Analysis of Colour Constancy Algorithms for Improving Segmentation of Malaria Images

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***Abstract*—Malaria is a very serious disease that caused by the transmitted of parasites through the bites of infected Anopheles mosquito. Malaria death cases can be reduced and prevented through early diagnosis and prompt treatment. Currently, microscopy-based diagnosis remains the most widely used approach for malaria diagnosis. The appearance of the infected red blood cells (RBCs) and their morphological features are very important for recognising the presence of malaria parasites. However, it is difficult to identify the presence of malaria parasites as well as observing its morphological characteristics due to the non-standard preparation of the blood slides; producing colour varieties in different slides. Thus, this study aims to apply colour constancy algorithms for standardisation of blood images in order to enhance segmentation of malaria parasites. In this paper, four different colour constancy algorithms namely Gray-World, white patch, modified white patch and progressive algorithms have been analysed to identify colour constancy algorithm that can give the significant segmentation performance. The experimental results show that segmentation on Gray-World images has successfully segmented 100 malaria images with average segmentation accuracy, sensitivity and specificity of 99.60%, 91.26% and 99.85%, respectively.**

***Index Terms*—Colour Constancy; Colour Standardization; Image Segmentation; Malaria.**

I. INTRODUCTION

Mosquitoes are known as most deadly insect worldwide because it carries infectious diseases from different species of microorganisms such as parasites. According to the World Health Organization (WHO), there are about 1 million people deaths because of the disease due to the mosquitoes every year [1]. Mostly, the death is due to malaria disease. In 2015, it was estimated that out of 214 million cases of malaria globally, 90% of the victims were discovered to be from African Region amassing a total of 438,000 death cases [2]. Nevertheless, malaria remains a major epidemic among children in sub-Saharan Africa as it is responsible for exterminating a child in every 2 minutes [2].

In general, there are five different species of malaria held accountable for human infection. However, Plasmodium Falciparum and Plasmodium Vivax species yield the most malaria infections worldwide. Each of the species undergoes specific life-cycle comprising of the ring (young trophozoite), mature trophozoite, schizont and gametocyte [3]. In the conventional malaria diagnosis, the early detection of the malaria parasite in the examined blood slide is important, while the recognition of species is a requisite to provide the necessary treatment. Despite the countless modernised cutting-edge techniques in malaria diagnosis, the typical manual microscopy examination of blood slide remains the gold standard for laboratory confirmation of malaria [4].

Malaria diagnosis begins by observing the presence of the parasites through their distinctive physical features alongside the appearance of the red blood cells (RBCs) that were infected. Colour plays a major role in the diagnosis of malaria infection. Identification of parasites is expedited by applying some colours as clues to microbiologists signalling the presence of parasites. Blood samples are prepared using Giemsa stain procedure to highlight the malaria parasites. However, it does not only highlight the malaria parasites, but it also includes other components inside the blood sample such as white blood cells (WBCs), platelets, artefacts and defects; obscuring the malaria parasites.

As a result, various applications of image processing techniques for segmentation of malaria parasites have been reported to necessitate the malaria diagnosis process. For instance, Panchbhai and Damahe [5] used a combination of Otsu's thresholding and RGB (red, green, blue) colour model to segment the malaria parasite. The aim of using the Otsu's thresholding is to find the threshold value where the sum of foreground and background spreads is at its minimum. The results indicate that the selection of green layer has given better segmentation result compare to the other layers.

A number of researchers have applied combined approaches of Otsu's thresholding and watershed segmentation for improving the segmentation results [6, 7]. Here, the normal and infected RBCs were segmented using Otsu's thresholding. Then, the watershed segmentation was performed on these segmented RBCs to separate the touching RBCs. Arco *et al.* [8] proposed an adaptive threshold technique for segmentation of blood cells and malaria parasite by selection of local features which significantly improved the accuracy of the algorithm as compared to other approaches.

Mandal *et al.* [9] performed segmentation of RBCs that were infected with malaria parasites by using an optimised normalised cut (NCut) algorithm. With this method, the results exhibited that the performance of the NCut was best in HSV colour model. However, the results show that the artefacts still appear on the segmented image. As this algorithm is based on global criteria, any unwanted noises can significantly reduce the segmentation accuracy. Somasekar and Reddy [10] utilised fuzzy c-means clustering to extract the infected RBCs. Abdul-Nasir *et al.* [11] proposed cascaded moving k-means (MKM) and fuzzy c-means (FCM) clustering algorithms for segmentation of malaria parasites. With this algorithm, the results exhibited that it can segment the infected cell areas from its blood cells background, especially in the case of overlapping RBCs.

Visual quality is extremely important for processing the malaria image. However, due to the unstandardized slide preparation technique, different slides tend to have variation in parasites and normal RBCs regions colours. The colour inconsistency is caused by the variation of the pH of the buffer used. Even though the visual quality of malaria image is extremely important, the majority of existing methods for processing the malaria image did not consider the quality of the captured malaria images. To the author's best knowledge, only a few have addressed this issue [10, 12, 13]. Tek [12] is widely credited for his proposal on colour normalisation which was tested on malaria images of a thin blood smear. The proposed method standardised the colour constancy of the images that have been captured from a variety of sources. The proposed method was reliably tested on various image samples and probably successful.

As colour played a major role in malaria diagnosis and based on the previous arguments, the current study will utilise the potential of various colour constancy algorithms for standardisation of colour in malaria images. Also, this study will also utilise the potential of image segmentation on these various colour constancy images to obtain the fully segmented malaria parasites.

II. Methodology

In this study, the proposed works compose of two main steps. These include image acquisition and image processing techniques. A summary of the procedures for segmentation of malaria parasite is illustrated in Figure 1.

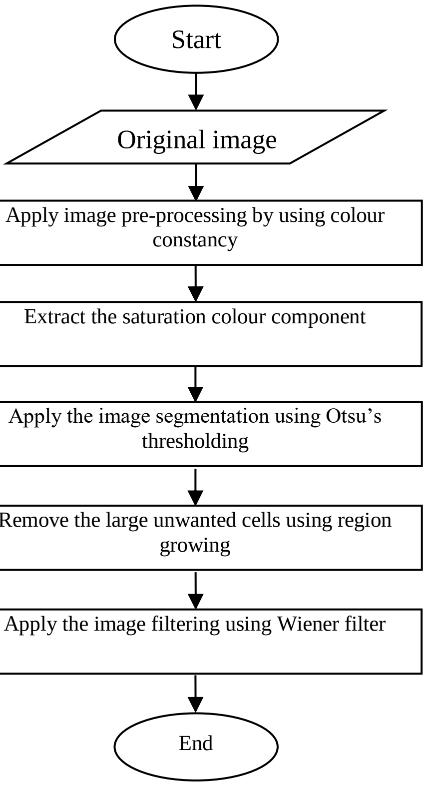
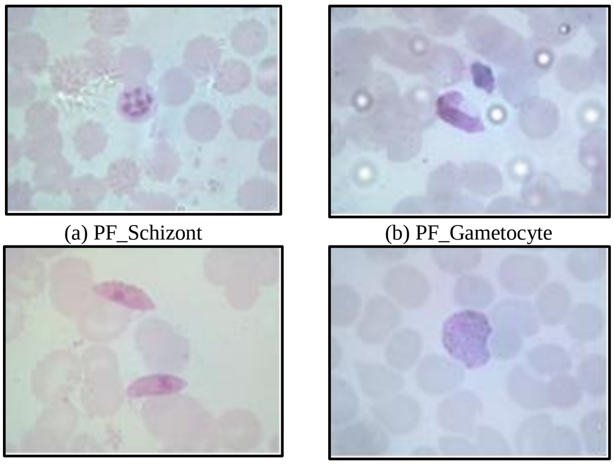


Figure 1: The procedures for segmentation of malaria parasite segmentation

A. Image Acquisition

The malaria thin blood smear samples were obtained from Department of Microbiology and Parasitology, Hospital Universiti Sains Malaysia (HUSM), Malaysia. The malaria slide was observed under 100X magnifications objectives of oil immersion lens. Then, a mounted Luminera Infinity-2 digital camera was used to capture the image. In this study, only three types of malaria samples will be considered to be analysed. These three types of malaria samples are PF_Schizont, PF_Gametocyte and PV_Gametocyte and the samples images are shown in Figure 2. Based on these malaria images, it can be seen that the colour of the parasites and normal RBCs regions varies in each slide due to the non-standard preparation of the blood slides.



(a) PF_Schizont (b) PF_Gametocyte
(c) PF_Gametocyte (d) PV_Gametocyte

Figure 2: Colour inconsistency of malaria images

B. Colour Constancy Algorithms

For microbiologists, the qualities and contrast of the malaria images are the main keys that could affect the accuracy of the interpretation. However, the captured microscopic images of malaria may suffer from some weaknesses. By referring to the malaria images as shown in Figure 2, can be seen that the colour of the parasites and normal RBCs regions varies in each slide due to the non-standard preparation of the blood slides. Therefore, it is necessary to apply colour constancy to malaria image before further processing or analysis can be conducted. Colour constancy is the ability to recognise the colour of objects independent of the colour of the light source. Colour constancy aims to observe consistent colour in objects, even though the lighting and wavelengths are a shift. This phenomenon demonstrates that our brains construct or experience the colour of an object through comparisons with other surrounding objects.

In this study, the colour constancy algorithm is applied to malaria images for the two main purposes. Firstly is to improve the visual quality of malaria image by standardising its colour. Secondly is to enhance the area of interest in malaria image for easing the segmentation process. As visual quality is extremely important for processing the malaria image, this study investigates the implementation of different colour constancy algorithms which are Gray-World, white patch, modified white patch and progressive.

C. Gray-World Algorithm

The Gray-World algorithm is one of the most popular and the simplest colour constancy algorithm [14]. This algorithm is based on the Gray-World assumption where the average reflectance of surfaces and the average of reflectance are achromatic under a white light source. To standardise the image i, the pixel value is scaled by:

$$Si = \frac{avg}{avg_i} \tag{1}$$

where is referring to the illumination estimate while avg_i is the channel mean. Normalizing is another method of normalization for the maximum channel by scaling by Si .

$$r_i = \frac{\max(avg_R avg_G avg_B)}{avg_i} \tag{2}$$

This means that the bulk of the image colours of an image under a white light source are aligned with the intensity axis, and the bulk of the image colours of an image under arbitrary light source are aligned with the colour of the light source.

D. White Patch Algorithm

The white patch algorithm [15] is based on the white patch assumption where it assumes that response in the RGB-channels is caused by a white patch. The maximum intensity in each channel is given by:

$$I_{imax} = \max\{f_i(x, y)\} \tag{3}$$

where fi(x,y) is the pixel intensity at position (x,y) in an image, as Ii is the illuminant in the section. All the pixel intensities are scaled according to the illuminant as computed by:

$$O_i(x, y) = \frac{f_i(x, y)}{I_{imax}} \tag{4}$$

In practice, this assumption is alleviated by considering the colour channels separately, resulting in the max-RGB algorithm.

E. Modified White Patch Algorithm

The modified white patch algorithm is the improvement of the white patch algorithm using image pixel sampling [16]. The modified white patch method consists in considering the mean of the highlights instead of the maximal values of the three channels of the image. This method is more robust to noise and clipping and gives a better estimation of the cast in highlights.

F. Progressive Algorithm

This algorithm reduces noise by deterministic annealing. Generally, this technique will produce almost the similar colour as the original image.

G. Segmentation of Malaria Parasites using Otsu's Thresholding

After the colour of malaria image has been standardised, the saturation component information of HSV (hue, saturation, value) colour model is extracted from these resultant images. According to Ruberto *et al.* [17], it is found that the appearance of the malaria parasite is mostly highlighted in S component image as compared to the H and V components images. Therefore, the S component image is segmented by using the Otsu's thresholding. Otsu's thresholding is one of the unsupervised image segmentation techniques that are mostly used by researchers to segment the malaria image. By using this technique, image histogram is analysed to obtain a threshold that maximises the separability between the foreground and background regions. The threshold is calculated by using total mean and variance.

H. Removing the Large Unwanted Cells and Image Smoothing

As segmentation based on Otsu's thresholding is solely relying on saturation information of the image pixels, a few large unwanted cells that share the similar colour properties with the malaria parasite are still contained inside the segmented image. Thus, region growing is applied to remove the unwanted cells with an area less than 3000 pixels from the image. Finally, Wiener filter is used to fill the holes as well as to smoothen the area of the segmented malaria parasite. This filter reduces the amount of noise in an image by comparing with an estimation of the desired noiseless image.

III. Result and Discussions

In this study, comparisons of Gray-World, white patch, modified white patch and progressive algorithms have been made to measure the colour standardisation performance on image segmentation. The primary criterion to assess the performance of colour constancy is based on its ability to produce fully segmented malaria parasite region as well as segmenting the malaria parasite from its blood cells background. Four original malaria images named as PF_Schizont, PF_Gametocyte_1, PF_Gametocyte_2 and PV_Gametocyte images are shown in Figures 3(a), (b), (c) and (d), respectively.

The results of images after applying the four colour constancy algorithms are shown in Figures 3(e)-(t). By applying the colour constancy, the colour of malaria images has been standardised, and the quality of the images has been improved. By comparing the results among these four algorithms, it can be seen that the colour of Gray-World and white patch images have been normalised to suit the human visual, while the contrast of modified white patch images have been enhanced. As for progressive algorithm, the resulting colour images are almost similar to the original colour image. Hence, nothing can be compared for this algorithm.

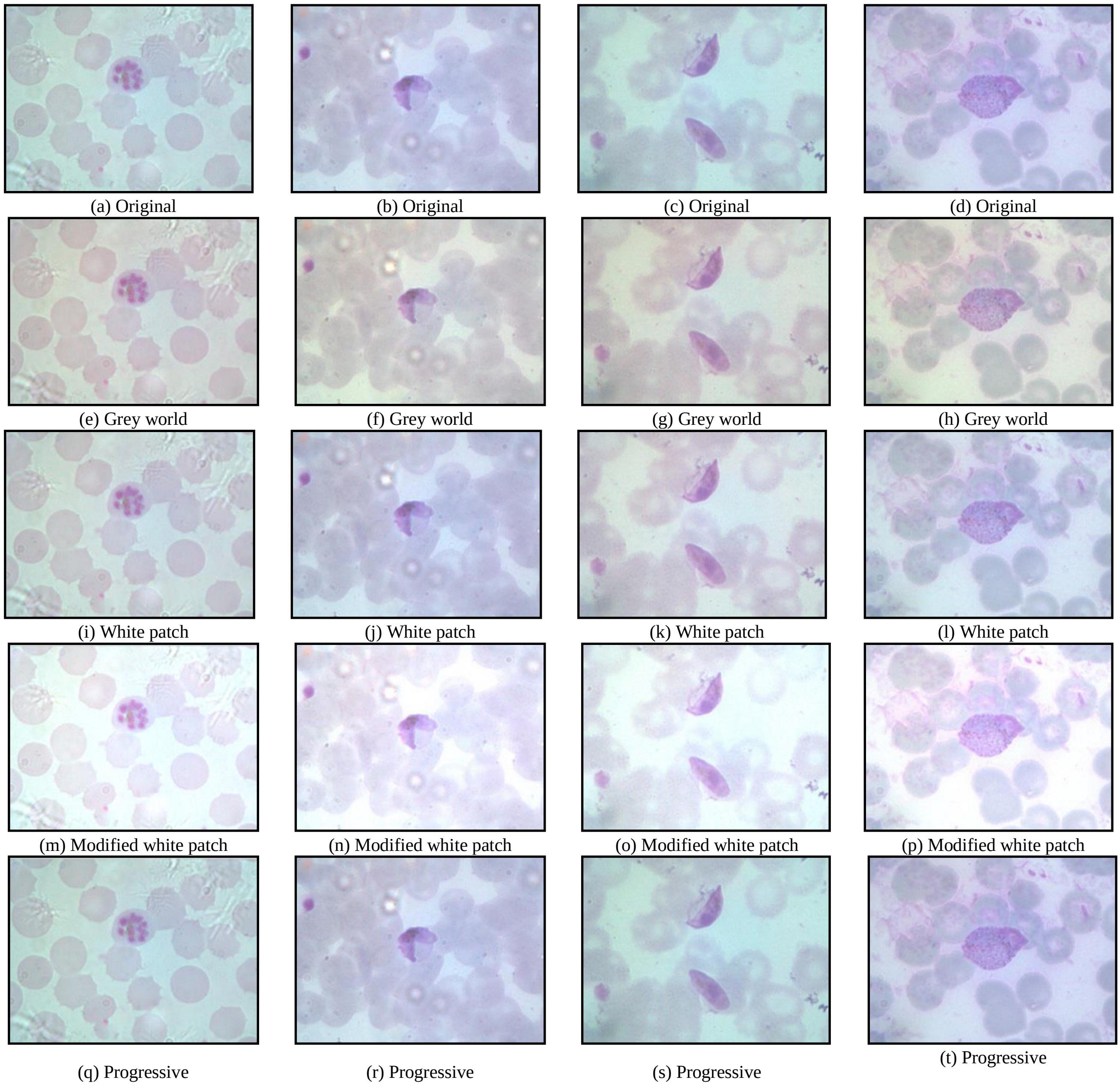
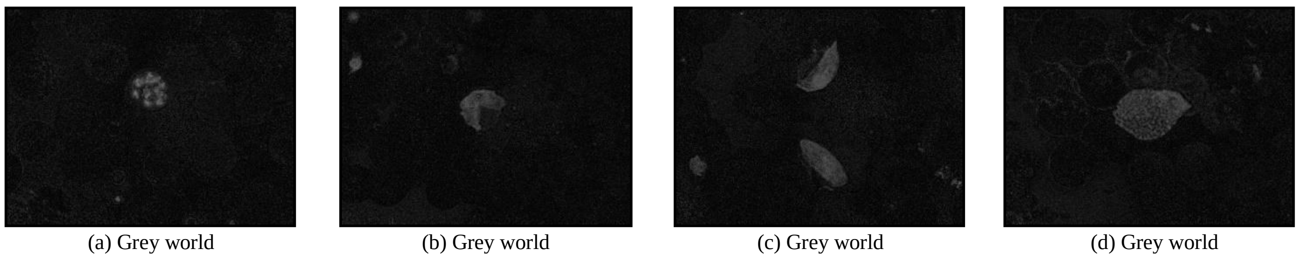
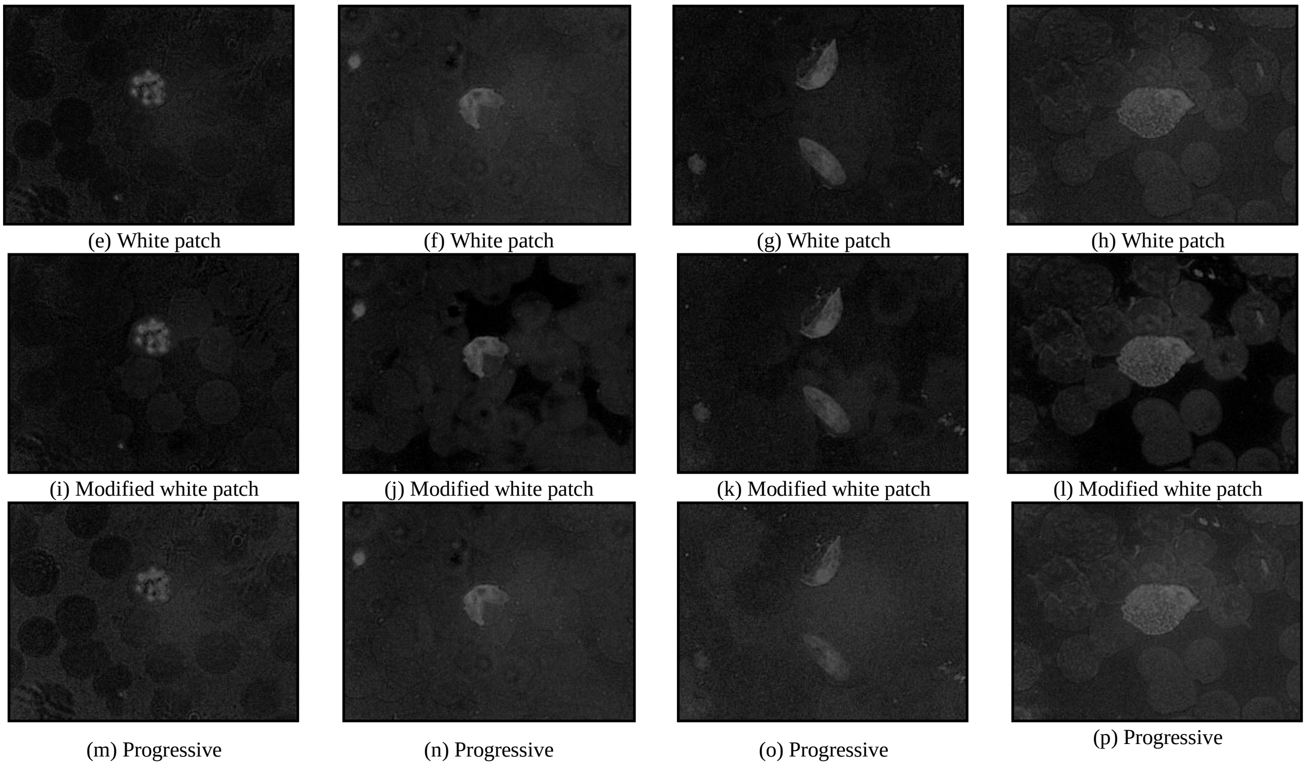


Figure 3: The original and colour constancy images

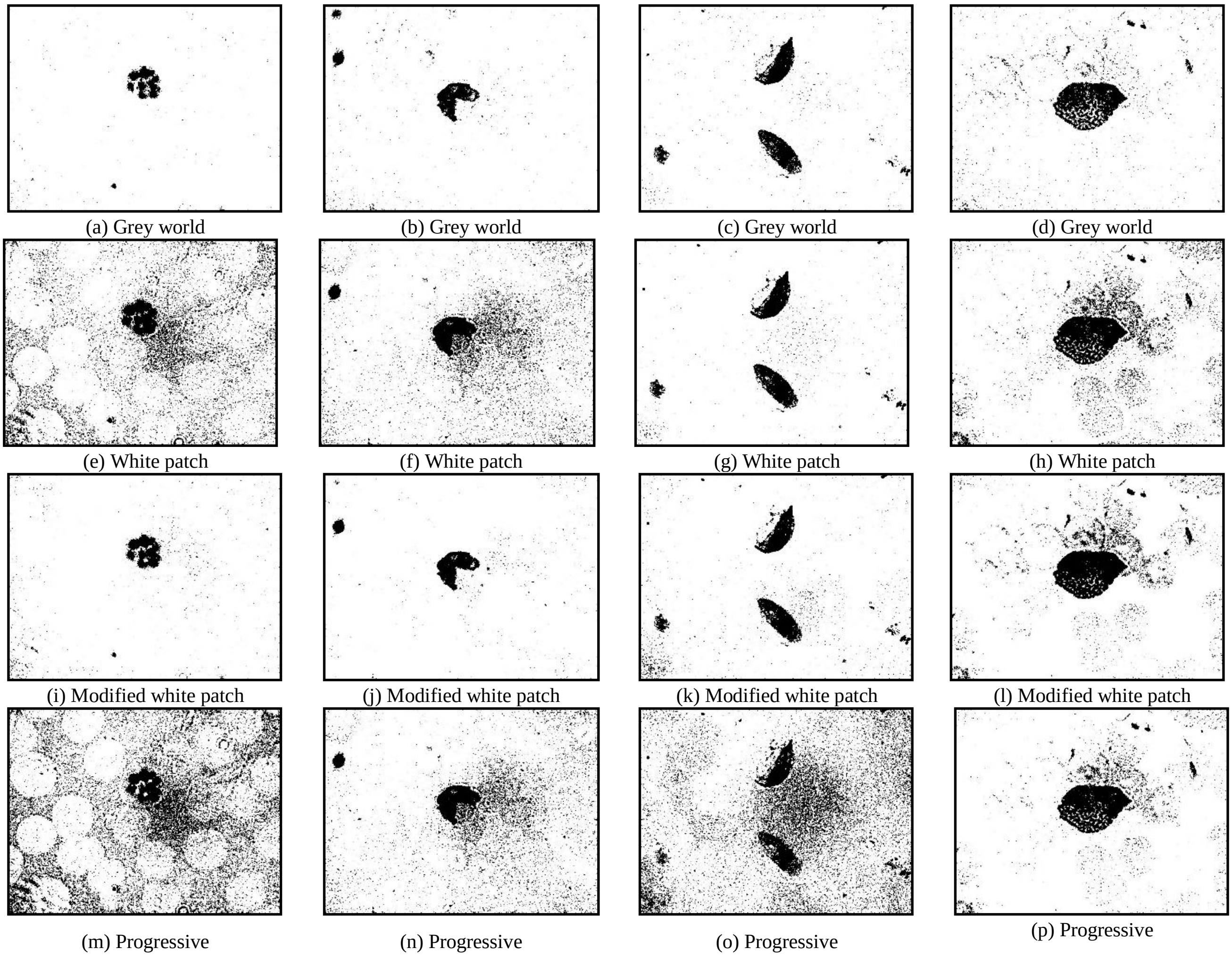
Then, Otsu's thresholding has been applied to segment the S component image into three different regions which are malaria parasite, RBCs and background regions. These results are shown in Figure 5. Regions which are less than 3000 pixels are considered as unwanted cells. Accordingly, these unwanted cells have been removed by using region growing. Finally, Wiener filter has been used to fill the holes as well as to smoothen the area of the segmented malaria parasite. Figure 6 shows the final segmented images after removing the large unwanted cells and filtering process. Based on these images, Gray-World shows good quality segmented parasite with clean segmented malaria image as compared to the results provided by other colour constancy algorithms.





(e) White patch (f) White patch (g) White patch (h) White patch
(i) Modified white patch (j) Modified white patch (k) Modified white patch (l) Modified white patch
(m) Progressive (n) Progressive (o) Progressive (p) Progressive

Figure 4: The S component images



(a) Grey world (b) Grey world (c) Grey world (d) Grey world
(e) White patch (f) White patch (g) White patch (h) White patch
(i) Modified white patch (j) Modified white patch (k) Modified white patch (l) Modified white patch
(m) Progressive (n) Progressive (o) Progressive (p) Progressive

Figure 5: Result of images after applying Otsu's thresholding

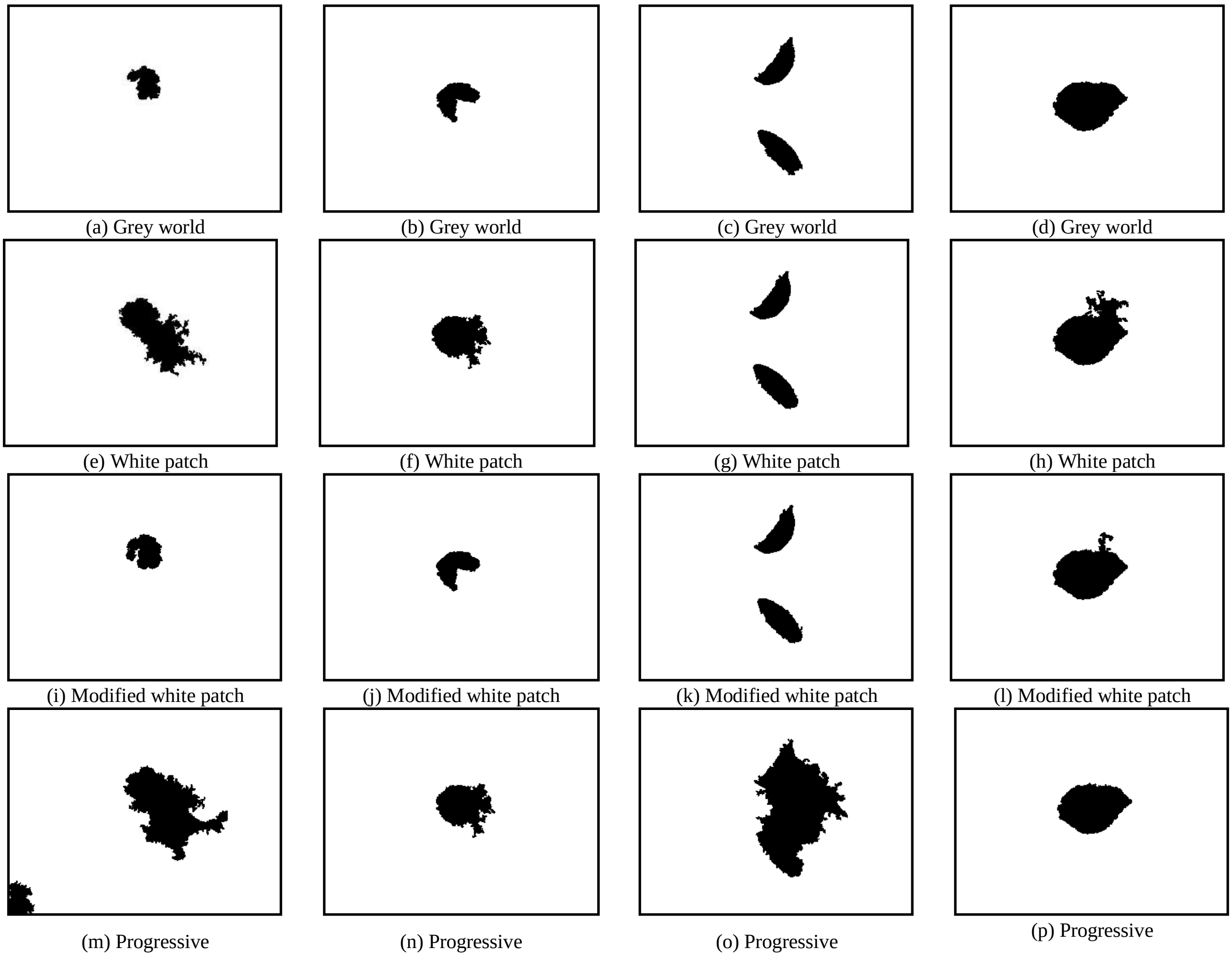


Figure 6: Results of final segmented images

The final segmented images are compared to manually segmented images to quantify the segmentation performance for each colour constancy algorithm. The accuracy of segmentation can be obtained by computing the percentage of pixels that are correctly segmented as malaria parasite or background region in the image. The sensitivity is obtained by computing the percentage of pixels that are correctly segmented as a positive region, while the specificity is obtained by calculating the percentage of pixels that are correctly segmented as a negative region. Higher pixel similarity indicates better segmentation performance.

Table 1 summarises the segmentation performances for each colour constancy algorithm. Based on the average segmentation result of 100 images as shown in Table 1, segmentation using Gray-World image has proven to be the best with segmentation accuracy and specificity of 99.60% and 99.85%, respectively. Hence, it is shown that proper selection of colour constancy algorithm for pre-processing step is very important for achieving a good result in segmenting the entire malaria image.

IV. CONCLUSION

In this paper, comparisons of Gray-World, white patch, modified white patch and progressive algorithms have been made to measure the colour standardisation performance on image segmentation. To obtain the segmented malaria parasites, the malaria images have undergone several image processing techniques such as image pre-processing, image segmentation and filtering process. Overall, the results indicate that segmentation using Gray-World image has proven to be the best in segmenting 100 malaria images with average segmentation accuracy and specificity of 99.60% and 99.85%, respectively. Thus, the results significantly demonstrate the suitability of Gray-World algorithm in enhancing segmentation of malaria images.

Table 1
Segmentation Performance based on Accuracy, Sensitivity and Specificity for the Segmented Malaria Images

Image	Colour Constancy Algorithm	Sensitivity (%)	Specificity (%)	Accuracy (%)
PF_Schizont	Gray world	68.53	**100**	99.39
	White patch	**97.64**	96.48	96.50
	Modified white patch	84.53	99.98	**99.68**
	Progressive	96.25	92.39	92.46
PF_Gametocyte_1	Gray world	97.81	**99.87**	**99.84**
	White patch	**99.62**	98.12	98.14
	Modified white patch	98.59	99.85	99.83
	Progressive	**99.62**	98.12	98.14
PF_Gametocyte_2	Gray world	92.05	99.87	99.59
	White patch	**94.20**	99.83	**99.63**
	Modified white patch	93.77	99.8	99.58
	Progressive	93.08	90.93	91.01
PV_Gametocyte	Grey world	98.24	**99.92**	**99.84**
	White patch	98.84	98.70	98.70
	Modified white patch	**99.16**	99.57	99.55
	Progressive	98.89	99.86	99.82
Average of 100 Images	Grey world	91.26	**99.85**	**99.60**
	White patch	**94.68**	98.17	98.04
	Modified white patch	93.27	98.43	98.26
	Progressive	93.93	95.94	95.82

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