A Modification to Otsu's Thresholding Method for ICV Segmentation

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Abstract

A modification is made to Otsu's thresholding method. It provides better results for ICV (Intracranial volume) segmentation on one kind of T2-weighted MRI data.

Keywords

Thresholding, Segmentation, Otsu Method,

Introduction

In our neurology software packages, for ICV (Intracranial volume) calculations, Otsu's thresholding method is used as the first step to separate tissues from the background. For data collected using our protocols, the threshold derived from Otsu's thresholding method provides poor segmentation results in about half of the cases. To adjust the threshold, we propose a modification to this method. Tests show that in most cases, the adjusted threshold derived from the modified method is better suitable and the final ICV results are more accurate.

Method

Let h(i) be the histogram of an Image data set of range N.

(1.1) $h(i),\ 0 \le i < N,$

Histogram (or grayscale) thresholding segmentation attempts to find a threshold T that divides image data into two groups, one with intensity less than T, and the other with intensity larger than or equal to T.

A function,

(1.2) $c(t),\ 0 < t < N,$

is said to be the target function of a thresholding method if it reaches the maximum at t=T.

We introduce a set of thresholding target functions with a parameter ω (ω>=0), as

(1.3) $c_{\omega}(t) = [p_1(t)p_2(t)] \cdot |m_1(t) - m_2(t)|^{\omega}, 0<t<N,$

where

(1.4) $h'(i) = h(i) / \Sigma_{0<=j<N} h(j)$, for $0<=i<N$;

(1.5) $p_1(t) = \Sigma_{0<=i<=t} h'(i)$, for $0<t<N$;

(1.6) $p_2(t) = \Sigma_{t<i<N} h'(i)$, for $0<t<N$;

(1.7) $m_1(t) = \Sigma_{0<=i<=t} i \cdot h'(i) / p_1(t)$, for $0<t<N$;

(1.8) $m_2(t) = \Sigma_{t<i<N} i \cdot h'(i) / p_2(t)$, for $0<t<N$;

Particularly, when $\omega = 0$, we have

(1.9) $c_0(t) = p_1(t)p_2(t)$, $0<t<N$;

$c_0(t)$ maximizes at $p_1(t) = p_2(t)$. When ω towards ∞, we have

(1.10) $c_{\infty}(t) = |m_1(t) - m_2(t)|$, $0<t<N$;

$c_{\infty}(t)$ maximizes the distance between $m_1(t)$ and $m_2(t)$. When $\omega = 2$, we have

(1.11) $c_2(t) = [p_1(t)p_2(t)] \cdot [m_1(t) - m_2(t)]^2$, $0<t<N$;

$c_2(t)$ is the target function of Otsu's thresholding method, and it maximizes the inter-class variance [1].

Generally speaking, the first part of the target function $c_{\omega}(t)$, $[p_1(t)p_2(t)]$, reflects the criteria of "evenness" where the threshold will tend to produce groups of equal mass. While the second part of the function, $|m_1(t) - m_2(t)|$, reflects the criteria of "separation" where the groups will tend to be widely spaced. The parameter, ω, is a weighting factor between the two criteria. Let T_{ω} be the threshold derived based on target function $c_{\omega}(t)$. When ω varies from 0 to 2, T_{ω} varies from T_0 to T_2.

Implementations

The proposed algorithm is a modification to two files distributed within the ITK package ([2] Section 9.1.2). The adjustment is made to introduce the variable w.

(I) itkOtsuThresholdImageCalculator.h

Current:

    Line-74   void Compute(void);

Modified:

    Line-74   void Compute(double w = 2.0);

(II) itkOtsuThresholdImageCalculator.txx

Current:

    Line-48 ::Compute(void)

Modified:

    Line-48 ::Compute(double w)

Current:

    Line-127 and Line-148   vnl_math_sqr(meanLeft - meanRight);

Modified:

    Line-127 and Line-148   pow(fabs(meanLeft - meanRight), w);

Note: In the code, actually, for each j, $0 < j < N$,

meanLeft = $m_1(j) + 1$, and meanRight = $m_2(j) + 1$; but meanLeft – meanRight = $m_1(j) – m_2(j)$;

Results

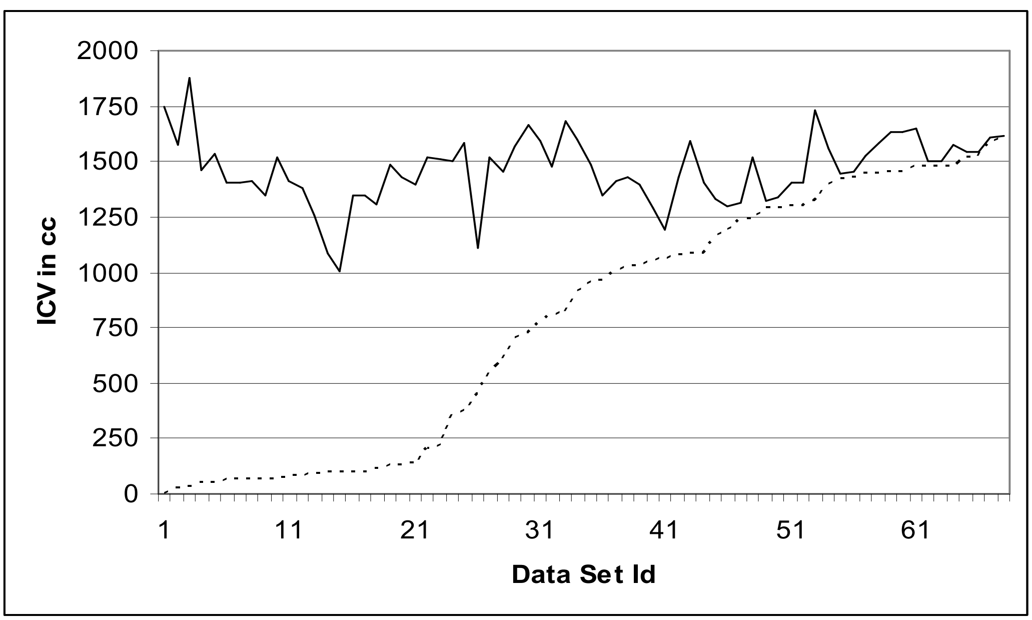
We did some tests on T2-weighted MRI image data collected under our protocols. The final ICV results with ω=1.5 are compared with those with ω=2.0 (Otsu's method). For majority of those 68 data sets tested, ICV calculation with ω=1.5 is clearly more accurate than that with ω=2.0.

Fig. 1 ICV plot.

Solid line: ICV with ω=1.5; (Mean: 1463, Std: 153)

Dashed line: ICV with ω=2.0; (Mean: 780, Std: 569)

Note: Data sets are sorted based on ICV (ω=2.0) for clarity



A slice of the data set labeled id = 33 is shown in Fig 2.2. This is a typical 256x256x57 8-bit T2-weighted MRI image data set. Its voxel size is 1.0x1.0x3.0 mm^3. When Otsu's method (ω=2.0) is applied to the data, the threshold derived is T=41 resulting in an ICV=820cc. While the modified version with ω=1.5 is applied to the data, the threshold derived is T=31 resulting an ICV=1682cc.

Fig.2.1 The histogram of the data

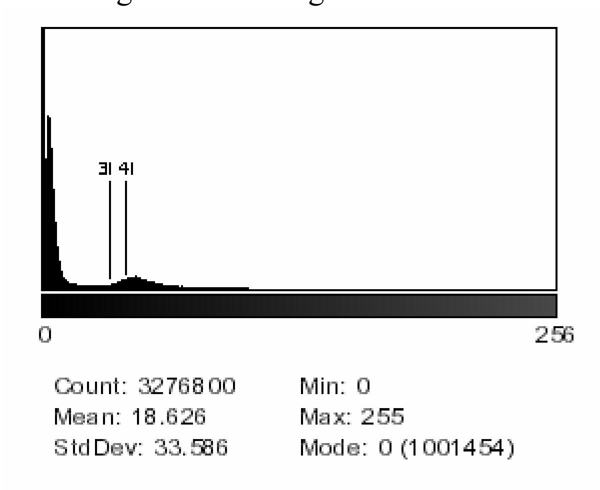


Fig.2.2 A slice of the data

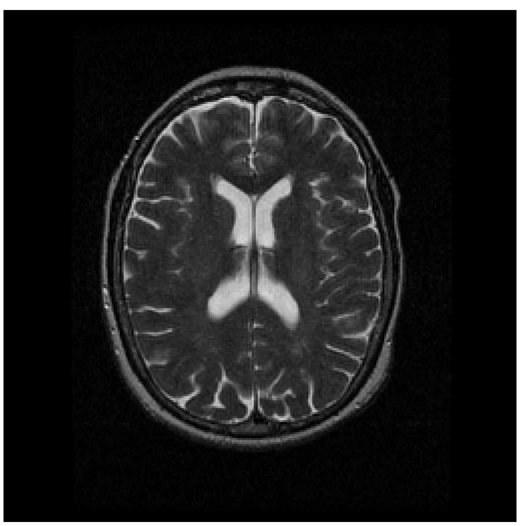


Fig.2.3 The slice with Pixels of intensity between 31 and 41 marked in red

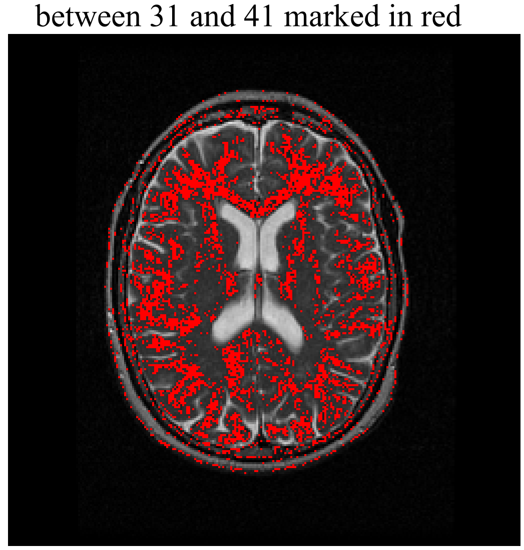


Fig.2.4 The slice blended with final segmented ICV mask (ω=2.0, T=41)

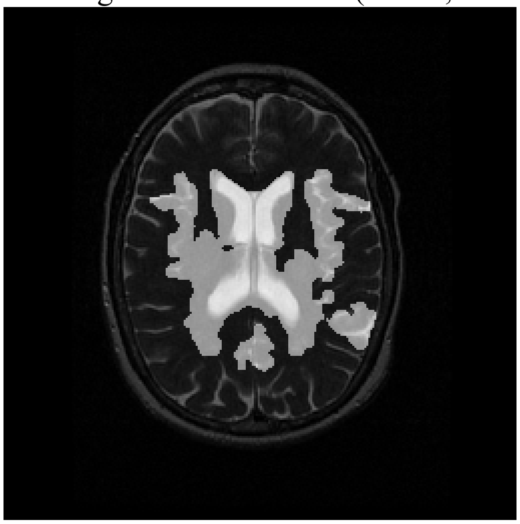
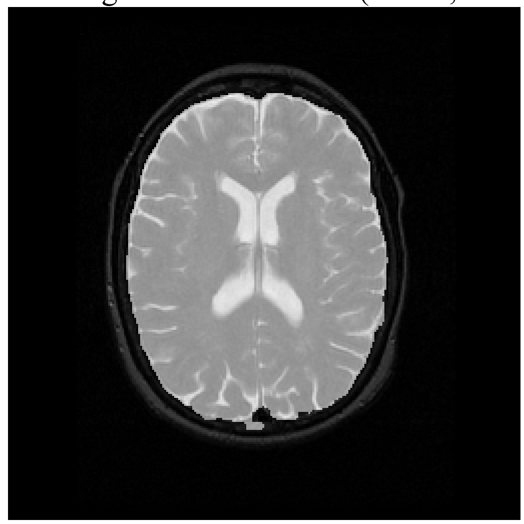


Fig.2.5 The slice blended with final segmented ICV mask (ω=1.5, T=31)



Conclusions

When Otsu's thresholding method is used for MRI neurology data ICV segmentation, our tests show that a modified version of Otsu's thresholding method, with target function (1.3) and parameter ω=1.5, provides better results.

References

[1] N.Otsu, "A Threshold Selection Method from Gray-Level Histogram," *IEEE Trans. Systems, Man, and Cybernetics,* vol. 9, pp. 62-66, 1979.

[2] Luis Ibanez, Will Schroeder, Lydia Ng, Josh Cates, "The ITK Software Guide", May 7, 2005.