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Detection of Stroke: A Proposed Method

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Abstract
Stroke, also known as a cerebral vascular accident (CVA), is the most common and the most threatening cerebrovascular condition and is one of the main factors contributing to the increase in global mortality. In this paper an approached is proposed for detection of brain stroke.

Keywords: CT Images, MRI, Pre-processing, Segmentation and stroke detection

Introduction
Stroke is a major cause of disability and death worldwide. Although different clinical studies and trials used Magnetic Resonance Imaging (MRI) to examine patterns of change in different imaging modalities (eg: perfusion and diffusion), we still lack a clear and definite answer to the question: "How does an acute ischemic stroke lesion grow?" The inability to distinguish viable and dead tissue in abnormal MR regions in stroke patients weakens the evidence accumulated to answer this question, and relying on static snapshots of patient scans to fill in the spatiotemporal gaps by "thinking/guessing" make it even harder to tackle. Different opposing observations undermine our understanding of ischemic stroke evolution, especially at the acute stage: viable tissue transiting into dead tissue may be clear and intuitive, however, "visibly" dead tissue restoring to full recovery is still unclear.
Stroke constitutes a major urgency and an important problem of public health, characterized by very high morbidity and mortality, disabling sequelae, representing exorbitant costs to the health insurance systems. Worldwide these kill five million people annually, and leave five million more with severe disabilities. The nervous system is made up of over 100 billion neurons which achieve the integration of the organism in the external environment and the coordination of the function of internal organs. Considered the most complex system of the human organism, the nervous system is constituted of an ensemble of organs, made up of nervous tissue, blood vessels and connective tissue [4]. The nervous system is made up of the parenchyma and the stroma. The parenchyma is constituted of the totality of nervous cells. The stroma is made up of glial cells, fine connective tissue and capillaries [5]. The parenchyma is divided into two morphologically and functionally distinct tissue structures - the grey matter and white matter. The grey matter is formed of the neuronal bodies, dendrites, the initial, non- myelinated of axons and neuroglial cells; moreover, there is a rich network of blood vessels, especially capillaries, within the grey matter, which allow an intense oxidative metabolism, specific of neurons. The white matter is made up mainly of parallel myelinated axons, grouped in fascicles and cords. Cerebral arterial vascularization is provided by an anastomotic system made up of the vertebral and the internal carotid arteries, a system situated at the base of the brain in the subarachnoid space. Carotid arteries make up 75 % of the cerebral blood flow. In its trajectory the internal carotid artery presents numerous collateral and terminal offshoots [6]. Terminal branches are represented by: anterior cerebral artery, the middle (sylvian) cerebral artery, the anterior choroidal artery and the posterior communicating artery. The most important ICA branch from a histopathological and clinical point of view is the sylvian or middle cerebral artery (MCA). Vertebral arteries (VA) supply the posterior region of the brain (brainstem, cerebellum and occipital lobe). The two VAs unite on the median line forming the basilar system, from which the pontine, labyrinthine, cerebellum antero-inferior and superior, and posterior cerebral arteries emerge.

Types of Brain Strokes

A stroke occurs when the blood supply to your brain is interrupted or reduced. This deprives your brain of oxygen and nutrients, which can cause your brain cells to die.A stroke may be caused by a blocked artery (ischemic stroke) or the leaking or bursting of a blood vessel (hemorrhagic stroke). Some people may experience only a temporary disruption of blood flow to their brain (transient ischemic attack, or TIA).

Two types of stroke can dramatically disrupt this normality:

Hemorrhagic stroke

Hemorrhagic stroke occurs when a blood vessel in your brain leaks or ruptures. Brain hemorrhages can result from many conditions that affect your blood vessels, including uncontrolled high blood pressure (hypertension), overtreatment with anticoagulants and weak spots in your blood vessel walls (aneurysms).

A less common cause of hemorrhage is the rupture of an abnormal tangle of thin-walled blood vessels (arteriovenous malformation) present at birth. Types of hemorrhagic stroke include:

- **Intracerebral hemorrhage:** In an intracerebral hemorrhage, a blood vessel in the brain bursts and spills into the surrounding brain tissue, damaging brain cells. Brain cells beyond the leak are deprived of blood and also damaged. High blood pressure, trauma, vascular malformations, use of blood-thinning medications and other conditions may cause an intracerebral hemorrhage.
- **Subarachnoid hemorrhage:** In a subarachnoid hemorrhage, an artery on or near the surface of your brain bursts and spills into the space between the surface of your brain and your skull. This bleeding is often signaled by a sudden, severe headache.

A subarachnoid hemorrhage is commonly caused by the bursting of a small sack-shaped or berry-shaped outpouching on an artery known as an aneurysm. After the hemorrhage, the blood vessels in your brain may widen and narrow erratically (vasospasm), causing brain cell damage by further limiting blood flow.

A brain hemorrhage occurs when a cerebral blood vessel bursts and blood leaks into or around brain tissue and causes failure of neuronal function. About 15-20% of strokes are hemorrhagic. High blood pressure stretches a cerebral artery wall and causes it to bleed. This results in blood leaking into the brain tissue (ie. intracerebral hemorrhage) or into the spaces surrounding the brain –eg meninges or cerebrospinal fluid around the brain (ie. subarachnoid hemorrhage). Hemorrhagic strokes account for approximately 20% of all strokes.

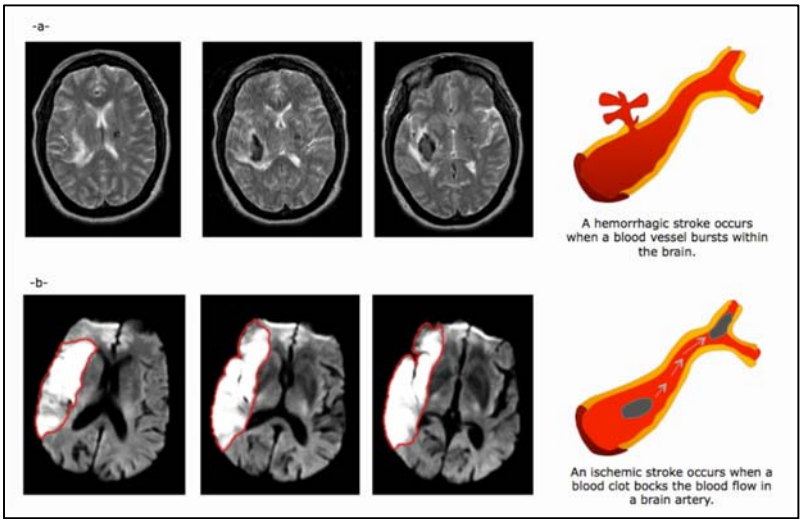

Fig 1: Subtypes of stroke. (a) Three axial slices from a T2-weighted MR brain scan showing a decrease in signal indicating a recent hemorrhagic stroke in the posterior aspect of the right lentiform nucleus. (b) Axial slices showing an ischemic stroke lesion on MR diffusion weighted imaging.

Ischemic Stroke

About 85 percent of strokes are ischemic strokes. Ischemic strokes occur when the arteries to your brain become narrowed or blocked, causing severely reduced blood flow (ischemia). The most common ischemic strokes include:

- **Thrombotic stroke.** A thrombotic stroke occurs when a blood clot (thrombus) forms in one of the arteries that supply blood to your brain. A clot may be caused by fatty deposits (plaque) that build up in arteries and cause reduced blood flow (atherosclerosis) or other artery conditions.
- **Embolic stroke.** An embolic stroke occurs when a blood clot or other debris forms away from your brain — commonly in your heart — and is swept through your bloodstream to lodge in narrower brain arteries. This type of blood clot is called an embolus.

The most recent definition considers the symptomatology to be a stroke either if the clinical symptoms have lasted for more than 24 hours, or if the symptoms remit below this threshold but imagistic show an acute ischemic lesion in concordance with the clinical picture of 5 the ictus [7]. Ischemic stroke is characterized by definitive ischemic suffering of the cerebral parenchyma in an area where regional blood flow drops below 10ml/100g of tissue/min, secondary to partial or total occlusion of an artery or cerebral vein. The factors which increase the risk of an ischemic cerebral vascular accident are numerous. They are

divided into factors which can be modified by treatment and a change in life style and factors which cannot be modified [7].

Factors which can be modified are represented by: hypertension, diabetes mellitus, high blood cholesterol, smoking, excessive consumption of alcohol, obesity, sedentarism, atrial fibrillation, acute myocardial infarction, cardiomyopathies, cardiac valvulopathies, hypercoagulation, the use of contraceptives pills. Factors which cannot be modified are: age, sex, race, family history of cerebrovascular events, personal history of cerebrovascular events. The decrease of cerebral blood flow below 10 ml/100g tissue/min determines the infarction of cerebral parenchyma, the size of the ischemic necrosis area being dependent on the caliber of the obstructed area and the efficiency of collateral circulation (communicant arteries of the Willis circle, extra - intracranial anastomosis, leptomeningeal arteries). In the first 24 hours around the central nucleus of the ischemic necrosis an area of "ischemic penumbra" persists, in which only a functional or metabolic alteration of structures is present, due to the persistence of a 15 - 25 ml/100g tissue/min perfusion ("misery perfusion"). In the peripheral hypoperfusion area cerebral function is maintained, with a regional perfusion of 25 - 80 ml/100g tissue/min [8]. The intracellular influx of water determines the cytotoxic edema, which predominates in the grey matter. Its histopathological basis is the perivascular astrocytes and endothelial cells edema. The collapse of the hematoencephalic barrier with the flow of water and protein macromolecules from the intravascular to the interstitial space determines the vasogenic edema, which includes both grey and white matter. The two processes which result in neuronal death are liquefactive necrosis and apoptosis. Liquefactive necrosis is based on the denaturation of proteins, both structural and enzymatic. The process is the basis of some phenomena through which cells die when their function or role is achieved. The patients with ischemic stroke must have priority access to cerebral imagistic, because time is crucial. Cerebral CT scan, which is generally available, can identify most pathologies which mimic stroke, can distinguish between ischemic and hemorrhagic stroke in the first 5 - 7 days [9-11]. Cerebral CT is highly specific for early identification of ischemic cerebral lesions [12-14].

Computed Tomography (CT) images are widely used to diagnose brain stroke for many reasons, lower cost, sensitiveness to early stroke and non-invasive technique.

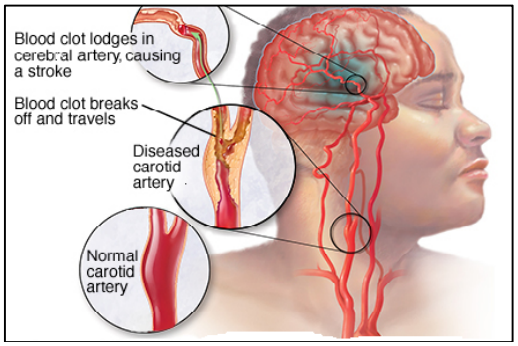

Fig 2: Ischemic stroke

Review Works

Andrius U. *et al*. describes a new method to segment ischemic stroke region on computed tomography (CT) images by utilizing joint features from mean, standard deviation, histogram, and gray-level co-occurrence matrix methods. Presented unsupervised segmentation technique shows ability to segment ischemic stroke region [15-17]. S. Fueanggan, *et al*. resents a new designed program to initially analyze Ischemic Stroke area from Computed Tomography Perfusion (CTP) based on Digital Image Processing Techniques. The new designed software can specify Ischemic Stroke Area by assigning Threshold level of CTP from CBV (Cerebral Blood Volume), CBF (Cerebral Blood Flow) and MTT (Mean Transit Time) images [18-22]. Santichai Fueanggan, *et al*. the objective of this research is to specify Ischemic Stroke Area by using Digital Image Processing principle to analyze Computed Tomography Perfusion (CTP) images from CBV (Cerebral Blood Volume) and CBF (Cerebral Blood Flow) images. By assigning Threshold level of CBV and Threshold level of CBF. results will be shown in N-Match (normal tissue areas), D-Match (dead tissue areas), Mismatch (blood clot tissue areas) and Undefined area. Then, separate the brain into left and right to compare distribution of mismatch and D-Match information in order to specify Ischemic Stroke Area. As a result of experiment, it is possible to sort elementary information of left and right side of the brain to specify Ischemic Stroke Area to compare the results with brain specialists [23]. Ming Sian, Lee, *et al*. in this study propose an Increasing visual perception brain stroke detection system. They used mathematic morphology to extract brain area. Then using median filter to remove noise, and using canny edge detection to find out the edge of the brain tissue, setting peak value in edge histogram as seed to perform region growing. Finally, they can clearly recognize the area of stroke [24-25].

Methodology

MRI can detect minute differences, even between areas that are similar (unlike CT scans, which are useful in imaging bone and soft tissue, but with less detail). MRI can often demonstrate brain abnormalities which are too small or located in regions of the brain that cannot be seen well by CT scans. The main and first process is pre-processing which is used to remove some features and to enhance the quality of image to make the next step easier. The pre-processing is done using weighted median filter for removing high frequency component.

Edge information is often used to determine the boundaries of an object. This is mainly used for analysis to derive similarity criterion for a predetermined object. The incidences of cerebral compression reduce the edge.

Edge detection is the process of finding sharp contrasts in intensities in an image. This process significantly reduces the amount of data in the image, while preserving the most important structural features of that image. Canny Edge Detection is considered to be the ideal edge detection algorithm for images.

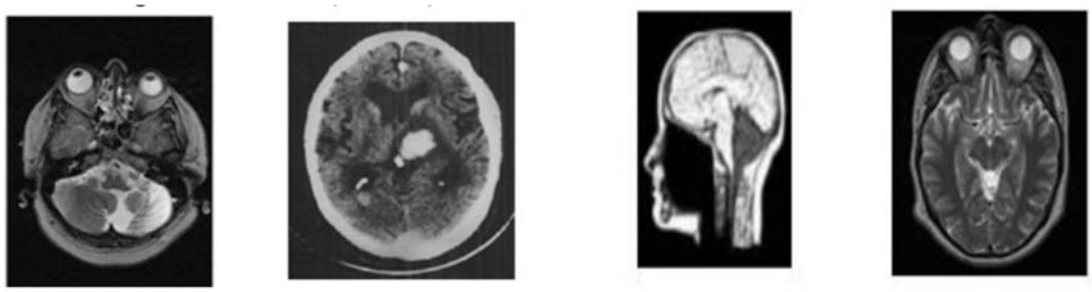

Fig 3: Input Image

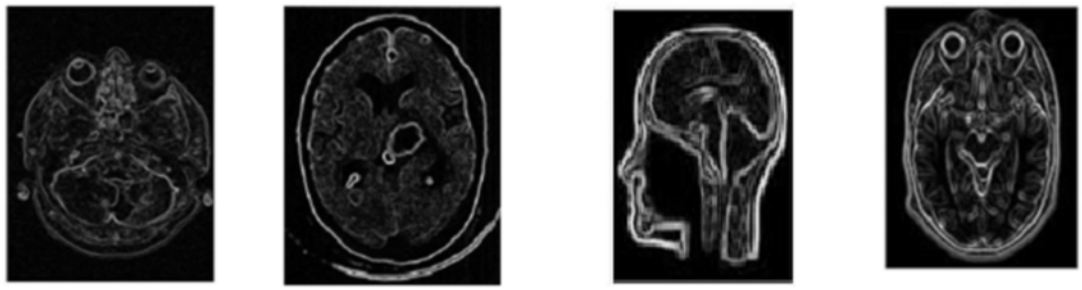

Fig 4: Computing magnitude and edge detection

The next step is to identify and remove those parts of the image that are non-brain tissue, such as the skull, nearby areas, and other areas not affected by the stroke. First, we take advantage of the obvious differences in values between the skull and the brain tissue and use the Otsu method to calculate an optimal threshold value to obtain the most appropriate threshold. We then remove obvious skull images and noise. Next, we use an anisotropic filter for blurring processing, which enables us to reduce noise and increase the brightness.

In the next step we distinguish the gray-white matter interface, which is the most common region for a stroke to occur. To do so, we use brain area segmentation and partition techniques. Professional radiologists know that the CT value of the brain tissue edge around a stroke area slightly differs from that of normal brain tissue. These differences are not easily detected for an inexperienced radiologist. To identify these slight differences, we use edge detection technologies and an unsupervised region growing algorithm to make the differences more obvious. In edge detection, there is a qualitative change in the CT stroke image, so we want to identify the edge of the stroke area. We obtain image edge information by using the canny edge detector to determine the optimal edge detection algorithm. This is an optimal edge detector that achieves good detection, good localization, and minimal response time, making it our method of choice for finding the edge of brain tissue.

Physicians tell us that stroke occurs mostly in either the left or right side of the brain. Medical statistics show that the probability of stroke occurring in both the left and right sides of the brain is under 20%. The average brightness in the stroke area is less than the surrounding areas [26]. Therefore, we calculate the brightness values of all areas for comparison and then identify the positions and color and modify the image to make the possible stroke areas more obvious. By doing so, we can assist physicians to better observe and identify stroke areas and improve diagnostic accuracy.

After partitioning the brain tissue images into eight regions, we next calculate the average brightness for each of the eight partitioned regions. Based on the knowledge that most strokes occur in one side of the brain only, we determine which area of the left or right brain is most likely to have experienced a stroke. To do so, we compare the calculated average brightness values for these eight regions. Finally, to identify regional locations for a stroke, we determine which areas have smaller brightness values by comparing the corresponding left and right side areas of the brain. After identifying four areas with smaller average brightness values, we divide them into three cases according to their different distribution positions. In the first case, the four areas with smaller average brightness values are all on the same side. In this case, we can then determine the presence of a possible stroke area in either the left or right brain tissue from the smaller average brightness values that are identical. The second case has three areas with smaller average brightness values on the same side and one area with a smaller average brightness value on the other side. From the position coincidence results, we then know whether the stroke occurred in the left or the right side of the brain. However, the system must further identify the stroke areas. In discussion with physicians, we learned that CT values between 30 and 36 indicate possible stroke regions. We are also informed that a stroke is more likely to occur in a dark area of the CT image than in the general brain tissue areas shown by the CT. So, we use 30% of the front of the brain tissue and temporarily assign CT values in this tissue as possible stroke area CT values. Next, we compare the colored images with the original images. If the CT value in the original lies within the 30% stroke area value, we mark it in red. If a value is not in this range, we restore the colored area to the original image value. Using this technique, physicians can better determine stroke areas and increase their diagnostic accuracy.

Experiment Results

For CT images, we used the Digital Imaging and Communications in Medicine (DICOM) format. We used an image resolution of 512 × 512, 4-bit color to store the metainformation and 12-bit color to view CT images at the 12-bit grayscale level. One pixel is equivalent to 0.2mm. The results are shown below.

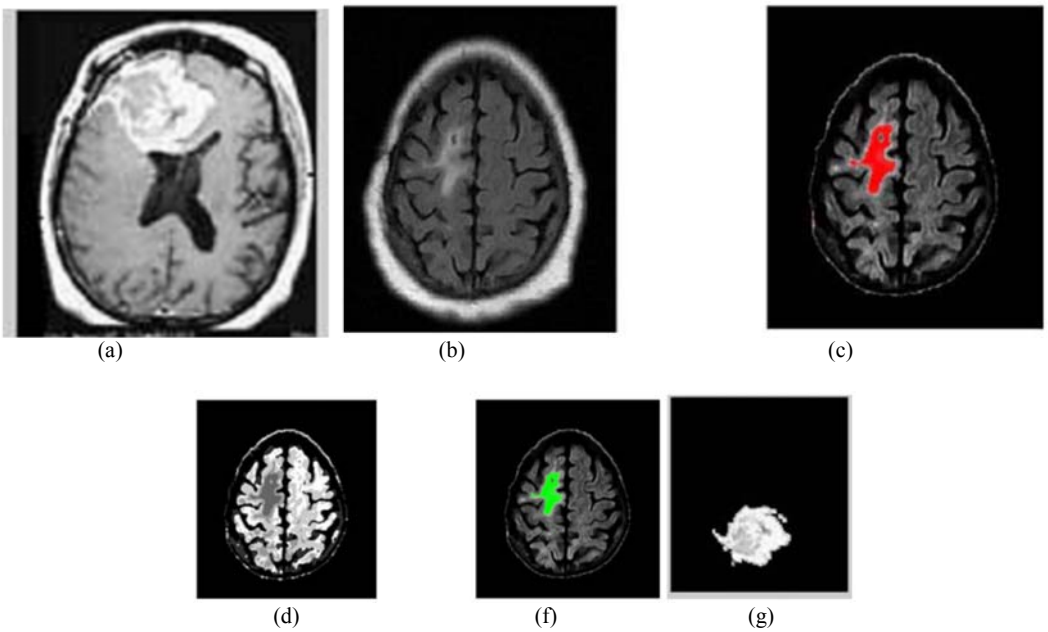

Fig 5(a): Input Image with Noise (b) Segmented Image (c)-(f) Isolated region of Interest (g) Isolated stroke region

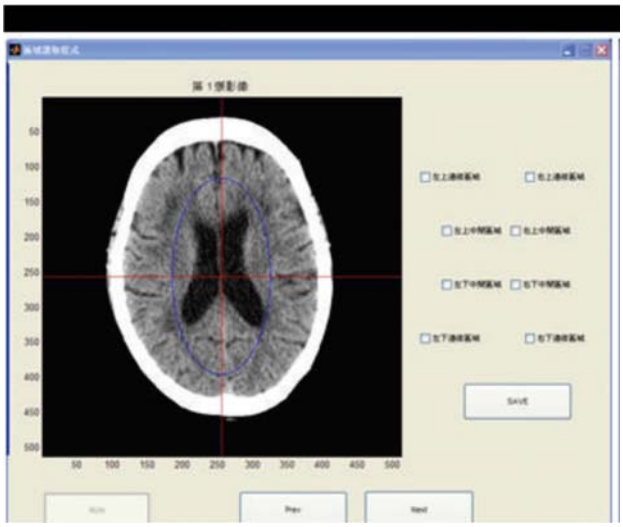

Fig 6: User interface for recording radiologists' assessment based on the original image

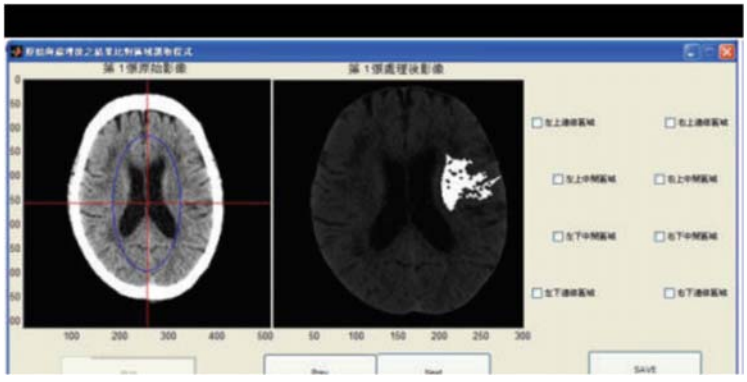

Fig 7: User interface for recording radiologists' decision after seeing the image results of our proposed system

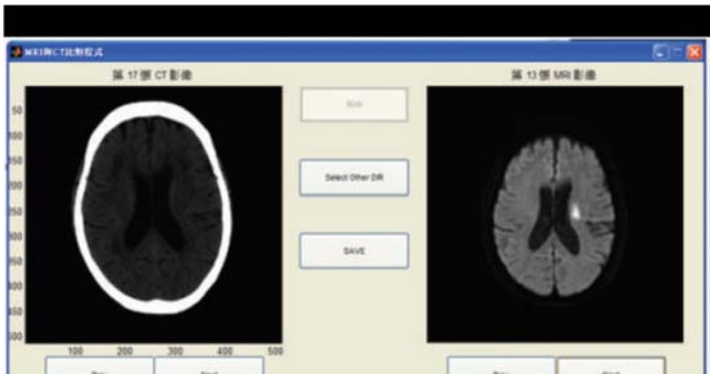

Fig 8: Typical user interface for obtaining an assessment by a professional radiologist. The left side shows a stroke patient CT image and the right side shows the corresponding MRI image of the same patient.

Conclusions

Stroke is the partial blockage of blood vessels in the brain that subsequently leads to brain tissue damage and can cause further brain damage, necrosis, and even death. This paper proposes a stroke detection system through a number steps and finally results show the isolation of stroke portion.

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