BROVEY TRANSFORM BASED IMAGE FUSION FOR IMPURITIES SEGMENTATION AND DETECTION ON EDIBLE BIRD'S NEST

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DECLARATION

This work has no previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree

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LIST OF ABBREVIATION

Symbols	Description
EBN	Edible Bird’s Nest
HIS	Intensity-Hue-Saturation
BT	Brovey Transform
PCA	Principal Component Analysis
PAN	Panchromatic
MS	Multispectral
UV	Ultraviolet
IR	Infrared
RL	Red Light
GL	Green Light
BL	Blue Light
UL	Ultraviolet Light
IL	Infrared Light
SR	Segmentation Rate
DSI	Dice Similarity Index

ABSTRAK

Sarang burung walit merupakan salah satu produk yang terpenting dalam industri makanan dan pertanian di Asia Tenggara. Di Malaysia, produksi sarang burung walit adalah tinggi bagi memenuhi permintaan pasaran luar. Jaminan kebersihan adalah salah satu kesulitan utama yang dihadapi dalam memproses sarang burung walit. Kaedah pembersihan sarang burung walit terkinivmemerlukan tempoh yang panjang, kos yang tinggi dan banyak bergantung kepada tenaga buruh. Sistem pemeriksaan automatik telah diperkenalkan tetapi ia wujud sebagai bidang yang mencabar dan masih dalam penyelidikan kerana tidak ada algoritma yang berkesan dalam pengasingan kotoran dari sarang burung walit. Kotoran-kekotoran yang mempunyai ciri yang sama dari segi warna dengan sarang burung walit merumitkan pemprosesan gambar dalam sistem pemeriksaan automatik. Dalam kajian ini, kaedah penggabungan gambar berasaskan transformasi Brovey telah digunakan bagi menonjolkan kekotoran dalam sarang burung walit dan memudahkan proses segmentasi. Pelbagai jenis gambar Multispektral (MS) telah digunakan dalam kaedah pengambunagn gambar. Penbandingan telah dilakukan antara gambar MS bagi memperoleh gambar MS yang paling sesuai dengan ketepatan segmentasi yang paling tinggi. Hasil yang terperoleh akan dinilai berdasarkan kadar segmentasi, presisi, akurasi, kadar kesalahan dan dice similarity index (DSI). Hasil optimal dicapai oleh gambar lampu hijau tanpa operasi erosi dengan kadar segmentasi 49,96%, presisi 48.78%, akurasi 40,00%, kadar kesalahan 60% dan DSI 0,571.

ABSTRACT

Edible bird's nest (EBN) is one of the most important products in food and agricultural industry in South East Asia. In Malaysia, the production of EBN soaring because of the exportation of EBN to meet the demand of overseas market. Assurance of cleanliness is one of the major difficulties faced in processing the EBN. Current cleaning method of EBN is labour dependency, time consuming and not cost effective. Automated inspection was introduced but still continues to exist as a challenging field of development as there is no effective algorithms for impurities segmentation. Some impurities have similar colour as EBN features which increase the complexity of image processing. In this study, Brovey transform based image fusion is used to highlight the impurities in EBN and ease the segmentation process. Various types of Multispectral (MS) reference images were considered in image fusion process. Comparison was made to obtain the MS reference image with highest accuracy of segmented region. The performances of fused images are evaluated based on segmentation rate, precision, accuracy, error rate and dice similarity index (DSI). The optimal performances were achieved by the green light without erosion MS reference image with an overall segmentation rate of 49.96%, precision of 48.78%, accuracy of 40.00%, error rate of 60% and DSI of 0.571.

CHAPTER 1 INTRODUCTION

1.1 Overview

A delicacy in the East, edible bird's nest (EBN) is the nutrient-rich salivary secretion of swiftlets which has dried and hardened. The nutrient contents of EBN makes it one of the best food product to be consumed by human for better health. It is perceived that consuming this delicacy can help improve human immune system and provide anti-aging effect [1]. The high nutritional and medicinal values of the EBN lead to the increasing of demand around the world. The high value of EBN make it becomes one of the major of food and agricultural industry in Malaysia. The quality and grading of EBN are determined based on three main elements which are authenticity, cleanliness, shapes and colour appearance of EBN. Swiftlet’s moult seasons will impact the value of EBN and make it difficult to fix a standard [2].

The high economic value of EBN lead to rampant adulteration by unethical manufacturers. A variety of adulterants such as tremella fungus, karaya gum, red seaweed, pig skin, egg white and vermicelli rice which are similar with EBN in term of colour, texture and taste are added into EBN to increase the size overall nett weight [3]. Therefore, various authentication methods are established to grade and detect the adulteration of EBN [4-6].

The cleanliness element of EBN is correlated with food hygiene. The food hygiene is an essential part in Food Act Malaysia to control the safety of food sold in order to protect public health. The cleanliness in this content refers to a condition of EBN that is free from any impurities or matter that is either foreign to the essence of EBN or unfit for human consumption. The raw EBN consist of impurities like sand particles, feathers, egg shells or any combinations of these [7]. The lower the containment of impurity features, the better cleanliness of EBN. Therefore, the EBN cleaning process is very important to ensure the EBN is hygienic and satisfactory to be consumed.

The cleaning process of EBN required huge amount of human effort to remove the impurity features manually. This process required high concentration over a long period in order to achieve high productivity rate. A person will take 8 hours to clean a total of 10 nests, which is very time-consuming [3]. The raw EBN is first soaked in water to absorb the water until it has expanded. Then the impurity features are removed manually by the trained human operators using tweezers-style tools. The cleaned strands subsequently being rearrange and molded into desired shape. The EBN are packaged for sale after being air-dried [8].

Rather than soaking and removing the impurity features manually, an alternative approach is to transform the EBN into powder before the cleaning take place [9]. This method proven to be effective, however the shape of the EBN is still the important criteria in selling price determination [2]. Hence, the industry still prefers to not drastically change the shape of EBN during cleaning process. Tremendous demand of labour force will result in the increasing of EBN's cost. Implementation of automation in industry can help reduce labour cost as well as to increase productivity. Due to the high demand for EBN in market, the total cultivation areas and yields for EBN have increased rapidly in recent years. Therefore, there is a need for the development of an accurate and fast inspection system in detecting the impurity features of EBN.

From the literature, some automation related work on inspecting the impurity features have been reported. Goh el at. [10] developed a method based on K-Means segmentation for detection of impurity features in EBN. The proposed method was aim to help improve the effectiveness of the conventional cleaning process. A combination of machine vision system and industrial robot system to accomplish a better processing system for EBN was proposed by Subramaniama et al. [11]. In addition to design an effective inspection system, materials and illumination interactions need to be studied and analysed. The quality and appropriateness of lighting are critical aspects in vision inspection. Materials reflect or absorb various wavelengths of light differentially. Different wavelengths of light appearing as various colours to vision receptors. Penetration depth increases with increasing wavelength. The selection of suitable illumination is a crucial element in determining the quality of the captured images. The contrast between EBN and impurity features will only be maximized when appropriate lighting is applied [12]. Failure to properly illuminate a target can result in the loss of information. Fluctuations in illumination must be avoided to ensure a constant image quality of EBN since image processing is part of vision inspection system.

The natural colour of EBN usually range from white and ivory. EBN is a translucent matter which allows light to pass through but in a scatter way, resulting the objects on the other side cannot be seen clearly and appear blurry. The translucency of

EBN may be influenced by the variation in thickness and this enables numerous degrees of light absorption, reflection, refraction and transmission. This feature increased the complexity of impurities detection. Besides, uneven surface of EBN is then rising the difficulty of detection of impurities.

Most of the impurities inside EBN are opaque matter which absorb the light that shines on them but allow a little of the light to reflect back in certain colour. Light cannot shine through opaque matter and either reflected or absorbed by the object and converted into thermal energy. Therefore, detection of impurities that is opaque matter may be easy. However, not all the impurities in opaque properties are dark in colour, some of them may have similar colour properties with EBN. Hence, a proper lighting system must be carefully designed to provide a consistent scene reduce the appearance of variation.

The scene is usually captured more than one conditions due to one single image cannot represent the scene accurately. However, for human and machine processing, it is more appropriated if only a single image is used. Hence, it is important to fuse all the images from several conditions into a single composite image with all relevant data. The term of fusion refers to an occasion when two or more things are combined. Image fusion is the process that merge or combine multiple images to produce a more informative image. The goal of image fusion is to contrast new image by integrating complementary information from multimodality images so that it is more appropriate for the purpose of human visual perception and computer processing. A Venn diagram is used to show the graphical representation of the image fusion process [13].

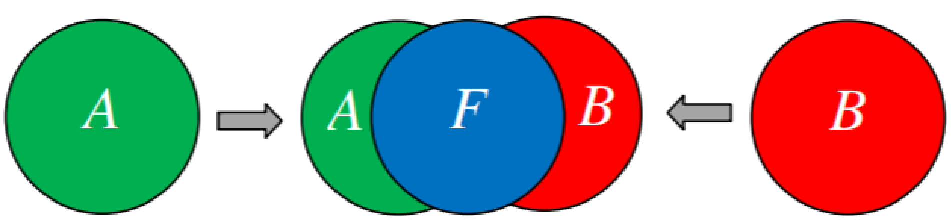


Figure 1: Graphical representation of the image information fusion process [13].

Various methods were proposed to perform the required fusion goal. Image fusion is practically discovered as a dominant assistant in a variety of critical applications such as remote sensing, satellite imaging and medical imaging. In this work, Brovey transform based image fusion is implemented to fuse different EBN images. A study is proposed to examine the application of image fusion method in order to improve the segmentation and detection of impurity features presented in EBN. A more and accurate information is aimed to be obtained by using this method. The research can be sorted into four main stages which are image acquisition, image processing, image fusion, image segmentation and analysis. The results of segmentation and detection of impurity features between the fused image and the captured input images will be analysed at the end of the paper.

This paper is structured into five chapters which are introduction, literature review, methodology, results and discussion and finally conclusion. Chapter one consists of brief introduction of the work. Chapter two briefly summarizes some prior work in impurities detection of EBN, lighting configuration and image fusion technique. Chapter three presents the methodology of this work. Chapter four discuss the results and findings. Finally, chapter five describes the conclusion and several recommendations for future work.

1.2 Problem statement

Current conventional EBN cleaning method is still a manual and time consuming process. A 100% detection rate of impurity features is hardly to achieve through the human vision inspection technique. Previous researches have been applied the machine vision inspection technique to segment and detect the impurities inside EBN. However, the results are unsatisfied due to low impurities detection rate. Besides, the lighting parameters are not optimized in current researches during the image capturing process of EBN in which the researches only focused on application of red colour light source. Several types of light sources need to be investigated to find out the optimal light condition. Image fusion technique creates a new enhanced image that contains more information than each of the individual images. Hence, it can be one of the potential image processing method to highlight the impurity features in EBN by fusing various images captured under different conditions.

1.3 Objective

The objective of this study are:

1. To highlight the region of impurity features extracted from the captured images under different LED lighting.
2. To develop a segmentation algorithm based on image fusion.
3. To analyse the information extracted from the fused image for segmentation, detection and classification.

1.4 Scope of Work

In this work, the primary goal is to examine the segmentation of impurity features from EBN image with the support of image fusion technique. In order to achieve that, the interaction between various illumination colour and EBN will be studied to discover the best scene of segmentation. The EBN images captured under different colours of light sources will be gathered and fused using Brovey Transform based image fusion. The best scene will be figured out through the information segmented from the EBN images using algorithms developed.

CHAPTER 2 LITERATURE REVIEW

The growing population and the increased expectation of food products with high quality and safety standards lead to a need for the development of rapid and precise quality determination of agricultural products. Machine or computer vision is an economic, uniform and fast inspection technique which have been applied progressively in various areas in industry for inspection and evaluation purposes [14] as the techniques allow assessment in high speed, uniform, economic and hygiene [15]. These techniques are widely used in food and agricultural research [16] as the traditional inspection method is time-consuming, slow and laborious.

Application of machine inspection into EBN cleaning process can provide a high level of flexibility and repeatability at a relatively low cost and high accuracy. Subramaniama et al. [11] proposed an automated system in which the machine vision was integrated with a robotic arm to remove the impurity features more efficiently. However, this proposed system has limitation because it only able to capture and process data of two dimensional (2D) image. Besides, the specimen used must be as flat as possible with thickness of not more than 2mm. Therefore, larger impurities cannot be extracted due to the limitation of thickness.

Goh et al. [10] introduced a machine vision inspection system to detect the impurities in EBN by using unsupervised classification which was achieved with K-Means segmentation. However, this proposed system had incorrectly identified holes in the EBN as impurities and the false detection rate is up to 57%. Moreover, the impurities which lie below the EBN is hard to identify. Besides, Fuzzy C-Means segmentation was also investigated in this proposed system. This classifier achieved almost same accuracy as K-Means, but the false detection rate was higher which is 70%.

Although the previous works on EBN impurities detection are just in small amount, there were other works that studied at the detection of impurities, defects or small objects in agricultural industry such as processed food products [15], wheat grains detection [17] or biscuit [18].

The quality of the image captured is extremely determined by the hardware system which is lighting configuration. Contrast is one of the factor which contribute to overall image quality [17]. A good lighting configuration should maximize the feature contrast while minimize the contrast of the rest. High contrast features simplify the integration and improve the reliability which easier the segmentation process in image processing [19]. Software system is able to extract, highlight and manipulate information from an image captured by hardware system. It cannot add information effectively to a captured image if the hardware system is bad. Image with poor contrast and uneven illumination require more effort from the software system and increase processing size.

Adelkahni et al. [20] designed a image acquisition chamber along with several light source, intensity and adjustable camera parameters to find the best combination for image processing algorithm. Three light sources which are LED, fluorescent and tungsten with three different intensities were investigated in this work. The designed system shown the best lighting conditions were obtained from LED lamp with a black background as it shown the least error frequency of imaging.

Gwee et al. [21] proposed a lighting solution which optimize several lighting parameters to improve the visibility of impurities in EBN. The lighting parameters which are type of lighting configuration, the angle of lighting for both front lighting and back lighting, the wavelength of light and the light intensity were considered in this work. The visibility of impurities in EBN images relies upon the contrast ratio between two features. This proposed work reported that the contrast ratio of the proposed lighting setup was improved by 36.2% compare to the normal fluorescent lighting setup.

A practical method for generating a high contrast image is to illuminate the object with particular wavelength of light. Each wavelength is a particular colour, thus it can turn feature with colour appear either bright or dark to the monochrome camera. A proper wavelength of light can be selected by referring to the colour wheel. A same colour light is to make the features bright and an opposing colour is to make the features dark. The designed lighting configuration needs to be able in producing high quality image that can extract the significant information from the image, thus it can ease and improve the accuracy of image processing process.

A good lighting system can increase the accuracy and reduce the complexity of image processing. Image fusion is one of the practical application in image processing techniques. Some of the main applications of image fusion include civilian, military, medical imaging, remote sensing and computer vision and robotics [22]. Image fusion is commonly used to improve interpretability of the images, increase spatial resolution, enhance the certain features that are not visible in either of the single data alone, improve classification accuracy by complement data sets and substitute missing information [23].

Image fusion can be performed at three different levels: Pixel-level image fusion, feature-level image fusion and decision-level fusion [23]. In pixel-level fusion, it is usually performed on the pixels of the source image. In feature level fusion, various features are extracted from different data sources of the same geographic area and combined for further processing. In decision level fusion, input images are processed one by one. The obtained data is refined and then combined to create a final fused decision. Certain decision rules are used to determine the differences in information. A visual interpretation of the concept of different processing levels of image fusion is shown in Figure 2.

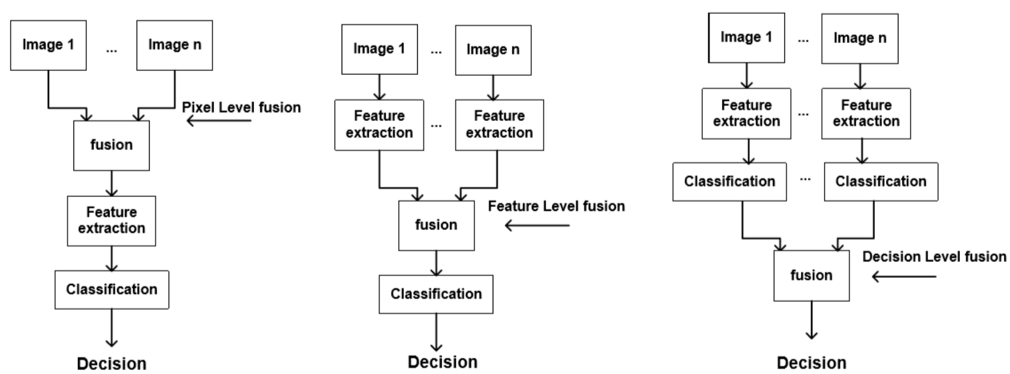


Figure 2: Image fusion levels [24].

Various approaches to image fusion can be Image fusion can notable, depending on the sequences of the fuse process. Image fusion algorithms are broadly classified into three group: spatial domain fusion, transform domain fusion and statistical domain fusion. Spatial domain technique directly deals with the pixel value of an image to achieve the desired results. Transform domain technique first transferred the pixel value into frequency domain by applying Fourier transform and the resultant image is obtained by applying inverse Fourier transform. Statistical domain fusion is used to solve colour distortion and dataset dependency that are caused in image fusion.

Since image segmentation is the process that dealing with pixel value in an image, spatial domain with pixel-level fusion is focused in this work. Spatial domain fusion can use to enrich the information content associated with each pixel in image created through integration of several images [25]. Hence, a better segmentation can be performed and more perceptive features can be extracted for further processing. The fusion methods such as Averaging, select Maximum or Minimum, Intensity-Hue-Saturation (HIS) transform, Brovey transform (BT) and Principal Component Analysis (PCA) based methods are fall under spatial domain approaches [26].

IHS is based on the transformation of RGB multispectral channels into IHS components by replacing the intensity components using panchromatic (PAN) image. The inverse transformation is then performed to obtain a high resolution multispectral (MS) image [27]. This method can improve the spatial details and the textural characteristics of the fused image, but a serious spectral distortion also occurs on the fused image [28]. Besides, IHS cannot be used to enhance certain image characteristics because the method cannot break up an image into different frequencies in frequency space [29]. The IHS is used for geologic mapping because the IHS transform could allow diverse forms of spectral and spatial landscape information to be combined into a single data set for analysis [30].

The BT is based on the chromaticity transform that uses ratios to sharpen the MS image [23]. In this method, MS bands is normalized and each band of the fused MS band is obtained by multiplying the normalized MS bands with the PAN image divided the sum of normalized MS bands [31]. This method is simple to use for merging the data from different sources but is limited to only involved three bands. An experienced analyst is required for clearly defined the parameters used to ensure a successful implementation of this method [32]. BT preserves the spatial information of PAN image well but the distortion of the spectral information is not acceptable.

PCA is based on the transformation of correlated data set to uncorrelated data set called principal components. The first principal component that contains high variance is replaced with PAN image. The inverse PCA is then performed to obtain a high resolution MS image [33]. The advantage of PCA over IHS is that arbitrary number of bands can be used. This method is aimed to reduce the dimensionality of input data set while maintaining the relevant information as much as possible. The loss of the image data can be decreased by using this method [23]. PCA produces the fused image with high spatial quality but spectral degradation is happened in fused image.

Among such methods, BT is chosen to apply in this study. It is a simple and fast method to merge the data from different sensors. BT provides superior visual and high resolution multispectral image and it is very useful for visual interpretation. Zhang et al. [34] studied the effects of BT on the information capacity of panchromatic and multispectral images. Their work reported that images merged by BT showed higher spatial resolution and better spectral features than the original. Hence, a further research about the application of Brovey transform based image fusion on EBN images may significantly increase the visual interpretation of impurities and ease the segmentation process.

CHAPTER 3 METHODOLOGY

3.1 Overview

In this chapter, the methodologies used to complete this work are presented. Stage one of the study involves the experiment setup during image acquisition. Stage two involves the image pre-processing and image fusion of the captured images by using MATLAB algorithms. Stage three involves the segmentation and detection of impurity features from the EBN as well as performance analysis of the proposed algorithms. The procedures were described and illustrated clearly in each subsection. Figure 3 shows the overview of operating procedure for the proposed system.

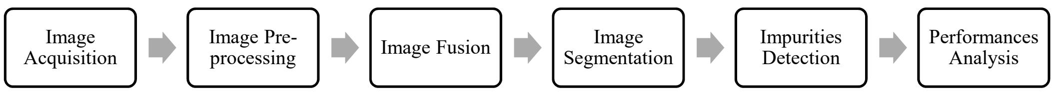


Figure 3: System overview.

3.2 Material Preparation

The specimen used for this project is Edible Bird Nest (EBN). The raw EBN samples were first soaked in water to absorb the water until it has expanded. Subsequently, the strands were being arranged into desired shape using tweezer. 7 set of samples with different shape are being prepared. The air-dried EBN samples were kept in air tight container for analysis hereafter. Figure 4 shows one of the EBN test samples.

Figure 4: EBN test sample.

3.3 Experiment Setup

The system is equipped with an industrial camera with lens, EBN specimen and a multi-spectrum system provided by TMS Lite Sdn Bhd. A Crevis MV-MQ60G camera is used. The lens used is Fujinon HF9HA-1B 9mm fixed local lens with C-Mount and locking iris. The lighting system used provide nine colours of lighting respectively. An Acrylic plastic background is chosen to optimize visibility between impurity features and EBN. Figure 5 shows the setup for illumination configuration.

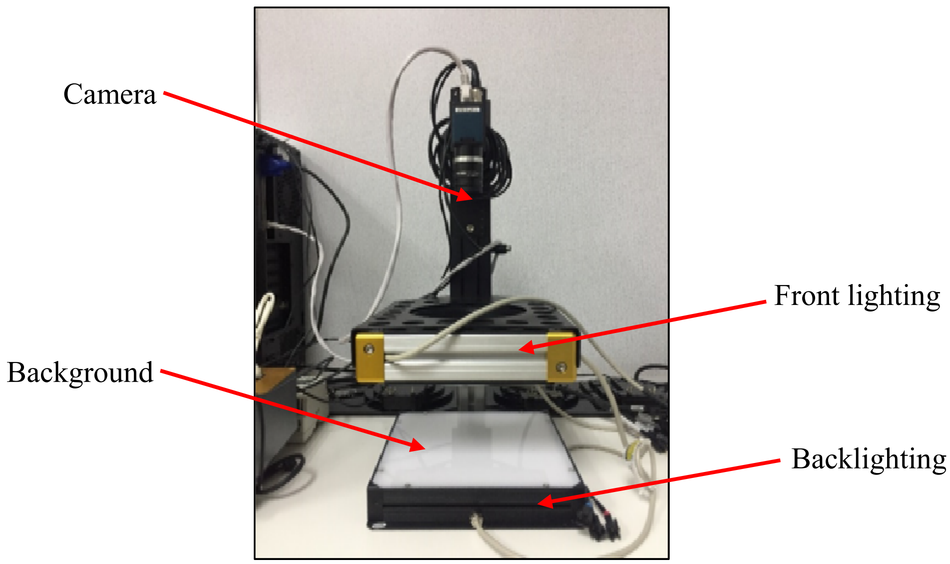


Figure 5: Illumination setup configuration for image acquisition.

3.4 Image Acquisition

To carry out this project, few samples of EBN were prepared and placed under the light source. The experiment was carried out in a dark room to eliminate the effect of ambient lighting. The image of EBN samples were captured using a digital camera equipped with a same sensor. The height between camera and sample was fixed. The camera was mounted on top of the sample at a fixed height of 160 mm. The camera was connected to a computer device. The captured images were stored in the computer using GigE interface for further image processing. The image was stored in BMP image format because this format reflects the original image of EBN accurately.

Illumination configuration will affect the overall accuracy of the system and also the quality of the image obtained. The interactions of light depend on the nature of the material and the wavelength of the light. Appropriate selection of light source can reduce the effect of noise, reflection, shadow and help to highlight the specific features in an image. Therefore, the illumination configuration and colour have to be considered when set up the illumination configuration. There are two illumination parameters being considered which are the type of illumination configuration and wavelength or colour of lighting. The variables of each parameter have been summarized in Table 1.

Table 1: Variables of each illumination parameter.

Light wavelength for each direction	Type of illumination configuration	
	Front lighting	Front lighting with backlight
Front	Red, green, blue, ultraviolet (UV), infrared	Red, green, blue, ultraviolet (UV), infrared
Back	N/A	Red, green, blue

A shadow is produced when direct illumination is obstructed by an object. Shadow often degrades the visual quality of images and causes the misclassification of background and foreground objects. Hence, it is necessary to reduce the shadow formed during image capturing by using a suitable background platform. In this work, images were taken under two different backgrounds which are white colour paper and Acrylic plastic. The comparison in made in term of the shadow formed by both backgrounds.

3.5 Image Processing

The images captured were read in Matlab software for further processing. In image fusion technique, all the images must be spatially aligned and have the same dimension. Therefore, image registration and image resampling were applied to ensure the position was same for all the images and to obtain the required image size. Figure 6 shows the basic steps involved in image fusion.

Figure 6: Pre-processing of image fusion

3.5.1 Image Registration

Image registration is the process of mapping the input images with the help of reference image or fixed image. The goal of such mapping is to transform the corresponding images into the same coordinate system to assist the image fusion process. Besides, it can be seen as a strategy of finding the distortion between two images. In this work, image registration is used to ensure all the images which are taken under different colour of light are at the same coordinate system. Two target images are used to test the efficiency of the proposed algorithms. The approach of intensity-based registration was applied. This process involves designing one image as the reference image and estimating and applying geometric transformations to the target images so that they align with the reference. The performance of the registered images should be verified and analysed quantitatively. In order to access the position of registered image is fixed or un-fixed, the "minus" algorithm is applied on the registered and target image, foreground area is used as the objective indicator. The foreground area of "minus" images are computed automatically by using algorithms. If the foreground area is equal to zero, the target image is at the same position with reference image or else the target image is at the different position with reference image. Figure 7 shows the flow chart of the proposed algorithms for image registration.

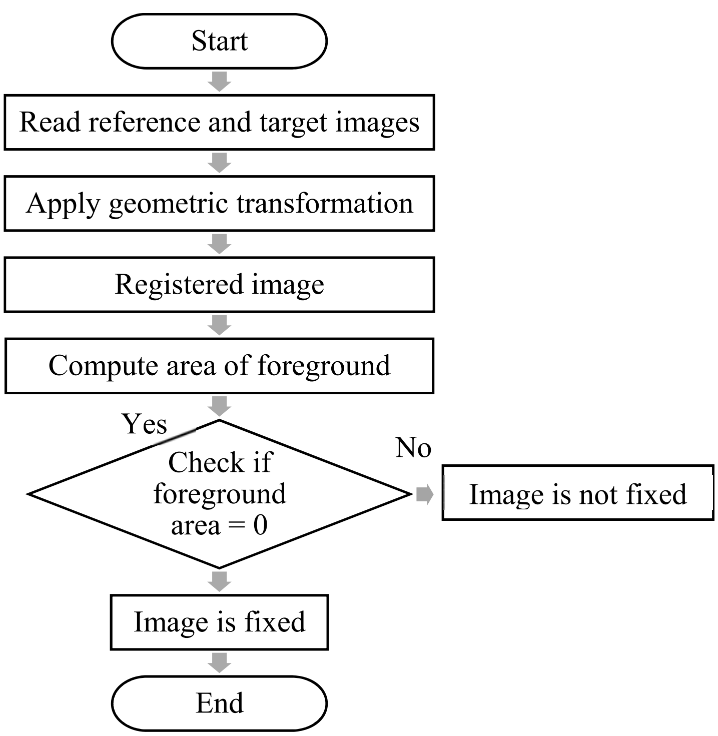
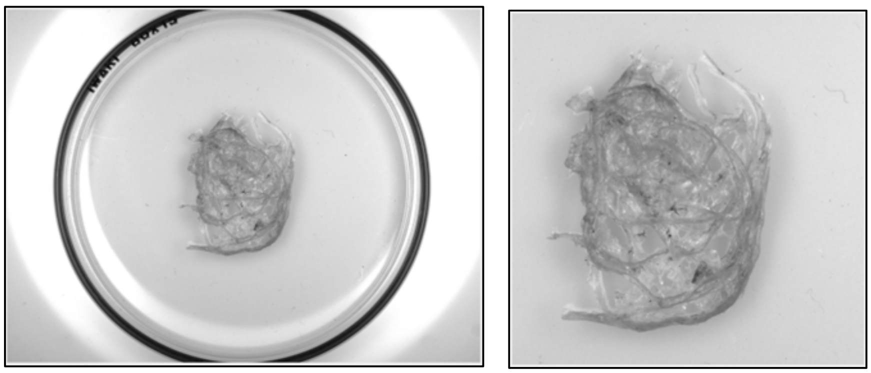


Figure 7: Flow chart of image registration.

3.5.2 Image Resampling

Image resampling is the process of changing the pixel dimension of an image with a different height and width. Extra or unrelated regions in the image should be removed in order to ease the image fusion process. In this work, image resampling is used to ensure all the images have the same dimensions. Down-sampling was applied to reduce the size of the images to a desired dimension. Figure 8 illustrates the results of down-sampling.



(a) *(b)*

Figure 8: (a) Original image and (b) Image after resized by using down-sampling.

3.5.3 Image Fusion

a. Morphological Operation

Erosion morphological operation is applied to the images before implementing fusion process. It makes the objects in bright regions smaller whereas dark regions get bigger. The EBN features and background is reviewed as bright regions while impurities in dark colour will consider as dark regions. This process used to increase the visibility of impurity features in the image by enlarging the pixel areas of related regions.

b. Brovey Transform (BT)

Brovey trasfrorm (BT) method is proposed to fuse the image in this work. The fused RGB image from BT can be described in the equation below.

$$R_{new} = \frac{R}{(R + G + B)} \times PAN$$

$$G_{new} = \frac{G}{(R+G+B)} \times PAN$$

$$B_{new} = \frac{B}{(R+G+B)} \times PAN$$

In this stage, there are two input parameters being considered which are the panchromatic (PAN) image and multispectral (MS) image. There are five variables for each parameter which are red light image (RL), green light image (GL), blue light image (BL), ultraviolet light image (UL) and infrared light image (IL).

In order to ease the comparison process, the selection of suitable MS images will be conducted based on the enhancement rate in the fused image. Enhancement rate in this study is visually accessed. It is defined as the amount of regions which the intensity level has been changed to zero in an image. Different input of MS image will lead to different enhancement rate of the image formed. The flowchart of proposed works for image fusion is given in Figure 9. Once the fusion process has been completed, segmentation algorithms can be applied.

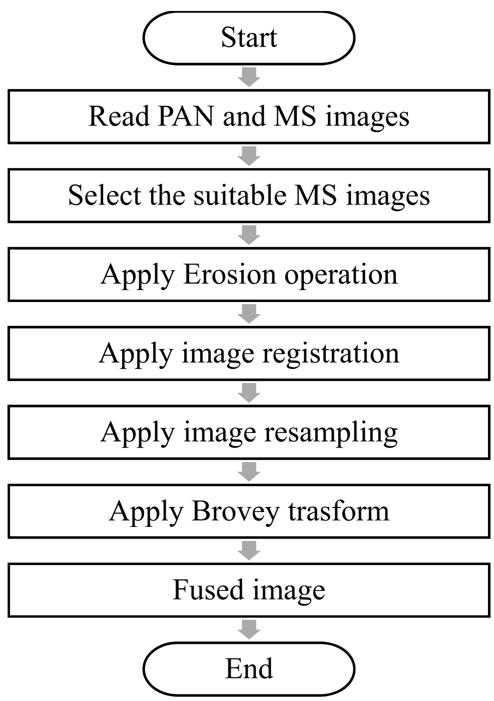


Figure 9: Flow chart of image fusion.

3.6 Image Segmentation, Detection and Analysis

Segmentation algorithms are developed to distinguish the impurity features and EBN. The parameters used to measure the performance of the proposed algorithms are segmentation rate (SR), confusion matrix and dice similarity index (DSI).

3.6.1 Thresholding

In this work, thresholding method was used to segment the impurity features from EBN. The segmentation is computed by comparing the intensity level with threshold value as:

$$\mathrm{S(x, y)} = \begin{cases} 1, t = 0(x, y) \\ 0, otherwise \end{cases}$$

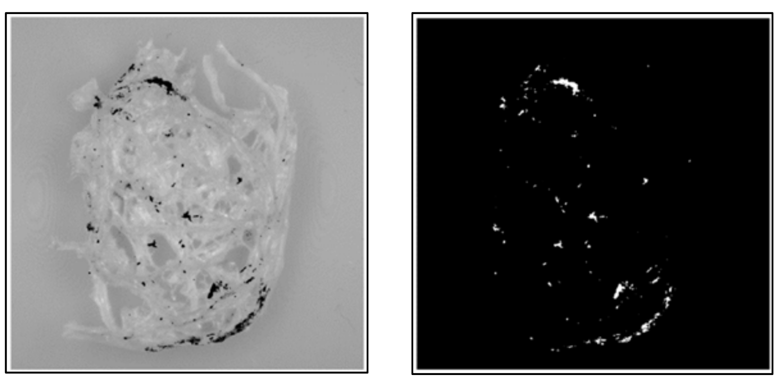
where

S = output binary image

x, y = pixel coordinates in I and S

t = static threshold of the intensity value

Thresholding divides the intensity level into two portions which are foreground and background. The pixels with intensity of equal to the threshold value is foreground. The pixels with intensity of not equal to the threshold is background. In this work, the EBN feature was categorized as background while the impurity feature was categorized as the foreground). Figure 10 shows the segmentation results by using the proposed thresholding method.



(a) *(b)*

Figure 10: (a) original image and (b) extracted impurities from the image by using thresholding segmentation.

After the segmentation process, the image was readied for impurities detection. The performances of the segmentation process were evaluated quantitatively.

3.6.2 Quantitative Analysis

In this work, the impurities observed from the fused image was evaluated and compared with the ground truth image. The ground truth is often generated manually by experts in the corresponding field and reflects the optimum results of segmentation. However, the experts sometimes are not available for algorithms testing. Hence, the ground truth image database is presented for the convenience. The impurity features on the EBN were inspected manually and marked which then serves as the ground truth of this work. Figure 11 shows the ground truth image of one of the EBN samples.

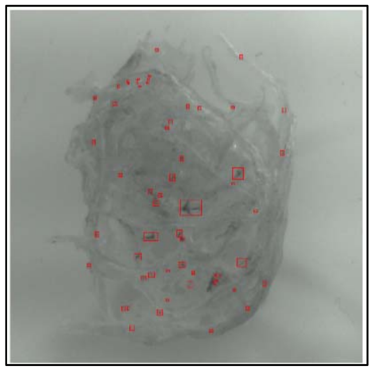


Figure 11: Ground truth image.

a. Segmentation Rate (SR)

The segmentation rate (SR) in this work defines how often the segmented area by proposed algorithms is impurities, not background or EBN features. It is expressed as:

$$SR = \frac{Pixel\ area\ of\ impurities}{Pixel\ area\ of\ segmented\ region} \times 100\%$$

b. Confusion Matrix

The confusion matrix is used to describe the performance of classification model on a set of data for which the trues values are known. The measurements that are often computed from a confusion matrix are precision, accuracy and error rate. Precision defines how often the true detection of impurities by proposed algorithm and is expressed as:

$$Precision = \frac{True\ Positive}{Predicted\ Yes} \times 100\%$$

Accuracy defines how often the classifier is correct in overall and is expressed as:

$$Accuracy = \frac{True\ Positive + True\ Negative}{Total} \times 100\%$$

Error rate defines how often the classifier is wrong in overall as is expressed as:

$$Error\ Rate = \frac{False\ Positive + False\ Negative}{Total} \times 100\%$$

where True positive indicates the impurities which are detected from proposed algorithms is in ground truth. True Negative indicates the impurities which are undetected from proposed algorithms is not in ground truth. False positive indicates the impurities which are detected from algorithms is actually not in ground truth. False negative indicates the impurities which are undetected from algorithms is actually in ground truth.

c. Dice Similarity Index (DSI)

The Dice similarity index (DSI) quantifies the region overlap between the automatic and manual segmentation [35]. In this work, it is used to define the quantity of the region of impurity features overlap between the ground truth data and the segmentation algorithms. It is expressed as:

$$DSI = 2\frac{|A_A \cap A_G|}{|A_A| + |A_G|}$$

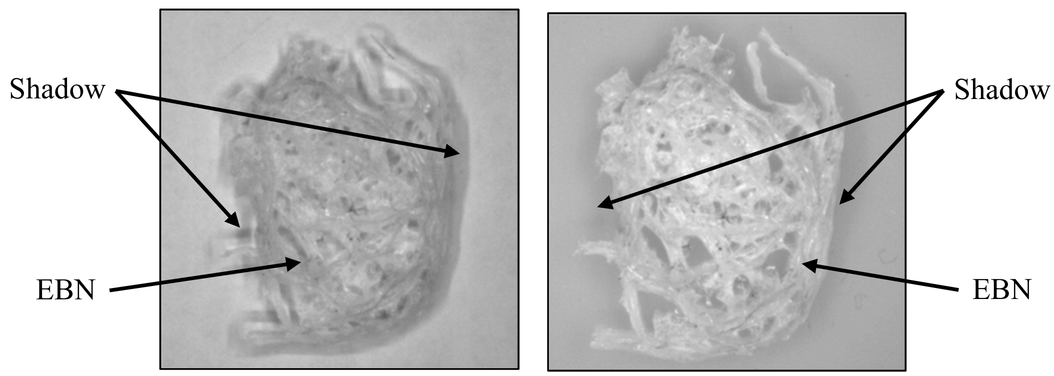
whereA_G indicates the region of ground truth of the impurities while A_A indicates the region of segmentation of the impurities by the proposed algorithms.

CHAPTER 4 RESULT AND DISCUSSION

4.1 Image Acquisition

4.1.1 Type of Background

Two type of backgrounds which are white colour paper and Acrylic plastic were considered during image acquisition. Figure 12 shows the images that captured under different types of background.



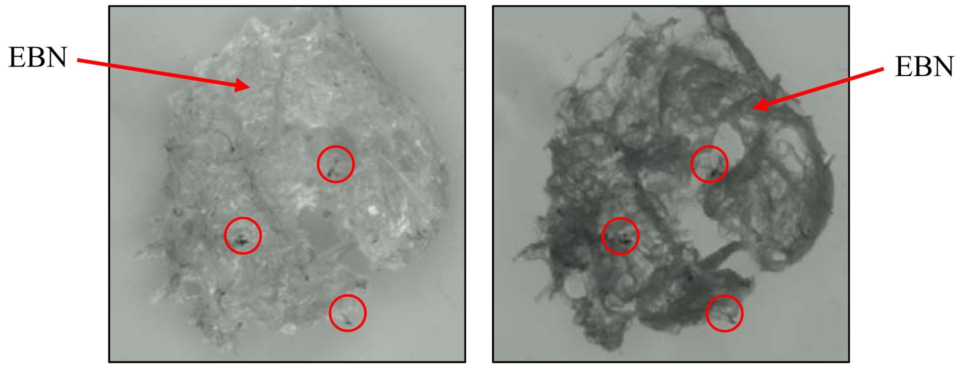
(a) *(b)*

Figure 12: Captured images under different type of background: (a) white colour paper and (b) Acrylic plastic.

From Figure 12, it is found that the shadow formed in Acrylic plastic background was lesser than white colour paper background. Shadow might cause the merging of objects in the image, leading to the occurrence of misclassification of background, EBN and impurity features. Selection of a better background with lesser shadow formed is a critical step to ease the image processing. Therefore, Acrylic plastic was chosen as the background for the image acquisition process in this work.

4.1.2 Type of Illumination Configuration

The illumination configuration used in this project are front lighting and front lighting with a back light. Figure 13 shows the images that were captured under different types of illumination.



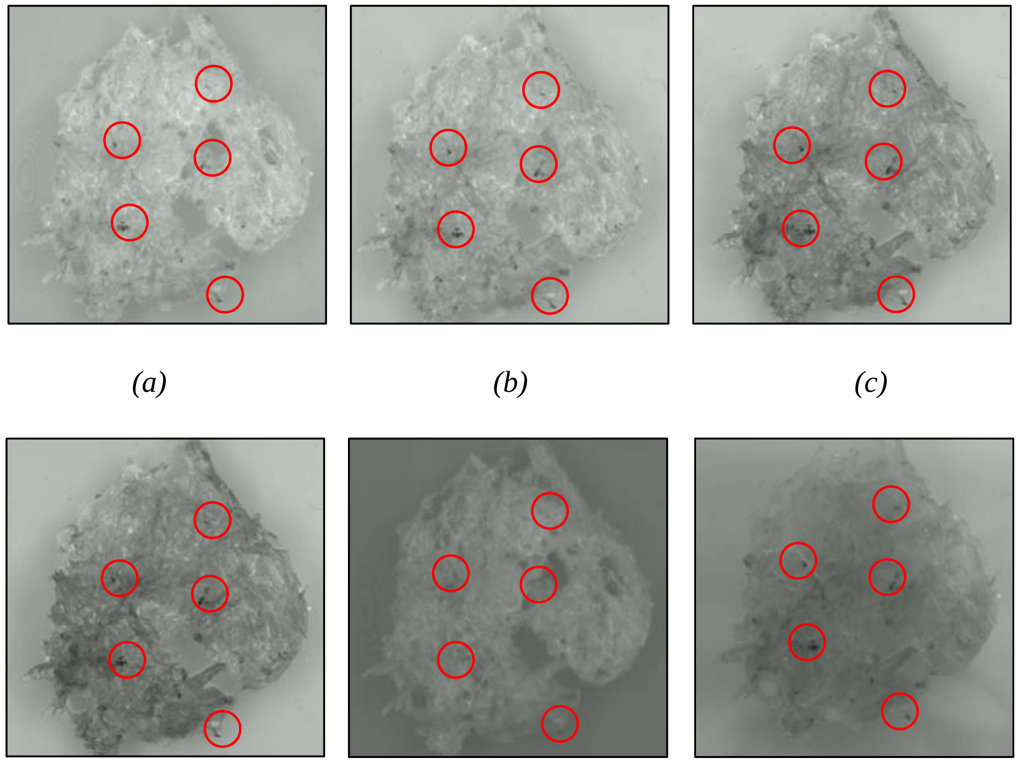
(a) *(b)*

Figure 13: Image captured under different types of illumination configuration: (a) front lighting, and (b) front lighting with backlighting. Red circles on the images indicate some location of the impurity features.

From Figure 13, it is found that the front lighting was able to highlight the impurity features as compared to front lighting with backlighting. EBN is a translucent object which is able to reflect, refract or transmit the light, whereas impurity is an opaque object which prevents the light from pass through. The translucency property of EBN creates a bright region while impurities create a dark region. The impurity features can be easily recognized with high contrast ratio. Therefore, impurity features can be easily recognized. Backlighting although able to deliver a particularly visible view of EBN strands, it yields a lower contrast between the EBN and the impurities. Since the contrast of image captured under front lighting configuration is better than front lighting with backlighting configuration, only the images that were captured under front lighting configuration will be used in this study.

4.1.3 Wavelength of Lighting

The wavelength or colour of lighting used in this project is are red, green, blue, ultraviolet (UV) and infrared (IR). Figure 14 shows the images that captured under different wavelength of lighting.



(a) *(b)* *(c)*

(d) *(e)* *(f)*

Figure 14: Image captured under different wavelengths of lighting: (a) red lighting, (b) green lighting, (c) blue lighting, (d) UV lighting, (e) IR lighting and (f) normal fluorescent lighting. Red circles on the images indicate some location of the impurity features.

From Figure 14, it is found that different wavelengths of lighting have different effects on the appearance of the EBN and impurity features. The red lighting, as shown in Figure 14 (a), brighten the EBN features and slightly darken the impurities. It presents the highest contrast ratio as compared to other colours of lighting. The green lighting, blue lighting and UV lighting, as shown in Figure 14 (b), (c) and (d) respectively, darken the impurities and some of the EBN features. It can be observed that the thicker the EBN strands, the darker the regions of the EBN in the image. Among the three colours of lighting mentioned above, green lighting shows the highest contrast ratio followed by blue lighting and UV lighting. The IR lighting, as shown in Figure 14 (e), brighten the EBN features but reduce the visibility of impurities. The colour of impurities is almost same with the colour of background.

4.2 Image Processing

4.2.1 Image Registration

The first step in image fusion is to register and resampling the input images. The results after the performing of image registration algorithms to two target images are shown in Figure 15.

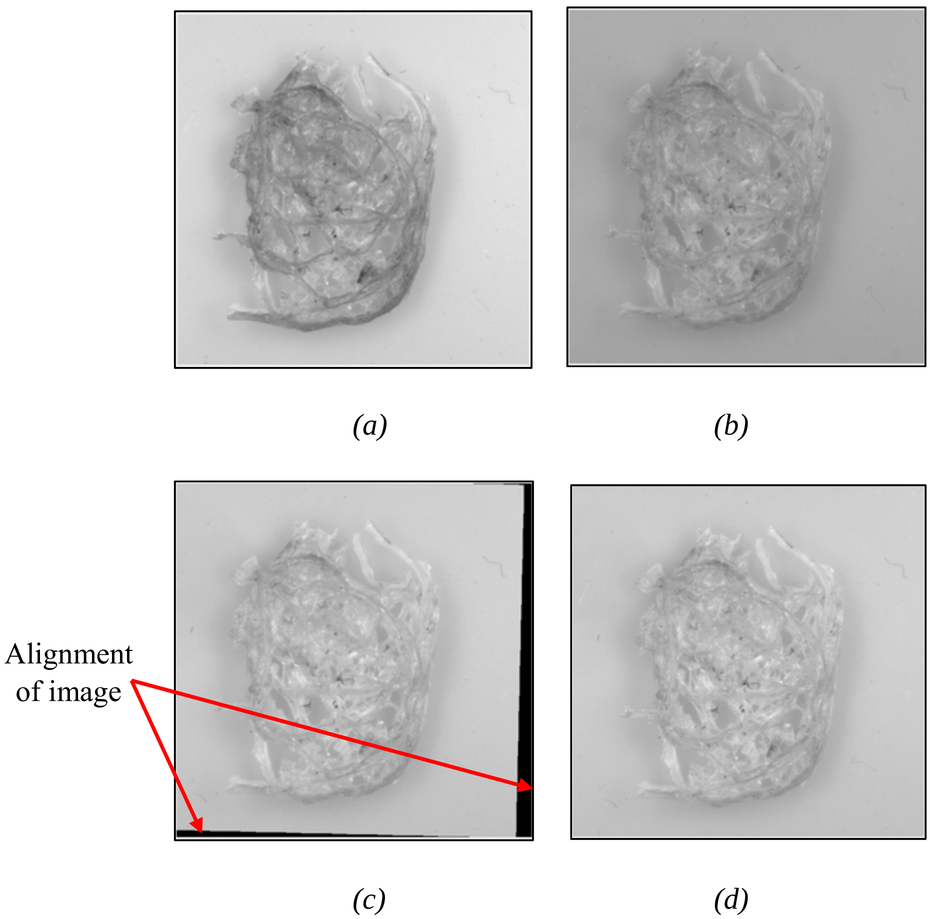
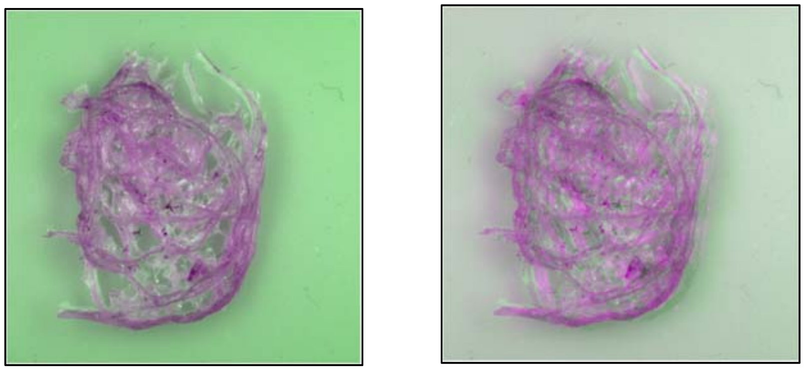


Figure 15: (a) reference image, (b) registered image for target image A, (c) registered image for target image B and (d) original image for target image B.

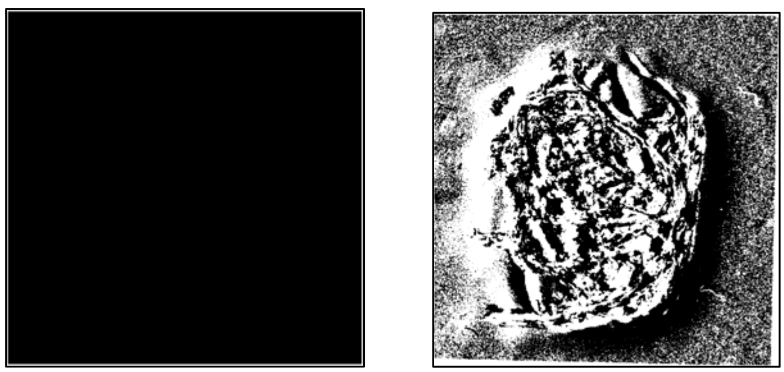
As observed in Figure 15, registered image of target image A does not shown any alignment whereas the alignment is occurred on the registered image of target image B. The object in target image B is aligned automatically to a desired position based on the reference image. The misaligned of the target images can be viewed by overlapping them with reference image, as shown in Figure 16.



(a) (b)

Figure 16: Misaligned images: (a) target image A and (b) target image B.

To verify that there is an alignment on the registered image, the “minus” algorithms is applied on the registered image and target image. The tested images after the performing of algorithms are represent in Figure 17.



(a) *(b)*

Figure 17: Tested images: (a) target image A and (b)target image B.

The foreground area is computed by using algorithms. It is found that the foreground area of target image A is equal to zero and not equal to zero for target image B. From the results, it can be proved that object in target image A is in the same position with reference image and but not for target image B. Although original position of object in target image B is different with reference image, but the registration algorithms can be performed to transform it to the same positon as reference image. Therefore, to make sure the position of EBN in all the input images is same for the image fusion, image registration must be applied before the image fusion process.