SPECIMEN FORMAT FOR THESES OF MONTH

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Branch/ Area:	:	Image Processing and Vision AI
Sub Subject Heading:	:	Artifact Removal in Cervical Image Processing
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Title of the thesis (i) In Roman Script (ii) In roman Script	:	Specular Reflection Removal on Smart Colposcopy Images using Deep Learning Inpainting Model for Enhanced Grading of Cervical Cancer
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Abstract within 300 words:

Cervical cancer is a significant global health concern, ranking as the fourth most common cancer among women, primarily caused by Human Papillomavirus (HPV) affecting the lower uterus. Despite preventive measures like HPV vaccination and screening programs, many women hesitate due to invasiveness. Smart colposcopy, an advanced non-invasive approach, captures cervix images for examination. However, white specular reflections caused by body moisture pose challenges, hindering accurate analysis and potentially leading to misclassification of dysplasia regions. This research aims to improve cervical cancer grading by identifying and removing specular reflection from smart colposcopy images. Initial focus lies on specular reflection identification, employing RGB and XYZ color spaces for optimal detection. The proposed intensity-based threshold method accurately identifies specular reflection on XYZ color, overcoming challenges posed by vaginal discharge and acetowhite regions.

In the second phase, pixel-wise segmentation models like Fully Convolutional Neural Network (FCN), SegNet, and UNet Model are employed.On comparison analysis of the segmentation model, the UNet model indeed demonstrates higher accuracy. However, when it comes to the intersection of Union, the UNet model falls short due to the overlapping of segmentation. To address this limitation, different versions of the UNet model are compared, and the UNet++ model emerges as the most promising, exhibiting higher intersection of union metrics. Subsequently, the UNet++ model is fine-tuned to optimize its performance in segmenting reflection regions. After segmentation of the reflection, the empty region should be filled with neighboring pixels to improve the quality of the images. A novel Bilateral-based Convolutional Inpainting model fills eliminated regions, improving image quality. This model outperforms traditional methods, particularly in medical image applications, showcasing efficacy across different masking ratios. Enhanced images, with removed specular reflection, undergo grading using DenseNet121, VGG19, and EfficientNet.

Trained on both enhanced and non-enhanced images, classification models achieve significantly improved prediction accuracy with enhanced images, underscoring the enhancement technique's impact on cancer stage classification. This research offers valuable insights into medical image analysis, presenting an integrated approach for cervical cancer grading. The proposed methodologies exhibit promising results, laying the groundwork for further advancements in women's health and cancer diagnosis.

i) Major objectives :

Primary Objective

- Detection and removal of the specular reflection (SR) region from the smart colposcopy images to enhance the grading of cervical cancer.

Secondary Objective:

- To develop a framework for the identification of specular reflection region on the smart colposcopy images.
- To build a model for filling the removed specular reflection regions with neighboring pixel on smart colposcopy images

ii) Hypothesis:

The hypotheses involved in this research work involved in the four phases are: Specular reflection identification, specular reflection (SR) segmentation, inpainting, and the overall enhancement of smart colposcopy images for cervical cancer grading.

- The intensity-based thresholding method (IBTM) effectively identifies specular reflection regions in smart colposcopy images, particularly when applied within a suitable color space (e.g., XYZ color space over RGB).
- A deep learning segmentation model, specifically a fine-tuned UNet model, accurately delineates the specular reflection regions in colposcopy images, outperforming other segmentation models.
- The proposed bilateral-based convolutional inpainting model effectively restores the areas affected by specular reflection in colposcopy images, leading to a natural and accurate reconstruction of the affected regions.
- The enhancement techniques applied in the previous phases, particularly the removal of specular reflections and the restoration of affected regions, significantly improve the accuracy and reliability of the grading process for cervical cancer in smart colposcopy images.

iii) Methodology :

The methodology adopted for the proposed research work will be presented in four phases, as listed below:

Phase I: Specular Reflection Identification

Phase II: Segmentation of Specular Reflection

Phase III: Inpainting for Image Enhancement

Phase IV: Enhanced Image Grading

Specular Reflection Identification

This chapter focuses on developing a threshold-based method for detecting glare regions in smart colposcopy images. The chapter begins with an introduction to the importance of glare region detection in improving the accuracy of image analysis. This chapter also discusses the critical step of identifying the most suitable color space for this task and explains the reasoning behind our choice. This chapter describes the proposed threshold method, which relies on intensity values within the chosen color space to identify the reflection region. Experiments were carried out to confirm the method's efficacy, and the results were reported. A thorough analysis of the findings is provided in the part that follows.

Segmentation of Specular Reflection

It discusses about the deep learning segmentation models for glare region segmentation in smart colposcopy images. The chapter begins with an introduction to the central focus and importance of accurate segmentation in image analysis. This chapter also describes the initial analysis of various segmentation models to identify the most suitable candidate for this specific task. The selection of the UNet model is explained in detail, supported by the analysis results that demonstrated its superior predictive performance. The fine-tuning and customization process applied to the UNet model to align it with the specific requirements of glare region segmentation. The chapter discusses the validation methodology and performance evaluation, providing concrete evidence of the model's accuracy. The customized UNet model with other UNet variations highlights the advantages and improvements achieved through customization. In conclusion, chapter 5 underscores the significance of the selected and customized UNet model in achieving precise glare region segmentation, which is pivotal for smart colposcopy image analysis.

Inpainting for Image Enhancement

It discusses the deep learning inpainting models for glare region restoration in smart colposcopy images. The chapter starts with an introduction, underscoring the importance of inpainting in addressing image imperfections. Initially, various convolutional-based inpainting models are analyzed by explaining the criteria for selecting and comparing these models. Integration of convolutional filters and other filtering techniques in the inpainting process is discussed to highlight their role in enhancing restoration quality. This chapter proposes a bilateral-based inpainting model, which is presented as the chosen approach for glare region restoration.

Enhanced Image Grading

It discusses the deep learning classification models for grading smart colposcopy images. The chapter begins with an introduction, highlighting the critical role of accurate grading in cervical cancer diagnosis and its connection to image enhancement. It also discusses the methodology for training deep-learning classification models, including using enhanced and non-enhanced cervical images for training. The architecture and configuration of the deep learning model are presented, followed by details on the experimental setup and training process. The grading results between enhanced and non-enhanced images demonstrate the impact of image enhancement on the grading process.

iv) Findings:

1. Finding in Specular Reflection Identification

The experimental result is compared with the existing method, which works with the reflection detection process using different color spaces. The XYZ is highly suitable for reflection prediction, and intensity-based threshold method predicts the reflection with higher accuracy.

2. Finding in Segmentation of Specular Reflection

The experimental result indicates that the UNet model segments the reflection with a higher accuracy. Consequently, various variations of the UNet model are employed to assess their performance in segmenting images. This UNet ++ predict higher, so the UNet++ model is fine-tuned to reduce the over-segmentation process. The fine-tuned UNet++ model segments the reflection region with a higher accuracy.

3. Finding in Inpainting for Image Enhancement

The outcome of experiment result shows that the bilateral-based convolutional inpainting model predicts the missing region more accurately.

4. Finding in Enhanced Image Grading

The experimental result validates that utilizes the classification models to improvise the grading of smart colposcopy images has improved the image quality through reflection detection and removal.

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