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Original Research Article

Automatic brain hemorrhage segmentation and classification algorithm based on weighted grayscale histogram feature in a hierarchical classification structure

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ABSTRACT

Brain hemorrhage is the first cause of death in ages between 15 and 24, and the third after heart diseases and cancers in other ages. Saving the lives of such patients completely depends on detecting the correct location and type of the hemorrhage in an early stage. In this paper, an automatic brain hemorrhage detection and classification algorithm on CT images is proposed. To achieve this purpose, after preprocessing, a modified version of Distance Regularized Level Set Evolution (MDRLSE) is used to detect and separate the hemorrhage regions. Then a perfect set of shape and texture features from each detected hemorrhage region are extracted. Moreover, we define a synthetic feature that is called weighted grayscale histogram feature. In this feature, valuable information from shape, position and area of the hemorrhage are integrated with the grayscale histogram of hemorrhage region. After that a synthetic feature selection algorithm is applied to select the most convenient features. Eventually, the segmented regions are classified into four types of the hemorrhages such as EDH, ICH, SDH and IVH by a hierarchical structure of classification. Our proposed algorithm is evaluated on a perfect set of CT-scan images and obtains the accuracy rate of 96.15%, 95.96% and 94.87% for the segmentation of the EDH, ICH, and SDH types, respectively. Also our proposed classification structure provides the accuracy rate of 92.46% and 94.13% for the first and second classifiers of the hierarchical classification structure for classifying the IVH from normal class and the EDH, ICH and SDH hemorrhage classes, respectively.

1. Introduction

Brain hemorrhage is one of the major threats to the health of human. Several factors can cause the brain hemorrhages such as head trauma, high blood pressure, intracranial tumors. Generally, the brain hemorrhages are divided into five main types such as Epidural Hemorrhage (EDH), Subdural Hemorrhage (SDH), Subarachnoid Hemorrhage (SAH), Intracerebral Hemorrhage (ICH) and Intraventricular Hemorrhage (IVH).

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Usually physicians observe Magnetic Resonance Imaging (MRI) or Computed Tomography (CT) scan images to identify the type and position of hemorrhages. This method has two main problems: it is very time-consuming and the probability of error may increase due to the physicians' carelessness. But, in Computer-Aided Diagnosis (CAD) systems recently the type and position of hemorrhages are determined by the image processing techniques on the CT scan images [1]. These systems have some advantages such as wide availability, good contrast and sensitivity in detecting the hemorrhage [1].

There are only a few studies on segmentation and classification of the brain hemorrhages [2,3]. We can classify the presented brain hemorrhage segmentation and classification algorithms into two main categories:

(1) To segment the brain hemorrhage, the researchers have used different methods such as thresholding [4–7], region growing [8,9], watershed [10], Fuzzy C-means (FCM) [11,12], active contour [9,13,14] and level-set algorithm [15,16]. By using the thresholding technique, each pixel of the hemorrhage is segmented in a region according to the segmentation thresholds [17,18]. This method finds an approximation position of the hemorrhage region. Therefore, for applications which precise position of the hemorrhage region is needed, this method is not recommended. The region growing technique detects a region by identifying the neighboring pixels in the image that have similar grayscales as the starting point. This algorithm is fast to initialize and execute but its segmentation results of the brain hemorrhage is not good. By using the watershed method, an grayscale image is considered as a topographic relief form, where a grayscale of pixel is interpreted as a relief elevation. This method has a running time close to the region growing method but in some cases, because of the image noise and some defects, it leads to an over-segmentation error [10]. The active contours are mathematical models of semi-elastic wires [19]. These methods such as Gradient Vector Flow (GVF) due to high execution time and also difficulty to initialization is not appropriate for the medical application. The level set is a robust implementation method of the active contours that is widely used to segmentation of the medical images but this method is time-consuming and complex due to its need to reinitialization [19].
(2) To determine the types of the brain hemorrhage regions, different studies have been performed by means of K-Nearest Neighbor (KNN) [20], Support Vector Machine (SVM) [21], Multi-layer Perceptron (MLP) [22], decision tree [23] and k-means clustering methods [11]. For example, Liao et al. [16] described a combination method based on the binary level set methods and image pyramids. This method segmented the hemorrhage region with satisfactory results but it was assessed only on the ICH hemorrhages. In another work, Lauric and Frisken [5] used soft segmentation, Bayesian classification, the FCM and Expectation Maximization (EM) methods together. Although those methods were able to segment the brain and Cerebro Spinal Fluid (CSF) in the CT scan images, they were unable to distinguish the gray matter from the white matter. In [11], the histogram-based threshold and k-means clustering algorithm is used to segment the brain hemorrhage. This algorithm had been only evaluated on the EDH hemorrhages.

There are some disadvantages in the most of previous works in the hemorrhage analysis such as (1) the existence of noise and excessive parts such as the skull, brain ventricles and soft tissue edema in the brain CT images, (2) the uncertain position of hemorrhage in some hemorrhage types, (3) the similarity of shape and texture between some hemorrhage types (for example the EDH and SDH occur with the same texture in the same intracranial space), which leads to extract redundant or useless features and consequently to low classification performance, (4) little attention and limited studies of the IVH hemorrhage (a dangerous hemorrhage type) because of its different position relative to other types of the hemorrhage.

Our aim in this paper is to introduce an independent detection and classification method to improve and accelerate the physicians' decision-making process. To overcome the problems of the related works in this field, in the preprocessing step of our algorithm, the noise, skull, brain ventricles and also soft tissue edema are removed. In the segmentation step, we use a modified version of Distance Regularized Level Set Evolution (DRLSE) segmentation method that does not require reinitialization. We initialize its level set function and set its parameters according to our application. In this way, the smallest or even the most uncertain hemorrhages are detected. In the feature extraction step, in addition to the usual features, a set of distinguishable features that consider the hemorrhage region from several important aspects is introduced. To improve the classification performance, an optimal synthetic feature selection algorithm by combining Genetic Algorithm (GA) and Adaboost algorithm are applied.

We evaluate our proposed algorithm on a wide dataset of CT scan images from the EDH, SDH, ICH and IVH hemorrhages. Because, in these types of hemorrhages, the patients' lives entirely depend on their early diagnosis, particularly in ICH hemorrhages, in which the hemorrhage is in the brain tissue.

The rest of this paper is organized as follows. Section 2 explains principles of our proposed segmentation and classification brain hemorrhage algorithm. In Section 3, the experimental results of proposed algorithm are described and reported and finally in Section 4 the conclusions are presented.

2. Proposed segmentation and classification brain hemorrhage algorithm

Block diagram of the proposed segmentation and classification brain hemorrhage algorithm is shown in Fig. 1. In the preprocessing step, the parts that may reduce segmentation performance such as the skull, ventricles of the brain, soft tissue edema and also noise are removed. In this step, by removing the ventricles of brain, the IVH hemorrhage is deleted because this hemorrhage occurs in the brain ventricles. In the next step, the hemorrhage regions (if there is a hemorrhage) are segmented from the CT images by using a modified level set method. But, if no hemorrhage region is detected, the hemorrhage belongs to the IVH hemorrhage or