Specular Reflection Analysis and Image Denoising in Cervix Images

Deepak B. Patil
Research Scholar
E&CE Department
BKIT Bhalki

T.S. Vishwanath, PhD
Professor
E&CE Department
BKIT Bhalki

ABSTRACT

Colposcopy is a crucial imaging technique for finding cervical abnormalities. Colposcopic image analysis, particularly the accurate segmentation of the cervical region, has significant clinical significance. It is suggested to divide and extract the cervical region in a medical and anatomical sense using a cervical segmentation approach based on the HSV colour mode. First, the histogram (Y) of the colposcopic image is examined using the histogram threshold approach. Pretreatment is required in the colposcopy image in order to remove the mirror reflection. The Preprocessed RGB pictures are used second.

Segmentation of the cervical region can be obtained by applying the area filter to smooth the edge. 100 common colposcopy photos that had been expertly tagged were evaluated and verified for our study. Accuracy, sensitivity, specificity positive predictive value, and negative predictive value were used to analyse and compare the findings. Our experimental findings demonstrate that the method's accuracy, specificity, and sensitivity are, respectively, 88.25%, 80.99%, and 95%.

Keywords
Colposcopy image, Image segmentation, Image mirror reflection. SR specular reflections, positive predictive value (*PPV*), and negative predictive value (*NPV*)

1. INTRODUCTION

The second most frequent cancer in women worldwide and the most prevalent cancer in developing nations is cervical cancer. The survival rate of cervical cancer patients is approximately 100% with early-stage discovery, but that percentage drops to 20-50% in the late stage [2, 3], according to a medical report based on cancer [1]. It is impossible to spread more sophisticated screening methods for cervical cancer in resource-poor communities due to the high complexity and high cost of the total screening process. As a result, cervical cancer still has a high incidence and fatality rate in underdeveloped areas [4, 5].

The three primary cervical cancer screening techniques now in use are the Papanicolaou (Pap) smear test, visual inspection with acetic acid (VIA), and human papillomavirus (HPV) testing, according to the World Health Organisation. The first two approaches are somewhat pricey and complicated, particularly for individuals in underdeveloped nations [6]. Colposcopy is still an essential procedure for biopsy detection even in the first two procedures. Colposcopy is crucial and ideal for use as a screening technique as a result. One of the most important diagnostic techniques for detecting cervical abnormalities in women is colposcopy. Colposcopy is used to locate lesions and assess their severity so that, if more thorough testing is required, it can be done.

One of the most important diagnostic techniques for detecting cervical abnormalities in women is colposcopy. Colposcopy is used to locate lesions and assess their severity so that, if more thorough testing is required, it can be done. A visual examination of the lower genital (cervical, vulva, and vaginal) systems, as well as those within the vicinity of the cervix, the emergence of metaplastic epithelium with transformation zones [7].

It has a binocular microscope with an integrated white light source so that colposcopy can receive more detailed picture information. When a 3-5% acetic acid solution was administered to the cervical surface during the inspection, the aberrant metaplasia epithelium turned acetowhite (AW) in that area. Colposcopy can be used to identify the aberrant morphological characteristics that are present in cervical precancerous lesions and invasive malignancies. However, only a clinician (a colposcopy specialist) can assess the lesion characteristics of the cervix, such as colour and opacity, edge division, and tissue form, in order to make a clinical diagnosis. The accuracy of colposcopy is heavily dependent on the doctor's experience and expertise due to the subjective aspect of the examination. Colposcopy hence has greater sensitivity and can prevent many biopsies [8].

The colposcopy image is a coloured representation of the RGB model that includes crucial clinical details including the cervical canal (CC), the squamous epithelium (SE), the columnar epithelium (CE), and the transition zone (TZ) between the latter two. The majority of cervical malignancies are found here [9]. The initial colposcopy image had a somewhat complicated imaging mode. The cervical region (the area encompassed by black curves), and the medical device are both visible in the original colposcopic image, as depicted in Figure 1. The primary area of study for medical diagnoses is the cervical region. Additionally, it has regions with intense light interference brought on by cervical mucus and Acetowhite Epithelium Original (AW).
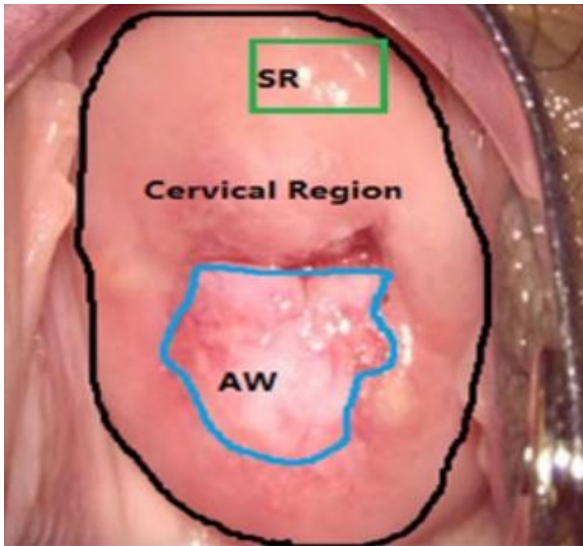
Figure 1. Tissue types of interest marked on a cervigram and Manual segmentation based on SR, cervical region, and AW of the original colposcopic images by human experts

Given that AW lesions are a key visual signal in cervical cancer diagnostic tests, precise (very sensitive and specific) detection of AW lesions is necessary for clinical value. The significance of removing specular reflections is demonstrated by early research into colposcopic picture segmentation. Every colposcopic image is produced with specular reflections (SR), also known as highlights, as a result of the imaging process. They conceal the target tissues, impacting various stages of automated segmentation. It is possible that instead of AW lesions, which are brighter than the bright parts of SR, there included. In addition, the steep gradients produced by SR amplify the local contrast, which leads to inaccurate findings when texture characteristics are extracted. A colposcopic image may be labelled incorrectly as a result of such a misidentification.

A less number of works addresses the problem of specular reflections in cervical images. A semi-automated algorithm was introduced by Hervet and Kardouchi[12] to detect specularities. An image is first segmented into different regions with large numbers. The user is asked to manually detect the segments belonging to specularities. After that histogram transform is applied between the highlight and the normal tissue region resulting in the removal of the highlights.

In the work, Van Raad [13] models in the RGB color space that the pixel distribution in an image as a Gaussian Mixture Model in which one Gaussian represents SR pixels and another one represents the remaining portion of the image. This model is developed based on a set of images. To differentiate pixels in an image to SR and non-SR pixels a linear distance measure is applied.

The research works to remove SR was extensively investigated in the last twenty years. Physics-based approaches use the Dichromatic Refection Model (DRM) which describes a color of dielectric materials as a linear combination of highlight color and an object color. Klinker [14] and Gershon [15] developed automatic algorithms for highlights elimination, based on the DRM.

The focus of this work is to detect SR in a particular type of medical images, the colposcopic images.

2. IDENTIFICATION OF SPECULAR REFLECTION

2.1 Test data set and SR detection using edge.

In this work, 100 data samples are recorded. Colour, Binary, and Grey are the available types, and depending on the need, these photos can be captured in .jpg, .jpeg, or .tif image formats. Only the portion of the colposcopic image containing the cervix is significant. The next step is to isolate the areas where there are strong reflections from the camera flash, which obscures other visual elements. Because of this, digitised Colposcopic pictures need to be preprocessed in order to identify the cervix region of interest (ROI), detect specular reflection (SR), and remove it before using automated lesion diagnosis.

The image Processing Toolbox of MATLAB programme is used to find specular reflection. The Edge Detection block locates the edges in an input image by approximating the gradient magnitude of the image given in the gradient equation when using IPT as the technique parameter and choosing Sobel, Prewitt, or Roberts.

By searching for the local maxima of the input image's gradient, the Edge Detection block uses the Canny edge detection method to identify edges. The derivative of the Gaussian filter is used to compute the gradient. To identify strong and weak edges, the Canny approach employs two thresholds. Only when weak edges are coupled to strong edges are they included in the output.

The gradient magnitude squared image's mean is used to calculate the automatic threshold in the edge detection block. The Threshold scale factor (used to automatically determine threshold value) parameter allows one to modify this threshold, though. To generate a new threshold value, the block multiplies the value you enter by the predetermined threshold value.

2.2 Identification of SR regions

Refection zones appear as little bright spots in images of moist tissues, such as colposcopic images, and are therefore associated with significant gradients in the area around them. By choosing, the pixels close to strong gradients are regarded as SR zones. Applying a threshold to the gradient's intensity's magnitude allowed for the identification of regions with strong gradients.

Regions of strong gradients were located by applying a threshold on the magnitude of the intensity gradient:

$$\nabla G = \sqrt{(\partial I/\partial x)^2} + \sqrt{(\partial I/\partial y)^2} > 0.15 \qquad (1)$$

The original information of the epithelial tissue covered by the specular reflection area cannot be recovered because the specular reflection area's proportion to the whole colposcopic image is low. As a result, in order to remove these highlight areas, the region-filling algorithm must be used to restore the area's epithelial tissue's original picture [18]. The CIN1 tissue's lesion cells were sporadic or patchy, and the positive intensity was low in the lesion area of the cell section. Full thickness continuous and distributed strong positives are present in the tissues of CIN2 and CIN3 [19, 20]. High brightness and poor colour saturation are typical traits of the specular reflection area [21].

The specular reflection area can be covered with an image texture and colour that matches the patch to get rid of these specular reflections [22]. The important theoretical concepts of

high light detection, elimination of highlights, and filling will be covered in the information that follows. With highlight identification concentrating primarily on the luminance component (Y) of the picture, colposcopic image analysis frequently analyses both the chromaticity component (U&V) and the luminance component (Y) of the image [23].

First, Eq. (1) is used to change the image's RGB colour mode to YUV colour space. The highlight region is then determined using the brightness threshold specified in Eq. (2), with Y(p) denoting the brightness value of the pixel. First, the colposcopy image's luminance histogram and luminance surface are calculated. According to the value of the overlap from the luminance histograms on several colposcopic images, the brightness of the specular reflection area of each colposcopic image is more than grey scale 220. Finally, on the recommendation of the doctors (cervical experts), the threshold involved in reducing the specular reflection is chosen to be between 220 and 255.

3. SYSTEM BLOCKDIAGRAM

The specular reflection component of the original colposcopy image is identified using the threshold value that has been set,

as indicated in the upper portion of Fig. 2, and the average luminance value of the area surrounding the highlight portion is then chosen for luminance replacement. Finally, using the neighborhood's average saturation, the saturation (S) patch is applied to this section.

used as input image for segmentation of the cervical region.The lower part of Fig. 2 shows that the *V* component inthe colposcopic image of the HSV color mode is extracted according to a clustering method to segment the cervical region. The cervix region in the colposcopic image occupiesthe center of the image, so the cervix region segmentation can be performed within a certain range from the center of the image according to the similarity of the *V* component.

Figure 2 clearly shows the flow of the cervical region segmentation method. The preprocessing part of this method focuses on the luminance component (*Y*) of the colposcopic image, which is also described in detail later in this section. Similarly, after the K-means segmentation, the operation ofthe image, the area filtering, the construction template, and the like are required to finally obtain the segmented cervical region.
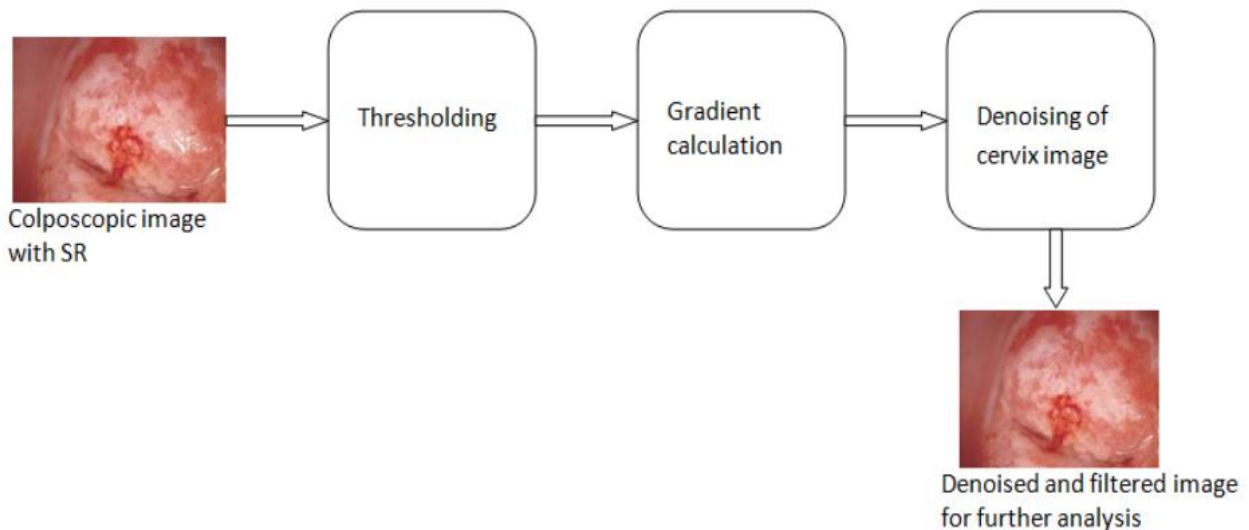

Figure 2. System block diagram: Identification of SRs and denoising of cervix images

4. DISCUSSION OF RESULTS

The purpose of segmentation of the cervical region is to divide the pixels of the colposcopy image into two ROI points and background points. In order to judge the segmentation result,a reasonable evaluation index must be introduced. Comparing cervical region segmentation results with expert annotation results, the final pixels are divided into the following four categories: (1) true positive (*TP*), which means the correct segmentation of the cervical region; (2) false positives (*FP*) indicate the point of excision of the cervical defect; (3) true negative (*TN*) indicates the correct background point; (4) false negative (*FN*), the wrong background point. Table 1 shows quantitative statistics of the segmentation accuracy of all test images.

The accuracy (*Acc*), specificity (*Spe*), sensitivity (*Sen*), positive predictive value (*PPV*) and negative predictive value(*NPV*) of the model can be calculated based on the above four-pixel classification types. And they are used as an importantindicator to evaluate the performance of the segmentation method. *ACC*

means that the pixel with the correct pixel size occupies all pixels; *Spe* means the ratio of the correct cervixregion to the total ROI region; and *Sen* refers to the ratio of thecorrect background point to the total background point. *PPV*indicates the possibility that the segmentation point does notinclude the background point, and *NPV* indicates the value of the possibility that the background point includes the segmentation point. The computed results are shown in Eqs. (2, 3, 4).

$$Acc = \frac{TP+TN}{TP+FN} \times 100\% \qquad (2)$$

$$Spe = \frac{TP}{TP+FN} \times 100\% \qquad (3)$$

$$Sen = \frac{TN}{TP+FN} \times 100\% \qquad (4)$$

Table 1 Accuracy of the cervix region extraction compared with themanual segmentation results.

Performance index standard	Maximum %	Minimum %	Median %	Mean %
Acc	87.38	87.15	87.22	87.25
Spe	98.07	53.43	90.20	81.99
Sen	100	82.14	97.35	96.70

The first step in determining the acetowhite zones is to choose a texture region. Then, acetowhite zones are retrieved using a combination of colour and texture data. The severity of the disease is finally determined by the detection and sorting of multi-level acetowhite zones according to colour ratings. Figure shows the specifics. According to the professional annotation of the acetowhite epithelium, the sensitivity and specificity demonstrate the hit or miss rate. The acetowhite epithelium is the only diagnostic feature in a VIA and a key feature in colposcopy.

5. ACKNOWLEDGMENTS

6. CONCLUSION

In this work, the specular reflection usually has the characteristics of high brightness and low color saturation. To eliminate these specular reflections, the specular reflection area is filled with a similar image texture and color as the patch. Firstly, the image is converted from the RGB color modeto the L a b color space. Then, the highlighted area is detected according to the brightness threshold set in Eq. (1), and the pixel brightness value is adjusted. Firstly, the luminance histogram and the luminance surfaceof the colposcopy image is calculated. The brightness ofthe specular reflection area of each colposcopic image is greater than grayscale 220, which can be determined by the value of the overlap from the luminance histograms on the different colposcopic images. Finally, the threshold involved in removing the specular reflection is set to be between 220 and 255 in conjunction with the advice of the doctors. Quantitative performance analysis can be used to examine the system's effectiveness. For the 100 human data samples, an overall sensitivity and specificity of 96.70% and 81.99%, respectively, have been noted. This way image denoising of cervix images is achieved as per the objectives.

7. REFERENCES

[1] Chen W, Zheng R, Baade PD, Zhang S, Zeng H, Bray F et al (2016) Cancer statistics in china 2015. CA Cancer J Clin 66(2):115–132

[2] Pfaendler KS, Wenzel L, Mechanic MB, Penner KR (2015) Cervical cancer survivorship: long-term quality of life and social support. Clin Therapeut 37:39–48

[3] Dempsey C, Govindarajulu G, Sridharan S et al (2014) Implications for dosimetric changes when introducing MR-guided brachy-therapy for small volume cervix cancer: a comparison of CT andMR-based treatments in a single centre. Australas Phys Eng Sci Med 37(4):705–712

[4] Cronje HS (2004) Screening for cervical cancer in developing countries. Int J Gynecol Obstet 84:101–108

[5] Sun YP, Sargent D, Lieberman R, Gustafsson U (2011) Domain-specific image analysis for cervical neoplasia detection based onconditional random fields. IEEE Trans Med Imaging 30:867–878

[6] Sun YP, Sargent D, Lieberman R et al (2011) Domain-specific image analysis for cervical neoplasia detection based on conditional random fields. IEEE Trans Med Imaging 30(3):867–878

[7] Gordon S, Zimmerman G, Greenspan H (2004) Image segmentation of uterine cervix images for indexing in PACS. In: Proceedings of the IEEE symposium on computer-based medical systems,pp 298–298

[8] Li W, Poirson A (2006) Detection and characterization of abnormal vascular patterns in automated cervical image analysis, Advances in Visual Computing. Springer, Berlin, pp 627–636

[9] Van Raad V (2003) Design of Gabor wavelets for analysis of texture features in cervical images. Engineering in Medicine and Biology Society. In: Proceedings of the international conference of the IEEE, pp 806–809

[10] Liu J, Li L, Wang L (2018) Acetowhite region segmentation in uterine cervix images using a registered ratio image. Comput BiolMed 93:47–55

[11] Obukhova NA, Motyko AA, Kang U et al (2017) Automated image analysis in multispectral system for cervical cancer diagnostic. In: Conference of Open Innovations Association, pp 345–351

[12] Hervet, E., Kardouchi, M.: Segmentation and histogram transform of color colposcopic images. In: International. Conference on Signal and Image Processing (ICISP). Volume 2., Agadir, Morocco (2003) 412{420}

[13] Van-Raad, V.: Frequency space analysis of cervical images using short time Fourier transform. in Proceedings of the IASTED International Conference of Biomedical Engineering 1 (2003) 77{81}

[14] Klinker, G., Shafer, S.A., Kanade, T.: The measurement of highlights in color images. International Journal of Computer Vision 2 (1988) 7{32}

[15] Gershon, R., Jepson, A.D., Tsotsos, J.K.: Highlight identification using chromatic information. In: Proceedings of the first International Conference on Computer Vision (ICCV). (1987) 161{171}

[16] Xue Z, Antani S, Long LR et al (2007) Comparative performance analysis of cervix ROI extraction and specular reflection removal algorithms for uterine cervix image analysis. Proc SPIE 6512(1):187–189

[17] Karapetyan G, Sarukhanyan H (2013) Automatic detection and concealment of specular reflections for endoscopic images. In: Computer science and information technologies, IEEE, pp. 1–8

[18] Guillemot C, Meur OL (2013) Image inpainting: overview and recent advances. IEEE Signal Process Mag 31(1):127–144

[19] Castle PE, Stoler MH, Solomon D et al (2007) The relationship of community biopsy-diagnosed cervical intraepithelial neoplasia grade 2 to the quality control

pathology-reviewed diagnoses: an ALTS report. Am J Clin Pathol 127(5):805–815

[20] Corrêa FM, Russomano FB, Oliveira CA (2012) Colposcopic triage methods for detecting cervical intraepithelial neoplasia grade 3 after cytopathological diagnosis of low-grade squamous intraepithelial lesion: a systematic review on diagnostic tests. São Paulo Med J Revista paulista de medicina 130(1):44–52

[21] Xue Z, Antani S, Long LR et al (2007) Comparative performance analysis of cervix ROI extraction and specular reflection removal algorithms for uterine cervix image analysis. Medical Imaging 2007: Image Processing.

International Society for Optics and Pho- tonics, pp 187–189

[22] Maheswari GU, Ramar K, Manimegalai D et al (2011) Short communication: an adaptive region-based color texture segmentation using fuzzified distance metric. Appl Soft Comput J 11(2):2916–2924

[23] Stehle TH (2006) Specular reflection removal in endoscopic images. In: Proceedings of the 10th international student conference on electrical engineering, vol 10, pp 1–6.