Interpolation Algorithm Research for Medical Image Registration

Jing-yu Li, Ya-na Liu, Li-guo Hao, Wei-bin Mu

Abstract

Owing to its property of applying multi-modality imaging information into the clinical usage has the Medical Image Registration been the research focus. The gray nearest neighbor interpolation and bilinear interpolation and cubic convolution interpolation method is used for medical image interpolation algorithm. It compares the characteristics of the three gray interpolations. Combined with the characteristics of the above algorithm is proposed based on gray-scale pixel intensity interpolation. The algorithm can be improved in the time and registration accuracy. It combined with the improved optimization algorithm in the proposed image registration of the simulation experiment, experimental precision subpixel image to verify the validity of the method.

Keywords: medical image registration; gray interpolation; optimization

1. Introduction

Gradation level interpolation technology main solution picture element gradation level evaluation question, after had determined reference image and fluctuation image space correlation in space parameter that needs to the matching image in the picture element gradation level evaluation, the realization evaluation method to have the forward mapping and the reverse mapping two big kinds. As the image in the computer is digital, the pixel value is only defined in the integer coordinates, the use of forward mapping method will have two major problems. First, the registration image may have some pixel assignment; the second is the original image of multiple pixels may be mapped to the same pixel of the registration image at the same time. Reverse mapping is usually easier to implement than forward mapping, so reverse mapping is generally used for the registration.

2. Commonly Used Gray Interpolation Method

2.1 Nearest neighbor interpolation

The most close neighbor interpolation realization method is: The matching image picture element obtains on primitive image floating point coordinates through the reverse mapping, carries on to it rounds up takes entire, obtains an integer coordinates correspondence picture element value is the matching image correspondence picture element picture element value

\(^1\)Dept. of Medical and Technologe Institute, Qiqihaer Medical University, Qiqihaer Heilongjiang 161006, China
while also is takes the point correspondence picture element value which the primitive image floating point coordinates most are close to bestow on for the matching image. In the image matching gradation level interpolation process that needs to process the frontier point frequently the question. Out point refers to the reverse mapping point beyond the original image regions, such as the geometry transform, reverse mapping point coordinates negative. For not in the original point, can it directly to the pixel value unified set to a fixed value (such as for gray image is set to 0 or 255, or black and white) or its grey value is equal to and its adjacent and mapping points in the original image pixel gray value.

2.2 Bilinear Interpolation Method

Bilinear interpolation method assumes that the interpolation point \( p \) by four points in the area of gray level change is linear, which can use linear interpolation method, according to four neighboring pixel gray value and calculate the grey value of interpolation point \( p \). Suppose that the floating image has a floating point coordinate on the reference image by inverse mapping is \( (i + \Delta x, j + \Delta y) \), where the \( I, j \) are the positive integers, \( \Delta x, \Delta y \) are the pure decimal belonging to the \([0, 1]\), then, we can get the following formula.

\[
f(i + \Delta x, j + \Delta y) = (1 - \Delta x)(1 - \Delta y)f(i, y) + \Delta x(1 - \Delta y)f(i, j + 1) + (1 - \Delta x)\Delta yf(i + 1, j) + \Delta x\Delta yf(i + 1, j + 1)
\]

(1)

2.3 Cubic convolution interpolation

The cubic convolution interpolation method calculates the weighted average value according to the gray value of the 16 pixels in the surrounding area of the inverse transformation point \( p \) according to a certain weighting coefficient to interpolate the gray value of the inverse transformation point. Suppose that the floating image has a floating point coordinate on the reference image by inverse mapping is \( (i + u, j + v) \), where the \( I, j \) are positive integers, \( u, v \) are the pure decimal belonging to the \([0, 1]\), then we can get the following formulas.

\[
f(i + u, j + v) = A \ast B \ast C
\]

(2)

\[
A = s(1 + v)s(v)s(1 - v)s(2 - v)
\]

(3)

\[
B = \begin{bmatrix}
  f(i - 1, j - 1) & f(i - 1, j) & f(i - 1, j + 1) & f(i - 1, j + 2) \\
  f(i, j - 1) & f(i, j) & f(i, j + 1) & f(i, j + 2) \\
  f(i + 1, j - 1) & f(i + 1, j) & f(i + 1, j + 1) & f(i + 1, j + 2) \\
  f(i + 2, j - 1) & f(i + 2, j) & f(i + 2, j + 1) & f(i + 2, j + 2)
\end{bmatrix}
\]

(4)

\[
C = \begin{bmatrix}
  s(1 + u) \\
  s(u) \\
  s(1 - u) \\
  s(2 - u)
\end{bmatrix}
\]

(5)

Where the \( s(w) \) represents the interpolation weighting function which can be expressed as follows.
2.4 Algorithm improvement and modification

Based on the above reasons, the image to grayscale, we can see the image brightness distribution of pixels. Pixel brightness absolute error of the image interpolation algorithm is to use a coordinate point after the brightness of the pixel value and the pixel value of the previous coordinates of the difference between the brightness and the pixel value of the previous coordinates of the brightness ratio to determine the application of the nearest neighbor Interpolation, or bi-cubic interpolation of a new image interpolation algorithm. Assuming that the brightness of the pixel at the \((i, j)\)-th point is \(L(i, j)\), the reading and storing of the image are performed sequentially from the bottom to the right of the image, so the previous point is \((i, j-1)\), the luminance of the pixel at the point \((i, j-1)\) is \(L(i, j-1)\), the difference of the two points is

\[
M = L(i, j) - L(i, j-1)
\]

with an absolute error of \(\lambda = \frac{|M|}{L(i, j-1)}\).

Set a critical value \(d\), the general value of 0.02-0.05, if \(\lambda \leq d\), indicating that the two points of the pixel brightness change is not obvious at this time using the nearest neighbor interpolation. If \(\lambda > d\), that the two points of the pixel brightness changes more obvious, this time using bi-cubic interpolation algorithm.

<table>
<thead>
<tr>
<th>Interpolation method</th>
<th>Time (s)</th>
<th>MI Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nearest-neighbor interpolation method</td>
<td>0.033</td>
<td>1.143</td>
</tr>
<tr>
<td>Bilinear interpolation method</td>
<td>0.065</td>
<td>1.256</td>
</tr>
<tr>
<td>Cubic convolution interpolation</td>
<td>0.291</td>
<td>1.271</td>
</tr>
<tr>
<td>Improved interpolation method</td>
<td>0.041</td>
<td>1.261</td>
</tr>
</tbody>
</table>

Table 1. Rotation 45 degrees time comparison table.
The obtained empirical datum analysis one may see from the matching result and the matching process: In the precision aspect, the improvement interpolation algorithm matching obtained MI value which this article uses must be smaller than the cubic convolution interpolation, surpasses other two methods; In the operation time aspect and this interpolation algorithm operation time approaches in the most close neighbor interpolation algorithm time, is smaller than obviously other two kind of interpolation algorithm time. From this one sees this algorithm is in by the precision receiving in exchange for operation time achieves one kind of operation time and precision intercoordinations.

3. Revised Powell Algorithm

In conjugate-based algorithms, it is important to keep n search directions linearly independent. However, in the basic Powell algorithm cannot guarantee the search direction of the linear independent, especially when the variable is very much the case even more so. In order to overcome these problems, an improved Powell algorithm is proposed.

Improvement Powell algorithm and basic Powell algorithm thought basic same, the difference mainly lies in the replace direction the rule to be different. In the basic Powell algorithm, each time can unconditionally replace the original search direction with the new search direction; But in improvement Powell algorithm, when replace search direction can consider the linear independence question. Improvement Powell algorithm, when initial search direction linear independence, can guarantee in each turn iteration sends the search direction for a row determinant is not a zero, therefore these directions are linear independent. Moreover along
with the iterative increase, the search direction conjugate degree strengthens gradually. The improvement Powell algorithm realization is as follows.

(1) The allowable error is given as $\epsilon > 0$. Starting point $x^{(0)}$ and $n$ linearly independent direction $d^{(1,1)}, d^{(1,2)}, \cdots, d^{(1,n)}$, and set the $k=1$.

(2) Set the $x^{(k,0)} = x^{(k-1)}$, start from the $x^{(k,0)}$, following the directions $d^{(k,1)}, d^{(k,2)}, \cdots, d^{(k,n)}$ to conduct the one-dimensional search, and get the $x^{(k,1)}, x^{(k,2)}, \cdots, x^{(k,n)}$. Calculate the $m$ and make the $f(x^{(k,m)}) - f(x^{(k,n)}) = \max_{j \in \{1, \ldots, n\}} [f(x^{(k,j-1)}) - f(x^{(k,j)})]$, set the $d^{(k+1,m)} = x^{(k,m)} - x^{(k,0)}$, and if $\|x^{(k)} - x^{(k-1)}\| < \epsilon$, stop the calculation or step to the procedure 3.

(3) Calculate the $\lambda_{m1}$ while making the $f(x^{(k,0)} + \lambda_{m1} d^{(k,m+1)}) = \min_{j} f(x^{(k,0)} + \lambda_{m1} d^{(k+1,j)})$, and set the $x^{(k+1,0)} = x^{(k,0)} + \lambda_{m1} d^{(k,m+1)}$. If the $\|x^{(k)} - x^{(k-1)}\| < \epsilon$, stop the calculation, or step to the procedure 4.

(4) If the $\left| \frac{f(x^{(k,0)}) - f(x^{(k+1,0)})}{f(x^{(k,m-1)}) - f(x^{(k,n)})} \right|^2$, make the $d^{(k+1,j)} = d^{(k,j)}, j = 1, \cdots, m-1$; $d^{(k+1,j)} = d^{(k+1,j)}, j = m, \cdots, n$; $k = k + 1$. Or $d^{(k+1,j)} = d^{(k,j)}, j = 1, \cdots, n$; $k = k + 1$ and step to procedure 2.

4. Experimental Analysis

4.1 Registration experiment

Figure 6 is in the map storage simulation brain database, then establishes the image array type as non-mark trueing 16. Then carries on the outline extraction with the Canny operator algorithm to the image the operation, the extraction and most greatly mutually the information matching plan and again benefits the interpolation algorithm and the improvement Powell algorithm which this article improves carries on the optimum value the search operation. Finally acts according to the optimum value angle which in the Powell algorithm obtains that carries on angle revolving to the image and completes the entire image the matching. Set the rigid transformation parameters $T=[\theta, tx, ty]$, where the $tx$, $ty$ are the translation of the floating image in $x, y$ direction (in pixels), $\theta$ is the rotation angle around the coordinate origin (in degrees).

Figure 6. MRI image (reference image). Figure 7. MRI image (float image).
Table 2. The registration results of several registration criteria.

<table>
<thead>
<tr>
<th>Image registration method</th>
<th>Registration results $T={\theta, tx, ty}$</th>
<th>Angle error (degree)</th>
<th>Time/s</th>
<th>Iteration time</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.026, 25.41, 34.86</td>
<td>0.025</td>
<td>33.67</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>0.034, 32.58, 29.45</td>
<td>0.034</td>
<td>65.48</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>0.079,43.16, 35.71</td>
<td>0.079</td>
<td>295.45</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>0.052, 38.69, 30.14</td>
<td>0.052</td>
<td>60.40</td>
<td>4</td>
</tr>
</tbody>
</table>

Methods: 1 = Interpolation method 2 = Nearest -neighbor interpolation method.
3 = Cubic convolution interpolation. 4 = Improved interpolation method.

4.2 Experimental results and analysis

The registration results and the analysis of the experimental data obtained in the process of registration as can be seen: in terms of accuracy, in this paper based on improved grey interpolation and improved Powell algorithm of the registration error is small, thus the accuracy of this algorithm is very high, reached the best effect of registration. In terms of operation time, the interpolation method in the process of image registration and improved Powell operation time of the bilinear interpolation algorithm is close to the time, much smaller than using cubic convolution interpolation algorithm of time, so as to improve the precision and velocity of registration.

5. Conclusion

This article proposed one kind of improvement image interpolation algorithm and improvement optimized algorithm Powell unifies the image matching method, this algorithm in has under the same time order of complexity premise, not only has completed the real-time interpolation and the better picture quality, and retained the primitive image detail information and the clear edge well, also obtained the very good effect in the vision, also must surpass other traditional interpolation algorithm obviously. Through the above experimental results and data analysis, we can see that in the image registration process using this algorithm, the image accuracy to sub-pixel level and improve the efficiency of registration, to achieve a good registration effect.

Acknowledgement

This research is financially supported by the Heilongjiang Provincial Department of Education Science and Technology Research Project (NO. 12511625).

References


