A Knowledge Discovery Approach to Diagnosing Intracranial Hematomas on Brain CT: Recognition, Measurement and Classification

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Abstract. Computed tomography (CT) of the brain is preferred study on neurological emergencies. Physicians use CT to diagnose various types of intracranial hematomas, including epidural, subdural and intracerebral hematomas according to their locations and shapes. We propose a novel method that can automatically diagnose intracranial hematomas by combining machine vision and knowledge discovery techniques. The skull on the CT slice is located and the depth of each intracranial pixel is labeled. After normalization of the pixel intensities by their depth, the hyperdense area of intracranial hematoma is segmented with multi-resolution thresholding and region-growing. We then apply C4.5 algorithm to construct a decision tree using the features of the segmented hematoma and the diagnoses made by physicians. The algorithm was evaluated on 48 pathological images treated in a single institute. The two discovered rules closely resemble those used by human experts, and are able to make correct diagnoses in all cases.

1 Introduction

Computed tomography (CT) is the imaging modality of choice for unconscious patients in the emergency room, many of them suffered from various type of intracranial hematomas, such as hypertensive intracerebral hemorrhage (ICH), subdural hematomas (SDH) or epidural hematomas (EDH) caused by trauma. These hematomas appear as hyperdense (whiter than the gray level of the brain) areas on CT slices. Compared to magnetic resonance imaging (MRI), CT is faster and can be safely applied to patients with unstable vital signs. Physicians make diagnosis by interpreting the result of CT scan. Although being digital in nature, quantitative evaluation of CT findings has not been standardized until recent 10 years, when it has been incorporated into clinical practice guidelines [1-4].

On the other hand, current textbook descriptions on diagnosis of intracranial hematomas remain qualitative. For example, EDH is described as "a hyperdense biconvex or planoconvex collection along the calvarium" [5]. This kind of expression is not
only far from quantification and standardization, but also difficult to be implemented in decision support systems. Moreover, the extrinsic hematomas (those outside the brain itself), namely EDH and SDH, located just between the isodense brain and the hyperdense skull, have CT numbers just between the brain and the skull. This makes segmentation of these two types of hematomas very difficult by applying thresholding alone. As a result, there has not been any published work focusing on automated segmentation of EDH or SDH, according to our knowledge. Evaluation of the interface between the brain and the skull, or the epidural/subdural space, has also been excluded in earlier rule-based labeling of brain CT images [6].

The goal of this paper is to develop an algorithm that can successfully recognize all types of hyperdense hematomas (ICH, SDH, and EDH). In addition to localization, we also hope to label the long and short axes of these hematomas and to discover rules that can distinguish one type of hematoma from another. Since the spatial resolution within each slice of a routine non-volumetric brain CT is far better than that between slices, we only consider planimetry on the slice containing the largest area of hematoma rather than volumetry to minimize errors caused by partial volume effect [5].

2 Materials and Methods

2.1 Materials

From July 2003 to June 2004, 86 consecutive patients were admitted to the intensive care unit (ICU) of Taipei Hospital, Department of Health. Forty-eight of them have significant hyperdense intracranial hematoma, including 26 ICHs, 16 SDHs and 6 EDHs. We define significant hematomas as ICH larger than 0.6cm$^2$ in size and EDH/SDH thicker than 0.4cm. These criteria are far smaller than the indications for surgical treatment [1-4]. Therefore, no hematoma requiring surgical removal would be missed. Hypodense (blacker than the gray level of the brain) or isodense hematomas are excluded because they cannot be separated from the brain by gray level criteria alone. All brain CT scans were done with a standard protocol. The field of view (FOV) was 25×25cm. Each image was 512×512 pixels in size, resulting in a resolution of 0.49mm per pixel. The original CT number was transformed with brain window (center 40, width 150) into 256 gray levels. The CT slice containing the largest area of hematoma is picked out by one of the human experts (CCL) and downloaded to a personal computer in JPEG format. We are currently developing algorithms that can automatically select the most pertinent pathological slice from the whole set of CT slices.

2.2 Preprocessing

The flowchart of our algorithm is shown in Fig. 1. The gray level of pixel (x,y) in the original CT slice is denoted as $G_0(x,y)$ in the range between 0 and 255. The coordinates satisfy $0\leq x\leq 511, 0\leq y\leq 511$. We strip the extracranial part of $G_0(x,y)$ to produce $G_S(x,y)$, containing only the skull and the intracranial pixels. We then perform a depth-dependent gray level normalization for $G_S(x,y)$ to produce $G_1(x,y)$, the image on which hematoma recognition, measurement, and classification will be done.