An improved edge detection approach and its application in defect detection

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Abstract. In this paper, a simple and efficient edge detection technique is proposed. It is based on the properties of the hyper smoothing function and the fundamentals of modified local binary pattern and hence, called as HY-LBP. The main advantage of the proposed approach is that the relationship between surrounding pixels and centric one is calculated effectively and extract the surrounding information discriminatively. The counting scheme that counts the number of image points whose pixel values are greater or equal than that of the central pixel help to reduce the noise and blurring effects. Thus, HY-LBP can effectively deal with the noises, blurring, and contrast variation. The effectuality and feasibility of the proposed approach is demonstrated on various synthetic and real time images. Experimental results have shown the effectiveness as well as the better performance of the proposed approach for edge detection as compared to the other existing methods. The presented method can be used in metal sheet defect detection applications.

1. Introduction

Over the last decade, X-rays are broadly used for noninvasive industrial detecting [1-3]. Computed tomography and digital radiography techniques are also popular and used in many applications such as diagnostic of fractures in the human body, defects and cracks in the products [4, 5]. However, such methods are expensive and demands a well trained and expert operator. Edge extraction is a good alternative to such conventional methods and plays an important role in computer vision and image processing applications. It is used in medical image analysis and understanding, remote sensing, object-based image coding, and image retrieval. Traditional edge extraction methods such as Canny and Sobel are amazing for their own special features. However, they are unable to keep the balance between noise elimination and edge preservation or they have to adjust parameters whenever the segmentation results are not satisfactory. Thus, a simple method with nice local property remains the challenge for researchers.

As the demand of edge detection in different applications, it has received considerable attention over the last several decades and numerous novel methods have been proposed in the literature [6-8]. Among these methods, local binary pattern (LBP) approach is one of the simple, less complex, invariant to monotonic gray scale and effective to describe textures of the image. However, LBP is sensitive to noise and it is unable to describe the difference of local region as well as degree of difference. Therefore, many researchers have been extended LBP’s binary patterns to trinary patterns (LTP) [9], quinary patterns (LQP) [10] and multiple patterns(LMP) [11], by including the several thresholds into the comparison function. These LBP-based methods are greatly used in real time computer vision application such as emotion recognition and classification, face recognition,
fingerprint identification, and automated cell phenotype image classification [12-15]. However, these approaches are based on the histograms with bins which are time intensive and memory consuming processes. In these methods the selection of threshold is crucial as well as difficult task.

Recently, Bi et al. [16] proposed an effective edge extraction method using improved local binary pattern (H-LBP) for blurry digital radiography (DR) image. This method is able to describe the relationships between pixels and less dependent on binarization. With a improved counting scheme that counts the number of pixels whose values are greater or equal to the centric one, H-LBP can deal with the noises, blurring, and contrast variation. However, it is observed that the edge extraction results and computational efficiency further can be improved using a new hyper smoothing function. Therefore, an attempt has been made and a simple and effective edge detection method based on hyper smoothing function and improved local binary pattern is proposed.

In this paper, LBP method is improved by embedding a hyper function and a counting scheme, so-called HY-LBP. The proposed approach is able to describe the relationship between surrounding pixels and centric one more accurately. With a counting scheme that counts the number of points whose pixel values are greater than that of the centric one, HY-LBP handle noises, blurring effect and obtained the fine edges.

2. Existing methods
Initially, LBP operator was introduced by Ojala et al. [6] for texture analysis and appearance-based face recognition. The LBP operator uses the neighborhoods of $3 \times 3, 8 \times 8$ or $16 \times 16$ pixel size. In this, operator labels the pixel $p_n (n = 0,\ldots,7)$ of an image by thresholding each pixel with the value of the center pixel $p_c$. The values in each pixel are thresholded with the center pixel value and a binary number is extracted. It is represented as:

$$B(p_i - p_c) = \begin{cases} 1 & \text{if } p_i \geq p_c \\ 0 & \text{otherwise} \end{cases}$$

(1)

The LBP can be computed as follows.

$$H_i = \sum_{i=0}^{n-1} B(p_i - p_c) 2^i, \quad \forall i = 0,2,3,\ldots,n-1.$$  

(2)

where $2^i$ is a binomial factor for each $B(p_i - p_c)$. This method is simple and easy to understand and therefore, it has been extensively used for pattern analysis as well as other applications [7, 10-11]. However, it is observed that the LBP method is more sensitive to noise and it cannot show the degree of difference among the pixel. To overcome these drawbacks, many researches extended the binary patterns to different patterns by adding a several threshold into the function [9-11]. Recently, Bi et al. [16] carried out an extensive work on edge extraction of blurry digital radiography images and proposed an effective technique based on the H-function commonly called as H-LBP. In this method the number of surrounding pixels are recorded whose gray-scale values are equal or greater than that of the central pixel.

$$\Gamma_i = \sum_{i=1}^{8} B(p_i - p_c),$$

$$B(\eta) = \begin{cases} 1 & \eta \geq 0 \\ 0 & \eta \leq 0 \end{cases}$$

(3)

The H-LBP is calculated as [16]
\[ H - LBP_{8,1} = \begin{cases} 
0 & T = 0 \\
\sum_{i=1}^{8} H_i (p_i - p_c) 2^i & 1 \leq T \leq 7 \\
0 & T = 8 
\end{cases} \] (4)

where \( H_i (p_i - p_c) = \text{compose } H(p_i - p_c) \).

The recorded number \( T \) can be used as a threshold to redundant fine gray-scale changes to abandon the isolated points and throw off the points lying in smooth area. The H-LBP approach is demonstrated using Figure 1. It is observed that the H-LBP is more complicated and requires more execution time as compared to existing methods.

![Figure 1](image)

**Figure 1.** Example of different regions with unequal H-LBP values.

### 3. Improved proposed approach

The proposed approach is based on the properties of the hyper smoothing function and the fundamentals of modified local binary pattern. To reduced the sensitivity to noise, a first number of surrounding pixels are recorded whose values are equal to or greater than that of the central pixel.

\[
T_h = \sum_{i=0}^{7} S(p_i - p_c), \quad S(\eta) = \begin{cases} 
1 & \eta \geq 0 \\
0 & \eta < 0 
\end{cases} \] (5)

where \( T_h \) is threshold value to redundant fine gray-scale changes. In LBP operation \( S(\eta) \) is the comparison function to describe the degree of differences between the pixels. However, this function has some insufficiencies. It is more sensitive to noise and unable to describe the difference between local region. To overcome these problems, a hyper smoothing function is proposed as:

\[
HY(\eta) = \frac{1}{2} \left( \frac{1}{\pi} \log(\chi_i) \right) \] (6)

where \( HY(\eta) \) is a hyper function in the level set method and acts a step function. The proposed HY-function is calculated as:

\[
HY(p_i - p_c) = \begin{cases} 
0 & p_i - p_c < T_h \\
\frac{1}{2} \left( \frac{1}{\pi} \log(\chi_i) \right) & Otherwise 
\end{cases} \] (7)

where
\[
X_i = \left( \frac{p_i + p_c}{p_i - p_c} \right)^4
\]  

Thus, HY-LBP with smoother function is calculated as

\[
HY-LBP_{8,1} = \begin{cases} 0 & T = 0 \\ \sum_{i=1}^{8} HY_c(p_i - p_c)2^{i-1} & 0 \leq T \leq 7 \\ 0 & T = 8 \end{cases}
\]

where, \(HY_c(p_i - p_c) = \text{compose}(HY(p_i - p_c))\) and \(T\) is the recorded number aims at throwing off isolated noises and points lying in smooth area. Moreover, \(T = 0\) represents the points isolated from noise while \(T = 8\) represent isolated points or points lying in smooth area.

The proposed approach is demonstrated as shown in Figure 2. It is observed from Figure 2, that the proposed approach gives the unequal results when the degrees of difference between \(p_i\) and \(p_c\) are not the same.

\[
\begin{array}{ccc}
91 & 68 & 33 \\
33 & 35 & 45 \\
20 & 35 & 14 \\
\end{array}
\quad
\begin{array}{ccc}
6 & 5 & 4 \\
3 & 5 & 5 \\
4 & 7 & 4 \\
\end{array}
\]

\[
\begin{array}{ccc}
0.032 & 0.045 & 0 \\
0 & 0.083 & 0 \\
0 & 0 & 0 \\
\end{array}
\quad
\begin{array}{ccc}
0 & 0 & 0 \\
0 & 0 & 0 \\
0 & 0 & 0 \\
\end{array}
\]

HY-LBP = 8  
HY-LBP = 0

**Figure 2.** Example of different regions with unequal HY-LBP.

Based on the above mathematical preliminaries a new edge detection method is proposed which is summarized in Algorithm 1.

**Algorithm 1** Proposed edge detection approach

**Step 1:** Given an acquired image \(I_p(x, y)\) of size \(M \times N\) pixels smoothen by \(3 \times 3\) mean filter and normalized by its energy defining as:

\[
\tilde{I}_p(x, y) = \frac{I_p(x, y)}{\sqrt{\sum_{x, y=0}^{N-1} [I_p(x, y)]^2}}
\]

such that \(\sum_{x, y=0}^{N-1} [\tilde{I}_p(x, y)]^2 = 1\).

**Step 2:** For each pixel in a \(3 \times 3\) neighborhood, count the number \(T_h\) using Eq. (5).

**Step 3:** Moreover, in a \(3 \times 3\) neighborhood, compute the \(HY(p_i - p_c)\) function using Eq. (7) for each surround pixel.

**Step 4:** Short the \(HY(\eta)\) values by \(HY_c(p_i - p_c) = \text{compose}(HY(p_i - p_c))\) and further weight these values using Eq. (9).
Step 5: Set the current pixel to white if HY-LBP values of the current pixel and previous pixel is non-zero.
Step 6: Repeat Step 2 to Step 5 for the entire image area.

Generally the digital radiography images are full of noises and artifacts which can be eliminated at the initial stage in the proposed algorithm. It can be done using mean, median filters or normalization process on the image. Further the threshold function $T_h$ is used to isolate the residuals of the noises and artifacts from the images.

4. Experimental results and discussion
In this section, the performance of the proposed focus measure is tested by performing a series of experiments on various images. All the experiments are carried out on Intel Core™ i3-370M 2.4, GHZ and 4 GB RAM processor, MATLAB platform of version R 2011.

The proposed approach (HY-LBP) is tested on blurry digital radiography and sheet metal plates images. All the digital radiography images as well as the sheet metal plates used in the experimentations are full of noises and artifacts. Therefore, the effectuality of the proposed approach is tested without simulating the images at different level of noises.

4.1. Blurred digital radiography (DR) images
In the first experiment, the effectuality of the proposed approach is tested on the blurry digital radiography (DR) images. Recently, Bi et al. [16] carried out the experimentations on various DR images. In this experiment same database has been considered for the fair comparison of the results. This database was acquired by scanning the railway side frame of 2286 mm length and 427 mm width and 695 mm height. These images are stored as gray scale images with cropped size of a $5876 \times 912$ pixel. An example of such blurry digital radiography image is shown in Figure 3(a).

The comparison of proposed approach HY-LBP, and the various existing edge extractions methods such as H-LBP, Canny, Sobel and LBP alone is shown in Figure 3. To observe the more details in the results, one important parts of casting is considered in the original image shown in Figure 3(a). In this image batch number (B) and low contrast area is seen clearly.

The various experimentations are carried on the original blurry digital radiography image. The obtained results are shown in Figure 3. The proposed approach called as HY-LBP shows the best results as shown in Figure 3(b). It is observed that the HY-LBP clearly shows the batch number (B) and low contrast area. Further, Figure 3(c)-(f) shows the result of H-LBP technique, Canny method, Sobel method, and LBP alone, respectively. It observed from Figure 3(d)-(f) that the batch number, low contrast and edges are not clear. Moreover, the HY-LBP results as shown in Figure 3(b) are comparatively better and clearer as compared to H-LBP technique. Hence the presented approach better than the well known existing methods such as H-LBP, Canny, Sobel and LBP method.

![Figure 3](image-url)

**Figure 3.** Comparison of edge extraction by different methods in DR image. (a) Original image (b) HY-LBP (c) H-LBP (d) Canny Method (e) Sobel Method (f) LBP alone.
4.2. Sheet metal plates images
In second experiment, the efficiency of the proposed approach is tested on the sheet metal images. The presented approach can be used to detect the defects and cracks on the metal sheet plates. To demonstrate this application, the various experimentations are carried out on the rolling metal sheets images. The rolling defects can be easily visualized and detected using the different edge detection methods. The comparison of presented approach, and the existing edge extraction methods such as H-LBP, Canny, Sobel and LBP alone is shown in Figure 4. It is observed from Figure 4 that the proposed approach HY-LBP results into more clear and accurate cracks and edges which may be useful in identifying the rolling defects on the metal sheets.

![Figure 4](image_url)

Figure 4. Comparison of edge extraction by different sheet metal plate image. (a) Original image (b) HY-LBP (c) H-LBP (d) Canny Method (e) Sobel Method.

4.3. Computational time
The comparison of computational time of proposed approach HY-LBP, H-LBP, Canny, Sobel and LBP alone is summarized in Table 1.

| Methods   | HY-LBP | H-LBP  | Canny  | Sobel  | LBP    |
|-----------|--------|--------|--------|--------|--------|
| Time (s)  | 1.143±0.031 | 2.741±0.020 | 0.481±0.016 | 0.28±0.012 | 0.134±0.0013 |

From Table 1, it is observed that the proposed approach requires less time as compared to H-LBP. However, the computational time of the proposed HY-LBP approach is slightly greater than the Canny, Sobel and LBP alone. Although the computational time of proposed approach is more, it is acceptable due to its overall better performance and robustness in the presence of blurred and noisy conditions.

5. Conclusions
In this paper, HY-LBP is proposed as an effective edge detection technique. The performance is improved due to the smoothing hyper function and the similarity distance measure, embedded with the conventional local binary pattern method. With a counting scheme that counts the number of points whose pixel values are greater than that of the centric one, HY-LBP handle the effects such as noise, blurring, and low contrast. Thus, it has high discrimination power in the presence of blurring effect and noises. The experimental results using the synthetic and real time images under blurred and noisy conditions show that the proposed approach performs significantly better in terms of noise robustness, edge discrimination capability, contrast invariance and computational time. Moreover, experimentations on the images show that the HY-LBP performs comparatively better than the existing edge extraction methods.
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