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Implementation of Double-Windows-Blending to Evaluate Traumatic-Brain-Injury in CT Head Images

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Abstract – This study aims to evaluate the traumatic-brain-injury on head CT images using a double-windows-blending algorithm in a single color image. Blending windows allows simultaneous viewing of both windows into one color image so that users do not need to changes the window settings. The double-window-blending algorithm was used to combine two windows on the CT images for the diagnosis of fracture and bleeding. This technique made the interpretation time more efficient because different information from two windows was displayed simultaneously in one image. Twenty cases were selected to present head trauma with diagnoses of fractures, acute bleeding, and tumors. The CT images were then processed with the double-windows-blending algorithm. We used two windows, namely the brain and bone windows. We found that the resulting images clearly visualize fractures and bleeding heads in a single color image. The double-windows-blending algorithm showed various pathologies in the head area in one image.

Keywords – Window Setting, Window Blending, Brain Window, Bone Window, Brain Injury, Medical Image Processing

I. Introduction

Image processing is part of the rapid development of computer technology. The scope of image processing covers very wide area, including for medical purposes and it is called as medical image processing [1]. Medical images are obtained from various imaging modalities, such as conventional X-ray, computed tomography (CT), ultrasound (US), and magnetic resonance imaging (MRI) [2]. CT scanner is one of the most widely used X-ray modalities in medical applications because it produces very high quality images [3-5] with very fast data acquisition [6]. Medical images are very helpful for medical personnel to diagnose patients, especially in patients with head injuries due to accidents [7]. The head is an area that is often scanned with CT because the head area is prone to traumatic-brain-injury [8-9]. Traumatic-brain-injury is a mechanical trauma that often occurs to the head [10]. This trauma occurs directly or indirectly and it causes neurological dysfunction such as physical disorders and cognitive disorders that can occur temporarily or permanently [11]. Traumatic-brain-injury can cause more complex disorders than trauma to other organs [12]. This is because the anatomical and physiological structures of the skull contents are more varied, so it requires detailed medical images displaying the anatomy of the head [13].

CT scanner produces axial images with two-dimensional (2D) mapping of the linear attenuation of body tissue expressed in Hounsfield units (HU) [14]. Because the range of linear attenuation coefficient values of all tissues is too wide, it is necessary to be normalized so that the water attenuation scale becomes a linear scale in HU. In the human body, HU ranges from -1000 to more than +3000 [15]. For example, the air pixel value is around -1000 HU, muscle is at +25 and +40 HU [3] , and bone density is between +1000 to +3000 [16,17]. However, most computer monitors only display 256 grayscale [16], and the human eye can only distinguish a narrower range than the computer monitor.

In general, CT images use the windowing technique by selecting the HU range to be displayed. The windowing technique is a method to display an image contrast as needed, by changing the image contrast through selecting appropriate window width (WW) and window level (WL) [18]. Window width is a range of HU values that are used to provide gray level will be displayed in the monitor [16]. Window level is the middle value of HU values which will be displayed on the console screen. Thus, using this windowing technique, we can display high contrast medical images [19]. Clinically, there are several types of windows such as soft tissue, bone, brain, lungs, and other windows [20-23].

In practice, to assess the pathology of an organ (for example, benign neoplasm) can be carried out using only one window. However, evaluating multiple diseases in a single-window is very complicated (for example, fractures and bleeding). To overcome the limitations of the linear window, several techniques have been proposed for displaying a wide dynamic range of CT in a single image [24]. Previously, the algorithms had been proposed such as adaptive histogram equalization (AHE) [25,26], contrast-limited adaptive histogram equalization (CLAHE) [27], multiscale adaptive histogram equalization (MAHE) [28,29], and relative attenuation-dependent image overlay (RADIO) [30,31] which allowed faster time interpretation than used combination of more than one window independently. However, the representation of pixel values in the blending window was inconsistent which caused misinterpretation among practitioners. For example, head fat and bleeding can be displayed in the same gray image. Recently, Anam et al [32] have provided a solution for windows blending in the form of a multiple-windows-blending algorithm in a red-green-blue color space. Baseb on the work of Anam et al [32], in this study, we modified it and proposed double-windows-blending and evaluated it on the CT images of the head with clinical traumatic-brain-injury.

II. METHODS

The flowchart of double-windows-blending algorithm was depicted in Figure 1. It shows that each image was processed using two windows. Each window has a different WW and WL depending on the density of the various tissue types expressed in HU units [14]. In this case, we used the bone and brain windows to visualize the fracture and bleeding cases simultaneously in color images. The WL and WW values on the bone window are 400 HU and 1000 HU, while the brain window are 35 HU and 70 HU.

This study was retrospectively performed on twenty patient images taken from the Pelni Hospital Jakarta. We selected ten cases of clinical head trauma with acute fracture and bleeding for evaluation.

After reading images of the head with the fracture and bleeding cases , then the first layer was adjusted using the bone window and the second layer was adjusted using the brain window. The results of the two windowing were then blended to form a single color image. The color value in the image can be treated as a probability in the range of 0-1 if each pixel value is divided by 255 [16]. The blending of the bone and brain windows in the head image is hoped to be able displaying fractures and bleeding simultaneously in one color window.

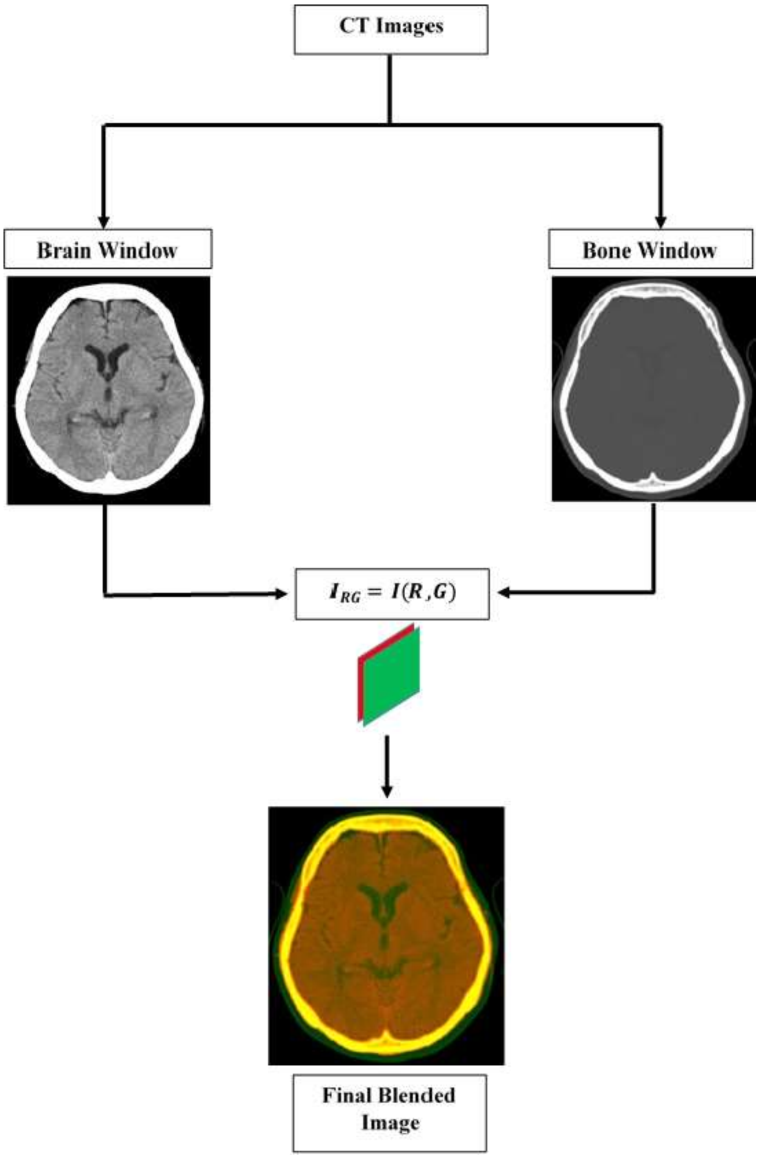

Figure 1. Diagram demonstrating the double-windows-blending algorithm applied to an axial image represented on a head CT. It uses two windows, namely the bone and brain windows which will be blended into one color image.

The double-windows-blending was implemented in MATLAB 2015b on a 64-bit Windows 10 computer with an Intel® core ™ i5-8250U 1.6 GHz 4GB RAM and NVIDIA ™ GeForce MX 150 Graphics Processing Unit.

III. RESULTS

The resulting images from the combination of two window settings have good contrast. Figure 2(a) shows image using a brain window. It shows bleeding around the parietal bone and temporal bone (indicated by the arrow). The brain window is good for showing the overall brain anatomy such as cerebral gyrus, lateral ventricles, cerebellum, and cerebrum. However, the brain window is less able to show fracture in the bone properly. Whereas Figure 2(b) displays the bone window. The bone window is great for viewing details of the bone. Fractures in the bone can be demonstrated using this window (indicated by the arrowhead). However, the bone window does not show bleeding in the brain comprehensively. The resulting image of double-windows-blending has very good contrast. For example, fractures of the left and right parietal bones (indicated by the arrow), and bleeding in the temporal and parietal bones (indicated by the arrowhead) have very high contrast. Double-windows-blending can also distinguish fat and bleeding simultaneously in one window (indicated by the arrow line).

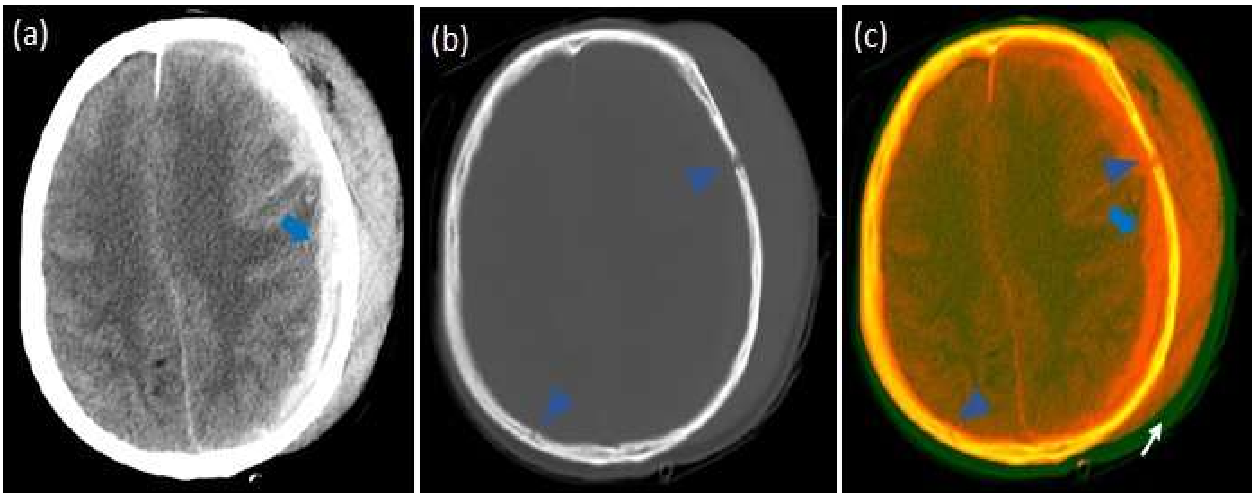

Figure 2. Image of the double-windows-blending of the brain with clinical fracture and bleeding. (a) brain window, (b) bone window, and (c) double-windows-blending.

Due to there are three fundamental colors, i.e. red, green, and blue, a choice of two from three colors should be performed. Figure 3 shows the six combinations of the bone window and the brain window. Theall resulting double-windows-blendings have good contrast detail so that details of the fracture of the right parietal bone (indicated by the arrowhead) and bilateral bleeding (indicated by the arrow) are clearly visualized. However, at first glance it appears that Figures (b) and (d) showing more clearly image than the images.

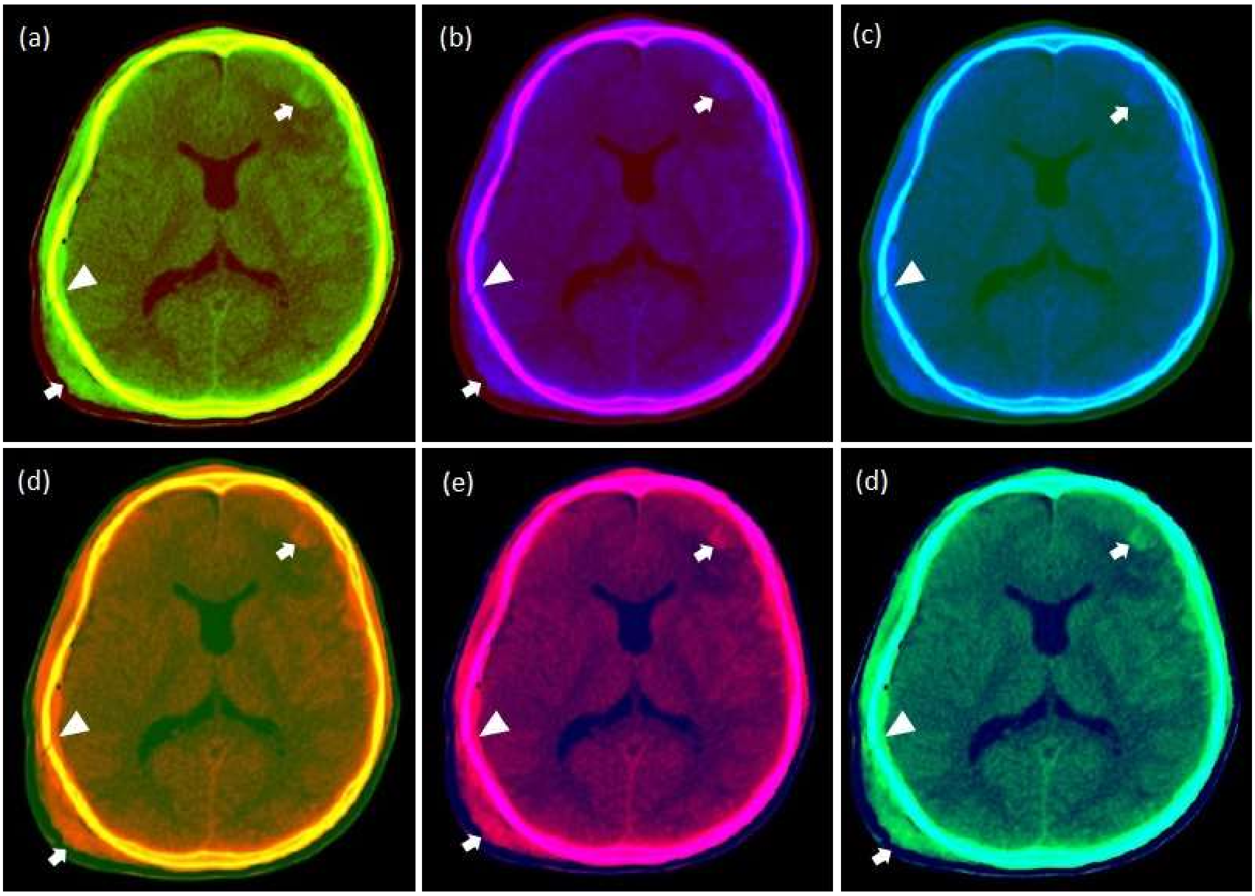

Figure 3. Six combination of double-windows-blendings using bone and brain windows. (a) Bone and brain window are in the red and green colors, (b) Bone and brain windows are in the red and blue colors, (c) Bone and brain windows are in the green and blue colors, (d) Bone and brain windows are in the red dan green colors, (e) Brain and bone windows are in the red and blue colors, and (f) Brain and bone windows are in the green blue colors.

The sample used in this study was twenty patients with clinical traumatic brain injury who underwent CT head examinations. In this paper only shows two images of clinical fracture and bleeding simultaneously in a single color image. However, all other images of other patients show the same results.

IV. Discussion

In this study, we have introduced and implemented a new algorithm on CT image visualization using double-windows-blending in the color space. This method has been performed on images of clinical patients with fractures and bleeding. This double-windows-blending technique allows the results of two windows to be displayed in one view so that users do not need to make changes to the windows settings [30,32]. This can speed up interpretation time because more information is seen in only one image. In particular, the bone and brain windows visualize different view significantly so that the user cannot view them in a single window setting [24]. Therefore, CT image of the head must be viewed in at least two window settings simultaneously, namely using the bone and brain windows [31].

To overcome the limitations of the linear window, several techniques have been proposed for displaying a wide dynamic range of CT in a single image. Previously, the algorithms that had been used were AHE, CLAHE, MAHE, and RADIO which allows faster time interpretation than conventional windows [25-30]. The use of window blending is capable of producing high contrast images to assess pathology simultaneously, according to the specified window settings [32]. For example, in cases of fracture and bleeding can be seen clearly. This representation cannot be achieved using conventional window techniques.

The method of double-windows-blending algorithms is different from other methods for the same purpose. The previous methods of representation of the pixel values of blending showed inconsistent window which may cause misinterpretation among the practitioners. For example, head fat and bleeding can be displayed in the same gray image. However, using the double-windows-blending algorithm, fat and bleeding can be distinguished according to their color in a single image (Figure 2(c)), so it can minimize the possibility of misinterpretation in diagnosing patients. In double-windows-blending (Figure 2), bilateral parietal bone fracture (indicated resources by the arrow) and bleeding in the temporal and parietal bones (indicated resources by the arrowhead) has very high contrast.

The use of the double-windows-blending algorithm in color space is a new method as an alternative to diagnose patients with good quality. Currently, there is no CT scanner has software capable of automatically producing combined images into one window in the color space. In the future, the double-windows blending may be integrated to the computer of CT as as an option to diagnose diseases. In addition to CT images, this algorithm can be used in other medical images such as MRI, mammography, and fluoroscopy.

The double-windows using this algorithm needs to be optimized by radiologists. This optimization requires further comprehensive study. In general, radiologists are only trained to interpret images at a grayscale scale, so they must practice interpreting double-windows-blending algorithms in color images.

V. CONCLUSIONS

Double-windows-blending algorithms have been successfully developed. This algorithm is able to show fracture and bleeding simultaneously in one color image to diagnose the pathology in the patient. This technique can also help the radiologist to differentiate between fat and bleeding with high contrast simultaneously in the color space. However, this method is something new, so it requires the adaptation of expert skills in radiology. Further research is needed to explore the clinical applications of new image representations. In the future, the use of double-windows-blending in color space can be used as an alternative to diagnose patient pathology.

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