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A Reflective Analysis of Image Processing Operations on Kato-Katz Images for the Pathological Diagnosis of Neglected Tropical Diseases

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***Abstract*— This paper gives an insight into the interdisciplinary work that has been carried out to diagnose some of the neglected tropical diseases, in particular micro-parasitic diseases, using image processing operations. The infections from micro-parasites are collectively called Helminthiasis. The Kato-Katz method is a slide scanning technique commonly used for the qualitative and semi-quantitative diagnosis of helminthiasis. This paper explains the image analysis and processing of Kato-katz images to extract meaningful information and convert the qualitative features of the images to quantitative data and thereby effectively diagnose the disease. This is the preliminary stage of a pioneering work done in the field of neglected tropical disease diagnosis and would be beneficial for thousands of people including children in the endemic regions.**

***Keywords:** Kato-katz, helminthiasis, image processing, image segmetnation, morphological operations.*

I. INTRODUCTION

Helminthiasis is an infection caused by a group of organisms that include the following species: the roundworm (Ascaris lumbriciodes), the whipworm (Trichuris trichiura) and hookworms (Necator americanus and Ancylostoma duodenale). According to the latest World health Organisation (WHO) report, helminthic infections are categorized under 'neglected' tropical diseases, as the people who are most affected are the poorest populations living in rural/conflict zoned tropical regions [1],[2]. The infections affect a ssignificant amount of the world population; around 24%, in tropical and subtropical areas [1]. They induce tissue reactions, intestinal obstruction, and stunted growth in children and could be fatal according to the Special Program for Research and Training in Tropical Diseases [3], [4].

Helminthiasis can be treated through the use of drug treatment, improved sanitation and health education [3]. However, consistent testing at regular intervals has to be done for the complete eradication of the disease. Helminthiasis can be diagnosed via numerous methods, such as kato-katz method, anti-body tests, formol-ether concentration (FEC), McMaster, FLOTAC and mini-FLOTAC [5]. The most common method of examining soil-transmitted helminths is the slide scanning technique, kato-katz method, which is inexpensive and effective [6]. The Kato-katz technique is based on manual microscopic examination of the prepared slide of human feaces to detect the parasitic eggs. The level of infection called parasitemia is calculated using the eggs per gram (EPG) [7]. This manual diagnosis is laborious, time-consuming and is prone to human error. An automated setup on the other hand will speed up the process and will avoid any misdiagnosis caused by the degradation of data quality with respect to time [8]. This paper describes the initial image analysis and processing techniques that were carried out to aid the automated diagnosis of helminthic infections. The paper also proposes an unsupervised method to develop the structuring elements for morphological filtering of the images that match the size and orientation of the objects of interests.

The WHO aims to eliminate global morbidity caused by helminthic infections in children by 2020 [1]. This increases the relevance of this project, as an automated, computerized diagnostic tool leads to faster diagnosis, or multiple diagnoses at one time. More importantly since these infections are widespread, accurate diagnosis is very important for better patient management and for monitoring transmission as well as deworming programs. This is one of the pioneering works done in the field and hence the testing and validation is performed in reference to manual expertise. The following sections of the paper are divided into 3 parts. Section 2 introduces the database and the methodologies. Section 3 and 4 discusses the results, reflective analysis, future work and conclusion respectively.

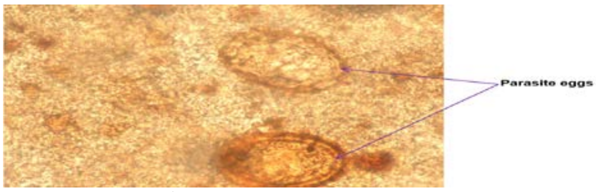

Fig. 1. Image of kato-katz slide under the microscope with 40x magnification.

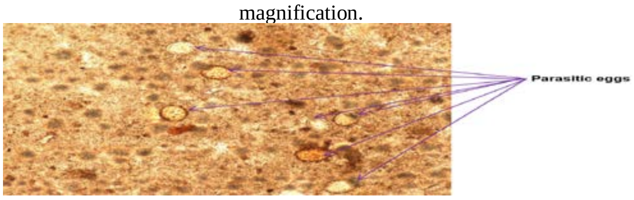

Fig. 2. Image of Kato-katz slide under the microscope with 10x magnification

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II. DATABASE AND METHODS

A. *Data collection*

The experiments were carried out using the images and physical slides provided by the Parasitology Scheme Manager- United Kingdom National External Quality Assessment Service (UK NEQAS), National Infection Services, Public Health England, UK. One important point to note during data collection is that the method by which the sample was mounted affects how clearly the parasites can be identified. There are two common mounting methods for kato-katz, wet mount (oil immersion versus iodine), or FECL (Formal Ether Sedimentation technique) [6]. In addition, the accuracy of the diagnosis can be improved by using at least 3 samples per patient [1].

As seen in Figs 1 and 2, kato-katz slide images are distinct compared to other microscopic images such as Giemsa stained blood images. The slides are generally observed under 10x and 40x magnifications. The images are textured with randomly distributed pixel intensities. The preliminary examination of the images highlighted few primary challenges that needs to be addressed while processing the images:

a) The heterogeneous background affected by non-uniform random features which should be categorized as ‘noise’ in relation to the objects of interest i.e. the parasitic cells.
b) The elliptical cell shape which may or may not be consistent with the images obtained. Any degradation of the slide can lead to disrupted eggs with irregular shapes.
c) The lack of continuous, distinctive edges which makes the processing difficult in terms segmentation based on similarity as well as discontinuity.

All the experiments were conducted using Matlab’s image processing toolbox [9]. In order to extract features for efficient diagnosis, the images had to be preprocessed. The preprocessing removes noise, enhance the features and highlight the foreground. The preprocessing steps included grey scale conversion, histogram analysis for contrast measurement, conversion of the color space to HSV for better feature enhancement as well as morphological filtering. The resultant images were then subjected to image segmentation, edge detection and classification.

B. *Pre-processing*

A histogram analysis was conducted initially to analyse the image and to find a threshold for feature extraction. As shown in Fig 3, the histogram reveals an intensity distribution ranging from around 50-250 with a single peak. These intensity distributions make it extremely difficult to establish a threshold that distinguishes the image between background and foreground.

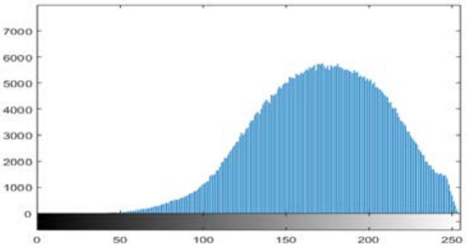


Fig. 3. Histogram of Image in Fig 2

Since this threshold is different for images taken under different acquisition set up, an initial calibration needs to be carried out. The next step is to remove the lighter background and enhance the foreground features. Since the parasitic eggs have distinct elliptical structure, morphological filtering was considered to be the best processing strategy. Morphological erosion for instance would remove any lighter background and enhance the darker regions [10]. However when applied to the image , the erosion proved to be rather destructive as it enhanced the textured darker pixels in the image as shown in Fig 4(a). Morphological opening, which is erosion followed by dilation using the same structuring element (SE) [10], when performed on the image also provided similar result but less destructive as shown in Fig 4(b).A top hat transformation is an effective morphological filtering to remove uneven background objects in an image [10]. This method when tested on kato-katz image not only enhanced the edges of the parasitic eggs but also highlighted the darker pixels in the background as shown in Fig 5(a). Another morphological operation that was carried out was the hit and miss transform to trace the cells [10]. A hit and miss operation when performed on the kato-katz image located the cells but also picked up unwanted background pixels as shown in Fig 5(b). In reflection, all the above experiments would have given successful results if the structuring elements had exactly the same morphology as the parasitic eggs. The SE used for the all the four morphological operations were disk shaped rather than ellipse. Creating a SE that matches exactly with the morphology of the object of interest is a tedious preprocessing task purely because the object characteristic in terms of size and orientation is different for different images, even under similar acquisition environment. Hence an automated algorithm to design SE based on the size and orientation of the corresponding parasitic eggs in the image is proposed in the following section.

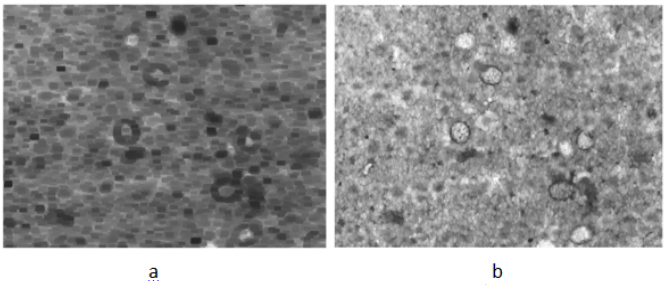


Fig. 4. a) Gray scale image represented in Fig 2 after undergoing morphological erosion. b) Same image after undergoing morphological opening.

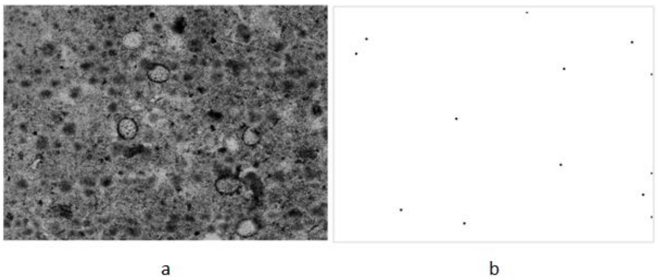


Fig. 5. a) The gray scale image represented in Fig 2 after undergoing Top hat transformation. The features are enhanced however the background noises and texture are also highlighted. b) The cell locations estimated using hit and miss transform applied to the image in Fig 2.

In order to determine the size and orientation of the ellipse, a granulometry technique should be performed initially to find out the size of the foreground object. Granulometry in morphological image processing is a repetitive process used for estimating object sizes or for characterizing textures based on their pattern in gray scale images [10].The size information coupled with the location information obtained from the hit and miss transformation can be used to identify the cell centre and the radius. A circular area will be defined based on the location as the centre and is divided into 4 quadrants. The standard deviation of the mean intensities of each quadrant will then be manipulated to determine the orientation of the structure.

C. Segmentation and classification

The various pre processing algorithms performed on the images as explained in the previous section were to an extent futile due to the intricacy of the image background. Hence the segmentation algorithms used for further analysis were carefully chosen so that an optimised technique could be developed as a combination of different methods. Even though this can increase the computational complexity, the diagnostic probabilities can be improved to a great extent. Following section explains the segmentation methods performed to extract the foreground features.

a) Edge detection

For the human eye the parasitic eggs had distinctive size and edge. However the pattern spectra are textured and intensity distribution within the cell is similar to the background. This has complicated the segmentation procedures and hence the standard edge detection techniques performed were not successful in extracting the edges of eggs effectively.

The edge detection operation used kernels of sobel operator, gradient operator and prewitt gradient operator [11]. Figure 6(a) is the resultant image after using a sobel operator. Fig 6(b) is the resultant image obtained after using a gradient mask , which gives the first derivative of the signal, where a single cells was distinguishable compared to the rest (as highlighted). Figure 7 (a) is the Prewitt gradient operator on gray scale image and Fig 7 (b) is the same prewitt gradient operator on binary image. None of the above operators were successful in separating the cells from the background.

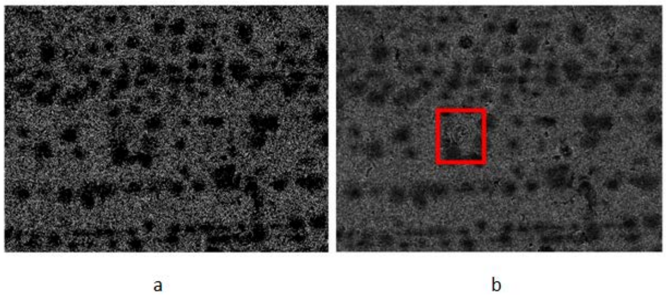


Fig. 6. a) Image segmented using a sobel operator. b) Image segmented using a gradient operator

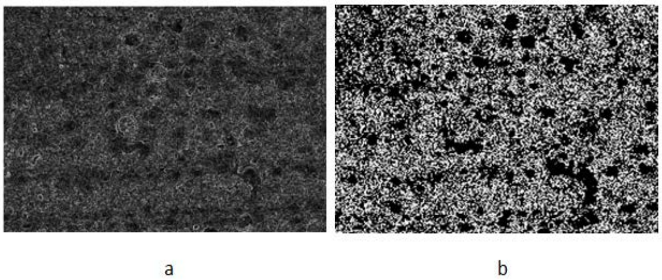


Fig. 7. a) Gray scale Image segmented using a Prewitt gradient operator. b) Binary Image segmented using a Prewitt gradient operator

b) Texture Segmentation/Entropy

These segmentation techniques were carried out to focus more on the general aspects of the image rather than pure noise elimination. Entropy is a measure of randomness in the image and can be used to characterise the texture of the image [12]. This texture segmentation procedure extracts elements in the image based on statistical randomness. However entropy segmentation is successful only if the texture is periodic, providing dominant peaks in the power spectrum, which is not the case with Kato-katz images as demonstrated in Fig 8.

a) Watershed segmentation

A surface plot of the kato-katz image in Fig 2 revealed unpredictable random peaks and troughs. The cell surface is also uneven with secondary peaks and troughs. This plot as shown in Fig 9(a) was analysed to assess whether the region growing algorithms such as watershed would have a useful effect on the images in terms of segmentation. The watershed transform decomposes an image completely and then assigns each pixel either to a region or a watershed [11]. Watershed technique work on images where there is a clear distinction between the foreground and background features. The textured nature and overlapped regions of the kato Katz image hence leads to oversegmentation as shown in Fig 9(b).

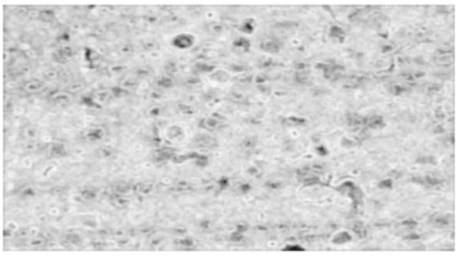


Fig. 8. Texture segmentation performed on gray-scale of the image in Fig 2.

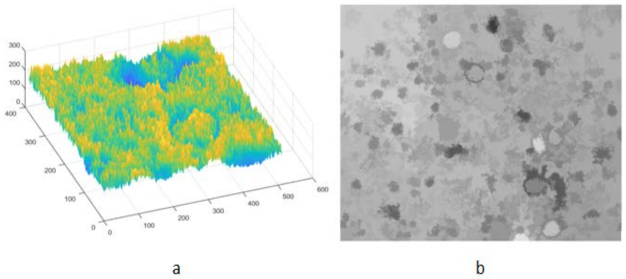
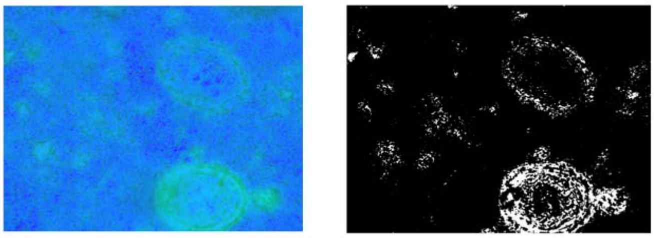


Fig. 9. a) Surface plot of Kato-katz image shown in Fig 2. b) Segmented image using watershed technique



a b

Fig. 10. a) Image in Fig 1 converted to HSV color space. b) Simple thresholding of HSV image

b) Processing on HSV colorspace

It is clear that kato-katz images are difficult to process due to its stochastic nature and texture intensity distribution. All the experiments conducted so far were on gray scale, which proved to be inconclusive. Hence further experiments were carried out after converting the image to Hue Saturation Value (HSV) colour space. The HSV images retain information on the colour portion, brightness as well as the amount of gray values in the image [11]. Hence the RGB (Red Green Blue) image was converted to HSV image in order to create a blanket operation that would allow the separation of the cells from the background. Simple thresholding in HSV gave a clearer segmented image than thresholding a grayscale image as shown in Fig 10. After thresholding, filters were applied to clear up the noise in the image. As can be seen from Fig 10, in the HSV image, the outer ring of the cell is very clearly marked and very easily identified. It was therefore very simple to differentiate the cells from the background noise via simple thresholding of the channels.

III. DISCUSSION

The paper describes a reflective analysis on the application of a number of image processing algorithms to process Kato-Katz images. Due to extreme nature and randomness of the pixel intensities, the Kato Katz images are difficult to process. A number of pre-processing and segmentation techniques were applied to the gray scale image of the original RGB and the results were analysed. However the experiments conducted on the HSV colorspace proved to be more effective than monochrome images of RGB colorspace in terms of noise removal and segmentation. This analysis helped to undertake future experiments on the resultant image for further processing and feature extraction. The research is further planned to work on Annular Ring Ratio (ARR) transform of the thresholded HSV image to extract the features. The ARR method is proven to be robust and insensitive to non uniform illumination and random distribution as far as some morphology is preserved [13]. Hence the future work will be to use the current findings to extend the experiments onto ARR transform for object identification and parasitemia estimation.

IV. CONCLUSIONS

The paper describes a preliminary step of image analysis and processing involved in the diagnosis of neglected tropical diseases. The findings are expected to help future experiments to be performed in the area. A reflective analysis on kato-katz technique pointed out that, while cheap and not requiring sophisticated laboratory equipment, manual diagnosis and processing of the samples requires expertise in microscopy and is extremely labour-intensive. Therefore, an automated system would be greatly beneficial to those affected communities with regards to deworming and eradication programs. This is a pioneering work and hence all the analysis and results contribute to the field to undertake further research. The experiments and analysis aims to lead to the development of an ultimate diagnostic tool that has high impact in the clinical field as a mass monitoring and qualitative analytical tool.

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