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Improvised kernel graph cuts and continuous max-flow optimization scheme-for enhanced segmentation in Cervical Cancer Detection

Ch. Rajarao[1], R.P. Singh[2]
[1]*Research Scholar, SSSUTMS,Bhopal,Madhya Pradesh*
[2]*Vice-Chancellor, SSSUTMS, Madhya Pradesh*
Corresponding Author: Ch. Rajarao

Abstract: *The cervical cancer refers to the uncontrolled growth of cells in the internal lining of the cervix part that connects the uterus region to the vaginal part of the women. This cervical cancer needs to be screened for identifying pre-cancers before they get transformed into invasive cancer. The Pap Smear Test is considered as the potential screening test essential for detecting pre-cancerous cells in the cervix, such that the uncontrolled growth of inter-uterine wall cells can be prevented. The majority of the segmentation schemes proposed in the literature for detecting cervical cancer failed in predominant localization of cytoplasm and nucleus boundaries from the pap smear extracted during the screening process. In this paper, an Improvised Kernel Graph Cuts and Continuous Max-Flow Optimization (IKGC-CMFO) Scheme is proposed for enhanced segmentation during the process of significant Cervical Cancer Detection. This proposed IKGC-CMFO Scheme wide opens the options of investigating the overlapping and hazy boundaries of the pap smear cells in order to ensure optimal level of cervical cancer detection. This proposed IKGC-CMFO Scheme utilized a kernel induced space in the generation of graph cut with an incorporated max-flow algorithm achieved through continuous multiplier. The simulation experiments and results of the proposed IKGC-CMFO confirmed a superior classification accuracy rate of 32% compared to the baseline Graph cut-based segmentation approaches considered for investigation.*

***Keywords:**. Cervical Cancer, Improvised Kernel Graph Cuts, Continuous Max-Flow Optimization, Cytoplasm Boundaries, Pap Smear Cells.*

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I. Introduction

In general, the cervical cancer pertains to the uncontrolled cell growth in the inner uterine walls that connects the uterus with the vagina of the women reproductive system [1]. This cervical cancer is difficult to be defeated in the invasive cancer stage and most of the symptoms is mostly not realizable in the precancerous stages [2]. Thus, the detection of cervical cancer needs to be facilitated through proper screening at the early stages of cancer [3]. This detection of cervical cancer is made feasible through the incorporation of screening tests like pap smear test and HPV DNA test [4]. The pap smear test is considered to be the most predominant test for detecting cervical cancer independent to the age of the women whose cervical cells are considered for examination. However, the pap smear test fails in the accurate detection of cervical cancer due to the inconsistent staining and poor contrasting properties of the abnormal cervical cells considered for investigation [5]. Hence, a need arises for formulating a significant segmentation approach that aids in facilitating better classification accuracy during the cervical cancer detection process. Moreover, segmentation schemes contributed using Graph cuts are determined to be a more significant in the accurate estimation of cytoplasm and nuclei boundaries of the considered input cervical pap smear cells towards abnormality detection in order to confirm the existence of cervical cancer [6]. Diversified number of graph cut-based cervical cancer cell detection schemes were contributed in the literature for effective segmentation process with the view to analyze the cytoplasm and nuclei boundaries of cervical pap smear cells [7]. In specific, Kernel graph cuts are determined to be more potent among the existing graph cut-based cervical cancer cell detection schemes, since they are suitable in the exact definition of the cytoplasm and nuclei boundaries of cervical pap smear cells. In addition, the incorporation of Continuous Max-Flow Optimization integrated with Kernel graph cuts is determined to be significant in feature optimizations that aids in better accuracy in classification during the process of cervical cancer detection [8].

In this paper, an Improvised Kernel Graph Cuts and Continuous Max-Flow Optimization (IKGC-CMFO) Scheme is proposed for enhanced segmentation during the process of significant Cervical Cancer Detection. This proposed IKGC-CMFO scheme utilizes the methods of bias correction, Continuous Max-Flow

Optimization, hyper reflexivity pixels and polynomial fitting process for effective formulation of graph cuts. The graph cuts developed through the implementation of this proposed IKGC-CMFO scheme aids in superior detection and investigation process during its deployment in the cervical cancer detection process. The simulation experiments and analysis of the proposed IKGC-CMFO scheme conducted using the evaluation metrics of accuracy, precision, sensitivity and specificity in order to estimate its significance on par with the considered benchmarked graph cuts-based cervical cancer detection schemes. The proposed IKGC-CMFO scheme is also investigated using mean Root Mean Square Error (RMSE) and Mean Absolute Deviation (MAD) for quantifying its corrective degree in noise elimination compared to the baseline graph cuts-based cervical cancer detection schemes considered for investigation.

The subsequent sections of the paper are organized as follows. Section 2 details on the survey conducted on the most recent graph cuts-based cervical cancer detection techniques contributed in the past three years for determining the gap in the literature. Section 3 depicts the detailed view of the proposed IKGC-CMFO scheme with its predominant merits involved during the process of cervical cancer detection. Section 4 highlights on the experimental investigations of the proposed IKGC-CMFO scheme evaluated using the parameters of accuracy, sensitivity, specificity, mean processing time, RMSE and MAD incurred in the process of segmentation. Finally, Chapter 5 concludes the proposed work with vital contributions and feasible future directions of research.

II. Related Work

In this section, the most recent graph cuts-based cervical cancer detection techniques contributed in the past three years were reviewed and presented with their merits and limitations as follows.

Initially, an integration segmentation approach that utilized Intersecting Cortical Model and Cuckoo Search Optimization for effective detection of cervical cancer was proposed [11]. This ICMSP scheme aided in eliminating noise by incorporating dynamic median filter for cervical image pre-processing. The Haar wavelet transform was used in the ICMSP scheme for preventing the influence of irregular staining of cervical images. This ICMSP scheme also utilized bit slice plane approach for the process of background subtraction. Then, Markov Random Field-based Segmentation Mechanism (MRFSM) was proposed using the merits of automatic label-map approach that estimates cytoplasm and nuclei background regions [12]. This MRFSM aided in classifying the regions of super pixel such that the complete image could be represented as a probabilistic graphical model. The accuracy, sensitivity and specificity of MRFSM is determined to be maximum under different rounds of the implementation process.

Further, a Graph Cut-based cervical cancer detection scheme was contributed for a graph through the process of image unfolding that aids in mapping ellipse shaped border of the cervical pap smear cells [13]. This Graph Cut-based cervical cancer detection scheme utilized prior constraints for enhancing the local cost function, such that it could be reflected in effective construction of grid image. An integrated Graph-based approach that utilizes Full Convolutional Networks was contributed for effective detection of cervical cancer pap smear images [14]. This integrated Graph Cut and Fully Convolutional Network were contributed for mapping the label mask in order to decide the boundaries of nuclei and cytoplasm of pap smear cells.

Furthermore, an automated abnormal region detection approach using improved Haar wavelet was proposed for effective detection of cervical pap smear cells [15]. This automated abnormal region detection approach derived the merits of SVM approach that aids in effective classification of normal cervical cells from cervical cancer pap smear cells. The classification accuracy, sensitivity and specificity of this SVM-based scheme facilitated a superior improvement in the effective definition of cytoplasm boundaries. Then, a cervical cancer detection scheme based on the assumptions that the cell nucleus is determined to be located in the center of the cytoplasm was proposed [16]. This cervical cancer detection scheme utilizes three steps that are related to the segmentation of overlapping cells, overlapping cell isolation and nucleus detection and inflammatory cell prevention. This cervical cancer detection scheme proved predominant results in terms of precision, accuracy, image processing time incurred in the execution process.

Finally, a cervical cancer cell detection approach that handles the multi-scale information for integrating classification and segmentation towards efficient nuclei and cytoplasm boundary detection was proposed [17]. This multi-scale information-inspired cervical cancer cell detection approach was determined to enhance the harmonic mean related to the specificity and sensitivity in the process of classifying the boundaries of nuclei and cytoplasm. In addition, Neutrosophiv Graph Cut-based Segmentation Scheme (NGCSS) was proposed .by utilizing the benefits of indeterminacy-based Neutrosphic Graph cuts [18]. This NGCS scheme incorporated indeterminacy filter that reduces the value of indeterminacy related to the spatial and information value of pap smear cells. This NGCSS achieved classification accuracy by splitting the preprocessed image into a number of non overlapping area that helps in superior classification accuracy.

III. Proposed Improvised Kernel Graph Cuts and Continuous Max-Flow Optimization (IKGC-CMFO) Scheme for Cervical Cancer Detection

The proposed Improvised Kernel Graph Cuts and Continuous Max-Flow Optimization (IKGC-CMFO) Scheme consists of six potential steps such as, a) Process of cropping nucleus and cytoplasm region from pap smear cells, b) Bias Correction-based preprocessing, c) Construction of kernel Graph cuts for definition of accurate cytoplasm and nucleus boundaries, d) Continuous Multiplier-Based Maximum Flow Algorithm and e) polynomial curve fitting for effective hyper pixel determination. The system implementation of the proposed IKGC-CMFO Scheme for effective segmentation under cervical pap smear cell cancer detection is depicted in Figure 1.

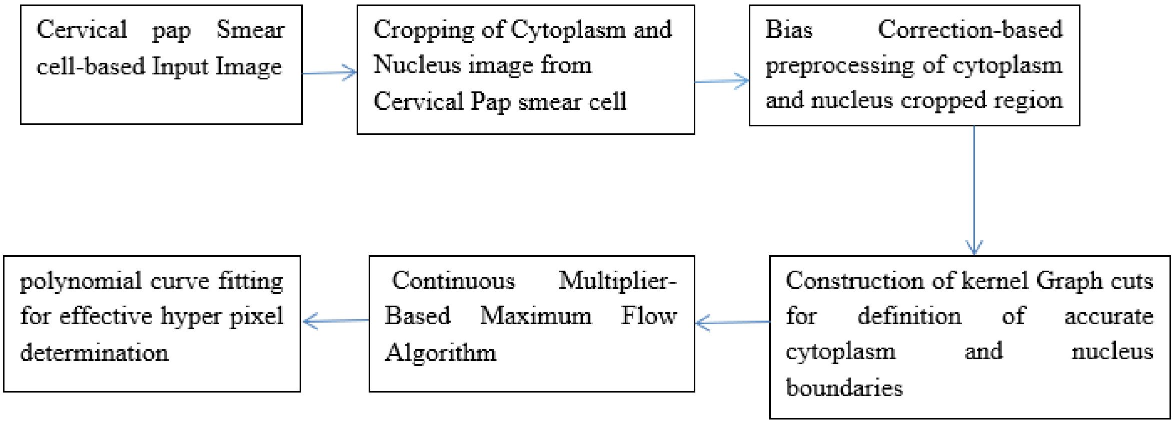

Figure 1: Implementation of the proposed IKGC-CMFO Scheme for segmentation in cervical cancer detection

3.2 Bias Correction-based preprocessing

Before this phase, the cropped cytoplasm and nucleus boundaries derived from cervical pap smear cells are not well defined, since they possess intensity inhomogeneity and noises. Hence, the method of Bias Correction-based preprocessing is employed for eliminating the issues of noise and intensity inhomogeneity for perfect definition cropped cytoplasm and nucleus boundaries. This Bias Correction-based preprocessing method aids in refining the imaging artifacts by computing the factor of residual bias, which is then enhanced by estimating the deviation between the corrupted image and residual bias field. Thus, the false positive rate of this proposed IKGC-CMFO scheme is greatly minimized through this preprocessing by enhancing the layer boundaries of cytoplasm and nucleus boundaries of cervical pap smear cells.

3.3 Construction of kernel Graph cuts for accurate detection of cytoplasm and nucleus boundaries

In this phase of the proposed IKGC-CMFO scheme, the accurate construction of graph cuts is facilitated by representing each and every cytoplasmic and nuclei boundary of the images into a Graph labeled $G=(V,E)$. This represented graph cuts consists of nodes (V) or vertices (pixels) and collection of directed edges (E) that connects each and every pixel with one another of the neighboring region. This graph cut consists of two specially designated vertices that correspond to the foreground terminal (source vertex-s) and background terminal (sink vertex-t) in the grid derived from the bias corrected preprocessing image. Further, 'E' is the set of edges that represent the link between each neighboring pixel existing in the image grid with the data edges or data links that connect the source vertex-s and sink vertex-t. This edges aid in establishing a pathway through which the complete graph can be traversed. However, the path is selected based on preferences estimated through the assignment of positive weights to each of the edge set in the image grid graph.In order to achieve superior segmentation, the traversed path in the graph must be determined based on the least cumulative weights of the edges that aids in traversing the graph from the source vertex-s and sink vertex-t. This traversed path in the graph with the least cumulative weights of the edges is the graph cut, which possess the significant in partitioning the image into two distinct partitions.

In this context, if there exists a graph cut that partitions the complete graph into two distinct partitions, then graph cut is considered as the graph cut with a subset of edges represented as $C_G \in S_{P(reg)}$. This graph cut $G(C_G) = < V, E \setminus C_G >$ aids in partitioning the region of the graph based on Equation (1)

$$S_{P(reg)} = A_P \cup B_P \text{ with } A_P \cap B_P = \phi \quad (1)$$

Where A_p and B_P represents the pixels of the image that are mapped as foreground and background.

Let us consider a binary labeling set for defining the effective segmentation functions $\{K_1, K_2, ...K_n\}$ of the graph, which is set to each and every pixel in the derived image grid. Hence, each segmentation function is estimated based on Equation (2)

$$S_{FUNC} = \alpha R_T + B_T \quad (2)$$

$$R_T = \sum_{p\in\Omega} R_T(L_A) = \sum_{A_P \in A} \sum_{p \in S_{A(P)}} -\log(\frac{D_{GP}}{IM_{region}}) \quad (3)$$

$$R_T = \sum_{p\in\Omega} R_T(L_A) = \sum_{A_P \in A} \sum_{p \in S_{A(P)}} (\beta A_p - DG_p)^2 \quad (4)$$

$$B_P = \exp(-\frac{(DG_p - DG_q)^2}{2\delta^2}) * \frac{1}{Euclid - dist(p,q)} \quad (5)$$

The segmentation function defined through Equation (7) is further optimized based on the incorporation of continuous multiplier-based maximum flow algorithm. This maximum flow algorithm is effective, since it is capable of dividing the problem of optimization into simpler sub problem with the enforcement of independent flow variables. This independent flow variables are furthermore optimized for effective segmentation of cervical pap smear cells for effective detection process.

3.4 Accurate detection of cytoplasm and nucleus boundaries using polynomial fitting

The segmentation of cytoplasm and nucleus boundaries, hyper reflectivity pixels (pixels that posses high value of intensity) are completely searched in the cervical pap smear images. This hyper reflectivity pixel pertains to the most reflexive layer of the segmented input image considered for identifying the cytoplasm and nucleus boundaries. At this context, the The sereching process Once the hyper reflexivity points derived from the ROI are selected, then the process of polynomial curve fitting is incorporated for constructing a curve that is suitable for ensuing best fit associated with the hyper reflexivity pixel properties. The degree of the polynomial curve considered in the proposed IKGC-CMFO scheme is assigned to 6.

IV. Experimental Results and Discussions

The predominance of the proposed proposed IKGC-CMFO scheme is investigated using Matlab 2013a by utilizing the renown Herlev dataset for evaluating its performance over the compared cervical cancer detection schemes. This Herlev dataset is mainly used in this proposed IKGC-CMFO scheme-based cervical cancer detection since,it is one of the publicly available dataset with image resolution of 0.201 micrometres per pixel. This Herlev dataset is collected at the Herlev University Hospital through a microscope and a digital camera with specimens that are stained using pap staining and pap smear staining methods. This Herlev dataset omprises of 917 numbers of pap smear images, in which 182 pap smear images are related to mild dysplasia, 192 pap smear images are associated with severe dysplasia, 150 pap smear images are related to carcinoma and the remaining 146 pap smear images are correlated to moderate dysplasia. The performance of the proposed IKGC-CMFO scheme is investigated using classification accuracy, sensitivity, specificity, image processing time, RMSE and MAD to identify its significance over the compared cervical cancer detection approaches.

Initially, Figure 3 and 4 demonstrates the potential of the proposed IKGC-CMFO scheme over the compared NGCSS, ICMSP and MRFSM using classification accuracy and sensitivity. The classification accuracy of the proposed IKGC-CMFO, NGCSS, ICMSP and MRFSM scheme is identified to be 99.61%, 99.43%, 94.52% and 94.12% respectively. Thus, the proposed IKGC-CMFO scheme is considered to be superior in classification accuracy by 0.08%, 5.19% and 5.49% over the comparable to the IKGC-CMFO, NGCSS, ICMSP and MRFSM schemes. This improvement in the classification accuracy of this proposed IKGC-CMFO scheme is mainly due to the incorporation of correction bias that aids in better estimation of cytoplasmic and nuclei boundaries aiming towards effective segmentation process during cervical cancer detection. Further, the sensitivity of the proposed IKGC-CMFO, NGCSS, ICMSP and MRFSM scheme is identified to be 98.82%, 98.41%, 96.12% and 95.64% respectively. Thus, the proposed IKGC-CMFO scheme is considered to be superior in sensitivity by 0.41%, 2.70% and 3.18% over the comparable to the IKGC-CMFO, NGCSS, ICMSP and MRFSM schemes. This improvement in the sensitivity of this proposed IKGC-CMFO scheme is mainly due to the incorporation of continuous max flow optimization method incorporated for effective optimizations, such that effective features are only considered for determining the cytoplasm and nuclei boundaries for facilitating effective segmentation process during cervical cancer detection.

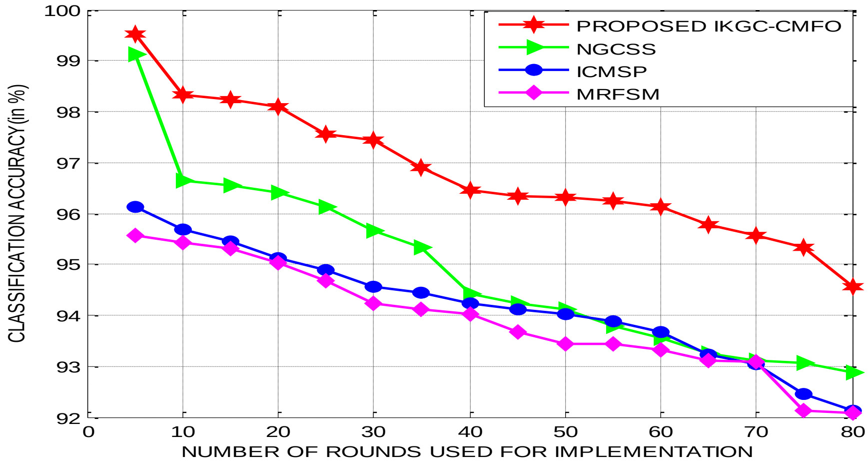

Figure 3: Proposed IKGC-CMFO scheme-Classification Accuracy under increasing rounds

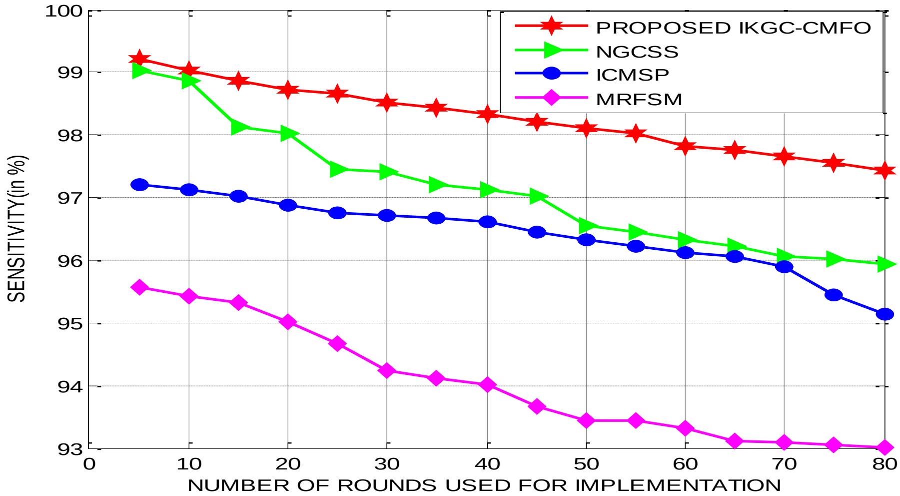

Figure 4: Proposed IKGC-CMFO scheme-Sensitivity under increasing rounds

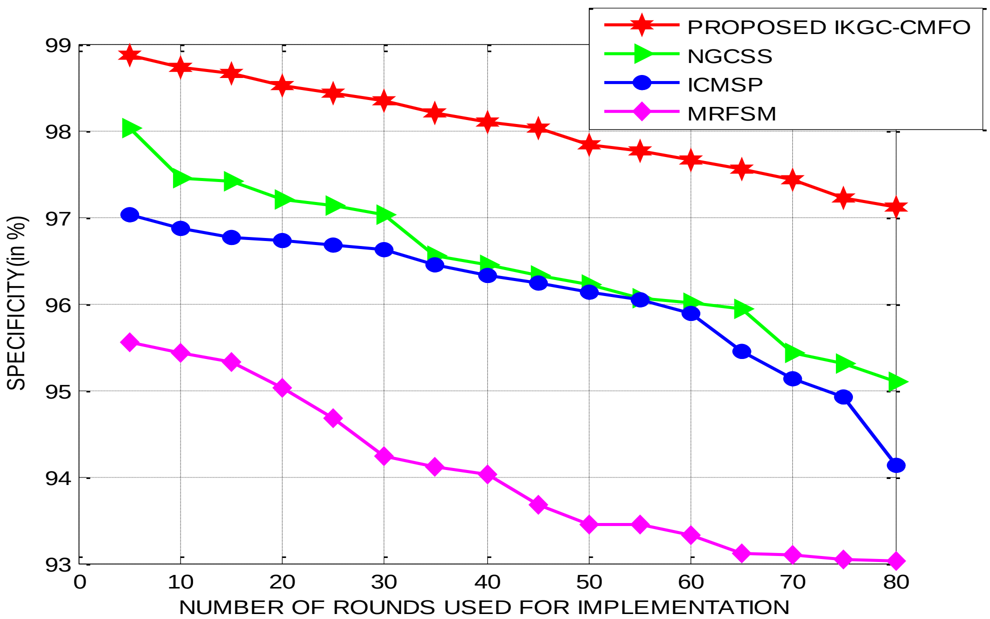

Figure 5: Proposed IKGC-CMFO scheme-Specificity under increasing rounds

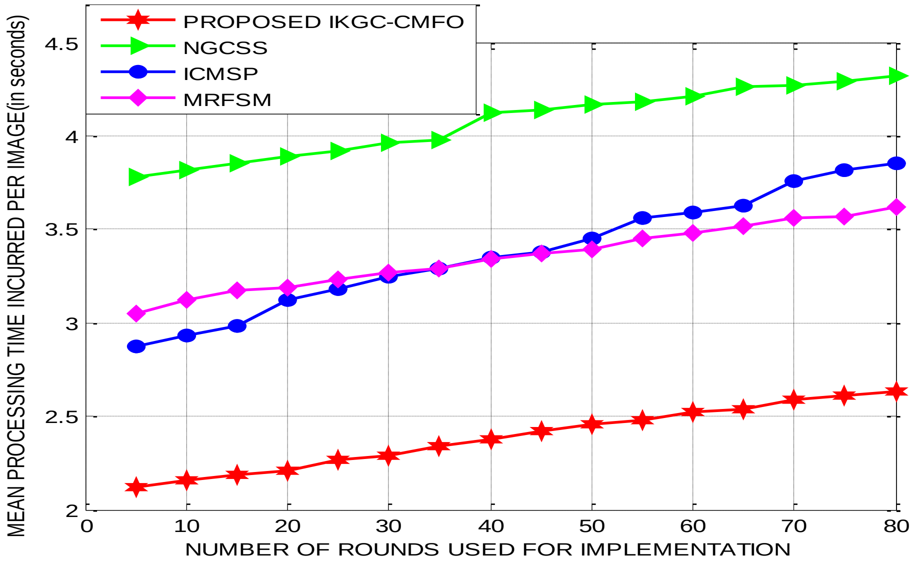

Figure 6: Proposed INGC-GDES approach- mean time for processing images

Furthermore, Figure 5 and 6 highlights the significance of the proposed IKGC-CMFO scheme over the compared NGCSS, ICMSP and MRFSM using specificity and mean processing image incurred for each image under investigation. The specificity of the proposed IKGC-CMFO, NGCSS, ICMSP and MRFSM scheme is identified to be 98.86%, 98.12%, 97.32% and 96.83% respectively. Thus, the proposed IKGC-CMFO scheme is considered to be superior in specificity of 0.74%, 1.54% and 2.03% over the comparable to the IKGC-CMFO, NGCSS, ICMSP and MRFSM schemes. The specificity of the proposed IKGC-CMFO scheme is considerably increased due to the use of adaptive foreground and background factors that contribute towards effective segmentation process. The mean processing time of the proposed IKGC-CMFO, NGCSS, ICMSP and MRFSM scheme is identified to vary between the range of 2.12-2.63 seconds, 2.87-3.85 seconds, 3.78-4.52 seconds and 3.05-3.62 respectively.

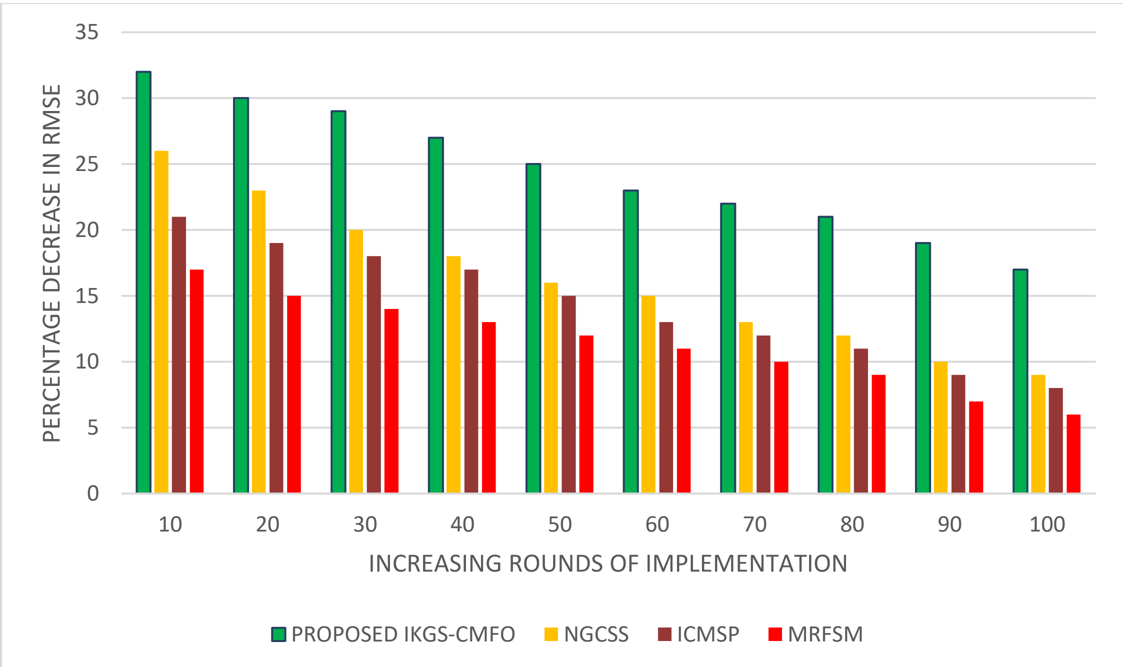

Figure 7: Proposed INGC-GDES approach- RMSE-varying implementation rounds

Thus, the proposed IKGC-CMFO scheme is considered to be superior in reducing the mean processing time per image to a significant degree of 2.31%, 3.87% and 4.51% superior to the benchmarked NGCSS, ICMSP and MRFSM schemes. This predominant reduction in the mean processing time of this proposed IKGC-

CMFO scheme is achieved effective features are only considered for determining the cytoplasm and nuclei boundaries for facilitating effective segmentation process during cervical cancer detection.

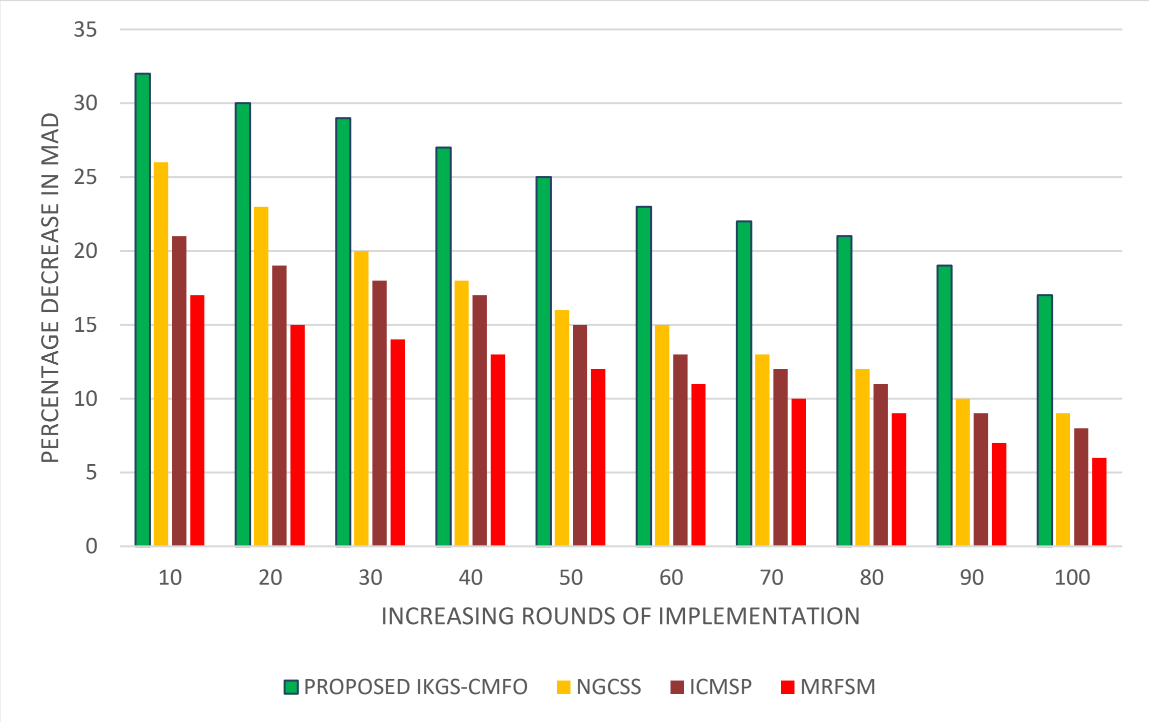

Figure 8: Proposed INGC-GDES approach- MAD under varying rounds of implementation

Finally, Figure 7 and 8 depict the significance of the proposed IKGC-CMFO scheme over the compared NGCSS, ICMSP and MRFSM using RMSE and MAD under an increasing number of rounds in implementation. The RMSE value of the proposed IKGC-CMFO is determined to be decreased by a considerable level of 31%, 26%, 24% and 22% remarkable to the existing NGCSS, ICMSP and MRFSM schemes. Likewise, the MAD of the proposed IKGC-CMFO scheme is also concluded to be minimized through a considerable margin of 24%, 21%, 17% and 13% remarkable to the existing NGCSS, ICMSP and MRFSM schemes. This proposed IKGC-CMFO scheme is considered to minimize the degree of RMSE and MAD, since it facilitates the process of cytoplasm and nuclei boundary detection using the method of polynomial fitting. This is due to the fact that, the polynomial fitting method aids in eliminating the possible hyper reflexivity pixels from the input image after preprocessing.

The forthcoming Figure 9 depicts the results of the systematic steps incorporated in the proposed IKGC-CMFO scheme Intermediate Squamous category of cervical cells derived from Herlev dataset. This result makes it obvious that the cytoplasm and nuclei boundary detection rate is determined to be superior due to the process of inheriting improved kernel graph cut and bias factor-based preprocessing phase. The results confirm that the estimation of nuclei and cytoplasm boundaries is excellently defined based on the incorporation of Bias Correction-based preprocessing which is potent in preventing the issues of noise and intensity inhomogeneity. The results also prove that the inherited kernel graph cut imposed maximum flow algorithm is highly suitable and applicable for exploring and isolating maximum of the problems that emerge during the process of cervical nuclei and cytoplasm boundary segmentation.

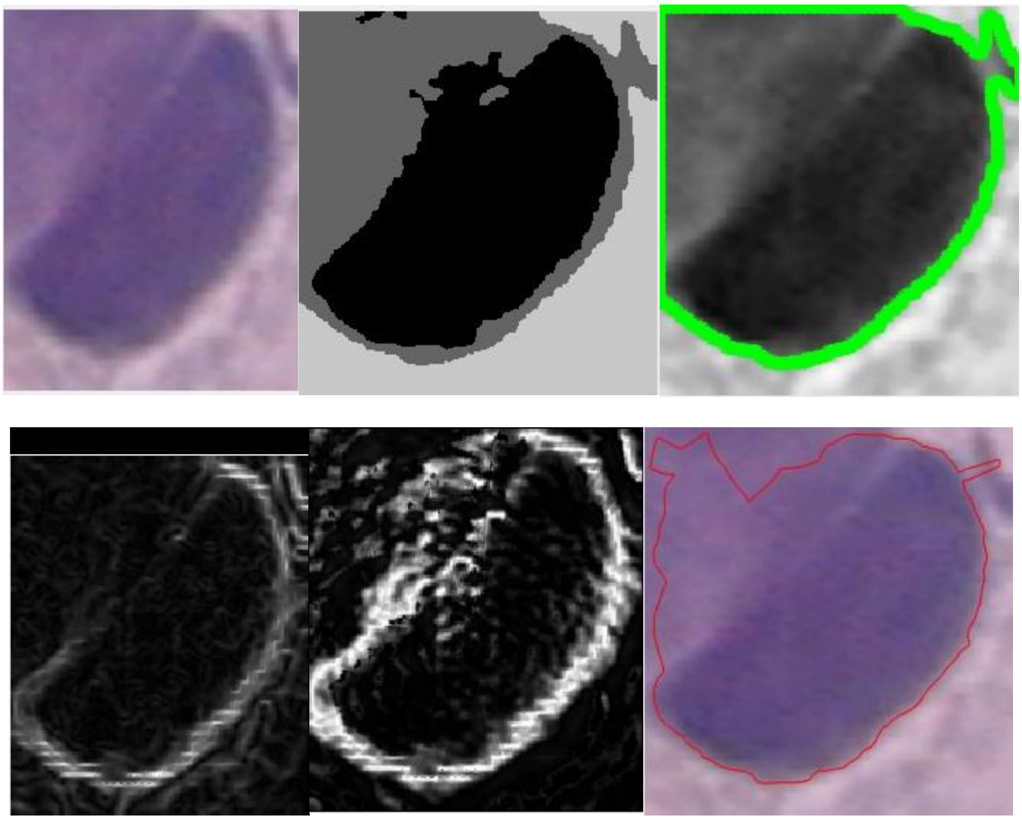

Figure 9: Steps of the proposed IKGC-CMFO based segmentation (the sub figure presented from left to right represents the original cervical cell image (a) image represents Intermediate Squamous category derived from Herlev dataset, (b) image represents results after the Bias Correction-based preprocessing, (c) represents results after the construction of kernel Graph cuts, (d) represents results after the employment of Continuous Multiplier-Based Maximum Flow Algorithm, (e) represents results after the incorporation of polynomial curve fitting for effective hyper pixel determination and (f) final segmented image after segmentation with accurate nuclei and cytoplasm boundaries

The forthcoming Figure 10 depicts the results of the systematic steps incorporated in the proposed IKGC-CMFO scheme using mild dysplasia category of cervical cells. This result makes it obvious that the cytoplasm and the nuclei boundary detection rate of the mild dysplasia is determined to be superior due to the process of inheriting improved kernel graph cut and bias factor-based preprocessing phase. Likewise, the results confirm that the estimation of nuclei and cytoplasm boundaries is excellently defined based on the incorporation of Continuous Multiplier-Based Maximum Flow Algorithm that plays a predominant role in eliminating the issues of noise and intensity inhomogeneity. The results also prove that the incorporation of polynomial curve fitting for effective hyper pixel determination kernel graph is highly suitable and applicable for exploring and isolating maximum of the problems that emerge during the process of cervical nuclei and cytoplasm boundary segmentation.

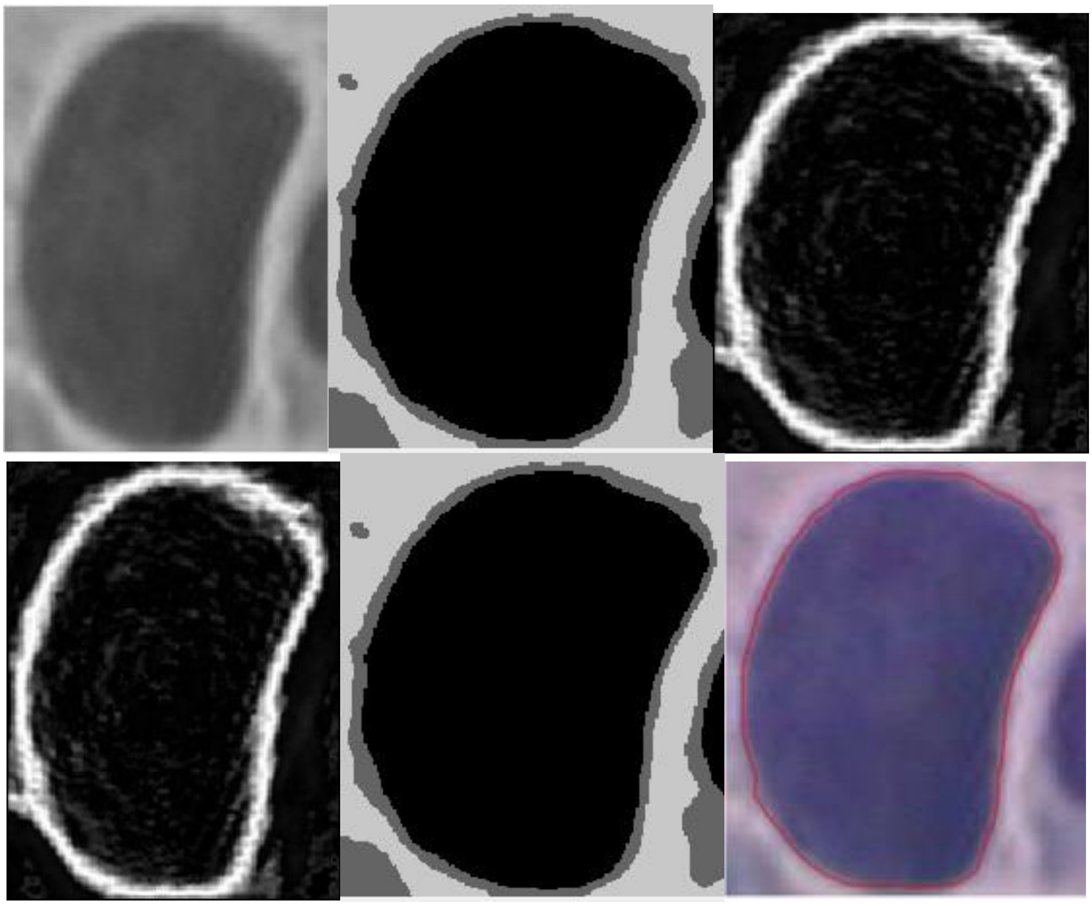

Figure 10: Steps of the proposed IKGC-CMFO based segmentation (the sub figure presented from left to right represents the original cervical cell image (a) image represents mild dysplasia category of cervical cells derived from Herlev dataset, (b) image represents results after the Bias Correction-based preprocessing, (c) represents results after the construction of kernel Graph cuts, (d) represents results after the employment of Continuous Multiplier-Based Maximum Flow Algorithm, (e) represents results after the incorporation of polynomial curve fitting for effective hyper pixel determination and (f) final segmented image after segmentation with accurate nuclei and cytoplasm boundaries

V. Conclusions

The proposed IKGC-CMFO scheme was presented as a reliable attempt for effective detection of cervical pap smear cancer cells through the enforcement of kernel graph cut that incorporates the bias correction, Continuous Max-Flow Optimization, hyper reflexivity pixels and polynomial fitting processes. The formulated graph cuts of the proposed IKGC-CMFO achieved superior detection under its deployment in the cervical cancer detection process by proper definition of cytoplasm and nuclei boundaries with highly reduced noise rate from the input pap smear image. The simulation experiments and analysis of the proposed IKGC-CMFO scheme conducted using the evaluation metrics of accuracy, sensitivity and specificity confirmed an improvement of predominant of 3.21%, 4.53% and 4.12% on par with the considered benchmarked graph cuts-based cervical cancer detection. The mean processing time of the proposed IKGC-CMFO is determined to lie between the range of 2.12-2.63 seconds, which is comparatively lesser than the benchmarked cervical cancer detection schemes. The RMSE and MAD of the proposed IKGC-CMFO is determined to be decreased on an average rate of 28% and 25% superior to the existing NGCSS, ICMSP and MRFSM schemes.

References

[1]. Plissiti, M. E., Nikou, C., & Charchanti, A. (2011). Combining shape, texture and intensity features for cell nuclei extraction in Pap smear images. Pattern Recognition Letters, 32(6), 838-853.

[2]. Marinakis, Y., Dounias, G., & Jantzen, J. (2009). Pap smear diagnosis using a hybrid intelligent scheme focusing on genetic algorithm based feature selection and nearest neighbor classification. Computers in Biology and Medicine, 39(1), 69-78.

[3]. Chen, S., Zhao, M., Wu, G., Yao, C., & Zhang, J. (2012). Recent Advances in Morphological Cell Image Analysis. Computational and Mathematical Methods in Medicine, 2012, 1-10.

[4]. Bergmeir, C., García Silvente, M., & Benítez, J. M. (2012). Segmentation of cervical cell nuclei in high-resolution microscopic images: A new algorithm and a web-based software framework. Computer Methods and Programs in Biomedicine, 107(3), 497-512.

[5]. Chankong, T., Theera-Umpon, N., & Auephanwiriyakul, S. (2014). Automatic cervical cell segmentation and classification in Pap smears. Computer Methods and Programs in Biomedicine, 113(2), 539-556.

[6]. Bergmeir, C., García Silvente, M., Esquivias López-Cuervo, J., & Benítez, J. M. (2010). Segmentation of cervical cell images using mean-shift filtering and morphological operators. Medical Imaging 2010: Image Processing, 1(1), 89-96.

[7]. Plissiti, M. E., Nikou, C., & Charchanti, A. (2011). Automated Detection of Cell Nuclei in Pap Smear Images Using Morphological Reconstruction and Clustering. IEEE Transactions on Information Technology in Biomedicine, 15(2), 233-241.

[8]. Achanta, R., Shaji, A., Smith, K., Lucchi, A., Fua, P., & Süsstrunk, S. (2012). SLIC Superpixels Compared to State-of-the-Art Superpixel Methods. IEEE Transactions on Pattern Analysis and Machine Intelligence, 34(11), 2274-2282.

[9]. Bengtsson, E., & Malm, P. (2014). Screening for Cervical Cancer Using Automated Analysis of PAP-Smears. Computational and Mathematical Methods in Medicine, 2014, 1-12.

[10]. Sajeena T A, & Jereesh A S. (2015). Automated cervical cancer detection through RGVF segmentation and SVM classification. 2015 International Conference on Computing and Network Communications (CoCoNet), 1(2), 15-25.

[11]. Lakshmi, G. A., & Ravi, S. (2017). Automated segmentation algorithm for cervical cell images by employing cuckoo search based ICM. Journal of Ambient Intelligence and Humanized Computing, 1(1), 67-82.

[12]. Zhao, L., Li, K., Wang, M., Yin, J., Zhu, E., Wu, C, Zhu, C. (2016). Automatic cytoplasm and nuclei segmentation for color cervical smear image using an efficient gap-search MRF. Computers in Biology and Medicine, 71(1), 46-56.

[13]. Zhang, L., Kong, H., Liu, S., Wang, T., Chen, S., & Sonka, M. (2017). Graph-based segmentation of abnormal nuclei in cervical cytology. Computerized Medical Imaging and Graphics, 56(1), 38-48.

[14]. Zhang, L., Sonka, M., Lu, L., Summers, R. M., & Yao, J. (2017). Combining fully convolutional networks and graph-based approach for automated segmentation of cervical cell nuclei. 2017 IEEE 14th International Symposium on Biomedical Imaging (ISBI 2017), 1(1), 78-89.

[15]. Chen, X., Hu, Y., Zhang, Z., Wang, B., Zhang, L., Shi, F., … Jiang, X. (2018). A Graph-based Approach to Automated EUS Image Layer Segmentation and Abnormal Region Detection. Neurocomputing, 1(1), 34-48.

[16]. Riana, D., Hidayanto, A. N., Widyantoro, D. H., Mengko, T. L., & Kalsoem, O. (2017). Segmentation of overlapping cytoplasm and overlapped areas in Pap smear images. 2017 8th International Conference on Information, Intelligence, Systems & Applications (IISA), 1(2), 56-68.

[17]. Garcia-Gonzalez, D., Garcia-Silvente, M., & Aguirre, E. (2016). A multiscale algorithm for nuclei extraction in pap smear images. Expert Systems with Applications, 64(1), 512-522.

[18]. Anousouya Devi, M., Sheeba, J., & Joseph, K. S. (2018). Neutrosophic graph cut-based segmentation scheme for efficient cervical cancer detection. Journal of King Saud University - Computer and Information Sciences, 1(1), 24-39.

[19]. Luo, Q., Qin, W. J., & Gu, J. (2013). Kernel Graph Cuts Segmentation for MR Images with Intensity Inhomogeneity Correction. Applied Mechanics and Materials, 333-335(1), 938-943.

[20]. Ghoumari, A., Nakib, A., & Siarry, P. (2018). Evolutionary algorithm with ensemble strategies based on maximum a posteriori for continuous optimization. Information Sciences, 460-461(1), 1-22.

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