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Determination of Hue Saturation Value (HSV) color feature in kidney histology image

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Abstract. The kidney is organ that plays an important role in the body's metabolism, especially the process of filtration and reabsorption of food waste. Currently the determination of kidney parts through kidney histology is still done manually by experts based on experience and knowledge. Therefore, to make it easier to determine the parts of the kidney, a histological image segmentation of the kidney was carried out. In the segmentation process, it is necessary to extract the color features of the parts of the kidney, namely the glomerulus and proximal tubule. The color features used are Hue, saturation, value (HSV) color space. The hue means the representation of color type. The saturation defines the amount of white color is mixed with hue. The value in HSV color space denotes the intensity or lightness or brightness of the color. The method consists of three steps such as pre-processing step, extraction feature HSV and statistical analysis. The result of statistical analysis showed that the hue and value features, glomerulus and proximal tubule had different ranges of values. However, the features of saturation, glomerulus and proximal tubule is overlap.

1. Introduction

For over two decades, digital pathology is being used for several clinical and nonclinical applications such as primary diagnosis, second-opinion consultation, archiving, education or training, research and image analysis [1]. A digital scanning device is calledwhole-slide scanners are capable of automatically producing very high-resolution images that replicate glass slides (so-called virtual microscopy or digital microscopy) [2]. Image from device can be analyzed with computational tools using image processing methods [3]. Developing image processing methods to analyze histology images has been computationally challenging. The aim of image processing is histology image classification to determine each part of tissue. Histology image classification started with segmentation. One of the most challenging in segmentation of digital pathology is kidney histology image. Segmentation of kidney histology image can be an initial step for automatic analysis of the kidney diseases in the computer-aided diagnosis system [4] and also lead to the development of new tools for analyzing histopathological slide [5].

Kidney histology image provides display some tissue in kidney. That image shows similar of shapes in all tissue. Characteristics of part of tissue is slight different is color and texture [6]. Important tissue in kidney histology was glomerulus and proximal tubule. Glomerulus is part of tissue in kidney that any changes in shape, cellularity, size or structure can be used as one of indicators of kidney diseases [7]. Number of glomerulus in a healthy human kidney reach more than 300,000 with an average mean size of 6.04 μm^3 (cubic micron) each [8]. Based on its physiological features, glomerulus has specific shape but because human body tissues are nonrigid and there exists influence of different factors during making slice, the shapes of glomerulus differ in thousands ways [9]. It can be concluded that shape features could not be recommended as features in segmentation of glomerulus.

The other important tissue in kidney is proximal tubule, which are a sub-region of the tubules, are epithelial tissue located between the bowman's sac and henle's loop. Function of proximal tubule is maintaining blood homeostasis by absorbing amino acids, glucose, water and ions such as sodium (Na), potassium and bicarbonate. Proximal tubule dysfunction is associated with the pathogenesis of many kidney diseases such as diabetic nephropathy, proximal tubular acidosis and renal fanconi [10]. In histology image, these two tissue have similarity in color. This study focuses to determine and compare the range number of color space as a feature in distinguishing the two tissues.

Color space is a mathematical model to represent color information as three or four different color components. Color space explains how the colors are represented and specify the components of color space accurately to learn how each color spectrum looks like [11]. HSV color space represents the Hue, Saturation and Value and three elements are independent. Hue is an angle from 0 to 360 degrees usually 0 is red, 60 degrees is yellow, 120 degrees is green, 180 degrees is cyan, 240 degrees is blue and 300 degrees is magenta. Hue indicates the type of color (such as red, blue or yellow) or the hue of the color where the color is found in the color spectrum. Red, yellow and purple are words that indicate hue. The second component of HSV color space is saturation. the saturation of a color is a measure of how pure the color is. Saturation is usually valued from 0 to 1 and shows a grayish color value where 0 indicates gray and 1 indicates pure primary color. The third component of HSV is value or intensity, which is a measure of how much brightness is a color or how much light comes from a color. value can be valued from 0 to 100%. A color with a value of 100% will appear as bright as possible and a color with a value of 0 will appear as dark as possible [12].

HSV color space, black and white grey color in the color pallete in order to obtain different color brightness and color saturation. HSV color space is more consistent way of describing the human visual experience and it is closer to people's perception of color compared with the RGB color space. When selecting the representation methods to describe the color features, since the color histogram has a better result, the color histogram representation method is mainly used in the experiment [13]. Extraction HSV color space in image have many advantage. Some research about HSV color space in image done by other researchers. Reference [14] success to dehazing image through HSV color space in image. Using HSV color space, segmentation on image is more efficient [15]. HSV color space also can be used for classification in color image data and it give better results [16,17,18].

2. Method

Methodology consists of input data, process and output data. Input data was kidney histology images and output data was range number of HSV. Meanwhile there were three steps in methodology such as pre-processing, extraction feature HSV and statisticalanalysis.Flowchart of research is shown in Figure 1. Input data divided into two type of data. First data was kidney histology image that consists of glomerulus is shown in Figure 2 (a)and Figure 2 (b) show proximal tubule in kidney histology image. Arrow sign in Figure 2 shows the location of glomerulus and proximal in kidney histology image according to instruction of experts. Images obtained in Histology Laboratory in Medicine Faculty Universitas Nahdlatul Ulama Surabaya. Total of images was twenty-eight images with category glomerulus in image as many as fourteen images and proximal tubule. Images have resolution 1428 x 1296 pixels. The first step was pre-processing step. The aim of pre-processing step was enhancement image and removing noise. Pre-processing step contains two processes such as resize and cropping. Resize is a process to change image resolution and pixel information of image as well. Resize was performed to get uniform image resolution among images [19]. The second process in pre-processing step was cropping, a process to removal some of the peripheral areas of image. Result of cropping process was images of glomerulus or proximal area.

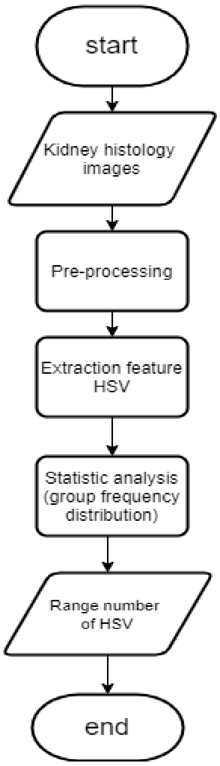
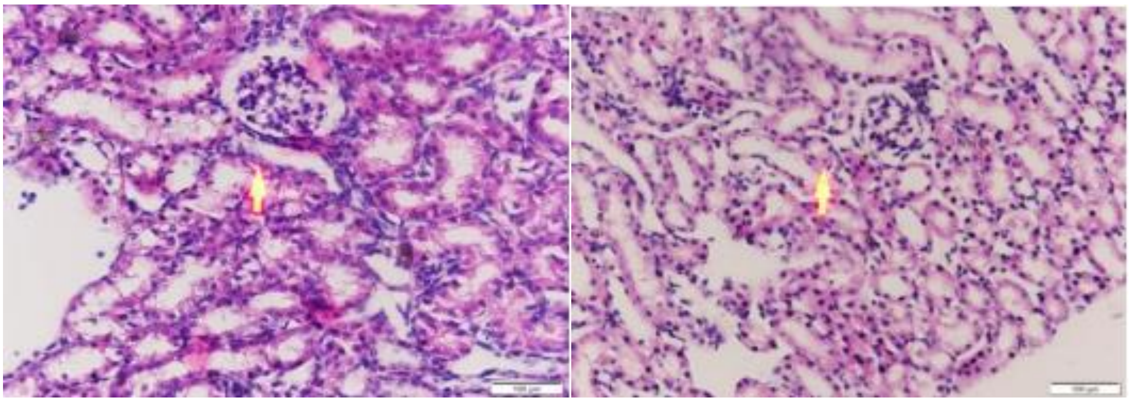


Figure 1. Flowchart of research.



(a) (b)

Figure 2. Kidney histology images contain glomerulus (a) and proximal tubule (b).

The next step after pre-processing was extraction feature HSV color space. Extraction feature HSV color space using histogram. Color histogram presented graphic that shows deployment of value of pixel in an image. Color histogram counts similar pixels and stores them. Color histogram is called a color descriptor with each descriptor contains a feature extraction algorithm [20,21]. This step using Matlab to build system of extraction feature HSV in image. Matlab was one of programming basic language that provide feature in image processing [22]. In the system, there is conversion process from RGB color space into HSV color space. The conversion is calculated using Formula 1 until Formula 7 [19]. Output of system was histogram of hue, histogram of saturation and histogram of value. Output of system is also output of this step.

$$r = R / (R + G + B) \tag{1}$$

$$g = G / (R + G + B) \tag{2}$$

$$b = B / (R + G + B) \tag{3}$$
$$V = \max (r, g, b) \tag{4}$$
$$S = \begin{cases} 0, & \text{if } V = 0 \\ 1 - \min (r, g, b) / V, & \text{if } V > 0 \end{cases} \tag{5}$$
$$H = \begin{cases} 0, & \text{if } S = 0 \\ (60 * (g - b) / S * V), & \text{if } V = r \\ (60 * [2 + (b - r) / (S * V)], & \text{if } V = g \\ (60 * [4 + (r - g) / (S * V)], & \text{if } V = b \end{cases} \tag{6}$$
$$H = H + 360, \text{ if } H< 0 \tag{7}$$

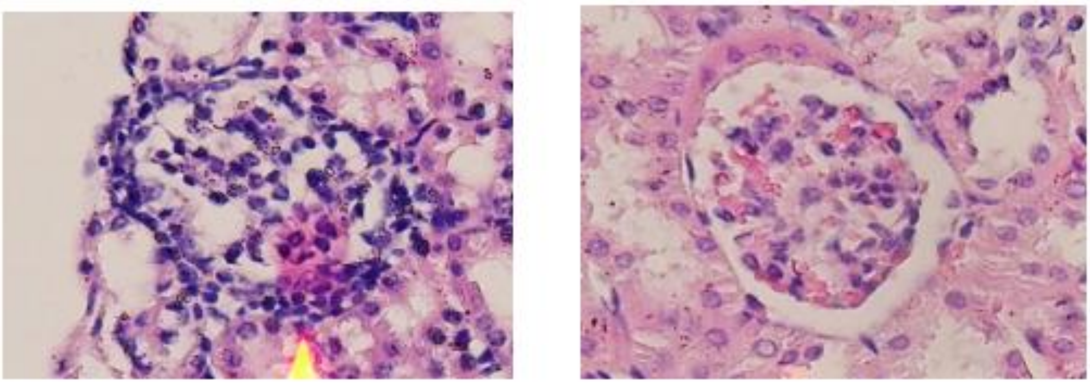
where R, G, and B represents red, green, blue before normalization, r, g, b is red, green and blue after normalization, H is hue, S is saturation and V is value.

The last step was statistical analysis using group frequency distribution. Group frequency distribution is a method to determine range number. From the previous step, HSV of images is obtained. Each image has histogram of HSV. In every histogram of HSV, highest value is obtained as representation of HSV in these image. Input in group frequency distribution is highest value in histogram of HSV. Group frequency distribution have two formulas with variables such as total data (n), total class (k), maximum value in data (t), minimum value in data (r) and interval class (i). Formula in this step is shown in Formula 8 and 9. Output from analysis step was range number of H, S and V in glomerulus and proximal tubule. From these range number, there would be comparison among H, S, and V in glomerulus and proximal tubule. In good result, when output is compared, range number is different between glomerulus and proximal tubule.

$$k = 1 + 3{,}3 * \log n \tag{8}$$
$$i = ((t - r) / k) \tag{9}$$

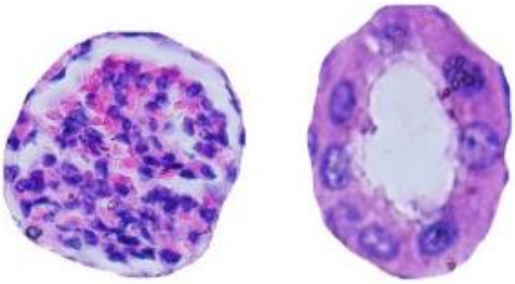
3. Main Results

In this step,the result of research is explained. The first process was pre-processing is consisted of resize and cropping. Result of resize is shown in Figure 3 with glomerulus in a and proximal tubule in b. Figure 3 show that kidney histology image have smaller size and image is focused in glomerulus and proximal tubule. The next process in pre-processing step was cropping to get peripheral area in image. Result of cropping process is shown in Figure 4 that consist of glomerulus area and proximal tubule area. Output of pre-processing was image with peripheral area that can be processed by extraction feature HSV.



(a) (b)

Figure 3. Result of resize in glomerulus (a) and proximal tubule (b).



(a) (b)

Figure 4. Result of cropping in glomerulus (a) and proximal tubule (b).

The second step was extraction feature HSV using system that implemented in Matlab. Input of system was image from result of cropping process in previous step. Each image will have three histograms such as histogram of hue, histogram of saturation and histogram of value. Beside histogram, image in hue, saturation and value is also displayed as output of system in Matlab. Output of system is shown in Figure 5 until Figure 7. Output image is different from input image because output image is consisted of one component in HSV. In Figure 5, Output image in hue is displayed as image with peripheral area in gray color and background area in black. The color of object area can be determined using histogram of hue in beside output image. In histogram of hue show that the highest peak of histogram is around right side leaning to white color. In Figure 6, Output image in saturation is shown as image with black in background area and object area with black color domination. From histogram of saturation, the highest peak is leaning to left side that indicate black color. Figure 7 show output image in value with background area in white and object area in dominant white color. Color of object area is determined in histogram of value that position in left side of histogram that indicate white color.

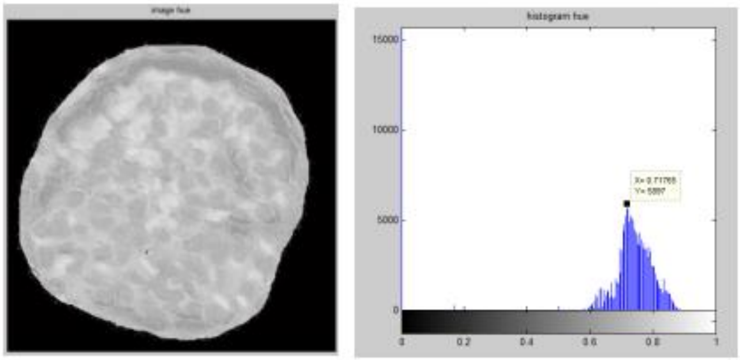


Figure 5. Image and histogram in hue.

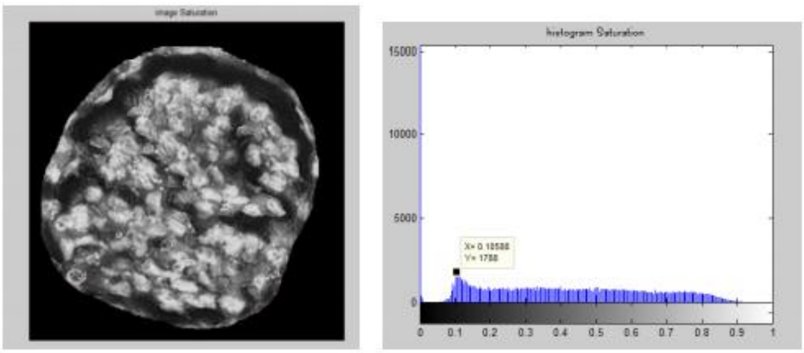


Figure 6. Image and histogram in saturation.

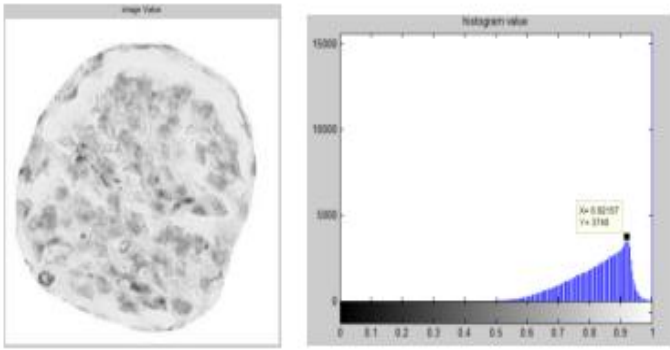


Figure 7. Image and histogram in value.

The next step was analysis data using group frequency distribution. From the HSV histogram shown in Figures 5 to Figure 7, the highest value for each HSV component is obtained. The highest value data for each HSV component were analyzed using the group frequency distribution method with Equation 8 and Equation 9. The results of data analysis on each HSV component in the glomerulus image and proximal tubule image are shown in Table 1 and Table 2. Table 1 and Table 2 have the same variable number of raw data (n) and number of classes (k), namely 14 and 4.78 which are rounded up to 5. Table 1 shows that the range number generated for the hue component is between 210.86 until 280.47, the saturation component is around 3.9 and 5.61 and the value component is from 87.18 until 90.22. The range number for each HSV component in the proximal tubule image shown in Table 2 is that the hue component produces from 293.31 until 303.61, the saturation component produces between 2.7 until 9.1 and the value component produces around 82.96 and 84.91.

Table 1. Analysis data in glomerulus image.

Detail	Component color		
	Hue	Saturation	Value
Number of raw data (n)		14	
Number of classes (k)		4,78 ≈ 5	
The highest data (t)	340,2	12,10	95,6
The lowest data (r)	2,52	3,9	81,1
Interval class (i)	70,61	1,71	3,03
Result	210,86 – 280,47	3,9 – 5,61	87,18 – 90,22

Table 2. Analysis data in proximal tubule image.

Detail	Component color		
	Hue	Saturation	Value
Number of raw data (n)		14	
Number of classes (k)		4,78 ≈ 5	
The highest data (t)	340,2	33,3	95,6
The lowest data (r)	283,68	2,7	81,5
Interval class (i)	11,3	6,40	2,95
Result	293,31 – 303,61	2,7 – 9,10	82,96 – 84,91

To make it easier to compare each component of HSV in the glomerulus and proximal tubule image, a comparison graph is shown as in Figure 8 to Figure 10. Figure 8 shows that the glomerulus and proximal tubule have different range numbers, which can be concluded that the hue component can be used as a differentiator feature. Figure 9 shows a comparison of the saturation components in the glomerulus and proximal tubule which results in overlapping range numbers. From the graph, it can be concluded that the saturation component cannot be used as a differentiator feature. In the last figure, Figure 10 shows a comparison of the value components in the form of a difference in the range number which causes the value component to be used as a differentiator feature. Based on the comparison results, the hue and value components can be used as distinguishing features between the glomerulus and the proximal tubule.

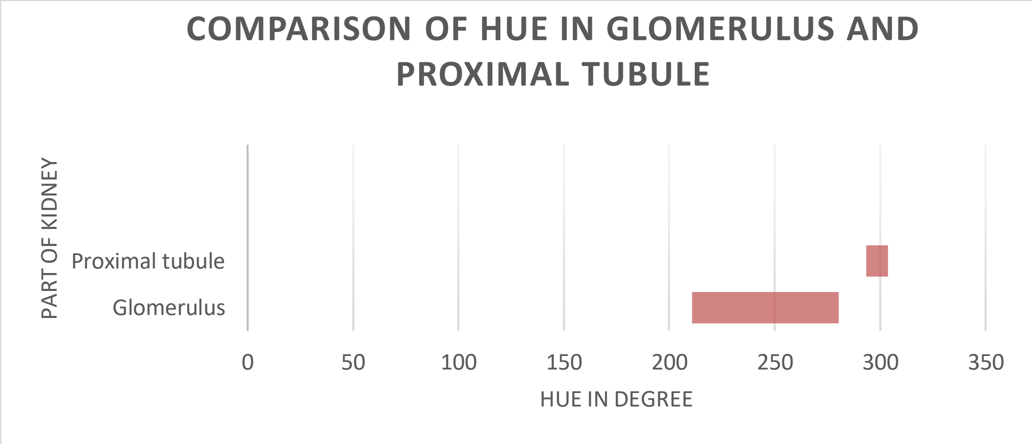


Figure 8. Graph comparison of hue in glomerulus and proximal tubule.

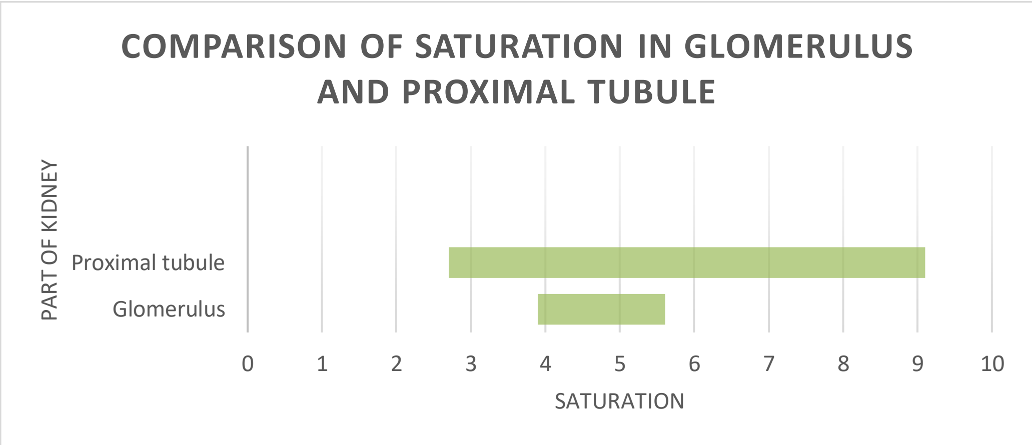


Figure 9. Graph comparison of saturation in glomerulus and proximal tubule.

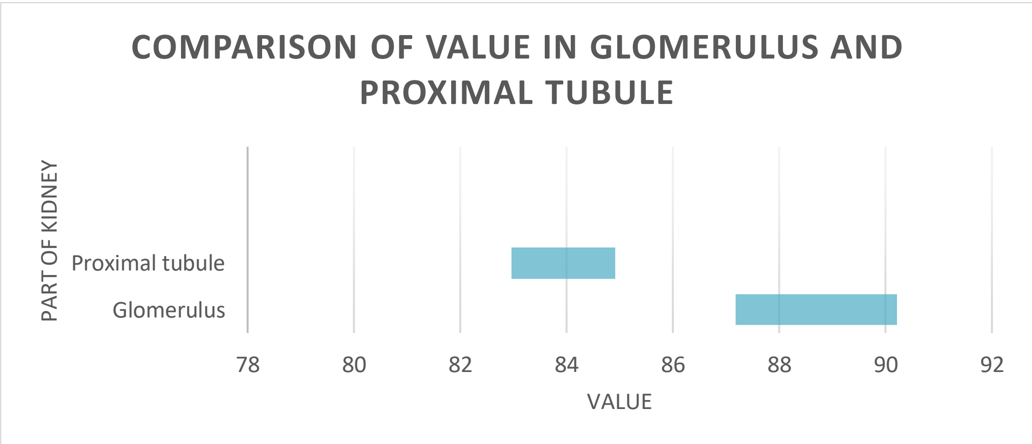


Figure 10. Graph comparison of saturation in glomerulus and proximal tubule.

4. Conclusions

Research has aim to determine and compare HSV color space of glomerulus and proximal tubule in kidney histology images to get differentiator feature in glomerulus and proximal tubule image. HSV color space consist of hue, saturation and value. The steps in study was preprocessing, extraction feature HSV, statistical analysis and comparison graph. The result show that image can be extracted into each component HSV. In glomerulus image, Range number of hue component was 210,86 – 280,47, the saturation component is 3,9 – 5,61 and the value component is 87,18 – 90,22. The range number for each HSV component in the proximal tubule image was the hue component produces 293,31 - 303,61, the saturation component produces 2,7 – 9,1 and the value component produces 82,96 – 84,91. From the comparison graph could be concluded that hue and value component can be used as differentiator feature in glomerulus and proximal tubule images.

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