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Study on Texture Descriptors in Super Resolution

* Kiran .P Patel

June, 2012

Abstract

The local geometry of an image is conveyed by image features such as edges, corners and curves. In this paper, I present study & overview of state-of-the-art Texture Descriptors, namely local binary pattern, uniform local binary pattern, local ternary pattern & noise tolerant local ternary pattern operator. We can encode these features with these operators. A new learning based technique to super-resolve a low resolution image using these Operators and a database of low resolution (LR) images and corresponding high resolution (HR) versions. The missing high resolution features of the low resolution observation are learnt in the form of discrete cosine transform coefficients from high resolution images in the training database.

Keywords : Index terms: Local Binary Pattern Operator, Uniform Local Binary Pattern operator, Local Ternary Pattern operator & Noise Tolerant Ternary Pattern operator

Binary Pattern Operator

Local Binary Pattern (LBP) [3] is an n-bit binary code at a pixel, c , in a gray scale image is generated by Equation (1), which compares c 's intensity with that of its n neighbours. These neighbours are located at uniform distances on a circle centered at c with radius r :

$$\text{LBP}_{n,r}(x_c, y_c) = \sum_{i=0}^{n-1} q(g_i - g_c) 2^i, \quad (1)$$

$$q(a) = \begin{cases} 1 & \text{if } a \geq 0 \\ 0 & \text{otherwise} \end{cases}$$

where (x_c, y_c) is the pixel co-ordinate of c, g_c , and g_i are the intensities of c and the i^{th} neighbouring pixel, respectively.

77	85	29
52	52	38
54	11	68

Threshold

1	1	0
0	(i,j)	0
0	0	1

Binary code: 11001000

(a) The LBP operator

The LBP codes can represent texlets such as edge, corner and line-end. The basic local binary pattern operator, introduced by Ojala et al. [6], was based on the assumption that texture has locally two complementary aspects, a pattern and its strength. In that work, the LBP was proposed as a two-level version of the texture unit to describe the local textural patterns. The original version of the local binary pattern operator works in a 3×3 pixel block of an image. The pixels in this block are thresholded by its center pixel value, multiplied by powers of two and then summed to obtain a label for the center pixel. As the neighbourhood consists of 8 pixels, a total of $2^8 = 256$ different labels can be obtained depending on the relative gray values of the center and the pixels in the neighbourhood. It has gained popularity for its computational simplicity and robustness against monotonic changes in illumination. It has already shown its capabilities in several image processing

applications such as face detection, face recognition, facial expression detection, moving object detection, finger biometric recognition and many others. However, LBP is very noise sensitive, especially in near uniform regions. Small changes in intensities due to noises in near uniform regions may lead to erroneous LBP codes. Even for small intensity fluctuations, which are very common in digital images, LBP and most of its variants fail to generate the same code for the same type of texture structures. Keeping this in mind, Tan and Triggs proposed Local Ternary Pattern (LTP) [14], which uses three-value encoding and shows tolerance to noise up to a certain level as they assume noises in an image usually vary within a fixed threshold (± 5).

Local structural variations of an image are reflected by image features in the form of edges, corners, junctions and curves. The next step in the algorithm is to model these image features with the help of local binary pattern (LBP) operator. LBP was originally proposed for texture classification by Ojala et al. [7]. The original LBP operator and its variants were then employed for various applications such as face recognition [21], object detection [23], license plate recognition [28] and smoke detection [22]. It is an effective descriptor to capture local structural variations. LBP code of a pixel is obtained by comparing its intensity with that of the neighboring pixels.

B. Uniform Local Binary Pattern Operator

An LBP is defined as uniform local binary pattern (ULBP) if there are at most two bit transitions in its binary equivalent.

$$U(\text{LBP}_{n,r}(x_c, y_c)) = |q(g_{n-1} - g_c) - q(g_0 - g_c)| + \sum_{i=1}^{n-1} |q(g_i - g_c) - q(g_{i-1} - g_c)| \quad (2)$$

For example, 11100011 is a uniform pattern, while 11101011 is not. When uniformity is taken into consideration, all the non-uniform patterns are accumulated in a single bin during histogram formation.

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C. Local Binary Pattern Operator

Local Ternary Pattern (LTP) [14] mainly follows the same spirit of Local Binary Pattern (LBP). The key difference is that it introduces a new bit to manage the intensity fluctuations. Thus, LTP becomes a ternary code at a pixel c , which is generated by Equation (1): The Local Ternary Pattern (LTP) [6] at a point c is defined by:

$$LTP_{n,t}(x_c, y_c) = \sum_{i=0}^{n-1} h(g_i - g_c) 3^i$$

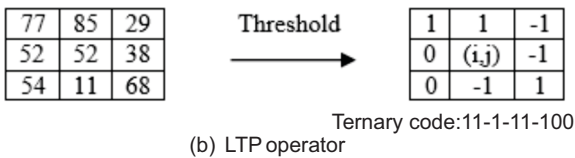
$$h(u, i) = \begin{cases} -1, & (u - i) < -t \\ 1, & (u - i) > t \\ 0, & \text{else} \end{cases} \quad (3)$$

We create a ternary pattern instead of a binary pattern where a 1 is stored if the neighboring pixel is greater than the center pixel, a -1 is stored if it is less and 0 is stored if they are almost the same. Sameness is defined w.r.t. to a threshold t . Then, the LTP vector is the vector of these ternary values over a given neighborhood (fig. 1(b)). Thus, the i th bit of the LTP

vector for the point c is given by:

$$LTP_c(i) = z(i_{ki}, l_c) \quad (4)$$

Where ki is the i th neighborhood point for c .



Tan and Triggs[1] create ternary patterns in the above way but while matching, they split the pattern into two binary codes, combining -1 with 0 (termed as Up LTP code (fig. 2(c(1)))) and 1 with 0 (termed as Down LTP code (fig. 2(c(2)))) in the two binary patterns (Fig. 2(c)).

However, as mentioned in the introduction, the method is susceptible to small Gaussian noise or intensity changes in homogenous regions. An adaptive noise band (ANB) can be defined to approximate the amount of noise contamination around a pixel up to a certain extent. Based on this ANB, we generate reliable codes named noise tolerant ternary pattern (NTTP) to represent the textures in an image. [19]

D. Adaptive Noise Band

An adaptive noise band [10] defines the maximum possible extent of noise that can be contaminated with the observed intensity, i , of a pixel, and can be approximated by the square root of that intensity. When the difference between two neighboring pixel values is within the ANB, we consider that the difference is due to noise. In some pixels, the ANB may result in inclusion of original texture patterns into the noise band. However, this may not cause much harm to the classification; rather this helps to distinguish prominent and less prominent patterns, which results in improved classification. The noise characteristics do not remain the same for different intensity regions. For low intensity region ($R1$), the dominant noises are independent of signal and remain constant. Another point here is that this PTC curve is calculated in the sensor domain (light space), but our focus is to deal with noises in the given image (image space). This problem is addressed by Faraji et al. in [17], where it is shown that this constant behavior is also observed in the image space. Since the gray levels at this region are low, the noises are usually higher than the square root of the observed intensity. We, therefore, slightly modify the ANB at intensity I as:

$$ANB_i = \begin{cases} \pm t & \text{if } i < R \\ \pm \sqrt{i} & \text{otherwise} \end{cases} \quad (5)$$

where R is the boundary point separating the low-intensity region in image space that corresponds to the $R1$ region in Figure 2, and t is a constant to be set empirically. The value of R can be found in different ways. According to the method in [17], the value of R can be picked from the plot of intensity vs. noise standard deviation.

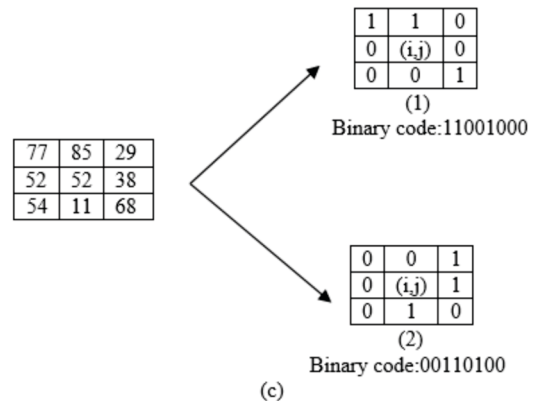
E. Noise Tolerant Ternary Pattern Texture Descriptor

The proposed NTTP [10] uses the aforementioned ANB to encode the texture pattern for a given pixel, where the NTTP code at a pixel c , coordinated at (x_c, y_c) is generated by comparing its intensity g_c with its neighbors according to Equation

$$NTTP_{n,t}(x_c, y_c) = \sum_{i=0}^{n-1} h(g_i - g_c) 3^i$$

$$h(u, i) = \begin{cases} -1, & (u - i) < -ANB \\ 1, & (u - i) > ANB \\ 0, & \text{else} \end{cases} \quad (6)$$

the remaining part is as LTP.



C. Searching similar features

F. Implementing Textures descriptors

Using appropriate algorithm, the algorithm searches the training database to find LR training images with similar features to that of the test image. For this we can divide the encoded test image using these pattern operators and LR training images into 8×8 image patches. We compare $8 \times 8 = 64$ pixels in each patch of the test image with the corresponding image patches of all the LR training images in the database and select the LR training image with maximum number of matching pixels in the patch under consideration as the best match for that patch. This indicates that there are maximum matching features such as edges, corners and curves in the patch of the test image and the best matching image patch of the LR training image. Thus we have a matching LR training image with similar features corresponding to all the 8×8 image patches of the test image.

Let $P_T(x, y)$ and $P_{LRp}(x, y)$, $1 \leq (x, y) \leq 8$ be the image patches of the test image and p th LR training image respectively. We search the best matching patch from the database by maximizing,

$$\hat{c} = \operatorname{argmax}_{x,y=1}^8 d(x, y) \quad (7)$$

with respect to c , where c is the index of the training image pair in the database and \hat{c} is the index of the best matching training image. Here, $d(x, y)$ is the distance measure defined as,

$$f(x, y) = \begin{cases} 1, & \text{if } P_T(x, y) = P_{LRm}(x, y) \\ 0, & \text{otherwise} \end{cases} \quad (8)$$

I apply this procedure to each image patch in the test image and find best matching LR training image for the corresponding patch.

IV. Conclusion

I have presented a study & overview on various texture descriptors, namely local binary pattern, uniform local binary pattern, local ternary pattern & noise tolerant local ternary pattern operator to super-resolve an image using single observation. Image features are recovered by representing them with these pattern operators that encodes the local structural variations into corresponding codes. It is understood that NTPP gives best results, then comes LTP, then Uniform LBP & LBP is least advisable in these four texture descriptors

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