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A Combined Statistical and Structural Approach for Texture Representation

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Abstract: A combined statistical and structural approach is presented in this paper for texture representation. A set of tonal primitives (Binary or Gray level based) have been suggested, called Texture Primitives which are of size (3×3). These primitives are basically tested for the presence of texture by conducting a suitable statistical test called Nair's test. The texture primitives are analogous to texture number as suggested by He and Li Wang. The set of universal primitives are labeled as local descriptor and the frequency of occurrences of these primitives is used as the global descriptor, namely Texture Primitive Spectrum for a given texture image. Since the occurrence of primitives and their placement rules uniquely define a texture image, the primitive spectrum is also unique, for a texture image. The primitive spectrums are presented for a variety of texture images of Brodatz album. These spectrums are shown to be effectively used for texture classification and promising results are obtained.

Key words: Texture-primitives-nair's statistical test-presence of texture-universal set of primitives-global descriptor-texture primitive spectrum-classification

INTRODUCTION

Digital Images can be of two types namely (i) Textured or (ii) Un textured (or consisting of uniform regions).Texture analysis is one of the major focused areas of research for the past two decades. The main idea behind this effort implies from the fact that most of the surface properties, remote sensed data, abraded surfaces etc. are of texture in nature. There are several algorithms have been proposed so far for the analysis of un textured images whereas very few for texture image analysis. The reason is that there was no unique definition or feature for the texture. With their own perspectives, a number of definitions for texture have been proposed and used by various researchers in their context of analysis. Few schemes for texture analysis have been suggested, either they are based on Statistical or Structural approaches. Using statistical approaches, several schemes have been suggested right from Co-occurrence matrix, run length matrix based, auto correlation, auto regression, MRF based, moments based etc. as found in literature[1-5].

In structural approach, the texture region is defined to have a constant texture if a set of local statistics or other local properties of the image are constant, slowly varying or approximately periodic.

An image texture is described by the number and types of its (tonal) primitives and the spatial organization or layout of the primitives. Textures could be rated as coarse, micro, macro, regular, periodic, aperiodic, directional, random, or stochastic[6].

The notion of texture appears to depend upon three components. They are

- Some local 'order' is repeated over a region which is large in comparison to the order's size.
- The order consists of the non random arrangement of elementary parts and
- The parts are roughly uniform entries having approximately the same dimensions everywhere within the textured region.

Texture analysis is an important step during low level analysis of textured images. Texture is defined as a structure composed of a large number of more or less ordered, similar elements or patterns. Observable textures can be characterized by the primitives and placement rules[7]. The main idea of our work is from the intuitive suggestion offered by this fact[7]. Any texture images can be generated by a set of primitives and their placement rules. Conversely any texture image, is identified or perceived to consist of primitives and their regular or

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random occurrences. If it is possible to find out the set of primitives and how they occur or the frequency occurrences of such primitives, we are succeeding in the representation of texture image. The success of any texture analysis scheme is inferred from the way it captures the textural features and the uniqueness. The textural properties of texture images carry more useful information for the discrimination purposes, it is important to develop features for texture based on suitable quantitative representation of some of these properties. Since the frequency of occurrences of such primitives is computed for the entire image, the representation becomes global descriptor Other recent approaches for texture analysis and synthesis may be referred from[8-10].

The objective of this study is to propose a statistical method for detecting the presence of micro texture in a given small image region. A set of texture primitives which are found to be textured are labeled as local descriptor and the frequency of occurrences of these primitives called texture primitive spectrum is used as the global descriptor. With the proposed set of primitives, number of spectrums have been obtained for various texture images collected from Brodatz Album[11].

This stydu is organized as follows. The study represents illustrates a brief account of texture number scheme as suggested by He and Li Wang,[12]. Since in their approach also a 3×3 image region is considered as a texture unit and used further for many texture related applications, it is appropriate to briefly review their work for our comparison purpose. Third section explains the model behind our work and the method of detecting the presence of texture by conducting suitable statistical test. A set of primitives along with labeling is presented. In the fourth section, with the proposed set of primitives textured images are represented by the global descriptor, namely Texture Primitive Spectrum and the experimentation with a set of standard Brodatz Textural Album[11]. Finally, the conclusion about our approach by combining statistical tests to form a set of primitives called local descriptor and the frequency of occurrences of these primitives. Further scope of this research work are also presented in this study.

Brief review of texture number scheme: He and Li Wang,[12]. Suggested that any gray level monochrome texture images can be conveniently represented by computing the occurrences of a small unit, called texture unit. Each texture unit is defined in an image region of size 3×3. The intensity of the center pixel in each texture unit is compared with the corresponding intensities of eight neighbors. The result of comparison, namely, equal, less or greater is coded as 0,1 or 2, respectively. Hence each texture unit is now transformed in to eight ternary digits. The equivalent decimal number of this 8 digit ternary number is called the texture number. Each texture unit is represented by the corresponding texture number computed using the formula as in Eq. 1.

$$TNU = \sum_{i=1}^{8} e_i \times 3^{i-1} \quad (1)$$

The total texture number ranges from 0 to 6560. In this proposal, the small texture units are not tested for the presence of texture. i.e., whatever may be the texture units under consideration, their equivalent texture numbers are computed. Sometimes, even an un textured images or regions could also be computed with the texture numbers and are used for further analysis without knowing that they are the results of un textured images. In order to avoid this situation, it is proposed in this paper to apply suitable statistical test to ensure the presence of the texture before they are further used for analysis. Entire theory behind the performance of this test along with the sample results are presented in the subsequent sections of this.

The texture number scheme has been experimented with images shown in Fig. 1. for four images. The corresponding texture spectrums are shown in Fig. 2.

The idea of texture primitive is obtained from the intuitive suggestion given by Julesz,[13]. In his study, he proposed that the first order and second order statistics computed out of the texture images are defined as the features. These features are either directly computed or derivable. Conversely, if the primitives have the said features and are used for constructing the texture images, they are discriminable. Julesz further proposed that two textures are not discriminable if their second order statistics are identical.

Texture primitives and representation: In the previous study, the texture unit with texture number has been discussed along with the conjectures of Julesz for placing the texture primitives to have discriminability. In this study, the presents of texture is detected by proposing a new statistical design of experiments based method for representation of micro texture. This is obtained based on the significant orthogonal effects due to spatial variations of gray levels. In this study, it is shown that an image region is decomposed in to two sets of orthogonal effects. The first set is considered to be contributing towards the presence of texture and the second one is for the noise. Suitable mathematical model and statistical tests for

Fig. 1: Texture primitives (serial numbers from TP_1 to TP_{92})

Fig. 2: Texture images collected from brodatz album

detecting the texture presence is presented in this section. Then a set of primitives are presented which are used as local descriptor. Finally any texture image is represented using the frequency of occurrence of the primitives called the Texture Primitive Spectrum.

Detection of texture presence: Texture is defined as a structure composed of a large number of more or less ordered similar elements or primitives in an image. Textures are normally ranging from micro to macro. A small image region which is a function of two spatial co ordinates, is represented by a set of orthogonal polynomials[14]. In this representation, the image region is considered to be a linear combination of un correlated (orthogonal) effects due to spatial variations. The uncorrelated effects due to the presence of textures have been separated successfully from those due to the presence of Gaussian noise[14]. The presence of texture in the image region under analysis is detected on the basis of the strength of the appropriate orthogonal effects.

Consider a (N x N) gray level image f (x,y), where x,y are the two spatial coordinates. The function f (x,y) which represents the gray level of the pixel, is a random variable in the presence of additive noise.

Thus, f (x,y) can be expressed as

$$f(x,y) = g(x,y) = +\eta(x,y) \qquad (2)$$

where g (x,y) accounts for the spatial variation in f (x,y) and ? (x,y) is the additive noise. The function g (x,y) can be thought of as the response function or the effects of controllable causes, whereas ? (x,y) is variation due to the uncontrollable causes and independent and identically distributed Gaussian variable with zero mean and standard deviation.

The spatial variation g (x,y) can be approximated by using an appropriate set of orthogonal functions. In this regard, a set of orthogonal polynomials have been proposed and the discrete-discrete formulation has been used to determine a set of orthogonal effects, Bij, due to the texture and noise[14]. These effects and their corresponding mean squares Zij are obtained as follows:

$$[B_{ij}] = ([H]^t[H])^{-1}([H]^t[f][H])([H]^t[H])^{-1} \qquad (3)$$

and

$$[Z_{ij}] = ([H]^t[H])^{-1}([B'^{2}_{ij}])([H]^t[H])^{-1} \qquad (4)$$

where $[B'_{ij}] = [H]^t[f][H]$. and [H] is the proposed orthogonal polynomial operator and [f] is a (3×3) image region. In order to characterize texture, the set of orthogonal effects [Bij] is divided in to two disjoint subsets, namely, the set $(B_{01},B_{02},B_{10},B_{20})$ of effects due to the presence of Gaussian noise and the set $(B_{11},B_{12},B_{21},B_{22})$ of interaction effects due to the presence of texture. The rationale behind this separation of effects is that in the presence of texture, the two spatial coordinates depend on each other.

The criteria for the separability of orthogonal effects due to noise from the effects due to texture can be tested by using the hypothesis that in the presence of texture, the mean square variances corresponding to the orthogonal effects due to the noise are, in fact, estimates of the same noise variance and therefore be used as an estimate of error. These can be tested by computing their divergence in the average variance. If the computed divergence in the average variance is less than the corresponding tabulated value, it is concluded that the divergence is insignificant and the hypothesis is accepted. The method of computing the divergence and the significant values for the divergence of various degrees of freedom are given in appendix.

For any given (3×3) image region, the set of variances due to the interaction effects are computed using Eq. 3 and 4. These variances are subjected for the Nair's test. If the computed divergence is more than the tabulated value, the variances are significant and the region is considered to have the presence of texture.

Construction of texture primitives: A texture primitive TP_i, is defined as a set of more than two adjacent pixels having intensities from (0 to 255) connected by an attribute (attribute for example, having small varied gray levels or within a tolerable limit). Smallest primitive is a pixel only. But is having only one fixed attribute. So a minimum region of size (3×3) is considered in our work for constructing the texture primitives. With 3×3 image region the intensities of the selected pixels are varied to impart the designated attribute . Thus pixels having the same attribute (or within a tolerance limit) contributes to the formation of texture primitive. Or in other words several primitives can be formed by combining different groups of pixels satisfying the attributes within the chosen region. Within (3×3) image regions, the following set of primitives are proposed as a set of universal primitives. These primitives are labeled from TP_1 to TP_{92} and shown in Fig. 1. The line joining segments shown here are basically the pixels satisfying the attribute with some tolerances.

Texture images have been shown generated by filling the region with one or more primitives in an ordered manner[15].

Primitive geration and vlidation: The texture primitives which are shown in Fig. 1. are generated by grouping of 3×3 pixels with any gray levels ranging from 0 to 255. The line joining in the primitives are considered to be adjacent and the intensities of these pixels are more or less same or well within a tolerable limit. These primitives are tested using the divergence principle to ensure the presence of texture as depicted in Appendix. Totally there are 600 such primitives considered for the test and the results of qualifying the tests are presented in Table 1. Almost all the sample primitives we have considered are passing the tests at various levels of significance levels. Among these primitives, around 80% of the primitives pass the test at stringent condition i.e., at 1% significant level. Another 15% of the primitives pass the test at some what relaxed significance level, namely, at 5% significance level. And the remaining 5% of the primitives pass the tests at more than 5% significant levels. This implies that some primitives are very less textured and hence the presence of texture is realized only when the stringent conditions are relaxed.

Using the set of primitives proposed in Fig. 3, texture images have been shown generated by filling the region with one or more primitives in an ordered manner[15].

Table 1: Texture validation results

Total number of primitives 1% significant levels	Number of primitives Passing at 5% significance levels	Number of primitives passing at included for the test	Number of primitives passing at more than 5% significance levels
600	484	90	16

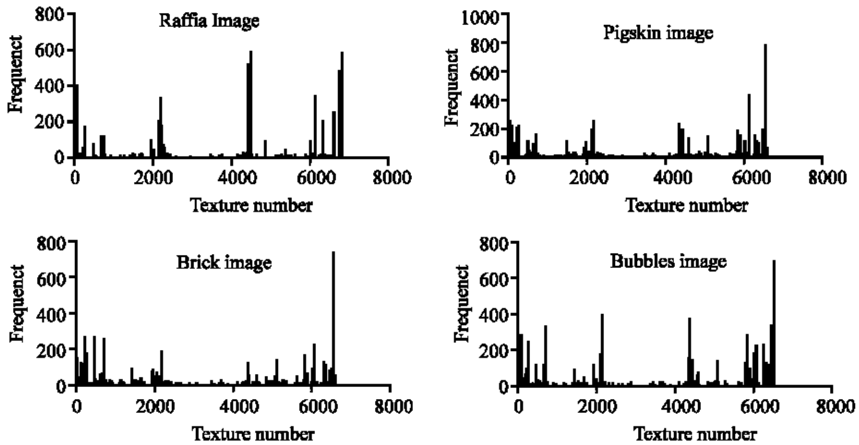

Fig 3: Texture Spectrum for the images shown in Fig. 2

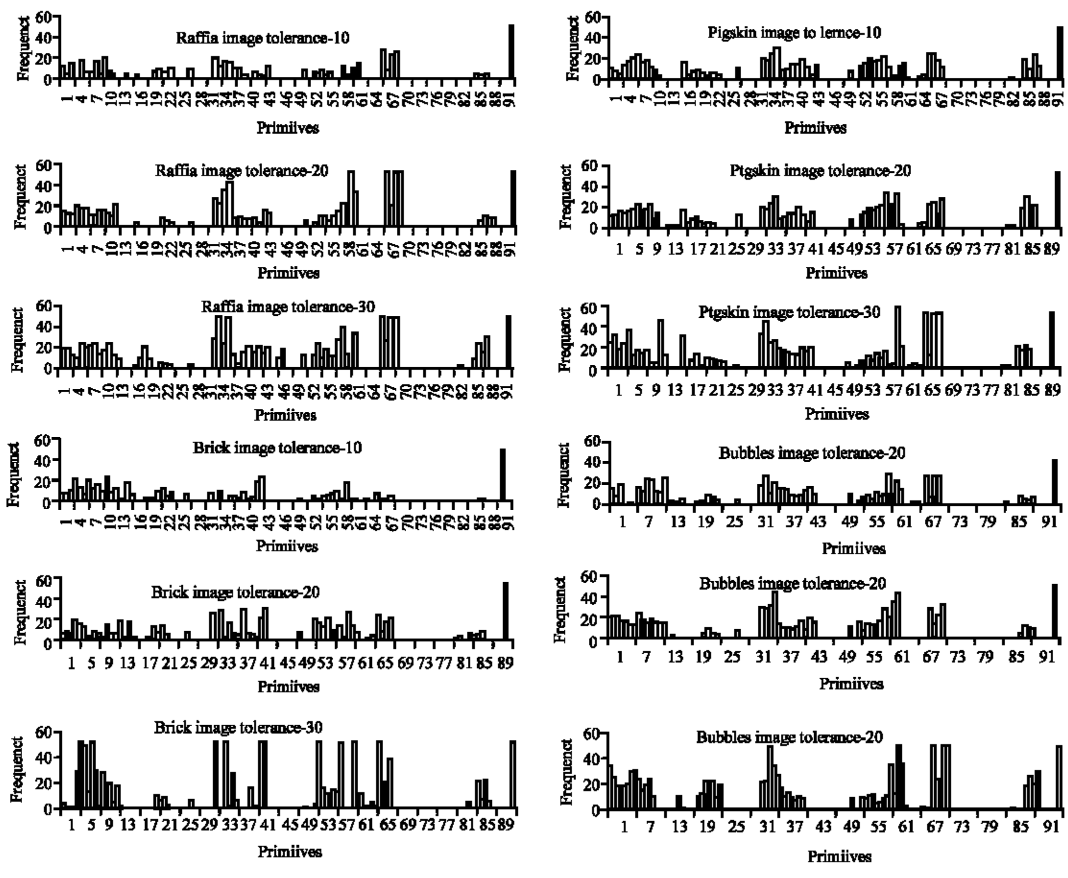

Fig. 4: Primitive Spectrum for the images shown in Fig. 2

Texture representation and experimentation: Texture images are considered to have these proposed set of 92 texture primitives. Different textured images look different because of the variations in the presence of such

APPENDIX

Bishop and nair's test: Let v_{a1}, v_{a2}, …, v_{ak} be the set of variances with V_1, V_2 …, V_k degrees of freedom, respectively. The average variance

$$V_{av} = 1/V = \sum_{i=1}^{K} v_{ai} V_i \quad (1A)$$

And the total degrees of freedom

$$V = \sum_{i=1}^{K} V_i \quad (2A)$$

Then the variances for computing the divergence among variances is

$$D = V \ln v_{av} - \sum_{i=1}^{k} V_i \ln(v_{ai}) \quad (3A)$$

The D values for various significance levels with different degrees of freedom were given earlier[16] and relevant values are provided in Table 2.

primitives. That is, various compositions of occurrences of the primitives make texture images look differently. Or in the other words each texture image is having primitives shown in Fig. 1, with different occurrences. The frequency of occurrences of each primitive in the entire image is the representation of the texture image. That is global descriptor. The texture images are looked into the presence of each primitive occurrences. Since images are having gray level variations from 0 to 255, primitives are also having these variations. For any given image, (3×3) image regions are considered from top-left corner. The contents of the images are compared looking for the presence of any one of the primitives already defined. If there is a match corresponding frequency of occurrences is incremented by one. This process is repeated for the entire image. Finally, the frequency of occurrences of all the primitives in an image constitutes the primitive spectrum, which is a global descriptor. Since, the occurrence of primitives in an image is different to that of another image, the primitive spectrums are also unique.

The overall gray level or illumination level variations in images are absorbed while they get match with primitives. Hence the global representation is not disturbed. While we look for match with similar primitives, if the attribute is not matching perfectively, tolerance is applied. For each tolerance level the occurrences of primitives and hence the corresponding primitive spectrums are obtained.

Table 2: Significant divergence(D) among variance (for different degrees of freedom K)

Values of K	2	3	4	5	6	7	8	9	10
5% Points	5.1	7.7	10.0	12.0	14.1	15.9	17.9	19.9	21.3
1% Points	8.3	11.5	14.0	16.5	18.9	21.0	23.1	25.2	23.2

Experimentation and results: A set of all texture primitives is presented in Fig. 1. These primitives are subjected to Nair's test for detecting the presence of texture and the validation results are presented in Table 1. Four images are considered from Brodatz Textural album which are shown in Fig. 2. They are Raffia (D84), Pigskin (D92), Brick (D94) and Bubbles (D112), each of size (128×128). He and Li Wang's, textures spectrum are computed and presented in Fig. 3. The overall ranges of texture numbers are from 0 to 6560.

The texture primitive spectrums for all the four images are shown in Fig. 4. These are obtained at different tolerance levels, namely, at 10, 20 and 30. As the tolerance levels get relaxed, the frequency of occurrences of primitives in these spectrum are more and more. This is the because at less tolerance limit, if a primitive is not occurred, the same may get occurred when the condition on attribute is relaxed. Similarly, the primitive spectrum for the remaining three images are also shown.

The usage of the primitive spectrums are found successfully when using in the texture supervised classification. An average correct classification of 92% is reported.

CONCLUSION

A combined statistical and structural approach is presented for texture representation. Statistical design of experiments based approach is applied for detecting the presence of texture. A complete set of texture primitives are presented. These primitives are of size 3×3. The frequency of occurrences of the primitives over an image is represented as a spectrum called the texture primitive spectrum. This is used as the global descriptor since the frequencies are obtained for the entire image. The occurrences of primitives are perceived at different gray levels constituting different spectrums each at different tolerance levels. The primitive spectrums are presented for the standard textured images. The usage of the primitive spectrums have been highlighted in the case of supervised texture classification. An average correct classification of 92% has been obtained. The authors are currently working with the proposal for unsupervised classification and edge detection of textured regions.

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