	1100000
ULBP Code	7	28	112	193

Fig.4: Line (Line) shape of ULBP.

The other ULBP code values with three different adjacent ones i.e. 14, 56, 131, and 224 forms a small L (SL) shape as shown in Fig.5.

0	1	1	0	0	0	1	1	0	0	0	0
0		1	0		1	1		0	1		0
0	0	0	0	1	1	0	0	0	1	1	0

ULBP	0000111	0011100	1000001	1110000
ULBP Code	14	56	131	224

Fig.5: Small L (SL) shape of ULBP.

The ULBP code values of 15, 30, 60, 120, 135, 195, 225 and 240 contains four adjacent ones and they form a different shape called an Elongated L (EL) shape as shown in Fig.6.

1	1	1	0	1	1	0	0	1	0	0	0
0		1	0		1	0		1	0		1
0	0	0	0	0	1	0	1	1	1	1	1

ULBP	0000111	0001111	0011110	0111100
ULBP Code	15	30	60	120

1	1	1	1	1	0	1	0	0	0	0	0
1		0	1		0	1		0	1		0
0	0	0	1	0	0	1	1	0	1	1	1

ULBP	1000011	1100001	1110000	1111000
ULBP Code	135	195	225	240

Fig.6: Elongated L (EL) shape of ULBP.

The ULBP code values with five adjacent ones i.e. 31, 124, 199 and 241 forms a Complete L (CL) shape as shown in Fig.7.

1	1	1	0	0	1	1	1	1	1	0	0
0		1	0		1	1		0	1		0
0	0	1	1	1	1	1	0	0	1	1	1

ULBP	0001111	0111110	1100011	1111000
ULBP Code	31	124	199	241

Fig.7: Complete L (CL) shape of ULBP.

The ULBP code values of 62, 143, 227 and 248 forms a Small U (SU) shape as shown in the Fig.8. These ULBP's are also having five adjacent ones but they form a different shape.

0	1	1	1	1	1	1	1	0	0	0	0
0		1	1		1	1		0	1		1
0	1	1	0	0	0	1	1	0	1	1	1

ULBP	0011111	1000111	1110001	1111100
ULBP Code	62	143	227	248

Fig.8: Small U (SU) shape of ULBP.

The ULBP code values of 63, 126, 159, 207, 231, 243, 249 and 252 forms Elongated U (EU) shape as shown in the Fig.9. These eight different ULBP's are having six adjacent ones.

1	1	1	0	1	1	1	1	1	1	1	1
0		1	0		1	1		1	1		1
0	1	1	1	1	1	0	0	1	1	0	0

ULBP	0011111	0111111	1001111	1100111
ULBP Code	63	126	159	207

1	1	1	1	1	0	1	0	0	0	0	1
1		0	1		0	1		1	1		1
1	1	0	1	1	1	1	1	1	1	1	1

ULBP	1110011	1111001	1111100	1111110
ULBP Code	231	243	249	252

Fig.9: Elongated U (EU) shape of ULBP.

The following four different ULBP unit values with seven adjacent ones i.e. 127, 223, 247 and 253 forms a Complete U (CU) shape as shown in Fig.10.

1	1	1	1	1	1	1	1	1	1	0	1
0		1	1		1	1		0	1		1
1	1	1	1	0	1	1	1	1	1	1	1

ULBP	0111111	1101111	1111011	1111110
ULBP Code	127	223	247	253

Fig.10: Complete U (CU) shape of ULBP.

The following four ULBP codes 191, 239, 251 and 254 contain seven adjacent ones. They form a Blob with Hole (BWH) shape as shown in Fig.11. They contains a hole (or value 0) at one of the corner pixel.

1	1	1	1	1	1	1	1	0	0	1	1
1		1	1		1	1		1	1		1
0	1	1	1	1	0	1	1	1	1	1	1

ULBP	1011111	1110111	1111101	1111111
ULBP Code	191	239	251	254

Fig.11: Blob with Hole (BWH) shape of ULBP.

The LBP code value 255 with all 1's i.e. eight adjacent ones forms a Blob (B) shape as shown in Fig.12.

1	1	1
1		1
1	1	1

ULBP 1111111

ULBP Code 255

Fig.12: Blob (B) shape of LBP.

The ULBP code value 0 forms a Hole (H) shape as shown in Fig.13.

0	0	0
0		0
0	0	0

ULBP 0000000

ULBP Code 0

Fig.13: Hole (H) shape of LBP.

Due to rotation LBP code/unit may vary. To have a rotational invariant LBP code one can choose max/min (LBP). By this the min (11000011) will become (00001111) = 15; max (11000011) becomes (11110000) = 240.

By rotational invariance i.e. by considering min/max (LBP code), the 59 different ULBP's forms into 9 different ULBP. The ULBP code 0 and 255 forms two different ULBP's. The minimum ULBP code (the rotational invariant ULBP code) with a single one i.e. 1, 2, 4, 8, 16, 32, 64 and 128 forms a single ULBP (00000001). The minimum code of 8 different ULBP codes which contains two adjacent ones i.e. 3 (0000011), 6 (00000110), 12 (00001100), 24 (00011000), 48 (00110000), 96 (01100000), 129 (10000001) and 192 (11000000) is a single rotational invariant ULBP code 3 (00000011).

The ULBP codes which contains three adjacent ones i.e. 7 (00000111), 14 (00001110), 28 (00011100), 56 (00111000), 112 (01110000), 131 (10000011), 193 (11000001), 224 (11100000) forms only a single rotational invariant ULBP code by considering the minimum value i.e. 7 (00000111). The above 8 different ULBP codes i.e. 7, 14, 28, 56, 112, 131, 193 and 224 forms only one rotational invariant ULBP unit but they form or derives two different shapes i.e. a Line and Small Line shapes on a 3×3 neighborhood as shown in Fig. 4 and Fig. 5.

In the same way the 8 different combinations of four adjacent 1's of ULBP code i.e. 15, 30, 60, 120, 135, 195, 225, and 240 derives only one rotational invariant ULBP code 15 (00001111) by considering the minimum ULBP code. All these 8 different ULBP codes forms only a single shape as shown in Fig.6.

There are 8 different combinations of ULBP's with 5 adjacent ones on a 3×3 neighborhood as shown in Fig.7 and Fig.8. Interestingly in this four ULBP codes 31 (00011111), 124 (01111100), 199 (11000111) and 241 (11110001) forms Complete L (CL) shape as shown Fig.7 and the other forms Small U (SU) shape as shown in Fig.8. The minimum ULBP code for five adjacent ones i.e.

rotational invariant ULBP for this is 31 (00011111). In the same way the rotation invariant ULBP code for six and seven adjacent 1's is 63, 127 and 191 forms three different shapes as shown in Figures 9, 10, and 11 respectively.
The above case studies on ULBP clearly indicates that by considering rotational invariant ULBP or min(ULBP) code some of the shape features will be lost/missed. To address this, the present paper derived shape features on a ULBP on a 3×3 neighborhood without taking in to account the rotational invariance. That means the present paper investigates the fundamental micro- level shape features of ULBP without considering the rotational invariance. The prominent ULBP shapes are those that play a significant and accurate role in classification of textures. The entire classification process is shown by the following flowchart of Fig.14.

4. Results and Discussions

The present paper collected some stone texture categories i.e. Marble, and Mosaic as one group and Sand texture as another group with a dimension of 256×256. All these textures are collected from the Google database. The 20 textures from each group of Sand, Mosaic and Marble are shown in Fig 15, 16 and 17 respectively. On these texture images the histogram of the 12 derived shape features of ULBP are evaluated based on the flow chart of Fig.14. The frequency occurrences of derived shapes on ULBP are listed in Table 1, 2 and 3 for classification of Sand, Mosaic and Marble textures respectively. The two categories of textures are classified precisely by considering the Small U shape feature of ULBP. Therefore the prominent shape feature for this classification based on ULBP is small U shape as shown in Fig. 8. Based on the histogram of the Small U shape feature of ULBP algorithm 1 is derived and based on histograms of ULBP and N-ULBP algorithm 2 is derived.

Algorithm 1:

```
Begin
if ( Small U shape >=2.0% ) && (Small U shape<=6.5% )
                        print ("SAND TEXTURE")
        else
        print (" MOSAIC OR MARBLE TEXTURE");
End
```

Algorithm 2:

```
TUP(Total Uniform Patterns )
Begin
    if (TUP>= 22000 && TUP <=4400)
            print(" SAND TEXTURE");
    else
            print("MOSAIC OR MARBLE TEXTURE");
End
```

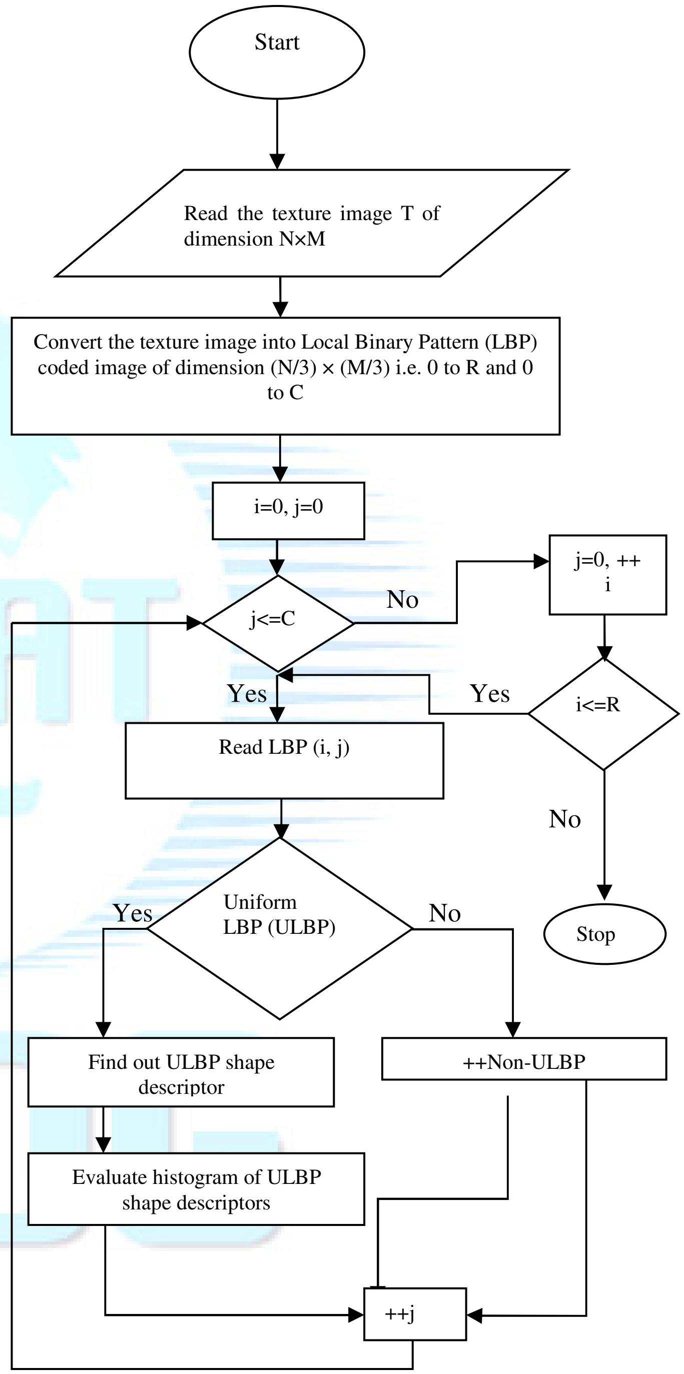

Fig.14: Flow-chart of entire classification Process.

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Table 4: Classification rate of the proposed method with ULBP and N-ULBP.

Texture Dataset	Classification rate using ULBP and Non Uniform Patterns	Classification rate using Small U shape
Sand	50%	80%
Mosaic	49%	82%
Marble	52%	83%

Based on algorithm 1 and 2, Table 4 indicates the classification rate using ULBP and Non-ULBP and also by considering the prominent shape feature i.e. small U of ULBP. The table clearly indicates a better classification rate by the micro level descriptors of ULBP than by considering ULBP and N-ULBP as a whole.

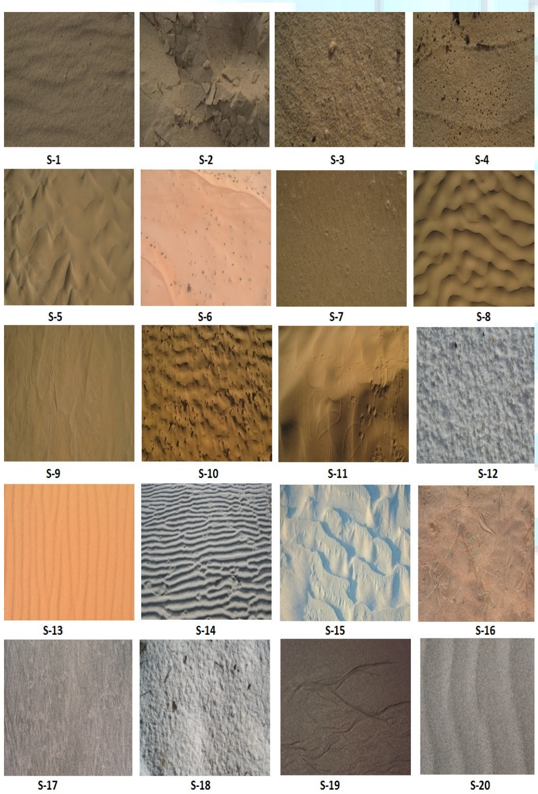

Fig.15: Images of Sand textures

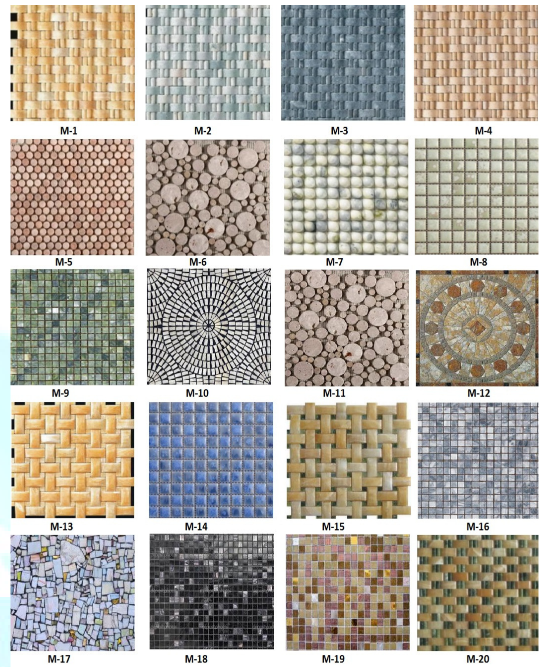

Fig.16: Images of Mosaic textures

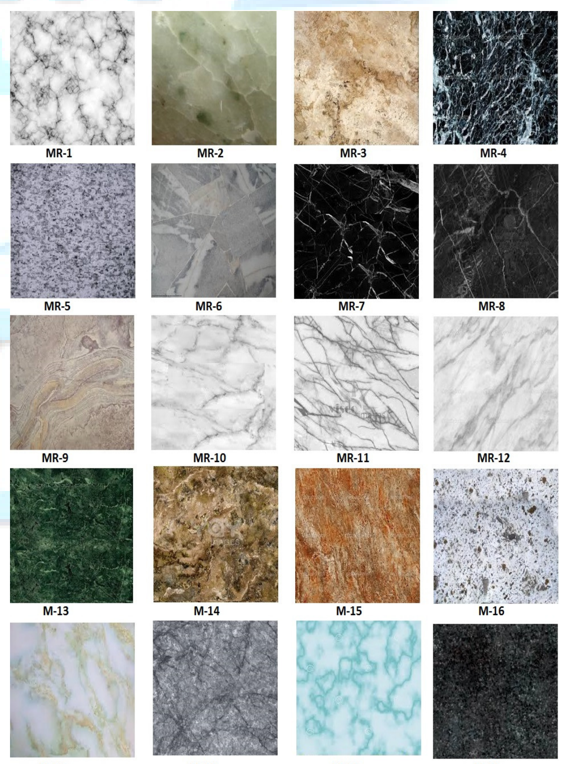

Fig.17: Images of Marble textures

5. Conclusions

The proposed descriptors are called as micro-level fundamental shape descriptors because they are derived from ULBP which represents fundamental properties of texture. The 59 ULBP patterns are classified into 12 shape features. The present paper further investigated by considering the rotational invariant property of ULBP (by considering min/max of ULBP code) some shape features may lose. The present paper derived a conclusion that 12 different shape features can be formed based on ULBP and 9 different ULBP codes by considering rotational invariant ULBP's. A simple histogram of ULBP and N-ULBP as a whole fails in classifying the considered categories and whereas the derived shapes feature Small U classified the textures. This clearly gives a conclusion that micro level ULBP shape features are very useful in various other applications like image retrieval, image recognition etc. Therefore there is a need to explore them further.

	Dot	%	Small Line	%	Line	%	Small L	%	Elongated L	%	Complete L	%	Small U	%	Elongated U	%	U	%	Blob with hole	%	Blob	%	Uniform_Total	Non_Uniform	Total
S1	3091	4.87	3460	5.45	1918	3.02	2321	3.65	5069	7.98	2656	4.18	1972	3.11	3969	6.25	1246	1.96	2749	4.33	0	0	28451	35053	63504
S2	4155	6.54	4229	6.66	2423	3.82	2452	3.86	5246	8.26	2582	4.07	2395	3.77	4516	7.11	1367	2.15	4288	6.75	0	0	33653	29851	63504
S3	3852	6.07	4803	7.56	2452	3.86	3056	4.81	5720	9.01	2777	4.37	2558	4.03	4339	6.83	1017	1.60	2932	4.62	0	0	33506	29998	63504
S4	2505	3.94	3325	5.24	2276	3.58	2199	3.46	5439	8.56	3172	4.99	2375	3.74	4879	7.68	1069	1.68	3145	4.95	0	0	30384	33120	63504
S5	5570	8.77	3309	5.21	1888	2.97	1326	2.09	3615	5.69	1533	2.41	1897	2.99	3959	6.23	2258	3.56	10891	17.15	0	0	36246	27258	63504
S6	3816	6.01	3174	5.00	2012	3.17	1528	2.41	3895	6.13	2013	3.17	2323	3.66	4942	7.78	2700	4.25	9726	15.32	0	0	36129	27375	63504
S7	3205	5.05	4286	6.75	2471	3.89	2590	4.08	5535	8.72	2492	3.92	2495	3.93	4056	6.39	963	1.52	2372	3.74	0	0	30465	33039	63504
S8	6536	10.00	2526	3.98	1094	1.72	1115	1.76	2160	3.40	1023	1.61	1105	1.74	2392	3.77	1721	2.71	13911	21.91	0	0	33583	29921	63504
S9	4232	6.66	3650	5.75	4563	7.19	1249	1.97	5277	8.31	1329	2.09	4841	7.62	4296	6.76	1898	2.99	6095	9.60	0	0	37430	26074	63504
S10	4813	7.58	4012	6.32	4035	6.35	1621	2.55	5380	8.47	2025	3.19	4400	6.93	4994	7.86	1575	2.48	11749	18.50	0	0	44604	18900	63504
S11	5515	8.68	3591	5.65	3186	5.02	1488	2.34	4355	6.86	1602	2.52	3470	5.46	4050	6.38	2017	3.18	9526	15.00	0	0	38800	24704	63504
S12	5358	8.44	4900	7.72	3390	5.34	2382	3.75	5611	8.84	2388	3.76	3425	5.39	4962	7.81	1644	2.59	6406	10.09	0	0	40466	23038	63504
S13	4758	7.49	3141	4.95	2239	3.53	1213	1.91	3793	5.97	1660	2.61	2459	3.87	4531	7.13	2376	3.74	5871	9.25	0	0	32041	31463	63504
S14	4194	6.60	2954	4.65	5922	9.33	694	1.09	4744	7.47	720	1.13	5892	9.28	2904	4.57	428	0.67	16430	25.87	0	0	44882	18622	63504
S15	4825	7.60	3729	5.87	3931	6.19	1264	1.99	4706	7.41	1311	2.06	3923	6.18	3770	5.94	1881	2.96	6126	9.65	0	0	35466	28038	63504
S16	3195	5.03	3533	5.56	2054	3.23	2182	3.44	4757	7.49	2320	3.65	2045	3.22	3927	6.18	1164	1.83	2928	4.61	0	0	28105	35399	63504
S17	3015	4.75	3700	5.83	2883	4.54	1920	3.02	4938	7.78	1783	2.81	2821	4.44	3412	5.37	1074	1.69	2072	3.26	0	0	27618	35886	63504
S18	4050	6.38	3944	6.21	3634	5.72	1567	2.47	5684	8.95	2082	3.28	3973	6.26	4900	7.72	1544	2.43	4993	7.86	0	0	36371	27133	63504
S19	2817	4.44	3556	5.60	1975	3.11	2506	3.95	5025	7.91	2274	3.58	1966	3.10	3498	5.51	925	1.46	2293	3.61	0	0	26835	36669	63504
S20	1942	3.06	2942	4.63	1645	2.59	2144	3.38	4381	6.90	2114	3.33	1755	2.76	3189	5.02	878	1.38	1457	2.29	0	0	22447	41057	63504

Table1: Frequency occurrences of ULBP shapes for Sand textures.

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	Dot	%	Small Line	%	Line	%	Small L	%	Elongated L	%	Complete L	%	Small U	%	Elongated U	%	U	%	Blob with hole	%	Blob	%	Uniform_Total	Non_Uniform	Total
M1	3662	5.77	3188	5.02	5927	9.33	1353	2.13	3915	6.16	1498	2.36	5949	9.37	3747	5.90	1343	2.11	18956	29.85	0	0	49538	13966	63504
M2	3543	5.58	3049	4.80	5659	8.91	1291	2.03	3720	5.86	1395	2.20	5706	8.99	3566	5.62	1183	1.86	21981	34.61	0	0	51093	12411	63504
M3	3919	6.17	3557	5.60	5711	8.99	1685	2.65	5075	7.99	2233	3.52	5832	9.18	5241	8.25	1566	2.47	16330	25.71	0	0	51149	12355	63504
M4	3263	5.14	2846	4.48	6664	10.49	1235	1.94	3469	5.46	1210	1.91	7051	11.10	3622	5.70	1277	2.01	20129	31.70	0	0	50766	12738	63504
M5	3963	6.24	3366	5.30	6690	10.53	1421	2.24	3946	6.21	1351	2.13	6558	10.33	3267	5.14	1045	1.65	17899	28.19	0	0	49506	13998	63504
M6	4000	6.30	2881	4.54	5944	9.36	1023	1.61	3401	5.36	1232	1.94	6068	9.56	2998	4.72	890	1.40	13381	21.07	0	0	41818	21686	63504
M7	3176	5.00	2625	4.13	5994	9.44	993	1.56	3134	4.94	946	1.49	5764	9.08	2746	4.32	1054	1.66	23298	36.69	0	0	49730	13774	63504
M8	3482	5.48	2765	4.35	5568	8.77	1147	1.81	3646	5.74	1227	1.93	5519	8.69	3260	5.13	1066	1.68	22236	35.02	0	0	49916	13588	63504
M9	3157	4.97	2854	4.49	6137	9.66	1141	1.80	3724	5.86	1341	2.11	6463	10.18	3728	5.87	1417	2.23	20236	31.87	0	0	50198	13306	63504
M10	5349	8.42	3816	6.01	5908	9.30	1367	2.15	3709	5.84	1223	1.93	5695	8.97	2910	4.58	529	0.83	11052	17.40	0	0	41558	21946	63504
M11	6221	9.80	4946	7.79	4216	6.64	2668	4.20	5931	9.34	2848	4.48	3957	6.23	4736	7.46	827	1.30	9107	14.34	0	0	45457	18047	63504
M12	3780	5.95	3059	4.82	3824	6.02	1709	2.69	4576	7.21	2686	4.23	4262	6.71	5833	9.19	2025	3.19	19335	30.45	0	0	51089	12415	63504
M13	5281	8.32	4680	7.37	3617	5.70	2217	3.49	5820	9.16	2332	3.67	3466	5.46	4987	7.85	1200	1.89	13387	21.08	0	0	46987	16517	63504
M14	5853	9.22	5147	8.11	3463	5.45	2815	4.43	5823	9.17	2757	4.34	3460	5.45	4887	7.70	1010	1.59	8671	13.65	0	0	43886	19618	63504
M15	3179	5.01	2689	4.23	4842	7.62	1029	1.62	3145	4.95	997	1.57	4824	7.60	2947	4.64	1073	1.69	26181	41.23	0	0	50906	12598	63504
M16	3135	4.94	2830	4.46	5600	8.82	1570	2.47	5045	7.94	2620	4.13	6251	9.84	5833	9.19	1611	2.54	16544	26.05	0	0	51039	12465	63504
M17	5653	8.90	4418	6.96	6138	9.67	1957	3.08	4495	7.08	1520	2.39	5718	9.00	3605	5.68	867	1.37	11578	18.23	0	0	45949	17555	63504
M18	4168	6.56	4595	7.24	9649	15.19	2205	3.47	5233	8.24	1827	2.88	9194	14.48	4316	6.80	1015	1.60	7240	11.40	0	0	49442	14062	63504
M19	5562	8.76	5000	7.87	3626	5.71	2859	4.50	5928	9.33	2813	4.43	3474	5.47	4924	7.75	999	1.57	6530	10.28	0	0	41715	21789	63504
M20	2963	4.67	3808	6.00	2823	4.45	2558	4.03	5633	8.87	2808	4.42	3164	4.98	4838	7.62	1477	2.33	4550	7.16	0	0	34622	28882	63504

Table2: Frequency occurrences of ULBP shapes for Mosaic textures.

	Dot	%	Small Line	%	Line	%	Small L	%	Elongated L	%	Complete L	%	Small U	%	Elongated U	%	U	%	Blob with hole	%	Blob	%	Uniform_Total	Non_Uniform	Total
M1	4015	6.32	4105	6.46	2447	3.85	2423	3.82	5286	8.32	2295	3.61	2712	4.27	4515	7.11	1738	2.74	5990	9.43	0	0	35526	27978	63504
M2	5474	8.62	4343	6.84	2947	4.64	2270	3.57	4616	7.27	2293	3.61	3020	4.76	4645	7.31	1272	2.00	15462	24.35	0	0	46342	17162	63504
M3	4558	7.18	3864	6.08	3326	5.24	2035	3.20	4974	7.83	2552	4.02	3704	5.83	5266	8.29	1595	2.51	16468	25.93	0	0	48342	15162	63504
M4	4970	7.83	4866	7.66	4108	6.47	2905	4.57	5595	8.81	2976	4.69	4038	6.36	4877	7.68	1190	1.87	8222	12.95	0	0	43747	19757	63504
M5	4614	7.27	4751	7.48	3574	5.63	2838	4.47	5894	9.28	3137	4.94	3418	5.38	5358	8.44	1396	2.20	6552	10.32	0	0	41532	21972	63504
M6	5845	9.20	5182	8.16	3930	6.19	2555	4.02	6546	10.31	2308	3.63	3462	5.45	4325	6.81	1205	1.90	4550	7.16	0	0	39908	23596	63504
M7	5264	8.29	4915	7.74	4373	6.89	2442	3.85	6613	10.40	2703	4.26	4487	7.07	5589	8.80	1333	2.10	7847	12.36	0	0	45566	17938	63504
M8	4811	7.58	4762	7.50	3350	5.28	2697	4.25	6121	9.64	3552	5.59	3454	5.44	6270	9.87	1540	2.43	8051	12.68	0	0	44608	18896	63504
M9	4974	7.83	4608	7.26	3971	6.25	2608	4.11	6075	9.57	2896	4.56	4187	6.59	5381	8.47	1167	1.84	10945	17.24	0	0	46812	16692	63504
M10	4856	7.65	4849	7.64	5612	8.84	2133	3.36	5452	8.59	1870	2.94	5571	8.77	4736	7.46	1528	2.41	6552	10.32	0	0	43159	20345	63504
M11	5843	9.20	4904	7.72	4116	6.48	2245	3.54	4887	7.70	1991	3.14	3818	6.01	3900	6.14	1072	1.69	9156	14.42	0	0	41932	21572	63504
M12	5660	8.91	5286	8.32	3400	5.35	3337	5.25	6557	10.33	2892	4.55	3280	5.17	4865	7.66	1108	1.74	8323	13.11	0	0	44708	18796	63504
M13	4144	6.53	4065	6.40	3947	6.22	2334	3.68	5364	8.45	2659	4.19	4136	6.51	4946	7.79	1414	2.23	11121	17.51	0	0	44130	19374	63504
M14	2355	3.71	3202	5.04	3864	6.08	2654	4.18	8087	12.73	5175	8.15	3846	6.06	6015	9.47	943	1.48	3222	5.07	0	0	39363	24141	63504
M15	5238	8.25	5593	8.81	3336	5.25	3438	5.41	5636	8.88	2830	4.46	3304	5.20	4756	7.49	1297	2.04	6555	10.32	0	0	41983	21521	63504
M16	3359	5.29	4287	6.75	5630	8.87	2402	3.78	5582	8.79	2530	3.98	5562	8.76	4849	7.64	1209	1.90	4849	7.64	0	0	40259	23245	63504
M17	4386	6.91	4160	6.55	5180	8.16	2190	3.45	5444	8.57	2460	3.87	5544	8.73	4940	7.78	1208	1.90	9646	15.19	0	0	45158	18346	63504
M18	3271	5.15	3753	5.91	7277	11.46	1701	2.68	5798	9.13	1638	2.58	7774	12.24	4170	6.57	1529	2.41	5040	7.94	0	0	41951	21553	63504
M19	4198	6.61	4181	6.58	7299	11.49	1849	2.91	4737	7.46	1726	2.72	7564	11.91	4018	6.33	1232	1.94	9877	15.55	0	0	46681	16823	63504
M20	5634	8.87	5096	8.02	3691	5.81	2452	3.86	5796	9.13	2715	4.28	3762	5.92	5319	8.38	1345	2.12	10300	16.22	0	0	46110	17394	63504

Table3: Frequency occurrences of ULBP shapes for Marble textures.

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