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Smoothness Processing of Infrared Image Based on AMSS

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Abstract—**The Infrared images have been applied in clinical diagnoses, but the images are noisy and blurred. Therefore the smooth processing that can keep edges is needed. Traditional smoothing methods have the common defect that they smooth not only the noise region but also the edges. AMSS (affine morphological scale space) algorithm can be used to better save the edge information, it has the Partial Differential Equation that is of morphological affine invariability and contrast invariability. The smooth processing method based on AMSS is introduced to handle the infrared image in this paper, and the better performance is obtained.**

I. Introduction

THE application of infrared image in clinical medicine can measure the spatial and temporal temperature of the body by precisely record the temperature changes of the body surface. As a non-invasive functional examination technology, it has the advantage of easy to use, it can image instinctively, and it is very sensitive with low cost [1].

The characteristics of pathological changes in most medical image could become hard to be identified due to the noise; it is especially serious in the infrared image. Because of the influences of thermal balance and other organization's thermal circulation inside the body, the infrared image has a strong spatial specification, low contrast and blurred visual effect, and with the interference of the external sources the image becomes uneven. Moreover, because of the low sensitivity of the thermal camera and high amplifications in the imaging process, the collected infrared image usually contains a great deal of noise, which is one of the most essential factors influencing the image quality. When the difference of decay coefficient between pathological organs and normal organs is subtle, we can not distinguish the focus which we are interested on the noisy infrared image. The medical diagnosis drives its conclusion from the difference between the normal or abnormal information, therefore the correctness of diagnosis is determined by the quality of images, and the high-quality infrared image is the pre-requisite towards accurate diagnosis. Hence noise reduction is the major aim [2]. Mostly the traditional denoise methods, such as median filter and mean filter [3], filter away the high frequency of the image. Since the detail and edge are also the high frequency components, the edge is always blurred at the same time.

In fact, digital image can be recognized as a function space that is composed of a special function $R^2 \to R$, which takes the piecewise continuous function to approach the true signal in the image with the edge of images as boundary and restrain a random noise among them [4]. In this paper, in the view of geometrical invariability and affine invariability we studied their differential property and introduced a partial differential equation AMSS (affine morphological scale space) [5], we tested it in the infrared image processing.

II. Methods

A. The Partial Differential Property of Geometrical Invariable Morphologic Algorithm

Let

$$H[\alpha] = T[x_1 + \alpha x_2^2](0) \tag{1}$$

where, T is the image transformation function which can transform one image u into another image Tu. Here, H is monotonous if the function T is monotonous [6]. Define

$$T_h[x] = hT[x] = hH[0] \tag{2}$$

$$T_h[x_1 + \alpha x_2^2](0) = hT[x_1 + h\alpha x_2^2](0) = hH[\alpha h] \tag{3}$$

and let D (0, M) be a circle centered at 0 with radius of M.

Let ψ is the bounded subset of R^2 ($\forall B \in \psi$, $B \in D(0,M)$), and it is isotropic ($\forall B \in \psi$, $RB \in \psi$, if R is a reserving distance transformation) [7], then

$$Tu(x) = \inf_{B\in\psi} \sup_{y\in x+B} u(y) \ \ (\text{or } Tu(x) = \sup_{B\in\psi} \inf_{y\in x+B} u(y))$$

and the related transformation with parameter t is as follows

$$T_h u(x) = \inf_{B\in h\psi} \sup_{y\in x+B} u(y) \ \ (\text{or } T_h u(x) = \sup_{B\in h\psi} \inf_{y\in x+B} u(y)).$$

Suppose $H(0) = T[x](0) = 0$, for every C^3 function u in R^2, and for every compact set $K \subset \{x, Du(x) \neq 0\}$,

$$T_h u(x) = u(x) + h\left|Du(x)\right| H\left(\frac{1}{2}hcur(u)\right) + Ox(h^3) \tag{4}$$

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where $D(u)$ is a differential operator, $\left|O_x(h^3)\right| \le C_k h^3$, the constant C_k depends on u and K, and

$$cur(u)(x) = \frac{u_{xx}u_y^2 - 2u_x u_y u_{xy} + u_{yy}u_x^2}{(u_x^2 + u_y^2)^{3/2}} \quad (5)$$

The conclusion of the function (4) is significant [8], it indicates the differential property of isotropic morphology operator, and for T_h we have: let $h \to 0$, $n \to \infty$, and $nh^2 = t$, then $u(t,x) = \lim_{h\to 0, n\to\infty} T_{hu_0}^n$ is the solution at the time of t of the initial value partial differential equation $\begin{cases} \frac{\partial u}{\partial t} = \left|Du(x)\right| g(tcur(u)) \\ u(0,x) = u_0(x) \end{cases}$, where g is a monotonous function.

B. The Partial Differential Property of Affine Invariable Morphologic Algorithm

For arbitray affine transformation *Aff*, if $Aff \circ T = T \circ Aff$ exists, then morphologic operator T is called to be affine. That means, for $\forall u, x$, it exists $Aff(Tu(x)) = T(Aff(u(x)))$, where, $Aff(u(x)) = u(Aff(x))$. Then every shift morphologic operator has the property of the following equation [9],

$$Tu(x) = \sup_{B\in\psi} \inf_{y\in x+B} u(y) \quad (6)$$

By adding a local parameter h into equation (6) we can construct the following equation

$$IS_h u(x) = \sup_{B\in h\psi} \inf_{y\in x+B} u(y) \quad (7)$$

where, $h\psi = \{hB, B \in \psi\}$.

Suppose the image transformation IS_h has the form of equation (7), there exists a constant c, $\forall \rho > \frac{1}{c}$, which satisfies that, if $\forall B \in \psi$, then $\exists B' \in \psi$, $B' \subset D(0,\rho)$ and $B' \subset \left\{x, d(x,B) \le \frac{c}{\rho}\right\}$. Furthermore, suppose image function u is C^3 in the neighborhood of x, then $\lim_{h\to 0} \frac{(IS_h u)(x) - u(x)}{h^{4/3}} = C_\psi \left|Du\right| (cur(u))^{1/3}(x)$ if $\left|Du(x)\right| \ne 0$, where C_ψ is the constant depending on ψ only. When the differential characteristic of an image is known, we can obtain the specific differential equation through the localized and iterative method. Let $h \to 0$, $n \to \infty$, $s = h^{\frac{3}{2}}$ and $nh^2 = t$, then $u(t,x) = \lim_{h\to 0, n\to\infty, nh^2 = t} (IS_s)^n u_0$ is the solution of the following equation with the initial value at the time of t

$$\frac{\partial u}{\partial t} = \left|Du\right| (curv(u))^{1/3} \quad (8)$$

The initial value at the time point zero is our original image $u_0(x)$, the solution of this equation at the time point t will be the filtered result of $u_0(x)$, and can be approximately written as

$$u_t = u_0 + t\left|Du\right| (curv(u))^{1/3} \quad (9)$$

The filter operation satisfies the affine invariability and contrast invariability, and is called as AMSS operator. The iterative process can be looked as a nonlinear filtering process. While it is applied to the smooth processing of infrared image, it better reserves the edge information.

III. Experiments and Results

An infrared grey image of a face is tested. The infrared camera for collecting image is ThermoVision TM A40-M in FLIR Systems. The environmental temperature was holding to be 25^{o}C, and there were no other illuminations. The infrared image was collected from a normal male, 25 years old. The original gray infrared image is shown in Fig. 1, and the grey value curves with the coordinates of y=247 is shown in Fig. 2. The different algorithms were applied and compared, and MATLAB was used for programming the algorithms.

Fig. 1 Original grey infrared image

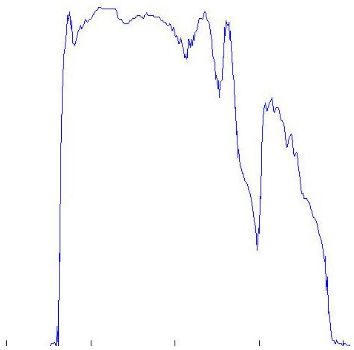

Fig. 2 The grey value curve of original infrared image (y=247)

The results of average filter and median filter with 5×5 template are shown in Fig. 3 and Fig. 4, respectively. From Fig. 3 and Fig. 4, we can see that visually the edges are blurred with contrast lost. The result using weight filter is shown in Fig. 5. We can see although the edge of the smoothed image is better reserved, it caused some noise. Fig. 6 shows the smoothed image of AMSS filter, which smoothed the image but reserved the edge information at the same time.

To demonstrate the effect of various smoothing algorithms, we show the grey value curves with the coordinates y=247 after different smoothing process in Fig. 7 to Fig. 10, respectively. We can see AMSS is of the better performance in several aspects. First, by comparing the burrs in the curve, we can evaluate how the noises are smoothed effectively, we can see that the curve of Fig. 9 brings some burrs obviously. Second, we need to reserve the sharpness of the curve, we can see that the wave crests of the curve of Fig. 7 and Fig. 8 are over cut and the wave troughs are over filled as well. It instructs the loss of the edge information in the image. In contrast to the traditional filter, AMSS operator got a much better result, as shown in Fig. 10.

Fig. 3 Smoothed image using average filter

Fig. 4 Smoothed image using median filter with template 5×5

Fig. 5 Smoothed image using weight filter

Fig. 6 Smoothed image using AMSS filter

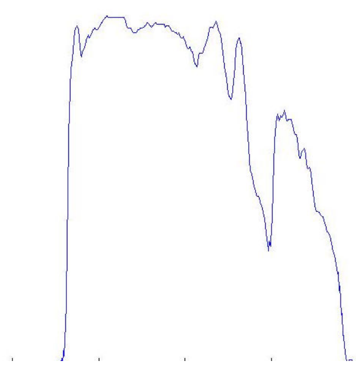

Fig. 7 The grey value curve of smoothed image using average filter (y=247)

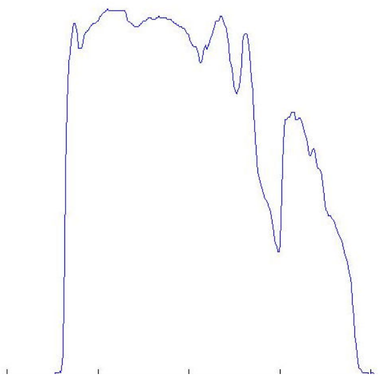

Fig. 8 The grey value curve of 5×5 template image via median filter(y=247)

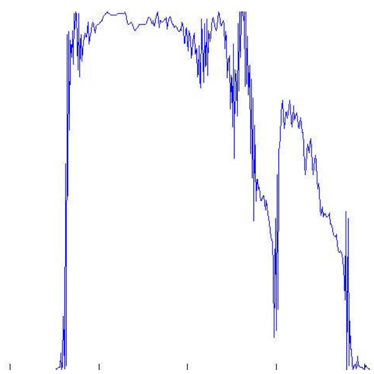

Fig. 9 The grey value curve of smoothed image using weight filter (y=247)

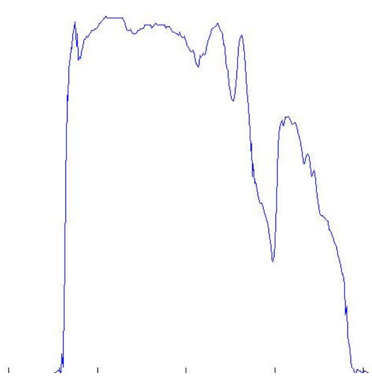

Fig. 10 The grey value curve of smoothed image using AMSS filter (y=247)

IV. CONCLUSION AND DISCUSSION

The traditional filter is built on the statistical model, while the AMSS filter is built on the morphological characteristics of partial differential equation. From the results we can see that the method based on AMSS operator with an advantage which the traditional algorithm does not have. It can better reserve the edge information of the image at the same time of smoothing noises.

In the process of smoothing, the parameter of the partial differential equation and the selection of time t can greatly influence the effect of the smoothed result. In further work, some optimization methods will be studied to select a preferable parameter of the partial differential equation and time t in order to improve the AMSS algorithm.

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