COLOR CONTRAST ENHANCEMENT BASED ON FUZZY MODEL FOR
THINPREP CERVICAL CELL IMAGES
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ABSTRACT:- ThinPrep monolayer cytology was introduced to overcome the limitations of conventional Pap smear test for screening of cervical cancer. This study proposes a contrast enhancement technique, which is only applied on the cervical cell of interest. The proposed technique is divided into two stages. Before enhancement the membership value for a pixel is identified using Fuzzy Trapezoidal membership function. The image is enhanced by the highest membership function value for a pixel. The cervical cell of interest will be applied with linear contrast algorithm and the proposed nonlinear algorithms namely non-linear bright, non-linear middle and non-linear dark contrast to enhance the contrast of the ThinPrep images. The results show that the proposed technique improves the image quality useful for further analysis by pathologists.

Index Terms:- Non-Linear Contrast, Trapezoidal Membership, Enhancement, Cervical cell.

1. INTRODUCTION

Cervical cancer is the most common malignancy in women of developing countries. Cervical cancer develops over a prolonged period covering two to three decades [1]. It is mainly caused by Human Papillomavirus. Therefore, the mortality related to cervical cancer can be substantially reduced through early detection and treatment.

ThinPrep monolayer cytology was introduced to overcome the limitations of the conventional Pap smear [2]. However, the cytology image of ThinPrep captured from the ThinPrep slide using standard image analyzer usually has low contrast quality due to the magnification and overexposure to the light built in the system of the image analyzer. In some cases, the ThinPrep images are hazy and afflicted by unwanted noises [3]. These problems can hide and obscure the important cervical cells morphologies, hence increasing false diagnosis rate.

Contrast is one of the factors that influenced the accuracy of interpretation of diseases based on medical images by pathologists or radiologists. To date, contrast enhancement process plays an important role in enhancing the quality and contrast of medical images [4]. Several previous studies have proven that contrast enhancement techniques are capable of removing unwanted noises and enhance the brightness and contrast of medical images [5].

Many studies have been done to overcome these problems, all intended to produce cleaner and clearer conventional Pap smear image. Most of researchers still focus on enhancing the contrast of conventional Pap smear images. Ghafar et al. (2003) has implemented bright and dark stretching method on the conventional Pap smear images [6]. The implementation results show that the contrast of the overall Pap smear images improved significantly. Mat- Isa et al. (2003) proposed contrast enhancement processing on the segmented conventional Pap smear images [4].

To obtain clearer image of conventional Pap smear, they used moving k-means algorithm to segment the image in to 60 regions and apply linear contrast algorithms to increase the image contrast.

Therefore, the current study proposes a contrast enhancement method for ThinPrep images by selecting a cervical cell of interest from a ThinPrep image, followed by enhancing the contrast of the preselected cervical cell.

2. COLOR CONTRAST ENHANCEMENT FUZZY MODEL (CCEFM)

The proposed CCEFM methodology is illustrated by the flow chart in Figure 1. The proposed methodology needs two image processing techniques, which are segmentation of cervical cell of interest and contrast enhancement on the segmented cervical cell.

During the screening process of a cervical precancerous cells, pathologists observe that the abnormalities of morphological features in cervical cells. These characteristics include [7]:

(i) Abnormal size and shape of cells
(ii) Abnormal biological changes in nucleus and cytoplasm

Most of the conventional contrast enhancement applied the technique to the whole Pap smear images, even though the features in the background areas are unnecessary in the screening process. As compared to these studies, work involved in this paper focused on enhancing the
contrast of the cervical cell of interest (nucleus and cytoplasm components) and ignoring the background areas. The proposed contrast enhancement technique will first, determine the cervical cell of interest. Then, the cervical cell of interest will be implemented with four contrast enhancement algorithms.

The four contrast enhancement algorithms that have been selected to increase the contrast of cervical cell of ThinPrep images in RGB colour are linear contrast, non-linear bright contrast, non-linear middle and non-linear dark contrast.

The trapezoidal curve is a function of a vector, \( x \), and depends on four scalar parameters \( a \), \( b \), \( c \), and \( d \), as defined in equation (1) & (2). The parameters \( a \) and \( d \) locate the "feet" of the trapezoid and the parameters \( b \) and \( c \) locate the "shoulders."

\[
f(x; a, b, c, d) = \begin{cases} 
0, & a \leq x \leq b \\
\frac{x - a}{b - a}, & b \leq x \leq c \\
1, & c \leq x \leq d \\
\frac{x - d}{d - c}, & d \leq x \leq 0 \\
0, & 0 \leq x \leq a 
\end{cases}
\] (1)

or, more compactly, by

\[
f(x; a, b, c, d) = \max\left(\min\left(\frac{x - a}{b - a}, \frac{x - d}{d - c}\right), 0\right)
\] (2)

The fuzzification gray value is divided into three trapezoidal membership functions namely ABC, DEFG and HIJ (see Figure 2). For a pixel the membership value is calculated for all three functions. The function with highest value will be implemented using particular non-linear contrast algorithm. The membership value will always be \( \geq 0 \) and \( \leq 1 \). The limit values for the function ABC, DEFG, HIJ are set manually for this CCEFM enhancement.

If the function ABC is having membership value greater than DEFG and HIJ, that pixel value is altered by non-linear dark contrast method. If the function DEFG is having membership value greater than ABC and HIJ, that pixel value is altered by non-linear middle contrast method. If the function HIJ is having membership value greater than ABC and DEFG, that pixel value is altered by non-linear bright contrast method.

This study also proposes a linear contrast enhancement algorithm is given in Equation 3 [7]. By implementing this algorithm, the narrow range of data in an image will be stretched linearly to the whole of histogram so that its dynamic range is fulfilled.

\[
R_{\text{RGB}}(u, f) = 255 \times \frac{R_{\text{RGB}}(u, f) - R_{\text{RGB}}(u, f_{\text{min}})}{R_{\text{RGB}}(u, f_{\text{max}}) - R_{\text{RGB}}(u, f_{\text{min}})}
\] (3)

where  
- \( R_{\text{RGB}}(u, f) \) : The new RGB value of the pixel
- \( R_{\text{RGB}}(u, f_{\text{max}}) \) : The original RGB value of the pixel
- \( u_{\text{RGB}} \) : Minimum RGB value
- \( u_{\text{RGB}} \) : Maximum RGB value
The three non-linear contrast algorithms are non-linear bright, non-linear middle and non-linear dark. The non-linear bright contrast algorithm is given in Equation 4. By implementing this algorithm, the narrow range of data that lie in the right side of histogram will be stretched while the data that lie in the left side of histogram will be compressed.

\[ f_{RGB}(i,j) = 255 \times \left[ \frac{x_{RGB}(i,j) - b_{RGB}}{x_{RGB} - a_{RGB}} \right] \]  

(4)

The second non-linear contrast algorithm is known as non-linear middle. This algorithm is able to expand the data that lie in the middle region of histogram. Thus the contrast of the middle region will increase. For this equation is same as equation (4) but we have to change the value of \( r \).

The third non-linear contrast algorithm is known as non-linear dark. This algorithm is able to expand the data that lie in the left side of histogram and compress the data that lie in the right side of histogram. Thus, the contrast of the dark area will increase and the contrast of the bright area will decrease.

\[ f_{RGB}(i,j) = 255 \times \left[ \frac{x_{RGB}(i,j) - a_{RGB}}{b_{RGB} - x_{RGB}(i,j)} \right] \]  

(3)

Where:
- \( f_{RGB}(i,j) \): The new RGB value of the pixel
- \( x_{RGB}(i,j) \): The original RGB value of the pixel
- \( a_{RGB} \): Minimum RGB value
- \( b_{RGB} \): Maximum RGB value
- \( r \): Typical constant value range between 1.01 and 1.05

3. EXPERIMENTAL RESULTS AND ANALYSIS

The CCEFM enhancement technique is tested on two ThinPrep images namely ThinPrep 1 and ThinPrep 2. The results for ThinPrep 1 and ThinPrep 2 are shown in Figure 3 respectively. Figure (a) shows the original ThinPrep image, Figure (b), (c), (d) and (e) represents the results after applying contrast enhancement algorithm; linear, non-linear bright, non-linear middle and non-linear dark contrast respectively.

Table 1 shows the optimum value for constant, \( r \) of ThinPrep 1 and ThinPrep 2 which have been implemented with non-linear bright, non-linear middle and non-linear dark contrast algorithm. The values were obtained after some try and error analysis.

The implementation results of linear contrast algorithm on segmented ThinPrep images are shown in Figure 3(b). The result shows that the linear contrast algorithm produces good contrast enhancement performance.

<table>
<thead>
<tr>
<th>Image</th>
<th>Non-Linear Contrast(r)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bright</td>
</tr>
<tr>
<td>ThinPrep 1</td>
<td>1.02</td>
</tr>
<tr>
<td>ThinPrep 2</td>
<td>1.02</td>
</tr>
</tbody>
</table>

The linear contrast algorithm has spread the RGB value of pixel linearly so that they will cover the full range of RGB histogram (0 – 255). Thus, the contrast of the nucleus and cytoplasm components in the ThinPrep image was successfully increased.

The second contrast enhancement algorithm is non-linear bright contrast. The implementation results of the CCEFM non-linear bright contrast algorithm are shown in Figure 3(c). The optimum value of constants, \( r \) for ThinPrep 1
and ThinPrep 2 images are shown in Table 1. For ThinPrep slide images, most of pixels in cytoplasm region lying on the bright side of RGB histogram (on the right of histogram) while pixels in nucleus region lying on the dark side of the histogram (on the left of histogram). Thus, when applying the CCEFM non-linear bright algorithm, only the RGB values of the cytoplasm pixels will be stretched while the RGB values of nucleus pixels will be compressed. As the result, the contrast of the cytoplasm area is increased higher than before the implementation of the algorithm.

Table 2: PSNR Value Comparison

<table>
<thead>
<tr>
<th>Image</th>
<th>PSNR Value(db)</th>
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<tbody>
<tr>
<td></td>
<td>Linear</td>
</tr>
<tr>
<td>ThinPrep1</td>
<td>18.634</td>
</tr>
<tr>
<td>ThinPrep2</td>
<td>33.504</td>
</tr>
</tbody>
</table>

From this comparison we conclude that Non-Linear bright contrast method gives better contrast than other contrast methods.

The third contrast enhancement algorithm is nonlinear middle contrast. The implementation results of the CCEFM non-linear bright contrast algorithm are shown Figure 3(d). The optimum value of constants, \( r \) for ThinPrep 1 and ThinPrep 2 images are shown in Table 1.

Finally, the images of ThinPrep 1 and ThinPrep 2 have been implemented with non-linear dark contrast algorithm. The results in Figure 3(e) that used the optimum value of constants, \( r \) given in Table 1 show that the contrast of the nucleus area is higher than before the implementation of the non-linear dark contrast algorithm. The CCEFM algorithm has been successfully implemented to stretch the RGB value of nucleus pixels in order to increase the contrast of the nucleus region. The RGB value of cytoplasm pixel has been compressed and causes the decreased in contrast for cytoplasm region. Therefore, after applying this algorithm, the morphological changes in the nucleus can be easily seen.

4. CONCLUSION

This work shows that the CCEFM contrast enhancement technique can be used to enhance the contrast of the preselected ThinPrep images. Linear contrast algorithm can be used to improve the overall contrast of preselected ThinPrep images. Contrast of specific area in an image can be increased by using the specific non-linear contrast enhancement algorithm. Morphological changes in cytoplasm and nucleus regions can be easily seen after implementation of non-linear bright, non-linear middle and non-linear dark contrast algorithm respectively. The CCEFM enhancement technique has successfully enhanced the cervical cells of interest and also improves the image quality so that the resultant images would be more useful for further analysis by pathologists.

From Table 2 Bright contrast for Thinprep 1 & Thinprep 2 and Middle contrast for Thinprep 1, there is no loss of data during enhancement process that is given by infinity value. In future work, we can select bright, medium or dark contrast method based on highest PSNR value for a block of pixels.

5. REFERENCES