Automated computer-aided decision support for traumatic pelvic and abdominal injuries

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Advanced image-processing and machine-learning methods automatically detect fractures, segment hemorrhages, and classify outcomes.

Traumatic pelvic and abdominal injuries are severe yet common events, frequently caused by motor-vehicle accidents or falls. Extensive bleeding is typical of pelvic fracture and is especially prevalent in high-energy fractures. Hemorrhage remains the major cause of death that occurs within the first 24 hours after these types of injuries. Consequently, the ability to quickly determine potential sources of bleeding is critical for proper diagnosis and treatment planning. Information contained in computed tomography (CT) images of the pelvis is particularly important for assessing the severity and prognosis of injuries. However, each pelvic CT scan includes many slices, each of which contains numerous pixels that are difficult to analyze thoroughly, accurately, and quickly by human visual inspection. Here, a computer-assisted pelvic or abdominal trauma decision-support system can greatly assist caregivers in making fast and accurate diagnostic decisions.

Pelvic bone segmentation (extracting bones from the CT image) is a vital step in analyzing pelvic and abdominal scans. However, very few studies have focused on pelvic fracture and hemorrhage detection. Some of these employed manual or semiautomated methods to segment bones, whereas other studies failed to capture all the bone information. We have developed a hierarchical segmentation algorithm (see Figure 1) that automatically extracts multiple-level bone structures by applying computational techniques that incorporate known anatomical information.

We begin by building models of the pelvic bone based on segment structures from consecutive 2D CT slices. We then apply a hierarchical algorithm based on wavelet transformation, adaptive windowing, boundary tracing, and masking to analyze all bones for fractures. If a fracture is detected, quantitative measurements—such as the length of the gap between the two pieces of the fractured bone ($d$, shown in Figure 1)—are automatically performed and reported. Results suggest that the method is capable of detecting both major and minor fractures.

The proposed system also detects arteries using the segmented bone information along with the best template match (i.e., Visible Human Project pelvic CT images) to locate arteries and extract gray-level information about them in the pelvic and abdominal regions. The system locates the source of the hemorrhage using a novel rule-based segmentation approach based on hemorrhage matching, rule optimization, and region growing (a technique for enlarging a region). The position and volume of hemorrhage are then determined to analyze severity. Figure 2 shows a sample hemorrhage detection (both

Figure 1. Computed tomography (CT) images showing detection and measurement of the gap between two pieces of a fractured bone (a) using a measure ‘$d$’ (b). (Images courtesy of Charles Cockrell and Yang Tang at the Radiology Department at Virginia Commonwealth University and the Virginia Commonwealth University Medical Center.)

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Figure 2. Hemorrhage marked in (a) is detected by the automated algorithm as shown in (b). (CT images courtesy of Charles Cockrell and Yang Tang at the Radiology Department at Virginia Commonwealth University and the Virginia Commonwealth University Medical Center.)

location and entire hemorrhage region) from a CT slice. Successful segmentation results—in other words, detecting the hemorrhage region exclusive of soft tissue and bone—indicate the effectiveness and robustness of our proposed algorithm. Our method also stacks up favorably against other approaches, such as ‘Snake’-based techniques.8

An important advantage of this fracture-detection system is automatic classification of the outcome (e.g., the expected number of days a patient will need to remain in the intensive care unit predicted at the time of admission) using features extracted from the medical images as well as patient medical records and demographics. We use a multistage feature-selection algorithm to select the predominant features and boosted logistic model trees to classify the outcome. We have achieved outcome prediction accuracy, specificity, and sensitivity of ~85%.

In summary, a new system tested on CT images of patients with traumatic pelvic injuries suggests that automatically detecting fracture, segmenting hemorrhages, and classifying outcomes is possible. As a next step, we plan to expand the system to incorporate additional images, physiologic biosignals (e.g., electrocardiogram), laboratory information, and demographics. Such an approach could be of significant value to health-care providers and patients by reducing missed injuries and enabling improved decision making earlier in the treatment process.

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