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**Study on Texture Descriptors in Super Resolution**

* Kiran .P Patel

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:

\[
LBP_c(x, y) = \sum_{n=0}^{n-1} q(g_c - g_i) \cdot 2^l,
\]

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

![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 x 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 28 = 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 [12]. 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.

\[
\sum_{i=0}^{n-1} \beta_i = 1
\]

For example, 11100111 is a uniform pattern, while 111101011 is not. When uniformity is taken into consideration, all the non-uniform patterns are accumulated in a single bin during histogram formation.
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 LocalTernary Pattern (LTP) [6] at a point $c$ is defined by:

$$\text{LTP}_{c}(x_i,y_j) = \sum_{i=1}^{n} h(x_i,y_j)3^i$$

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

where $R$ is the boundary point separating the low-intensity region in image space that corresponds to the R1 region in Figure 2, and 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 $(x, y)$, is generated by comparing its intensity $g_c$ with its neighbors according to Equation

$$\text{NTTP}_{c}(x_i,y_j) = \sum_{i=1}^{n} h(x_i,y_j)3^i$$

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

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 $8 \times 8$ 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 $8 \times 8$ image patches of the test image.

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

$$\hat{c} = \underset{c}{\text{argmax}} \sum_{x,y=1}^{8} d(x, y)$$

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,

$$d(x, y) = \begin{cases} 1, & \text{if } P_{LR}(x, y) = P_{LR}(x, y) \\ 0, & \text{otherwise} \end{cases}$$

(c) The Tan and Triggs[14] LTP operator.
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 NTTP gives best results, then comes LTP, then Uniform LBP & LBP is least advisable in these four texture descriptors.

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