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A Novel Tuning Based Contrast Adjustment Algorithm for Grayscale Fingerprint Image

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Abstract: In Filtering contrast, brightness and normalization of the image are performed with an ultimate goal to remove or reduce the noise to a maximum extent. Contrast and Brightness are two major factors, which affect the superiority of an image for easy or stainless or pleasant viewing. Equalization through Histogram (HE) is a very famous approach for image contrast adjustment or enhancement in image processing. In general, the histogram equalization distributes pixel values consistently and produces an outcome in a superior image with the linear increasing histogram. Contrast adjustment is the part of image preprocessing and specifically filtering noise. In this paper, the new algorithm is discussed for a Grayscale Fingerprint image. The algorithm tunes pixel intensity value to a higher intensity value based on a constant value τ. In this paper, we compare the new algorithm with Histogram Equalization and try to find its advantages and disadvantages. This method is effectively used in Fingerprint Identification/verification purpose as an alternative for image filtering. The algorithm is implemented using MATLAB2015a.

Keywords: Contrast Adjustment, Fingerprint recognition, Grayscale Image, Histogram Equalization, Image filtering, MATLAB2015a.

INTODUCTION

Contrast adjustment methods are extensively used for image processing to attain wider dynamic range and which is considered as preprocessing stage, especially in Automatic recognition system based on different types of images like a fingerprint, face, iris etc. When brightness is too high all the pixels of the image turn into lighter, conversely when the brightness is too low all the pixels of the image turn into darker. When the intensity is a too high, lighter area of the image becomes lighter and darker area of the image becomes darker [1].

Automatic Fingerprint Identification System (AFIS) consists of different steps like preprocessing, enhancement, segmentation, thinning, feature extraction, post-processing, minutiae orientation and alignment [2-9]. The distinctiveness of fingerprint is added forward by using ridge patterns and it has been proved that the information in small regions of friction ridges is in no way repeated.

Distinct contrast enhancement methods have already been developed and advanced which make use of easy linear or non-linear gray level transformation functions in addition to complicated evaluation of special image capabilities. Amongst them, histogram equalization (HE) [10-13] is a very popular technique for contrast adjustment or enhancement of images, especially grayscale images. Contrast adjustment or filtering algorithms are extensively used in medical clinical image enhancement for diagnostic purpose [14]. Global histogram equalization (GHE) [10] makes use of the entire information of the input image to map into new distinct intensity levels of the image. Although this Global technique is suitable for ordinary or general enhancement, it fails to consider with the local brightness capabilities of the entered image. The gray ranges with very excessive frequencies (wide variety of occurrences) dominate over the opposite gray levels having decrease frequencies in an image. In any such situation, GHE remaps the gray levels in a way that the contrast stretching turns into confined in some dominating gray levels having large image histogram components, and it causes sizable contrast loss for other small ones.

Fingerprint recognition is one of the interesting and complex image processing problems, which requires a constant and continuous contribution to new research from the research community especially in filtering and image enhancement process [4].

Local histogram equalization (LHE) [10] can overcome the problem encountered in GHE. LHE uses a small window that slides on all pixel of the image sequentially and handiest the block of pixels that fall within this window are taken into consideration for HE and then gray level mapping for enhancement is carried out for the center pixel of that window. Therefore, it may make splendid use of local information also. But, LHE requires excessive computational cost and occasionally reasons over enhancement in some part of the image. Another shortfall of this approach is that it also enhances the noises inside the input image. To overcome the problem of high computational cost one more approach is to use the non-overlapping block for HE [10]. But almost all times this method produces checkerboard effect.

In this paper a new algorithm for contrast adjustment is proposed, which is based on a constant valueτ. The algorithm, enhances the pixel intensity range to higher intensity range and which is in between 245to 255, for a 256 × 256 sized grayscale image. The remaining part of the paper is organized as follows. Section 2 describes relative research on the contrast adjustment algorithm. Section 3 describes objective of the research. Section 4 describes τ-tuning based algorithm. Section 5 describes flowchart of new algorithm. Section 6 makes analysis of the algorithm using time complexity and also compares with histogram equalization. Section 7 concludes the paper.

RELATED RESEARCH

In literature, many types of research are centered on image or video contrast adjustment or enhancement [15-20]. Mean preserving bi-histogram equalization (MPBHE) proposed to get rid of the brightness problem issues [16, 18]. MPBHE separates the entered or captured input image or video histogram into two classifications as mean of the input before equalizing them independently. Some other variants of bi-histogram equalization are a similar area or equal area or place dualistic sub-image or picture histogram equalization (DSIHE) [21], minimum or lower mean brightness or luminance error bi-histogram equalization (MMBEBHE) [20, 21]. DSIHE technique uses entropy value for histogram separation. MMBEBHE [20, 21] is the extension of BBHE technique that offers maximal brightness maintenance. Even though these strategies can carry out exact contrast adjustments, additionally they generate some side effects depending on the variation of gray level distribution in the histogram [22]. Recursively Separating the mean and finding histogram Equalization (RMSHE) another up gradation of BHE [20] however, it additionally is not free from drawbacks. Moreover, such strategies won't ensure desirable upgrades of all of the partitions. The difference in the ranges of upgrades of various components might also create undesired artifacts in the image. There are many variations MPBHE are Recursive Separated and Weighted HE (RSWHE) [24], Multipeak HE (MPHE) [25], Brightness preserving Weight Clustering HE (BPWCHE) [26], Brightness preserving Dynamic HE (BPDHE) [27] and HE with Range Offset (HERO) [28, 29].

In Global Histogram Equalization, Suppose that an image k (x, y) consists of distinct gray levels in the range of (0, R-1). The transformation function T (d_k) is defined as

$$G_k = \mathrm{T}\,(d_k) = \sum_{j=0}^{l} \mathrm{P}\,(d_j) \;=\; \sum_{j=0}^{l} \frac{m_i}{m}$$

Where $0 \le Gk \le 1$ where l=0, 1, 2 ...R-l. In above equation, m_i depict the count of pixels having gray level d_k, m is the maximum count of pixels in the entered image and P (d_j) correspond to Probability Density Function (PDF) of the input d_j. The cumulative density function here refereed as T (d_k). G_k, is a mapping function, which maps to dynamic range of [0, R-1] values by multiplying it with R-1.

In 256 × 256 sized gray scale images the above equation value of G_k is $0 \le G_k \le 255$ where l can take distinct 256 values from zero to 255 and a maximal number of pixels are 65536 (256 × 256). G_k, is a mapping function, which maps to a dynamic range of (0, 255) values by multiplying it with 255. GHE typically offers a good image enhancement, but sometimes ends up with some artifacts and unwanted aspect results along with the washed out look. In Eq. 1, larger values of m_i purpose the respective gray levels to be mapped aside from every different that guarantees precise enhancement.

OBJECTIVE OF THE STUDY

The objectives of the study are;

- To propose a new τ -tuning based contrast filtering algorithm for grayscale fingerprint image, with an intension to maximize intensity value.
- To compare the new method with GHE with the aid of MATLAB coding.
- To find out time complexity of the new algorithm

THE TUNING BASED CONTRAST FILTERING ALGORITHM

The input for this algorithm is row image referred as I, and final output will be I_{filter}. Initially maximum intensity value of the image is found. We consider here 256 × 256 sized grayscale image. If the input fingerprint image is greater than this size then it will be converted into 256 × 256 sized grayscale image. The maximum intensity value in a 256 × 256 sized grayscale image is 255. The range of values is 0 to 255, which means that minimum value is 0 and maximum value is 255. Maximum intensity value of the image is represented as max (I). Each pixel intensity value is compared with max (I). If pixel value is equal to max (I), then that pixel is assigned to ρ_{max}. The ρ_{max} is individual count of maximum intensity value. The total count of ρ_{max} is represented using lower case delta symbol δ_{max} and is calculated as follows.

$$\delta_{max} = \frac{\sum \rho_{max}}{R \times C} \qquad \text{(Eq. 1)}$$

Where R, and C, are total number of rows and columns respectively. $\sum \rho_{max}$, indicates all pixels, whose intensity value is equal to maximum intensity value of the grayscale fingerprint image (I). Next minimum intensity values of the grayscale image are found and are referred as min (I). If pixel value is equal to min (I), then that pixel is assigned to ρ_{min}. The ρ_{min} is individual count of minimum intensity value of the image. The total count of ρ_{min} is represented using lower case delta symbol δ_{min} and is calculated as follows.

$$\delta_{min} = \frac{\sum \rho_{min}}{R \times C} \qquad \text{(Eq. 2)}$$

As like Eq. 2, R, and C, is total number of rows and columns respectively. $\sum \rho_{min}$, indicates all pixels, whose intensity value is equal to intensity value of the grayscale fingerprint image (I).
Each row of the intensity matrix of the image is considered as a window and is represented as δ_w, which is expressed as

$$\delta_w = \delta_{max} \left(\frac{\delta(l) - \delta_{min}}{\delta_{max} - \delta_{min}}\right)^{\epsilon} \qquad \text{(Eq. 3)}$$

Where ϵ value is 0.5, which is a constant. $\delta(l)$ is low or minimum value of each row. The difference value of $\delta(l) - \delta_{min}$ is divided by $\delta_{max} - \delta_{min}$. The quotient is multiplied by δ_{max}.
∂_w which is almost equal to Histogram equalization, cumulative density function, of window l is represented using 'tho' or partial derivative symbol and is defined as

$$\partial_w = \sum_{l=0}^{l_{max}} \frac{\delta_w(l)}{\sum \delta_w} \qquad \text{(Eq. 4)}$$

Where $\sum \delta_w$ represents summation value of all window l or summation of δ_w. $\sum \delta_w$ is calculated as follows

$$\sum \delta_w = \sum_{l=0}^{l_{max}} \delta_w(l) \qquad \text{(Eq. 5)}$$

The final output of this proposed algorithm (I_{filter}) is obtained using following equation

$$I_{filter} = \left(l_{max} \times \left(\frac{I(i,j)}{l_{max}}\right)\right)^{\tau} \qquad \text{(Eq. 6)}$$

In Eq. 6, (τ) is an important value, which filters or maps input pixel intensity value to new intensity value in the output image and is defined as

$$\tau = round(1 - \max((\partial_w(:))) \qquad \text{(Eq. 3.7)}$$

The Eq. 7 is rounded to 6 decimal points to get higher precision or accuracy.
The output of the robust tuning based algorithm (proposed method), I_{filter} is converted from grayscale 256 × 256 uint8 to double type for the purpose of grayscale image adjustment. The 256 × 256 double image consists of only two intensity values as 0 and 1. 0 represents dark and 1 represents bright or 0 dark black and 1 bright white. Here in image enhancement we focus more on τ- Tuning Based Filtering Algorithm.

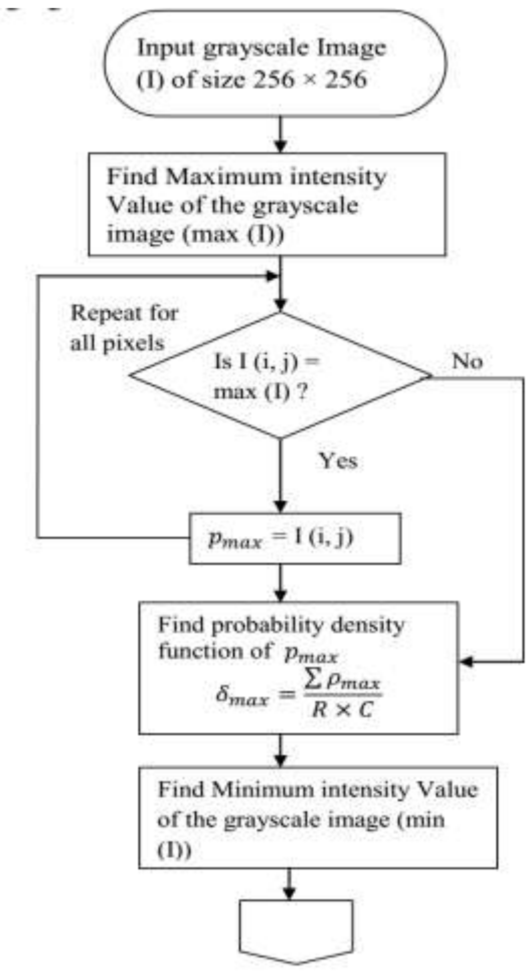
Proposed Filtering Algorithm

Input: Raw Image; I
Output: Filtered Output Image,I_{filter}
Step-1: for i=1 to R \\ R→ Row size of input image

Step-2: for j=1 to C \\ C→ Column size of input image
Step-3: if I (i,j)= =max(I)
Step-4: $\rho_{max} = I(i,j)$; end if;end for
Step-5: $\delta_{max} = \frac{\sum \rho_{max}}{R \times C}$
Step-6: for i=1 to R \\ R→ Row size of input image
Step-7: for j=1 to C \\ C→ Column size of input image
Step-8: if I(i,j) = = min(I)
Step-9: $\rho_{min} = I(i,j)$; end if; end for
Step-10: $\delta_{min} = \frac{\sum \rho_{min}}{R \times C}$
Step-11: $\delta_w = \delta_{max}\left(\frac{\delta(l)-\delta_{min}}{\delta_{max}-\delta_{min}}\right)^{\epsilon}$ \\ ϵ→Constant; $\epsilon = 0.2$
Step-12: $\partial_w = \sum_{l=0}^{l_{max}} \frac{\delta_w(l)}{\sum \delta_w}$
Step-13: $\sum \delta_w = \sum_{l=0}^{l_{max}} \delta_w(l)$
Step-14: $\tau = round(1 - \max((\partial_w(:)))$ //round to 6 decimal points
Step-15: $I_{filter} = (l_{max} \times (\frac{I(i,j)}{l_{max}}))^{\tau}$

Flowchart for proposed Algorithm

The above algorithm is explained using flowchart. The input for this algorithm is row grayscale fingerprint image of size 256 × 256 which is represented as I. The final output is filtered image is I_{filter}. The figure 1 is extended to two pages and cross symbol with in circle represents joining point or works as a connector between two pages. In order to analyze the algorithm Benchmark fingerprint dataset is considered from FVC ongoing 2002 DB1_B [30]. The table 3.1 shows the range of grayscale intensity values for the few of FVC 2002 DB1_B datasets before using the proposed filtering algorithm and after applying filtering algorithm.



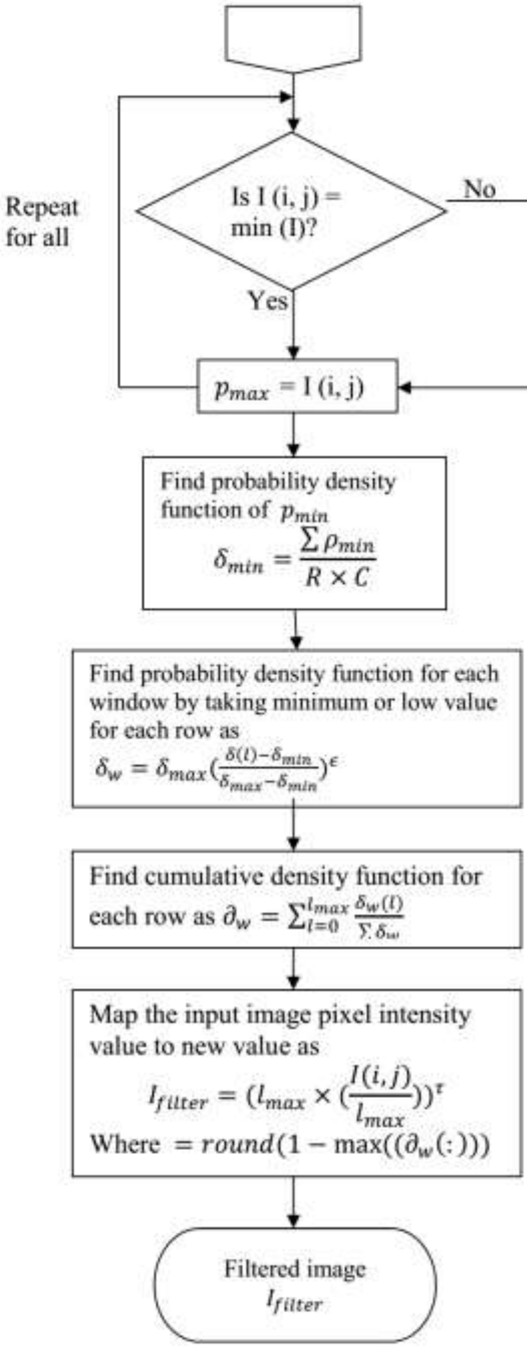


Fig-1: Flowchart of proposed filtering algorithm

The different workflows of the proposed algorithm are listed out below.

- Find maximum intensity value of the grayscale input image
- Find maximum intensity value pixels total count in the grayscale image
- Find probability density function of maximum intensity value
- Find minimum intensity value of the grayscale input image
- Find minimum intensity value pixels total count in the grayscale image
- Find probability density function of minimum intensity value
- Locate minimum value for each row
- Locate probability density function for each row
- Find cumulative density function for each row
- Find the value of τ
- Map the intensity value of the input pixels to new intensity value in the output image.

- Generate filtered image

ANALYSIS OF PROPOSED FILTERING ALGORITHM

The Table-1 shows range of grayscale intensity values using Histogram equalization. In this benchmark dataset each user's different eight fingerprints are considered for training or testing purposes. From the Table 1 it is clear that proposed method having less intensity range compared to Histogram equalization. In Robust τ- Tuning Based Filtering Algorithm, dark pixels are highest dark and bright pixels are either highest or near to high bright values. This algorithm is best suited for grayscale fingerprint image, especially 256 × 256 sized. Figure 2 shows output of filtered image (I_{filter}). Table 3.2 shows the number of occurrence of each grayscale intensity value for the proposed algorithm, for the same image considered in Table 1. As like histogram equalization one of the pixel intensity values dominates over other. So this algorithm is not best for natural image because it may cause wash out appearance. But this is very good and robust for grayscale fingerprint image. In fingerprint image usually black colour represents ridges and white color represents valley.

Table-1: Range of intensity values in 256 × 256 sized grayscale fingerprint image

Fingerprint Image Name	Range of Intensity values before applying proposed filtering algorithm	Range of Intensity values after applying proposed filtering algorithm	Range of Intensity values using Histogram Equalization
101_1.tif	0 to 255 (256 values)	0, 250, 252 (3 values)	0, 4, 8, 12, 16, 20, 24, 28,32, 36, 40, 45,49, 53, 57, 61, 65, 69, 73, 77, 81, 85, 162, 255 (24 values)
102_1.tif	0 to 255 (256 values)	0, 249, 250, 251, 252 (5 values)	0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 45, 39, 53, 57, 61, 65, 69, 73, 77, 81, 85, 89, 93, 97, 101, 162, 255 (24 values)
103_5.tif	0 to 255 (256 values)	0, 249, 250, 251, 252 (5 values)	0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 45, 49, 53, 57, 61, 65, 69, 73, 77, 81, 85, 89, 93, 97, 101,105,109, 113, 117, 121, 125, 130, 134, 138, 194, 255 (37 values)
104_4.tif	0 to 255 (256 values)	0, 249, 250, 251, 252, 253 (6 values)	0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 45, 49, 53, 57, 61, 65, 69, 73, 77, 81, 85, 89, 93, 97, 101, 105, 109, 178, 255 (30 values)
105_8.tif	0 to 255 (256 values)	0, 246, 247, 248, 249, 250, 251, 252, 253 (9 values)	0, 4, 8, 12, 16, 20, 24, 28, 32, 36, 40, 45, 49, 53, 57, 61, 65, 69, 73, 150, 255 (21 values)

Table-2: Intensity and frequency count of the fingerprint image for the proposed filtering algorithm

Fingerprint Image Name	Intensity value and frequency count of the fingerprint image for the proposed algorithm	
101_1.tif	0	8084
	250	57196
	252	256
102_1.tif	0	5300
	249	43808
	250	14954
	251	1222
	252	252
103_5.tif	0	25855
	249	23914
	250	14237
	251	1020
	252	510
104_4.tif	0	14152
	249	34515
	250	15333
	251	1024
	252	256
	253	256
105_8.tif	0	3053
	246	245
	247	252
	248	756
	249	41592
	250	15006
	251	3165
	252	1228
	253	239

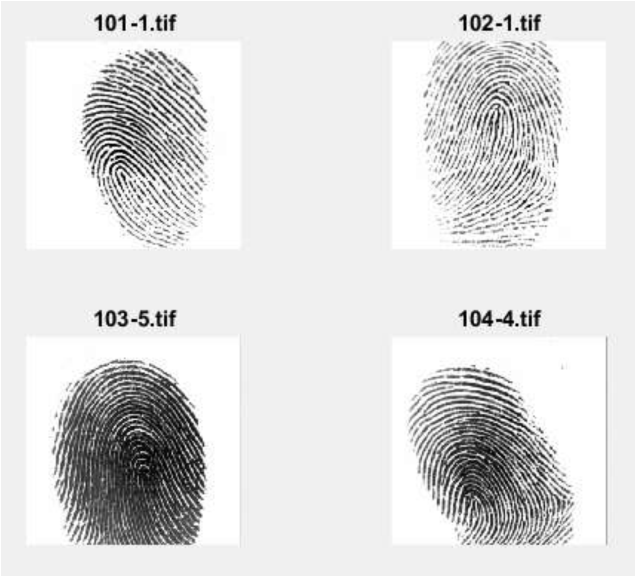


Fig-2: Sample original fingerprint images of FVC ongoing 2002 DB1_B dataset

In the Table 2 we can note that the dominating intensity values usually falls in upper boundary region of intensity range, which makes the image brighter. Figure 3 shows some sample images of FVC ongoing 2002 DB1_B benchmark datasets with labels as 101_1.tif, 102_1.tif, 103_5.tif, and 104_4.tif.

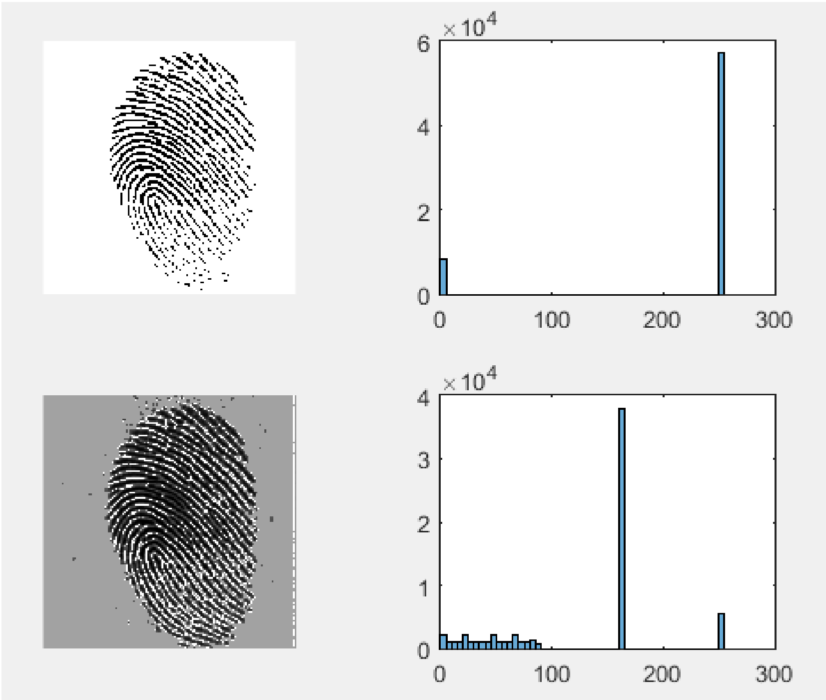


Fig-3: '101_1.tif'-Sample fingerprint image of FVC ongoing 2002 DB1_B after filtering process. (Top left: Filtered image using proposed method, Top Right: Histogram of top left, Bottom right: Filtered image using Histogram Equalization, Bottom right: Histogram of bottom left)

Time complexity Analysis of the Algorithm

In this research study the new algorithm is analyzed for time complexity using hypothetical Model Machine. Some characteristics of the Hypothetical machine are given below.

- Single processor machine
- 32-bit architecture
- Sequential Execution
- Arithmetic and logical operation takes 1 unit of time

- Assignment statement takes 1 unit of time
- Function return takes 1 unit of time

In order to calculate time complexity of the algorithm, the entire algorithm is divided into different fragments, time complexity for them is calculated first and later all this fragments time complexity is added in order to get overall time complexity of the algorithm. The different fragments time complexity is shown in Table-3.

Table-3: Time complexity of different fragments of Tuning based contrast adjustment algorithm

Sr. No	fragments of new algorithm	Time complexity
1	Finding the Maximum and minimum intensity of the input image and probability density value of min and max intensity	$6n^2$ +10
2	Finding the lowest intensity value (local minimum) in each row and then finding total number of local minimum and probability density value of local or row minimum.	$3n^2$ + 11n + 1
3	Finding cumulative density function of local minimum	3n+3
4	Map the input image pixel intensity value to higher intensity rage using the value τ.	$13n^2$ + n + 1
5	Overall	$22n^2$+ 15n+15

f (n) = $22n^2 + 15n + 15$
g (n) = n^2
f (n) = O (g(n))
f (n) ≤ cg(n) , c > 0, $n_0 \geq 1$
$22n^2 + 15n + 15 = cn^2$ where c=23, n ≥ 16
So the rate of growth of the time for new algorithm is O (n^2). [Big (Oh) of n^2].
Rate of growth of time for Histogram equalization is also O (n^2).

CONCLUSION

Contrast adjustment filtering is very essential in fingerprint image preprocessing stage. Contrast and Brightness are two major factors, which improves the persistence of vision. The novel tuning based contrast adjustment algorithm enhances the intensity range to very higher value compared to histogram equalization. The new algorithm and histogram equalization algorithm utilizes same time complexity of O (n^2) for very large input. We have represented time complexity using hypothetical model machine. In this paper we have proposed theory of the new algorithm and also tested using FVC ongoing 2002 dataset with aid of MATLAB2015a

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