Automatic determination of scan angle and range for brain CT

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Purpose

Computed tomography (CT) of the brain is the screening examination of choice for many acute neurologic presentations [1, 2].

In general, based on the orbitomeatal (OM) line [3, 4], the scan range and angle are determined. Therefore correct and reproducible identification of the OM line is important for comparative diagnosis between current and previous study in the same patient.

However, the OM lines determined by CT operators often fluctuate, because identifying the line on scout image, which is 2-dimensional X-ray projection image, is not easy (is subjective).

Figure 1 on page 2 shows pre-operation (a, b) and two-month-post-operation brain images (c, d) of the same patient scanned by different operators. This difference made the comparative diagnosis difficult for a radiologist.

The purpose of our study was to propose a method which automatically determines the scan angle and range on the scout images.

Images for this section:
Fig. 1: Pre-operation (a, b) and two-month-post-operation (c, d) brain images of the same patient scanned by different operators. White lines indicate OM-lines set up by the operators. (a, c): scout images. (b, d): axial non-contrast CT images of fourth ventricle level.
Methods and Materials

The study protocol was approved by the local ethics committee and informed consent was obtained from all patients.

**CT images**

Brain CT images of 30 patients (18 men, 12 women; mean age 59.2 years, range 17 to 81 years), including after the operation of the cerebral aneurysm clipping and coiling cases and the brain tumor cases, are used. The scan parameters were the following.

- Tube voltage: 120 kV
- Rotation speed: 2.0 seconds
- Beam pitch: 0.562
- Scan field of view (SFOV) and display field of view (DFOV): 250mm
- Slice thickness: 5.0 mm
- Detector configuration: 0.625 x 16
- Reconstruction filter algorithm: Standard
- Noise index of automatic exposure control: 3.0 HU
- The CT scanner: 16 slice CT

These images were processed by a computer algorithm we developed for the automatic scan range and angle determination. The results were statistically analyzed and compared with actual determination results by the CT operators.

**Outline of image processing**

Figure 1 on page 6 shows an outline of the image processing procedure using the new algorithm. 200 × 512 pixels images clipped from original scout images were used for the image processing. After the noise filtering using median filter with a 3 × 3 kernel, Hough transformation conversion for the angle determination and cross-correlation technique for the scan range determination were applied to the images.

**Methods of the scan angle detection (angle of the OM line)**
Figure 2 on page 6 shows procedure of the scan angle detection.

We determined the OM line angle by utilizing an angular difference between the OM line and the supra orbitomeatal line (SOM line) [4], which is mostly constant in each skull.

Since the SOM line is almost parallel with a skull base line, the OM line angle can be determined by identifying the skull base line which can be easily detected by image processing due to its high contrast edge.

We measured the angular difference between the OM line and the SOM line by using the volume rendering images of 30 cases as shown in figure 3 on page 7.

As shown in figure 2 on page 6, the skull base line was detected from subtraction image of longitudinal detection image and lateral detection image. Then, the skull base line angle was calculated by Hough transformation.

Methods of detection of the scan range

In our scan protocol, the posterior cranial fossa is used as the scan start position. Because the distance of skull base line and posterior cranial fossa is almost constant, the start position is determined by the detected skull base line and the distance. In advance, the averaged distance was measured from ray-sum images of 30 clinical cases manually as shown in figure 4 on page 8.

Figure 5 on page 9 shows detection procedure of the scan end position. The scan end position was detected by a template matching method.

Verification of results of determined scan angle and range

1. We compared the OM line angles determined by our proposed methods with true values. The true values were obtained by manual measurement using multi planar reconstruction (MPR) reconstructed from the thin slice images.
2. We compared the OM plane images of pre- and post-operation of the patient in figure 6 on page 10, which are created by MPR technique using the automatically determined angles.
3. The five radiological technologists (RTs) who had not been given any information about the patients evaluated the validity of the scan angles and ranges automatically determined. The validity was graded on the following four-level scale:

Grade A: Both range and angle were acceptable.
Grade B: Angle was acceptable, but range was needed amendment.

Grade C: Range was acceptable, but angle was needed amendment.

Grade D: Both were not acceptable.

Images for this section:

Fig. 1: Outline of the image processing for the scout image in our proposed method.
Fig. 2: Procedure of detecting the skull base line and its angle. We used the skull base line for determining the OM line angle because the skull base line had a high contrast and can be easily detected by image processing.
**Fig. 3**: Method of measurement of the angular difference between the SOM-line and the OM-line. We averaged the measured angular difference of 30 cases. In a result, the value was $10.2 \pm 0.9$ degrees.
**Fig. 4:** The scan start position (posterior cranial fossa position) is positioned at a constant distance from detected skull base line. In advance, we measured the constant value by using ray-sum images of 30 cases manually. The scan start position was determined by subtracting the mean value from detected skull base line position.
**Fig. 5:** Procedure of detecting parietal position. The template image was hemicyle with 9.5-cm diameter and two pixel width. The parietal position was detected at a position that indicated the maximum cross-correlation values.
Fig. 6: Pre-operation (a, b) and two-month-post-operation (c, d) brain images of the same patient scanned by different operators. White lines indicate OM-lines set up by the operators. (a, c): scout images. (b, d): axial non-contrast CT images of fourth ventricle level.
Results

Angular difference between the SOM line and the skull base line

The averaged of angular difference of 30 clinical cases was 10.2±0.9 degrees.

Distance of skull base line and posterior cranial fossa position

The averaged distance between the skull base line and the posterior cranial fossa of 30 cases was 19.3±2.8 mm.

Detection of the skull base line and parietal

Figure 1 on page 13 shows three examples of detection results for the skull base line (solid lines) and parietal (arrows). As shown in figure 1b on page 13, we could accurately detect the skull base line despite of metal shadows of clips and bone fixation devices. In this case, the median filter in the pre-processing was effective to reduce bad effect of metal shadows. As for figure 1c on page 13, an adverse effect of a platinum coil for intervention therapy of brain aneurysm on the Hough transformation was effectively reduced by the subtraction technique in pre-processing.

Verification of results

1. Figure 2 on page 13 shows five examples of the results of the OM line angle and true values. The difference between them ranged 0 - 2 degree. The average difference of 30 images was 0.1±1.7 degree.
2. Figure 3 on page 14 shows a comparison of the OM-plane and fourth-ventricle level MPR images for pre- and post-operation brain images. The slice levels and angles of pre- and post-operation showed approximate coincidence respectively.
3. Figure 4 on page 15 shows the results of evaluated grade by five RTs. Results of the 28 cases (93%) were evaluated as acceptable.

Miss-detection cases

Figure 5 on page 16 shows two cases given the D-grade scores. In one case (figure 5a on page 16), the highlighted edge of Anbu bag caused a bad influence on correct detection. In another case (figure 5b on page 16), the patient's jaw was extremely elevated. For this case, the miss-detection will be avoided by a pre-processing such as scout image rotation utilizing head shapes.
Fig. 1: Figure shows three examples of detection results of the skull base line (solid lines) and parietal (arrows) for (a) a screening case, (b) an after-clipping case and (c) an after-endovascular coiling case. All of these cases were given the A-grade scores.
Fig. 2: Comparison of scan angles determined by our proposed method and true values.

<table>
<thead>
<tr>
<th>Scout Image No.</th>
<th>Our method</th>
<th>True value</th>
<th>Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Image 1</td>
<td>-3.0°</td>
<td>-2.0°</td>
<td>1.0°</td>
</tr>
<tr>
<td>Image 2</td>
<td>4.0°</td>
<td>4.0°</td>
<td>0.0°</td>
</tr>
<tr>
<td>Image 3</td>
<td>2.0°</td>
<td>4.0°</td>
<td>2.0°</td>
</tr>
<tr>
<td>Image 4</td>
<td>6.0°</td>
<td>5.0°</td>
<td>1.0°</td>
</tr>
<tr>
<td>Image 5</td>
<td>11.0°</td>
<td>10.0°</td>
<td>1.0°</td>
</tr>
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</table>

Average of all images 0.1±1.7°
**Fig. 3:** Comparison of the OM-plane and fourth-ventricle level MPR images for pre- and post-operation brain images, which were reconstructed using angles determined by our method. The slice levels and angles of pre- and post-operation showed approximate coincidence respectively. (a, b): pre-operation. (c, d): post-operation.
Fig. 4: Results of visual evaluation by five radiological technologists (RTs). RTs visually evaluated the clinical scout images on which the automatically determined scan angles and ranges were displayed.

<table>
<thead>
<tr>
<th>Grade</th>
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<th>RT 4</th>
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<tr>
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</table>
**Fig. 5:** Figure shows two cases (miss-detection cases) given the D-grade scores. In (a) one case, the highlighted edge of Anbu bag caused a bad influence on correct detection. In (b) another case, the patient jaw was extremely elevated.
Conclusion

We developed a method which automatically determines the scan angle and range of brain CT by analyzing the head scout images. For the 30 clinical cases, the accuracy of the determined scan angle was 0.1±1.7 degrees, and the determined scan ranges were evaluated as "acceptable" by five RTs in 93% of the cases we examined. It was suggested that the miss-detection cases (two cases) will be resolved by simple improvements of our algorithm.

Our proposed method indicated an accurate and reproducible performance for the automatic scan angle and range determinations of the brain CT. Therefore, this method will be useful for correct comparative diagnosis and improvement of image quality in brain CT.

References


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