Enhanced Region-specific Algorithm: Image Quality Analysis for Digital Kirlian Effect

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Enhanced Region-specific Algorithm: Image Quality Analysis for Digital Kirlian Effect

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***Abstract*—Research on digital Kirlian effect especially its quality after certain algorithm taken part is overlooked. Thresholding the image in binary form couldn't give an analysis enough details on its significant features. This study is introducing an Enhanced Region-specific algorithm, ERS to extract the captured digital Kirlian effect as human radiated energy inside an EPI (Electrophotonic Imaging) image. By utilizing image morphology transform, ERS is improving the procedure of blob extraction process by fitting an absolute arithmetic process in-between the gray-level and binary slice of the image. Henceforth, this paper is focusing on the image quality analysis after the process, subsequently offers a new diagnostic information on captured Kirlian effects through an EPI image. This paper present that the quality of processed digital effect under ERS algorithm are in lower MSE and higher PSNR with its correlation coefficient to its original image better than segmented and binary slices. Significant and most-significant details on the image are able to being preserved to its better quality using the proposed algorithm.**

Keywords—Electrophotonic image, EPI Analysis, ERS algorithm, Enhanced Region-specific, Blob extraction, image morphology, Kirlian effect, Human Biofield

I. Introduction

EPI/GDV is an imaging technique works based on computer image analysis to quantify captured photons in an image form, emitted by a subject under high impulse of electromagnetic field [1]. A specific algorithm is integrated inside the Bio-Well software to remove the less significant pixels in estimating the region of interest by EPI Area parameter [2]; starting with image background filtration and then neighboring pixel adjacent analysis followed by fragmentation and pseudo-coloring based on the image intensity or brightness [3]. Through this image processing technique, a visual estimation known as BIO-gram as shown through Figure 1 is produced. Apart from two papers, Halkias and Maragos [4] also Köppen et al. [5], research on defining the digital features of Kirlian effect in an image form by highlighting the image processing technique that has been used in the process is limited. Recent advances in Electrophotonic image processing as reviewed by Korotkov [6] stated that EPI technique advancing its own Bio-Well processing technique to verify the Kirlian effect through BIO-gram with its own patented algorithm. This exclusive data is not published and technically hard to decipher on how the image depicted the energy possessed by a person is calculated using image processing technique. Hence by introducing a specific algorithm in quantifying the captured radiated energy of the effect in an image form, this research is seen have its significant contribution to the image processing field, afterwards provide an analysis method to study the quality of the digital Kirlian effect after ERS algorithm is implemented on the process.

II. Related Work

In EPI technology, Gas discharge visualisation (GDV) and electrophotonic camera (EPC) recognized as one of the electrotherapy techniques used in medical diagnostic [7]. GDV is a diagnostic system consists of hardware and software (Bio-Well) to processes the captured images of coronal discharge through EPC optic sensor of human fingertips, and together this application of technology named as Electrophotonic Imaging or EPI [8]. Bio-well analysis works based on the fusion of medical diagnosis from Oriental medicine techniques [6].

In overall, EPI technique is proved to be useful in alternative medicines especially in diagnosing human mental health status [9]. Through review studies on EPI or GDV since early of 21st century until now, it is observed that most of the researchers focus on examining the capability of EPI in diagnosing disease and human psychology state [10]. As a medical imaging machine, EPI frequently used to measure symptoms of psychology disturbances in patients [11]. Although, above all of the success, the fundamental explanations on how the recorded image digitally depicts the energy levels of human body's electromagnetic field is still left behind [12]. At this stage, an explanation of how the digital Kirlian effect is being processed digitally is significant to be discussed.

Halkias & Maragos [4] implementing Alternative Sequential Filter (ASF) to the original image before segmentation process by morphology. It is well known that the ASF is a smoothing process in binary image. As studied by Bai and Zhou [13], in morphology, ASF does not perform very well in image detail smoothing for opening and closing operation. Thus, it is observed that the algorithm applied by Halkias and Maragos [4] at the first place furnish the morphology process with poor smoothing technique and doesn't restore significant details on the image.

A heuristic measurement using Genetic Algorithm is used to provide the quantitative measure that visual similarity between EPI images studied by Köppen et al. [5]. Through their research, the building-block or schemata and the image *bitstring* called as *searchspace* is represented in elements of zero (0) and one (1) extracted straight from the image in a binary form. Without considering the noises that that contaminated the image also its significant and the most significant region, it is might be the reason why this algorithm found that the basic physical mechanism of corona discharge is no proper model for the appearance of the typical features on EPI image for the same person. Plus, by treating the image in binary form is slightly inaccurate to deals with the complex digital features of EPI image.

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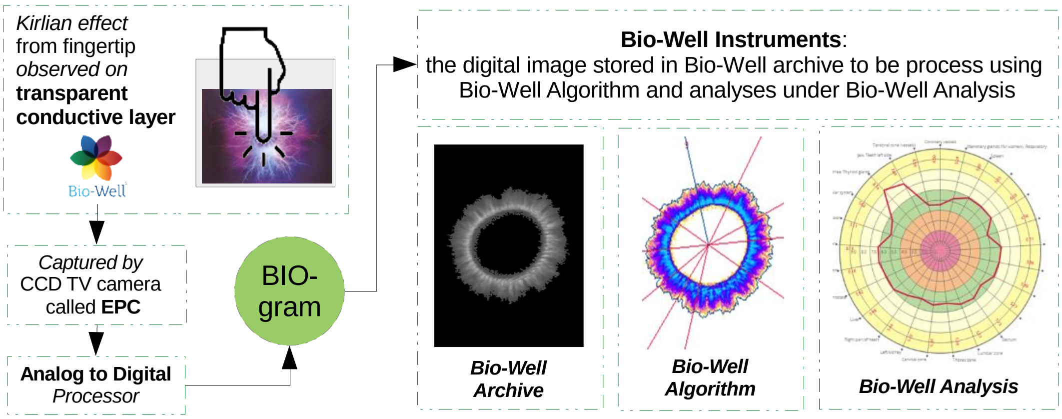


Fig. 1 Overview of GDV Instrument technique and its Bio-Well Instruments

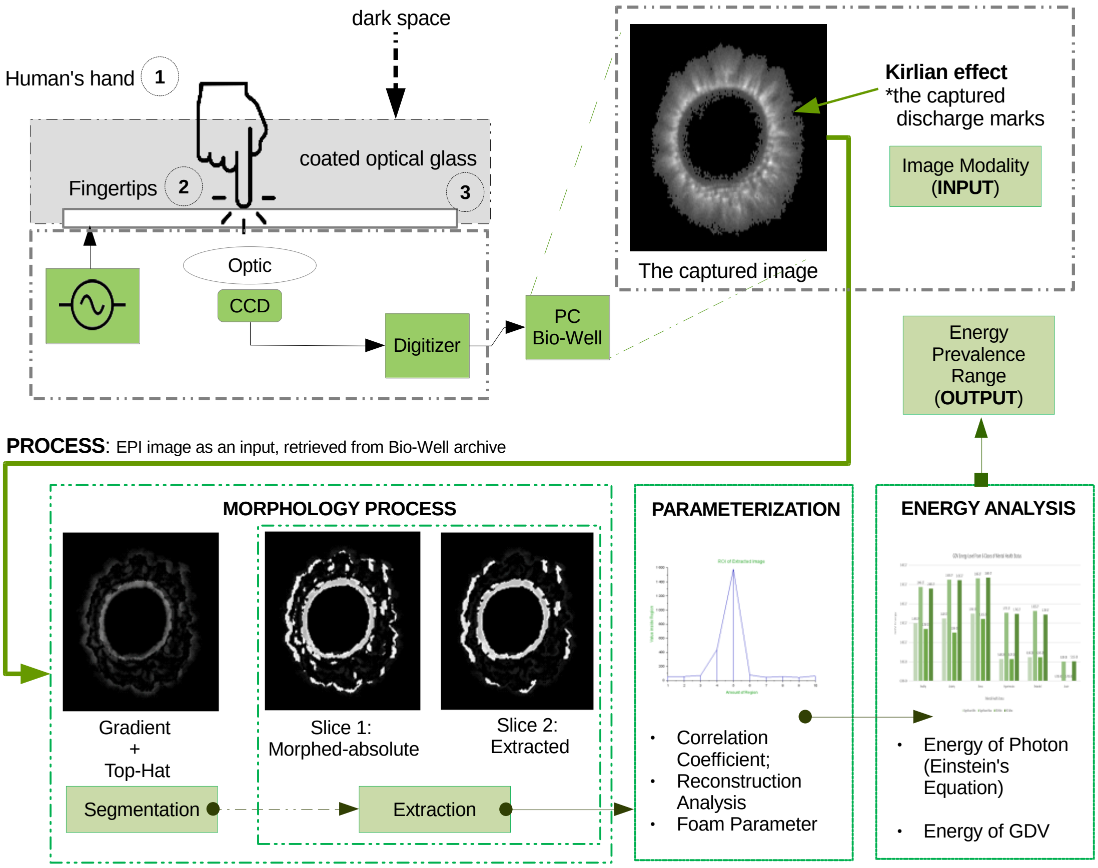


Fig. 2 Overview of the proposed ERS Algorithm Framework

III. Materials and Method

Beforehand, once a research focusing on the structure of Kirlian effect in an image form, the contribution of image processing techniques is the perspective of this research takes an account. The size and geometrical structure of multi-faceted description of EPI image is studied by Halkias and Maragos [4]. Through their research one could define that the image demands an appropriate filtering process as the complex geometrical structure of the image appears along with some significant noises. A minutiae-based processing technique to process the effect is crucial to preserve the significant details on the image

A. Image Modality

The proposed algorithm, ERS is tested on 160 images (from 10 fingertips of 16 subjects). The images are retrieved from Bio-Well archive (refer Figure 1 and Figure 2 for the overview process), where 5 subjects are healthy and the others are considered having some kind of mental problems such as stress, hypertension, anxiety, retarded, and acute psychosis. The retrieved images from Bio-Well are stored in Bitmap uncompressed lossless 24-bit depth double precise.

This type of image modality is chosen to assured that the quality of the captured discharge marks on EPI image is in its optimum details. At the morphology transformation, the ERS produced two (2) slices of images; the first slice is called 'morphed-absolute', which contains the significant signal of the image, while the second slice is named as 'extracted' where the most significant signal is collected (the peak signals), as a frame to garner the peak values of the signals inside the EPI image. This slice of image is recognized as the region of interest (ROI). From both slices, the widespread signal of captured energy of Kirlian effect through an EPI image is able to be quantified.

B. Algorithm Framework

An overview of the proposed algorithm, ERS framework is depicted on Figure 2. In this paper, an upgrade from the introduced pre-processing analysis for the Kirlian effect by Alipal et al. [2] is executed. The process is based on the implementation in sequence of image morphology techniques to extract and analyze the properties in the significant region and the region of interest (ROI) of the Kirlian effect inside an EPI image. The overall proposed ERS technique has been executed using IPVC 2017 toolbox in Scilab 6.0 and the process is summarized as the following sequence;

```
Input
  1.  Read image;
      Resize→Normalized→Double Precise;
      FOR morphological operation;
            Creates texture, ellipse [row1, co1l];
            END
Process
  2.  FOR segmentation:
            Apply Gradient→Tophat;
            Convert to gray level→segmented image;
            Apply Global Otsu→binary image;
            END
       Write→Read: gray and binary;
       Compute absolute difference of gray and binary;
       Write→Read: Im : morphed-absolute slice;

       FOR ROI blob extraction:
            Creates texture for Im, ellipse [row2, col2];
            Im2←Labeled blob properties;
            Im2←Apply Close;
            END
       Write→Read: Im2 : extracted slice;
       END
Output
      3.    Features analysis…
              Calculate the Blob Area; and
              Analyse the quality of Im and Im2 comapared
              to original;
```

To extract the significant feature of Kirlian effects on the digital EPI image, there are two main stages of the image morphological process involved in the ERS above. First stage is the edge detection and segmentation on the brightest components in the image using gradient morphology and top-hat filter. Second is the blob extraction process, being execute on the absolute gray-level-significant-intensity, where taken from the differential absolute arithmetic operation between binary image and its gray-level segmented image. The ROI of the image is brighter than its background. By performing peak detector to segmentize the significant glow, such as top-hat gradient technique, the image opened by structuring element is subtracted from the original image. Hence the brightest spots on the image are highlighted from the dark background. This process allowed us to hold the remarkable outlines of the objects and use it to find the differences between input and its opening for removing the small area on the image (less significant glow) [2].

Gradient morphology is used to detect the edge of the blobs by differentiating dilation and erosion process to indicate the contrast intensity in the close neighborhoods [14]. Meanwhile, the top-hat used to enhance the bright ROI in a dark background [5]. The mathematical model of the gradient and the top-hat segmentation done during Kirlian's blob extraction process are explained briefly by Halkias and Maragos [4]. From that absolute gray-level image, we perform the closing technique to extract the most significant blob features at the same time removing the small holes around the blob so that we will get the solid isolines in the ROI [2]. By referring research layout on Figure 2, the proposed process starts with retrieving the Kirlian images from 10 fingertips of a subject inside Bio-Well archive to the Scilab working directory. There are 16 patients with different mental health status were chosen as the studied subject. Next is modification process of those images into a structure that fit the dedicated morphology process. The images by defaults saved in BMP 24-bit file then cropped in Bitmap 8-bit file in square dimension to floats the image in double matrix vector. This double matrix vector will represent the 8 bit-depth of 2-D image in matrix vector.

To perform the absolute morphology, 'absolute-arithmetic' procedure is done after Gradient-Top-Hat. The process is performed by calculating the absolute difference of gray-level image and its binary image. This absolute filtering process is introduced before the blob extraction taken part. Here, the size of two subtracting images must be in same width, height, class and number of channels. The build in function through **IPVC 2017** toolbox that working on this process are **imcreates** (to creates an ellipse structuring elements), **imgradient** (to highlight the edge of the glowing part in Kirlian image), **imtophat** (to increase the contrast of the glowing part so it's become the foreground to the process), and **imabsdiff** (to do the absolute filtration process between gray level image and its binary).

On the blob extraction process, the processed image is being written in the working directory first, and then read to apply the **imlabel** function (use to all the components on the image). This is next to executing features labelling process on the extracted absolute-foreground object from its background. This function will enable users to differentiate between the most and less significant discharge mark in the foreground. From here, truncating the less significant glow on EPI image is become possible by setting the threshold value above mean of significant region. Once all the components on the image labelled and the less significant glowing part has been removed, **imblobprop** function is applied to find and define the components properties, area, and bounding box used to indicates the pixel's lumen-incident and lumens intensity inside the significant region and the ROI of EPI image. Write and read this processed images in the working directory as 'morphed-absolute' and 'extracted' image.

C. Image Analysis

To measure the quality of the processed image after the proposed algorithm is apply in the image transformation; this research carries out an image analysis based on the image correlation coefficient, Mean Squared Error (MSE) and Peak Signal-to-Noise Ratio (PSNR) amongst images. These three variables will become an indicator of the efficiency of the proposed algorithm to quantify the captured Kirlian effect inside an EPI image. Correlation coefficient as studied by Eugene and Johnston [15] is a variable used to examine the relation of any processed image with its original features. The formula is given as in equation (3.1). The closer the value of this coefficient to one (1), meaning that the processed image is having features with higher similarity with the original image. This coefficient has range values from positive one (+1) to negative one (-1), where zero (0) indicates no association. More than zero means that the image got a positive association with the original image, while less than zero considered as its negative association. In overall, the correlation coefficient in this research is used to measure the strength of linear relationship between original gray level images with it transformed type; binary, segmented, morphed-absolute, and extracted image.

$$r = \frac{\sum_i (x_i - x_m)(y_i - y_m)}{\sqrt{\sum_i (x_i - x_m)^2} * \sqrt{\sum_i (y_i - y_m)^2}} \tag{1}$$

$$MSE = \frac{\sum_{m,n} [I_{ori}(m,n) - I_{noise}(m,n)]^2}{m * n} \tag{2}$$

$$PSNR = 10 \log_{10} \frac{R^2}{MSE} \tag{3}$$

In addition to the analysis, the MSE and PSNR of the processed image are also proposed to be in the calculation. To compute MSE and PSNR, equations as in (2) and (3) are used in the algorithm. Both variables are used to measure the quality of the reconstructed image after image transformation is applied. Through these variables, one could verify the significant signal withstand in the image during restoration. Theoretically, lower the MSE usually has higher PSNR. It means that the studied image is in better reconstruction quality and have strong significant signal in it to be restored.

IV. Results and Discussion

This study proposed parameterization and Energy Analysis (refer Figure 2) as the procedure for the image analysis, i.e. a process done after image morphology; the segmentation and the features extraction process. The image after segmentation process in this study is called as "segmented" image, while after the blob extraction process the image are in two types of slices. The first slice is called as "morphed-absolute" image, and the second one is called as "extracted" image. Morphed-absolute image is the slice that provides image analysis with significant pixels on the EPI image. Concurrently, the pixels for region of interest (ROI) are gained from the second slice of the extraction process, named as extracted image.

Normal and Hotcolormap view of the slices are depicted in Table 1. From this table, the visual views, variance, standard deviation, and correlation coefficient of the slices compared to its original gray-level, segmented, and binary image are presented. Normal blob extraction process in Kirlian image as studied by Halkias and Maragos [4] also by Koppen et al. [5] is implemented on the binary image. In general, binary image provides only two types of lumens levels, either zero (0) or the highest, which are 255. The lumens level of the binary image is represented in Boolean type, zero (0) for lowest lumen and one (1) for the highest lumen.

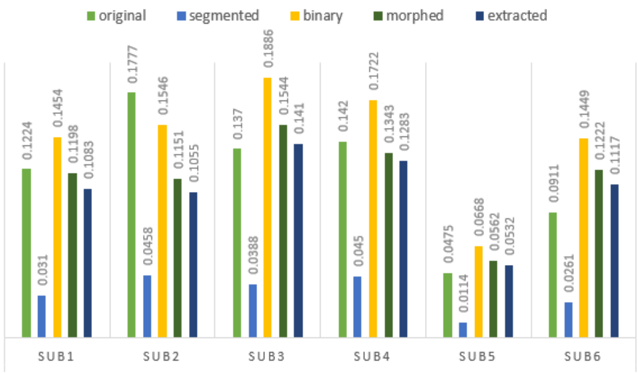


Fig. 3 Bar Plot for Standard Deviation of Original Gray-level and Processed Images from Six (6) Clusters of Studied Subjects (Healthy, Stress, Anxiety, Hypertension, Retarded, and Acute Psychosis)

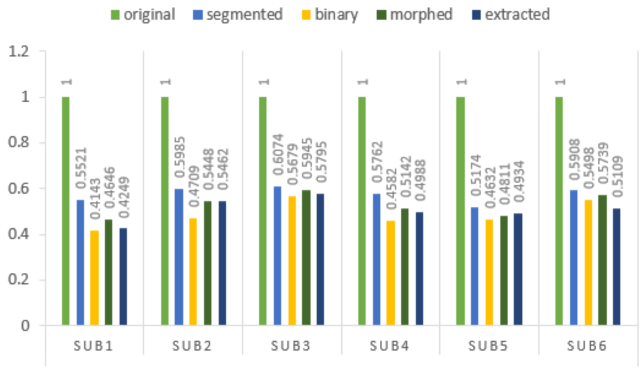
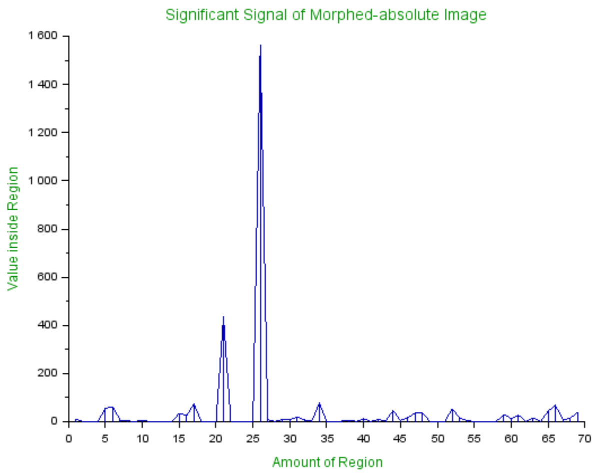


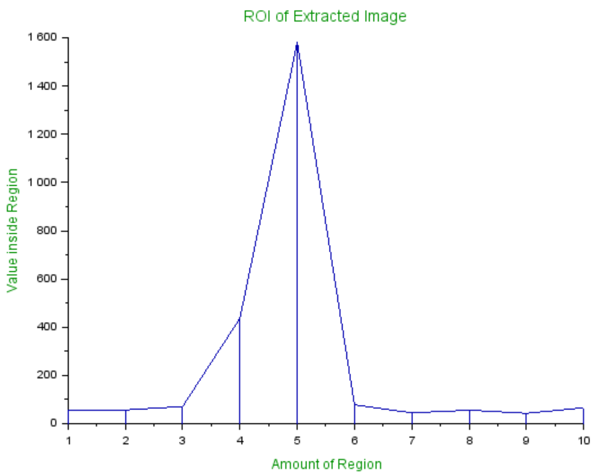
Fig. 4 Bar Plot for Correlation Coefficient of Original Gray-level and Processed Images from Six (6) Clusters of Studied Subjects (Healthy, Stress, Anxiety, Hypertension, Retarded, and Acute Psychosis)

As a result, by implementing normal blob extraction process, the extracted region through binary image itself gives the process some limited lumen's details especially if a dedicated analysis needs to quantify the variation of lumens level on the extracted region. As a solution to the issue, instead of using binary image, the proposed algorithm applies the blob extraction technique on two slices of modified gray level image after the segmentation process. This step provides image analysis more feature details of lumens level on the extracted region. Collected data through ERS as recorded in Table 1 shown that the proposed slices from six (6) studied images of different mental health status give better variance, standard deviation and correlation coefficient in comparison to the binary image, even better from its original image.

In theory, the lower the standard deviation, the better the quality of the image [16]. Based on the simulation data as plotted in Figure 3, segmented image performs way better than the original image. This is an indication that the algorithm at the first place during the segmentation process is preserving the significant signal on the image better than general gray-level image. On the other hand, it is observed that the binary image records the highest standard deviation among all slices. Data from Table 1 for another image of different subjects also shown that the standard deviation of binary image and its original gray level image way higher that the morphed-absolute and the extracted slice.



(a)



(b)

Fig. 5 The signals from *(a) Morphed-absolute slice; (b) Extracted slice.*

To measure the strength relationship between images, correlation coefficient as studied by Eugene and Johnston [15] is used as the indicator. Based on the simulated data as depicted on Figure 4, the correlation coefficient between all images is in positive association to the original gray-level image. From this figure, again the analysis proved that the extracted data from binary images hold lower correlation coefficient in comparison to the segmented, morphed-absolute and the extracted slice. Throughout this bar plot (Figure 4), by comparing to a normal extraction process, the simulated data interpret that the algorithm is performing better to preserved the variation level of lumens inside the significant region of the image, subsequently provides more details inside the extracted region for the ROI analysis.

Since the morphed-absolute slice provide the process with significant pixels on the image, to extract the ROI from these significant details, selection of the thresholding heuristically the best happened at above mean value of the image. Figure 5(a) is the visual of the significant signal inside morphed-absolute image. It is observed that the region below 50 is nearly offset to be less significant to the peak value. It means that the process to capture peak signal away from average region value gives second stage perspective to the analysis about the region. The region, which is above mean value, is recognized as the region of interest (ROI) of the processed image. The signal of ROI, extracted from morphed-absolute image is depicted on Figure 5(b). It is observed that from almost 70 regions of detected blob on morphed-absolute slice, only 10 regions are above the mean value. On this stage of process, throughout the extracted slice, the algorithm provides the analysis details of area for most frequent incident of lumens in the image. Thus, the second slice of the processed image holds the strongest signal of captured Kirlian effects on the studied image.

In practice, an image from any imaging techniques is always contaminated by noise, either addictive or multiplicative [17]. The output from the imaging process is an image that being constructed from the original signal, either one dimensional or multi-dimensional features. In this process, the output image which is segmented and extracted slices are being reconstruct from the original image retrieved from Bio-Well archive. To quantify the quality and signal withstand of those reconstructed images compared to its original gray-level image, the peak signal-to-noise ratio (PSNR) and mean square error (MSE) are calculated. In image statistical analysis, the lower the MSE, the lower the cumulative squared error becomes and the higher the PSNR [16]. Meaning that, an image with better reconstruction coefficient will postulate lower MSE and higher PSNR value. To test the signal-withstand inside the reconstructed images, noisy image with zero mean and 0.7 variance is used as a fixed comparative variable to the process. As a result, Figure 6 visualized the scatter-plot-with-line of the data for all MSE and PSNR values of original, segmented, morphed-absolute, and extracted image of six (6) subjects with fixed tested noises level; addictive and multiplicative.

Through Figure 6, the original image performs better (lower MSE and higher PSNR) on addictive noise but not on the multiplicative noise. Segmented image reacts the best on multiplicative type of noise but higher MSE and lower PSNR on addictive noise. Meanwhile, the extracted slice gives better performance on both noises in comparison to the morphed-absolute. The extracted slice seen to be relatively withhold with the noises in fair records of MSE and PSNR which is in between segmented and original image. Throughout the graph of both noises, the extracted slice shown that the quality of morphed-absolute slice is enhanced since the extracted slice itself holds the most significant signal from morphed-absolute slice. This is the reason why the extracted slice became the ROI of the image to the process. This extracted slice is a frame of where the peak signal garnered, subsequently indicates the highest energy on region of captured Kirlian effects in the EPI image.

V. Conclusion

In the nutshell, the correlation analysis between original gray-level image and processed images indicates that, for the next image analysis, the energy signal from binary image will not be considered. This is because of the quality of the signal from the binary image is being outperformed (highest standard deviation and lowest correlation coefficient) by the morphed-absolute and extracted slice of the extracted image. Moreover, the lower standard deviation of segmented image compared to the original is verify that the algorithm is providing the extraction process the fine details of features on image to capture the most significant region, which consist the strongest signal inside the ROI. As a result, by processing the image using the proposed algorithm, the output image is in its highest quality and details.

In additions, it is observed that the quality and signal withstand of the proposed image slices are better than the original gray-level, only in presence of multiplicative variable but not for an addictive type. This linear statistical comparison study proved an insight that the ROI of the extracted image using ERS algorithm gives a stable quality and strong signal withstand to the noises compared to its significant region, morphed-absolute image. This is come to the reason why the proposed algorithm considering a data of area is gained not only from the image significant signals but also from its most significant signal too.

In a way of an image analysis to be able to define the significant signals of captured Kirlian effects on EPI image, ERS algorithm provides new diagnostic information. Instead of using binary image, to threshold the region of interest and significant area on EPI image as studied by Halkias and Maragos [4] also by Koppen et al. [5], ERS introduced absolute arithmetic before blob extraction process. By executing the ERS algorithm on 160 images from different clusters of mental health, this research able to grasp wider range of lumens intensity and its lumens-incident on the significant and the most significant region of interest in the image. Overall, ERS achieved to improve the quality of the EPI image after being processed.

Acknowledgment

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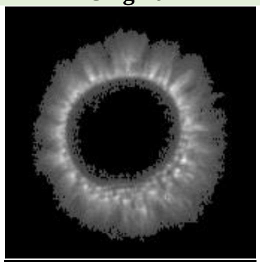
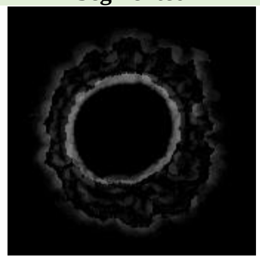
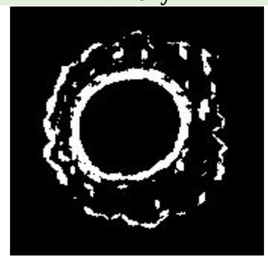
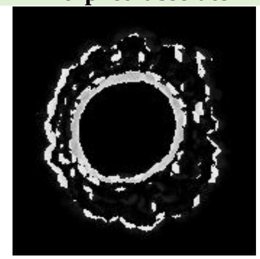
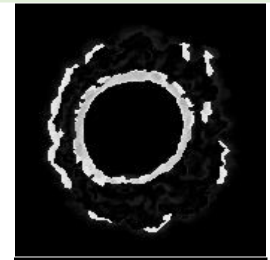
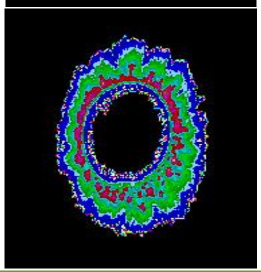
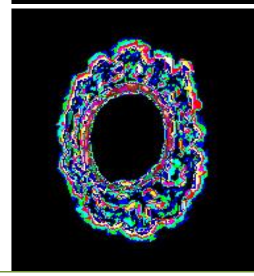
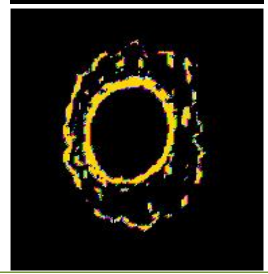
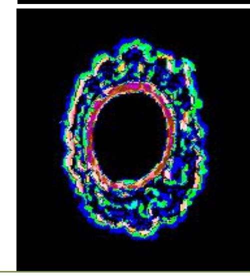
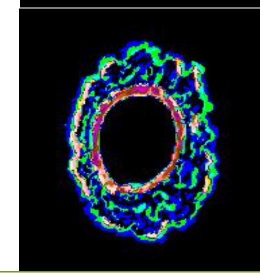
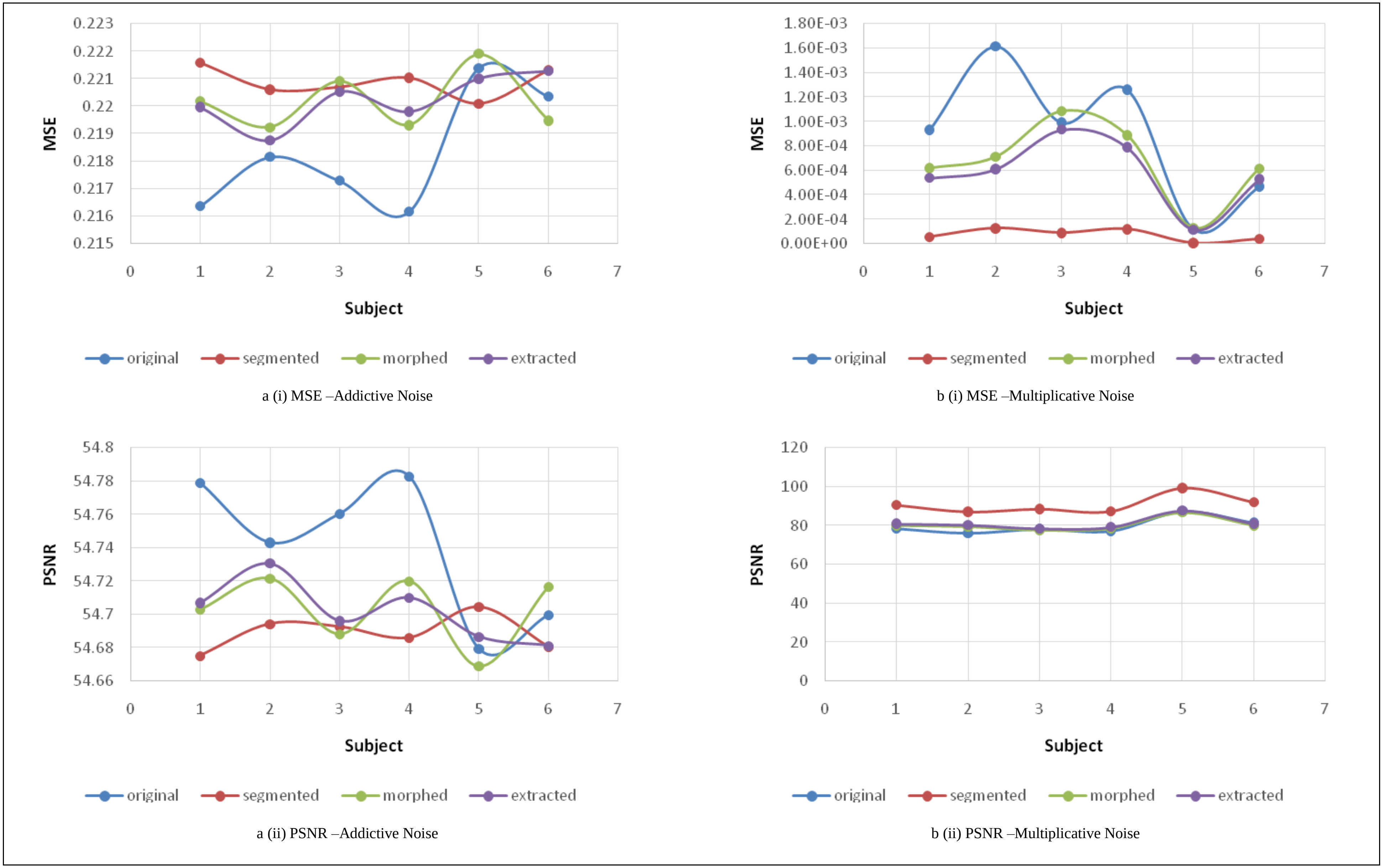
TABLE I. NORMAL AND HOTCOLORMAP VIEW OF ORIGINAL GRAY-LEVEL AND PROCESSED IMAGES

Details	**EPI image for Subject 1: Healthy**				
	Original	**Segmented**	**Binary**	**Morphed-absolute**	**Extracted ROI**
2D View (general view)					
Gray-level (Hotcolormap view)					
Variance	0.0150	0.0010	0.0212	0.0010	0.0117
Standard Deviation	0.1224	0.0310	0.1454	0.1198	0.1083
Correlation Coefficient	1.0000	0.5521	0.4143	0.4646	0.4249

SUBJECT	**Original**	**Segmented**	**Binary**	**Morphed-absolute**	**Extracted ROI**
Image 2			**Subject 11: Stress**		
Standard Deviation	0.1777	0.0458	0.1546	0.1151	0.1055
Correlation Coefficient	1.0000	0.5985	0.4709	0.5448	0.5462
Image 3			**Subject 16: Hypertension**		
Standard Deviation	0.1370	0.0388	0.1886	0.1544	0.1410
Correlation Coefficient	1.0000	0.6074	0.5679	0.5945	0.5795
Image 4			**Subject 8: Anxiety**		
Standard Deviation	0.1420	0.0450	0.1722	0.1343	0.1283
Correlation Coefficient	1.0000	0.5762	0.4582	0.5142	0.4988
Image 5			**Subject 5: Acute Psychosis**		
Standard Deviation	0.0475	0.0114	0.0668	0.0562	0.0532
Correlation Coefficient	1.0000	0.5174	0.4632	0.4811	0.4934
Image 6			**Subject 12: Retarded**		
Standard Deviation	0.0911	0.0261	0.1449	0.1222	0.1117
Correlation Coefficient	1.0000	0.5908	0.5498	0.5739	0.5109



a (i) MSE –Addictive Noise

b (i) MSE –Multiplicative Noise

a (ii) PSNR –Addictive Noise

b (ii) PSNR –Multiplicative Noise

Fig. 6 Graph for MSE and PSNR for; (a) *Images + Addictive Noise,* (b) *Images + Multiplicative Noise*