Development of a Graphical User Interface Training System for Early Infarct Detection

Chung Sheng Ee, Fung Fung Ting, Kok Swee Sim, and Chih Ping Tso

Abstract—**A graphical user interface (GUI) is developed for early infarcts detection using non-contrast brain computed tomography images. This newly developed GUI is used to train medical practitioners to detect early infarcts within the golden hours (1 to 3 hours). A number of early infarct cases are selected randomly without repetition from the stand-alone database, and brain DICOM images of each selected case are displayed. The user is given a time limit to diagnose the early infarcts locations, with the assistance of windowing technique, colorization method, and 3D modeling method that can enhance the CT images. The performance of the practitioner is determined from the time taken and the marks obtained, after comparing the practitioner's answer with the expert diagnosis.**

Index Terms—**Training system, early infarcts, window settings, colorization.**

I. Introduction

Early infarct refers to acute ischemic stroke. The Internet Stroke Centre (2009) [1] reported that 80% of all strokes are accounted for by ischemic stroke, caused by blood clots from other parts of the body [2] that damages of brain soft tissues. Common imaging modalities for early infarcts detection are computed tomography (CT) and magnetic resonance imaging (MRI). It is hard to determine whether CT scan or MRI is better, as it depends on the case [3]. The Royal College of Radiologists issued guidelines for doctors and stated that CT is often sufficient enough in early infarcts detection, even though MRI has better sensitivity [4]. CT image is chosen as the main material to train practitioner, due to its low cost, wide availability, high reliability and short scan time. It is also sensitive in differentiation of tissues types, even for tissues with slight variation in density [5]. The initial brain scanning technique for acute ischemic stroke is often CT imaging [6], [7].

Digital Imaging and Communications in Medicine (DICOM) is the standard format for all medical images with associated information [8]. DICOM images are 16-bit grayscale images and do not apply any enhancement, image processing, or other techniques that can change the properties of the image. 12-bit of each DICOM images is used for image visualization and the rest 4-bit stores the related medical information [9].

Due to the high dynamic range of DICOM image, it is impossible to read all the details. Therefore, windowing technique is introduced to convert it into grayscale image and display the region of interest (ROI) [10]. This technique rescales each pixel of DICOM image into Hounsfield Unit (HU) which determines the pixels in the form of degree of radiation absorption [11]. Then, a lookup table (LUT) is built according to the window width (WW) and window center (WC). Finally, the system maps the HU to the calculated greyscale unit with the LUT so created.

The setting of imaging modality determines default values of WC and WW, before storing in the DICOM Meta file information [12]. The WC determines the midpoint of the region of interest, while WW determines the maximum number of grey shades to be displayed on the greyscale. Both WC and WW values are selected based on Table I, to visualize the soft tissues of brain, which is the ROI in this study [13]. Therefore, the suitable values chosen for WC and WW are 40HU and 80HU, respectively, as shown in Fig. 1.

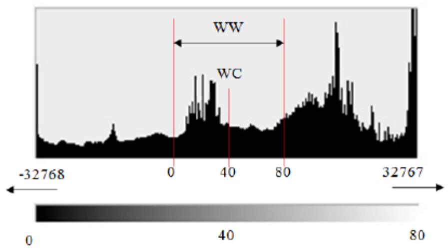


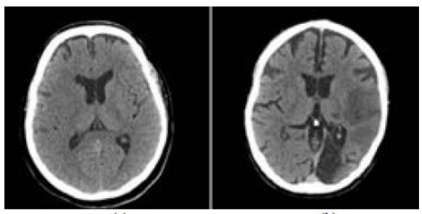
Fig. 1. Region covered by windowing technique in histogram of a 16-bit DICOM image, when WC = 40HU and WW = 80HU.

TABLE I: HU Ranges for Different Types of Brain Soft Tissues

HU Range	*Brain Structure*
0-15	Cerebrospinal fluid
20-30	Early infarct
30-40	White matter
45-55	Grey matter

II. Motivation for the Interface

Fig. 2 shows the brain images of ischemic stroke, taken at different time frame. Fig. 2(a) is an early infarct case and Fig. 2(b) shows a case 7 hours later. Fig. 2(a) shows that early infarcts are subtle in their appearances in brain scan images and those less experienced medical practitioners may miss out such subtle signs. This is because the early infarct regions have low density in first few hours, thus early infarcts have low contrast in the image. Infarct regions have higher density when time taken after stroke is longer, as shown in Fig. 2(b).



(a) (b)

Fig. 2. The difference between the brain images of ischemic stroke, taken at different time frame (a) 2 hours after stroke (b) 7 hours after stroke.

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Early infarcts are known to be subtle in their appearances in brain scan images, and the less experienced may overlook the subtle signs. Even in this modern age, the clinical diagnosis of early infarcts is still dependent on traditional medical diagnosis methods, which include experiences on CT brain images manual interpretation and physical contact with patients. However, the diagnosis is subjected to possible human errors, thereby reducing the effectiveness of these methods. Also, for the new practitioners, the process can be quite long, and it takes years to acquire the necessary experience to process efficiently. Generally, the diagnostic process on CT brain images is affected by the following factors [14]:

- Degree of personal expertise, training, experience, and detailed interests,
- Fatigue of the reader,
- The condition of the medical imaging equipment used, including noise and artefacts effects,
- The quality of technical work, and
- The lack of general rules and protocols, which acts as a standard in the diagnosis.

Hence, it is desirable to design a training system to improve the efficiency and effectiveness of diagnosis.

III. Proposed Solution

The training platform is implemented with windowing technique, colorization method and 3D model method to train and assist practitioners in early infarct detection in brain DICOM images, within the golden period of 1 to 3 hours. The type of brain DICOM images used in this training platform is non-contrast computed tomography (NCCT). There are practice mode and test mode in the training system, but this paper will only focus on the test mode.

Firstly, all practitioners are given an early infarct tutorial before the test. This tutorial includes introduction to early infarcts and process to determine early infarcts. The test begins from Login GUI as shown in Fig. 3. This GUI requires the practitioner to enter his/her name before pressing the start button to initiate the detection training test, or else a message box will pop out to remind the user to key in the name before proceeding further.

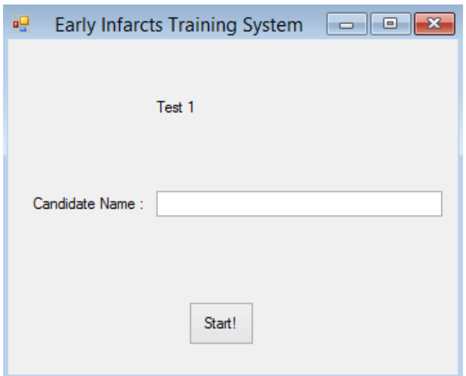


Fig. 3. Login GUI.

Fig. 4(a) shows the main GUI. The name of practitioner entered at login GUI is shown in the name text box. Next, 5 cases and their respective CT brain images folders are randomly selected without repetition and arranged in sequence from a stand-alone database by using the Fisher-Yates shuffle method [15]. Therefore, each practitioner has different cases to work on, even though they are attending the same training. It is possible that some practitioners have one or two similar cases, but they will occur in a different sequence. However, the possibility of this situation is very low, since there are more than 100 cases in the storage.

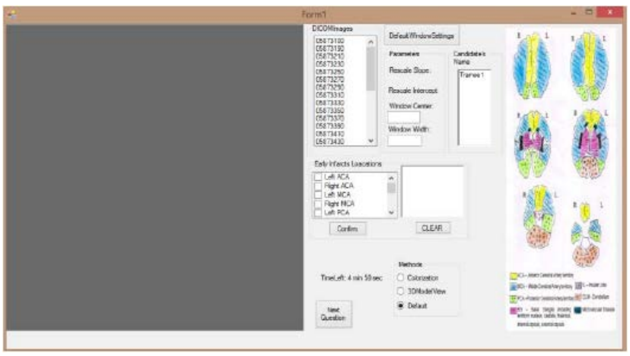
Next, the randomly selected images will be listed in the DICOM image list box, as shown in Fig. 4(b). Any image in the list box can be transferred to the picture box at the left side of GUI in Fig. 4(a). The CT brain image shown is an 8-bit grayscale image after conversion from a 16-bit DICOM image with default windowing parameters. Based on Fig. 4(c), windowing parameters here includes window width and window center. This parameter is adjustable and changes of this parameter will affect the grayscale image shown in picture box. The default window settings can be recovered by clicking on DefaultWindowSettings button, to restore or change the value of window parameters to default values, which are WC = 40HU and WW=80HU.

At this stage, as shown in Fig. 4 (d), the selected brain CT image is initially set to use the default method to process the image, which is conversion of selected DICOM image into grayscale image. Therefore, default radio button in Methods group box is also initially selected by the system, and colorization radio button and 3DmodelView radio button, in order to inform the user about the current method used in processing the selected brain DICOM image.

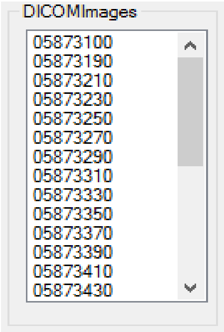
The situation is vice versa when colorization method is chosen by practitioner. The colorization method improves the visibility of early infarct. Firstly, the selected brain CT image is converted into grayscale image based on selected WC and WW values. Then, a color map consisting of 5 colors is created with the same window values as reference. Next, these values are used to create a LUT before colorization with 5 colors according to the range of HU as shown in Table II. A color gradient technique is implemented to produce smooth and clear colors.

TABLE II: Colors Assigned for Different Range of Grayscale Unit, When WC = 40HU, and WW = 80HU

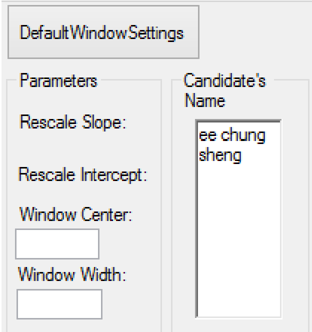
Color	*Grayscale Unit*
Black	Less than 64
Red	64-96
Blue	97-128
Yellow	144-176
White	More than 160



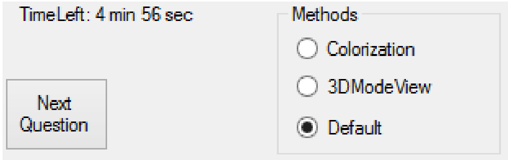
(a)



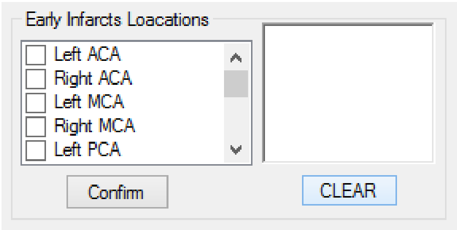
(b)



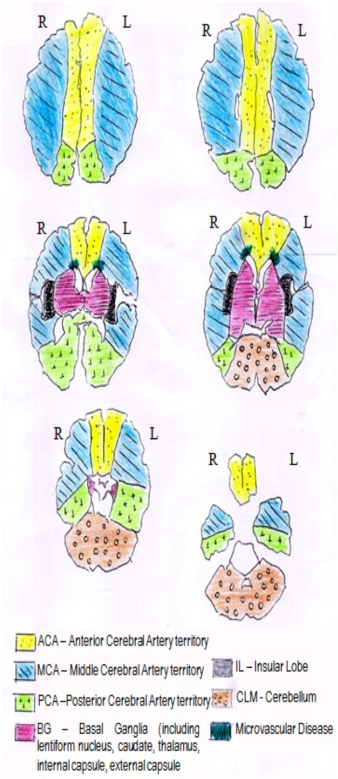
(c)



(d)



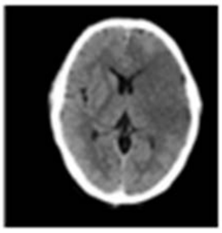
(e)



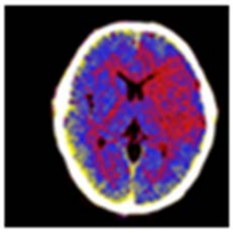
(f)

Fig. 4. (a)Main graphic user interface, (b) DICOM images list box, (c) Window parameter settings (left) and name of candidate box (right), (d) Early infarcts locations identification box, (e) Time limit (left top), next question button (left bottom), and enhancement methods selection box (right), and (f) Brain soft tissue structure reference.

Fig. 5 shows a sample for determining the occurrence of early infarcts using both methods. There are two conditions required to be fulfilled to confirm the existence of early infarcts. First condition is that early infarcts have lower HU than normal brain tissues, as shown in TABLE I, thus early infarcts appear darker using the default method, and appear red after colorization. The second condition is that all dark regions or red regions that appear in the brain CT image may not indicate the existence of early infarcts, but early infarcts may exist within the dark region or red region on either the left brain hemisphere or the right brain hemisphere, which is not symmetrical. After determining the existence of early infarcts, the next step is to assign the location of early infarct.



(a)



(b)

Fig. 5. A slice of brain CT image with early infarct using (a) Default method (b) Colorization method.

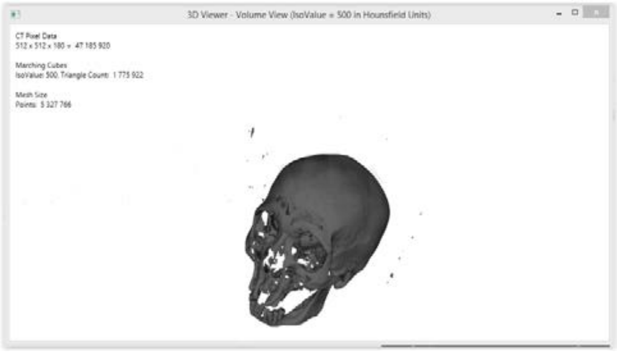
Next method is 3D model function. It builds up a 3D model from selected case. When 3DModelView radio button is selected, all the selected medical images will be combined and form a mesh. That mesh is colored by solid brush function and formed a 3D model from the selected medical images. The system will popped out a new window to show the 3D model built. Practitioner can either rotates or zoom the three dimension (3D) model for better visualization experience. Fig. 6(a) shows the three dimensional (3D) DICOM model window, while Fig.6 (b) shows the attribute section of the 3D viewer which contained patient's CT volume dimension. CT pixel data were calculated by using (1).

$$CT\ Pixel\ Data = Width * Height * No.of\ images \quad (1)$$

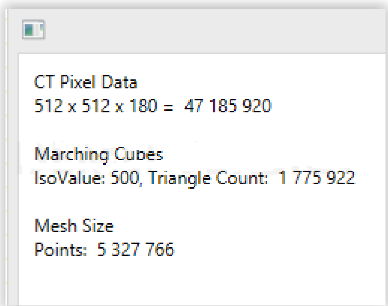
Whereby the Isovalue is measured in Houston units and predetermined by user. According to the marching cubes algorithm, all vertices of the surface mesh will be counted as a point and three points will form a triangle. Thus, the mesh point value is a triple of triangle's value.

This 3D function is based on Viewport3D UI element of Microsoft C Sharp programming language. Inside this UI element, there is ModelVisual3D UI element which inherited from the abstract class Model3D. After the appropriate 3D model environment is set up, a mesh is built up using all triangles. These triangles formed a small surface which calls as facet. Corresponding coordinate of the triangle's vertices are collected from the selected DICOM images. A geometry mesh is formed by using the coordinated information of selected medical images. This mesh is colored using 'Solid Brush' function of C Sharp's model 3D class. The pixel data, total counted triangles and mesh size was shown on the top left corner of the 3D model window.

The Marching Cube algorithm was adapted from Bourke [16]. This algorithm is used for rendering Isosurface in volumetric data and enables the application to map the vertices under the Isosurface to the intersecting edges. By determining which edges of the cube are intersected by the Isosurface, triangular patches created and divided the cube between regions within the surface and regions outside. All patches from all cubes on the Isosurface boundary combined and connected to form a surface representation. This 3D visualization gives better understanding of the patient's condition.



(a)



(b)

Fig. 6. (a) Three-Dimensional (3D) DICOM model window, (b) The attributes of the current volume.

Fig. 4(e) shows there is an Early Infarcts Location group box which provides a list for selection of the early infarct location, based on the brain structure reference of Fig. 4(f). In the reference, there are 6 brain CT slices and they are labeled into 7 territories with different colors. Anterior Cerebral Artery territory (ACA) is coloured with yellow and Middle Cerebral Artery territory (MCA) is blue. Then, Posterior Cerebral Artery territory (PCA) is assigned green, while for Basal Ganglia (BG) area, magenta is used. Basal Ganglia (BG) area includes lentiform nucleus, caudate, thalamus, internal capsule and external capsule. Grey colour area is representing the Insular Lobe (IL) area, while brown is assigned to the area of cerebellum (CLM). Next, microvascular disease is assigned with sea green. At the same time, each of the brain CT slices also determines the area of left brain and right brain. Both settings in this reference structure provide assistance and guidance to identify early infarcts.

After the desired answers are selected from the list, the confirm button is clicked to enter the answers to the rich text box, beside of the list. Additional comments are allowed to be entered into the rich text box too. Clear button can be clicked for erasure all answers. When the user is not satisfied with the current selection, the locations can be re-selected. If no early infarcts are detected, the healthy option in the list can be selected, which will also automatically delete the others answers.

For each case, the allotted answer time is 5 minutes, as shown in Fig. 4(d). If answered within the time limit, the next case button can be clicked to proceed to the next. If the time limit is exceeded, the system will skip to the next case. For both situations, the system stores the answers on the rich text box and the time taken into the database, before proceeding to the next case. The process is repeated until all the cases are exhausted, then a message box is popped out to inform end of test. Then, the user clicks the OK button to close the message box and the main GUI will hide. Finally, the results of the test.is displayed on the screen.

Fig. 7 shows a sample final results of GUI. The data related to this quiz include name of quiz, name of the practitioner, marks gained by the practitioner and time taken for each case. Also displayed are the average mark and average time taken. These data can be stored in the database by clicking the InsertToDatabase button. The practitioner can click the SaveAsWordFile button to save the results as a word file for storage or for printing propose. The calculation on marks is to evaluate the results in terms of the number of correct, wrong, and missed cases. Correct means the diagnosis of the practitioner has the same results as the diagnosis of the expert, and wrong means the practitioner has clicked a region which does not coincide with the expert diagnosis. Missed means the trainee has missed one infarct region. The marks for each case are calculated based on the (2):

$$\text{Marks} = \left(\frac{\text{Correct}}{\text{Correct+Wrong+Missed}}\right) \times \left(\frac{100\text{ marks}}{\text{Number of cases}}\right). \quad (2)$$

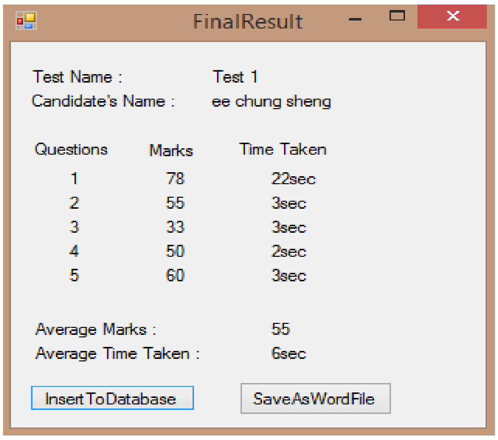


Fig. 4. Final results of GUI.

IV. Concluding Remarks

This paper describes the design of a GUI as a training program, for practitioners with biomedical knowledge, to detect early infarcts. The program aims to improve the accuracy and shorten the time taken by practitioners in the diagnosis process, when compared with the manual interpretation method. To achieve this objective, the windowing technique is used to display ROI of brain area. Then, the colorization method improves on the visibility of early infarcts, while 3D model method provides a better visualization for early infarct locations with the 3D model built. These techniques make the diagnosis procedure easier for the practitioner. After that, the practitioner is given a time limit to make diagnosis with the assistance of a sample brain structure as a reference. The results are recorded in the form of marks and time taken. The developed GUI has great potential to improve the skills of the practitioners.

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