The Application in Edge Detection of Medical Image Based on the Improved B-spline Wavelet Transform

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Abstract: *The edge information of a medical image is the basis of the analysis and processing of that medical image. The medical image contains the muscle, blood vessels and other interference information, which is large but leads the edge detection to become very difficult. So the research into an image edge detection algorithm has become one of the key technologies in image processing, and has important significance in the field of practical application. A new edge detection algorithm based on wavelet transform is proposed in this paper on the basis of regression analysis. Firstly, the signal is decomposed into approximate part and detailed part by the wavelet transform. Secondly, the wavelet coefficients of the detailed part are influenced by the threshold. Finally, the regression function of the signal is obtained by reconstructing wavelet coefficients. The experimental results show that the signal-noise ratio of the improved algorithm is clearly higher than the original, and it is helpful for improving the regression accuracy in terms of the wavelet transform. The algorithm can effectively remove noise, and the local feature of the signals is fully retained.*

Keywords: *Wavelet transform, Medical image, Edge detection, B-spline.*

Introduction

In recent years, with the development of computer vision technology, the accuracy of disease diagnosis in clinical medicine has correspondingly increased. 3D medical images can provide accurate parameters and pathological data for doctors, and are the basis of computer aided diagnosis. The edge detection of a medical image is the first step of 3D reconstruction, which can extract the edge of the image accurately and quickly, so it is a widespread current research topic with many scholars [1, 9, 19, 20]. The edge detection operator uses the classical edge detection algorithm. Common edge detection operators include the Roberts operator, Prewitt operator, Sobel operator, Canny operator and others. These are based on the derivative of the edge operator, which is the convolution of the original image and 2×2 or 3×3 convolution operator, and then the appropriate threshold as the basis for the extraction of the edge is selected. The Roberts operator is the partial derivative function of ∞ and y by a 2×2 template. Its advantage is its fast detection speed, and simple algorithm, but it is easy to lose detail and is sensitive to noise. The Prewitt operator is the partial derivative function of x and y by a 3×3 template. The advantage of this algorithm is simple and directional, but the detection is not accurate and has too many break points.

Marr et al. [12] propose an LOG operator to smooth the image by using a Gauss filter. The calculation of two order derivative Laplace operator is used to smooth the image, and reduce the impact of noise on the Laplace derivative effectively, but the detection direction of the LOG operator is not good. The Canny operator is also used to smooth the image by the Gauss filter [4]. The difference from the LOG operator is that the non-maximum suppression of the gradient amplitude is calculated after smoothing the images and computing the gradient values by the Canny operator. The image edges are determined by double threshold detection [16]. The Canny operator is an optimal operator with filtering, enhancement and detection functions. It has the advantages of high accuracy and a low false positive rate, but its computational complexity is high, and it is sensitive to noise.

The wavelet transform in image edge detection has attracted the wide attention of scholars, because of its accurate locating and noise suppression ability [6]. In 1992, Mallat and Wang [11] used the two order B-spline wavelet transform to realize multi-scale edge detection, which laid the foundation for the wavelet edge detection. Lu and Wang [8] proposed a multi-scale edge detection algorithm based on two B-spline wavelet, which can effectively smooth and suppress pseudo edges. Wang et al. [18] reconstructed a multi-scale similarity matrix according to the multi-resolution characteristics of the wavelet. The computational speed of the operation is fast, and the edge extraction accuracy is high.

Aiming at an X-ray chest image, it contains vague information, and the edge detection shows a weak performance. A new edge-detection algorithm based on improved B-spline wavelet transform is proposed. In this paper, we propose a 3 B-spline wavelet as the basic wavelet, and introduce the character of multi-scale analysis of the wavelet. The experimental results show that the improved algorithm obtains a better edge image, which synthesizes the characters in each scale. It keeps more original image edges, and decreases the false edges and noises in quantity. In particular, the edge detection results are clear by using the improved algorithm. It is convenient for medical diagnoses and subsequent processing. It is preferable to the original algorithms and has more application value.

Introduction of edge detection algorithm

The edge is one of the most basic features of the image; it is the dividing line between the object and the background. The most significant part of the variation of the local brightness of the image is the reflection of the boundary between the contour of the object and the different surfaces of the object [5]. The formation of the edge is due to the different objects of the material or the different surfaces, which causes the edge of the image in the presence of light, color, texture changes. Therefore, the border of the edge can be obtained by checking the different gray, color and other characteristics of the region in the image [10].

The Definition of edge detection

The detection of an object in an image can be set up as a maximization problem using a separability measure as the objective function [2]. The edge means the end of an area and the beginning of another region, which generally exists between the target and the background. If a pixel falls on the boundary of an object in the image, then its neighborhood will have a gray level. The magnitude and direction of the edge can be expressed by the gradient vector. The edge reflects the difference of the characteristics of the local area, which is the most important feature of the image segmentation, and also has the important information about the texture feature. In the quantized digital image, the edge of the image is not continuous, and the most important feature is the discontinuity of the gray level of the adjacent pixels. Compared to the image itself, the data is much less than the image itself, so it is convenient to quantify and compare. It is suitable for detecting and locating the object position in the image, and it can also reveal the important characteristics of the object. The purpose of edge detection is to detect the discontinuity of the gray level in the image, and determine the exact location of the image in the image at the same time.

Edge detection is a very fundamental research area in image analysis and measurement. The results of the detection affect the accuracy of the subsequent processing and the degree of difficulty directly. Because of the complexity of the natural scenery and the interference of all kinds of noise sources, the image is very complex. In this case, it is very difficult to detect the actual edge of the image.

It is basic requirement to have a low error rate and high positioning accuracy. Low error rate requirements do not miss the actual edge, and deal with a false edge. The high positioning accuracy requires the edge to be equal to, or less than, the width of a pixel to be determined in its actual position. But it is difficult to achieve this goal. The reasons are as follows:

1) The actual image contains noise, and the noise distribution, variance and other information are also unknown. At the same time, noise and edge are high frequency signals; while the smoothing filter can eliminate a part of noise, it can also lead to blurring of the edge, and detection of the edge is often difficult.

2) Due to physical reasons, the edge of the actual image often occurs at different scales and the scale information of each edge is unknown. The edge detection operator using a single fixed scale is unable to detect the edge at the same time.

3) Due to physical reasons, the boundary is not very clear, so the edge of the actual image is also ambiguous in how it can be understood. At the same time, the complexity of the algorithm and the difficulty of hardware and software realization are contradictory. Based on the above three reasons, edge detection has not been satisfactorily resolved.

Classical edge detection methods

The essence of edge detection is to use an algorithm to extract the boundary between the object and the background in the image. We define the edge as the region edge of the sharp change of the gray level in the image. The gray-level change of image can be expressed by the gradient of the image intensity distribution, so we can use local image differential techniques to obtain an edge detection operator. The classical edge detection method uses a small neighborhood of the pixels in the original image to construct the edge detection operator. The following is a theoretical analysis of several classical edge detection operators.

Differential edge detection algorithm

The detection of singular points can be carried out by using the first order derivative operator of the pixel gray level. It represents the edge strength of the point at a certain point. Edge images can be further obtained by setting thresholds for these values. But when the difference is used to detect the edge, we must make sure that the direction of the difference is different and the direction is perpendicular to the edge. The difference operation needs to be carried out in images with different directions, which increases the complexity of the actual operation.

The differential edge detection method is the most original and the most basic method. According to the principle that the first derivative can reach the maximum in the place where the gray level changes, the edge detection is carried out by the derivative operator. Because the operator is directional, this algorithm requires that the difference direction is perpendicular to the edge direction, and the operation thus becomes more complicated.

Roberts edge detection operator

The Roberts edge detection operator is the difference between the two adjacent pixels in a diagonal direction, according to which the gradient is calculated by the difference in the vertical direction [3]:

$$\Delta_x f = f(i,j) - (i+1, j+1), \quad \Delta_y f = f(i, j+1) - f(i+1, j), \tag{1}$$

$$R(i,j) = \sqrt{\Delta^2{}_x f + \Delta^2{}_y f}\ . \tag{2}$$

In practical computation, we reach its approximate value as follows:

$$R(i,j) \approx \Delta_x f + \Delta_y f\ . \tag{3}$$

The convolution operator is as follows:

$$\Delta_x f = \begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}, \ \Delta_y f = \begin{bmatrix} 0 & 1 \\ -1 & 0 \end{bmatrix}. \tag{4}$$

An appropriate threshold selection Th is set, when $R(i, j) > Th$, (i, j) is the step edge point and $\{R(i, j)\}$ is the edge image.

The Roberts operator uses the difference between the adjacent two pixels in a diagonal direction to detect the edge of the gradient magnitude. The effect of the horizontal and vertical edges is better than that of an oblique edge. The positioning is highly accurate and sensitive to noise.

Sobel edge detection operator
For each pixel of the digital image, the definition of Sobel operator is as follows [17]:

$$\begin{aligned} s(i,j) &= |\Delta_x f| + |\Delta_y f| = \\ &|(f(i-1,j-1) + 2f(i-1,j) + f(i-1,j+1)) - (f(i+1,j-1) + 2f(i+1,j) + f(i+1,j+1))| + \\ &|(f(i-1,j-1) + 2f(i,j-1) + f(i+1,j-1)) - (f(i-1,j+1) + 2f(i1,j+1) + f(i+1,j+1))|. \end{aligned} \tag{5}$$

The convolution operator is as follows:

$$\Delta_x f = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}, \quad \Delta_y f = \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}. \tag{6}$$

An appropriate threshold selection Th is set, when $s(i, j) > Th$, (i, j) is the step edge point and $\{s(i, j)\}$ is the edge image.

Sobel operators are easy to implement in space. The Sobel edge detection method not only produces a better edge detection effect, but also is less affected by noise. When using a large neighborhood, the noise resistance performance will be better, but it increases the amount of computation and the edge is also rough. The Sobel operator has a smooth effect on noise and provides more accurate edge direction information. But it also detects a lot of false edges, and edge positioning accuracy is not high enough.

Edge detection based on wavelet transform

The mathematical definition of wavelet function is defined as follows: $\psi(t)$ is set as a square integral function, that is $\psi(t) \in L^2(R)$, if the Fourier transform of $\psi(t)$ equals $\varphi(t)$, which satisfies the following conditions in the function space $L^2(R)$.

$$C_\Psi = \int_R \frac{|\varphi(\omega)|^2}{|\omega|} d\omega < \infty . \tag{7}$$

Then $\psi(t)$ is called a basic wavelet or wavelet generating function, and the condition above is called the condition of the wavelet function.

The mother function of wavelet $\psi(t)$ is carried out by dilation and translation. The scale expansion factor and translation factor are set as a and b respectively, and the wavelet function family $\psi(t)$ can be expressed as the following formula:

$$\psi a, b(t) = \frac{1}{\sqrt{|a|}} \psi\left(\frac{t-b}{a}\right), \tag{8}$$

where $a, b \in R$, and $a \neq 0$. This form of the wavelet function family constitutes a set of standard orthogonal basis in space $L^2(R)$. Therefore, the essence of the wavelet transform is to express and approximate the original signal by using this set of wavelet basis functions. Theoretical study shows that an accurate signal approximation can be obtained by using fewer wavelet coefficients.

$\psi(t) \in L^2(R)$ is a wavelet function, and it has the following properties:

(1) The image has a wave shape. If the mathematical condition meets at $\int_{-\infty}^{+\infty} \psi(x)dx = 0$, the wavelet function has at least a zero-order vanishing matrix.

(2) From the time domain, it only has a small range of fluctuations. If it lies beyond a certain range, the amplitude of its fluctuations decays to zero quickly.

(3) From the frequency domain, its spectrum is limited to a small frequency band, a common band pass filter.

The discrete wavelet transform

The scale expansion factor a, and the translation factor b are discretized in the Eq. (8). We set that $a = a_0^j$, $b = kb_0a_0^j$, where $a_0 > 1$, $b_0 \in R$, $j, k \in Z$, so we obtain the formula as follows:

$$\psi_{j,k}(t) = a_0^{-j/2} \psi(a_0^{-j} t - kb_0). \tag{9}$$

The discrete wavelet transform is defined as follows:

$$DW_{j,k} = \int_{-\infty}^{+\infty} f(t)\overline{\psi_{j,k}(t)}dt = a_0^{-j/2} \int_{-\infty}^{+\infty} f(t)\overline{\psi(a_0^{-j}t - kb_0)}dt . \tag{10}$$

The discrete wavelet transform is a time-frequency analysis. At the same time, the scaling factor a_0 is used to stretch or produce a series of wavelet compression wavelet functions to form the wavelet family.

Edge detection based on wavelet transform

Edge detection is an important part of image analysis. The edge can draw the outline of regional shape, which transfers most of the image information and has many other advantages. So edge detection is the key to dealing with many problems [7].

Wavelet theory provides a multi-scale approach to do with image edge detection, and edge detection can be performed by determining the local extreme of the wavelet coefficients [13]. From the point of view of edge detection, we not only need perfect detection performance, but also the accurate positioning of the edge. The basic idea of the image decomposition algorithm based on wavelet multi-resolution analysis is that the appropriate orthogonal wavelet bases are selected first of all, and then the image is decomposed by wavelet transform. $\theta(x)$ is a smooth function, which meets at $\int_{-\infty}^{+\infty}\theta(dx)=1$, and $\lim_{x\to\pm\infty}\theta(x)=0$.

Generally, the energy of the smooth function is concentrated in the low frequency band, so the smooth function can be regarded as a system of the low pass filter. Thus convolution $(f*\theta)(x)$ between $f(x)$ and $\theta(x)$ reduces high frequency information of $f(x)$,which replaces changing the low frequency part, and the $f(x)$ is smoothed. $\theta(x)$ is a two-order differentiable function.

$$\psi'(x)=\frac{d}{dx}\theta(x),\ \psi''(x)=\frac{d^2}{dx^2}\theta(x). \tag{11}$$

The wavelet transform of $f(x)$ with scale s and position x involved with the wavelets $\psi'(x)$, $\psi''(x)$ is defined as follows:

$$W_s'f(x)=f*\psi_s'(x),\ W_s''f(x)=f*\psi_s''(x). \tag{12}$$

Defined by the usual integral wavelet transform, the two following formulas can be obtained:

$$W_s'f(x)=f*(s\frac{d\theta_s}{dx})(x)=s\frac{d}{dx}(f*\theta_s)(x), \tag{13}$$

$$W_s''f(x)=f*(s^2\frac{d^2\theta_s}{dx^2})(x)=s^2\frac{d^2}{dx^2}(f*\theta_s)(x). \tag{14}$$

In particular, when $\theta(x)$ is set as a Gauss function, zero crossing detection is equivalent to the Marr-Hildreth edge detection, and extreme detection is equivalent to Canny edge detection. If the scale factor s is large, the convolution between $f(x)$ and $\theta(x)$ eliminates small changes in the signal. So it only can detect a bigger upheaval, which is just the wavelet decomposition of the low-frequency signal detection. Therefore, the s corresponding to different sizes can be obtained at different scales of the change points. It indicates that the detection is carried out by wavelet decomposition of the different frequency bands of the signal, which is multi-scale edge detection.

Edge detection algorithm based on improved B-spline wavelet transform

When the scale is given, the wavelet transform is equivalent to the image of the band pass filtering. It excludes the influence of noise to a certain extent, but at the same time, it also removes some fuzzy edges. What is required is to find a kind of wavelet function with good denoising performance. At the same time, it can extract the edge accurately, and reflect the change of image gray.

The wavelet basis function used for edge detection should be a compact branch of the odd function wavelet. It is optimal edge detection of wavelet, which meets three criteria for determining edge detection operators by Canny. B-spline wavelet [15] has the following features:

1) The base is a finite compact support.
2) It is a smooth function, which has a very high regularity and easy to program on the computer.
3) The spline function expresses the problem clearly, making it easy to carry out a thorough analysis of the problem.
4) Spline functions can be easily constructed with high dimensional spline wavelets, such as *m*-order cardinal B-spline wavelet operators.

In summary, the B-spline wavelet is better in the comprehensive performance index of edge detection, so it is chosen as wavelet basis function of image edge detection based on wavelet transform.

Edge detection algorithm based on proposed B-spline wavelet transform

As Shannon and Wong [14] described the features of the X-ray, most areas of a rib X-ray image are located in the area of the lungs, which are usually less dense than the surrounding area. This means that this part of the region does not have a uniform characteristic. Compared with the ribs in the middle of the lung area and the ribs near the edge of the lung, the contrast with the former is smaller, and the edge information is weaker. Therefore, before extracting the X-ray of the rib, the gray scale resolution of the image can be processed. The image must be reprocessed before the wavelet transform is carried out. It is conducive to detecting the edge of the image which is easier to see clearly in the following step, to obtain more obvious detection results.

For the re-processed image, the image edge detection algorithm based on a B-spline wavelet transform is used for edge detection. The original image is a re-processed histogram equalization function in MATLAB directly, whose process is as follows. Firstly, the image is obtained in order to carry out image grayscale equalization. Secondly, the wavelet transform and edge detection are carried out. Because of the gray equalization pretreatment, the gray distribution of the image tends to be uniform. The image is occupied by the pixel gray distance, and increases the image contrast and improves the visual effect, so the purpose of strengthening is achieved. The detection results are improved slightly, but the detection results still have many false edges.

In using the image edge detection algorithm based on B-spline wavelet transform edge detection, false edges can be produced, because the extreme points are not necessarily edge points, so their assessment is not accurate enough. Therefore, after the extreme points of the image in each row in each column are obtained, the difference is calculated between the extreme contiguous points one by one. Then, threshold processing is carried out using the difference. Although after preprocessing, the gray distribution of the image tends to be uniform, the edge difference between adjacent extreme points changes if it is true, and the edge is adjacent with extreme point difference in small changes if not. Because the difference may contain the small, fragile edge information of the image, we recorded the difference over a threshold of the location of the region firstly in the processing of the difference. Then the difference in the recorded area was given by the negative change positive position to the start was marked, and the difference was given an end tag to the position of the positive negative change. Finally, the difference between the start and end tags was detected.

The implementation steps of the proposed algorithm

The implementation steps of the image edge detection algorithm based on an improved B-spline wavelet transform are as follows:

(1) The image is read, and the filter image is obtained through filtering.

(2) Each line of the given image is performed by the above algorithm to calculate the value $W_2 f(x, y)$.

(3) After each image is calculated, the difference between adjacent bits $W_2 f(x, y + 1) - W_2 f(x, y)$ is calculated one by one.

(4) The difference is recorded if it is beyond a certain threshold.

(5) The difference in the area under the record is given a start tag from the negative to positive position. The one is given an end tag, if its difference is from positive to negative.

(6) The detection of wavelet extreme value is carried out between the start and end tags.

(7) Each column of the image is calculated, and step (3), step (4), step (5), and step (6) are repeated.

(8) The value of each pixel of the image is set as the following formula in two detections of the extreme value

$$f(x) = \begin{cases} 255, & one\ is\ the\ extreme \\ 0, & otherwise \end{cases} \tag{15}$$

(9) The above steps are repeated, until $j = J$.

Results and discussion

In this paper, the simulation experiments were carried out on a PC with MATLAB 2014, and the experimental image is 94*106 pleural image with BMP format. Image edge detection algorithm based on improved B-spline wavelet transform in this paper was carried out to compare with the original algorithm. The edge detection image results of the corresponding different scale values were as follows: Fig. 1 shows the original pleural image and Fig. 2 shows the different results by different methods.

Fig. 1 The original pleural X-ray image

a) Result of original algorithm   b) Result of improved algorithm

Fig. 2 Experimental results of different algorithms at scale 2^1

Fig. 2(a) shows the result of the original algorithm and Fig. 2(b) shows the result of the improved algorithm. From the above experimental results, we can find that the improved B-spline wavelet transform detection algorithm has yielded fuzzy detection results, but it is better than original image edge detection algorithm. The useful information of edge maintenance is better than before, and has better visual effect and more accurate position. In the above detection results, we can see the position of the rib more clearly. The edge of rib is accurate and clear, and the edge information is kept intact. Compared with the original algorithm, the number of the background points in the false edge and the image is much fewer. In particular, from the left lower edge of the three weak ribs in the image, because the difference between the background and the gray is very small in the original image, the original algorithm cannot detect its location clearly. However, the improved algorithm can detect it very well, and the impact of noise is significantly reduced. It is very helpful for the follow-up treatment and the doctor's diagnosis. With the increase of wavelet decomposition scale, the edge location is more accurate and clear, and the background of the image is reduced.

Conclusion

In this paper, the principle of wavelet based image edge detection algorithm and the nature of image edge detection are studied. In the chest X-ray images, most of the ribs contain fuzzy image information, which have the characteristics of weak edges. On this basis, an image edge detection algorithm based on an improved B-spline wavelet transform is proposed. The simulation results show that this method can obtain the edge of the medical image with the characteristics of different scales. Compared with the image edge detection algorithm based on the wavelet transform and based on the B-spline wavelet transform, the original image information can be preserved better by using the improved algorithm. Our method reduces the number of false edges and background points in the image. It is useful for medical diagnosis and has application value.

References

1. Abozahhad M., R. R. Gharieb, S. M. Ahmed, E. B. Donkol (2014). Edge Detection with a Preprocessing Approach, Journal of Signal and Information Processing, 5(4), 123-134.
2. Ahmd M. K., S. Didas, A. Hasanov, J. Iqbal (2015). Sharp Operator Based Edge Detection, Journal of Signal and Information Processing, 6(2), 180-189.
3. Bansal B., J. S. Saini, V. Bansal, G. Kaur (2012). Comparison of Various Edge Detection Techniques, Journal of Information and Operations Management, 3(1), 103-106.
4. Cai S. C. (2007). Detection Based on Mathematical Morphology and Application on Medical Image Processing, Qingdao University, 35-47.
5. Choy E. Y. H., W. T. Hung (2010). An Object Detection Method Based on the Separability Measure Using an Optimization Approach, Int J Bioautomation, 14(2), 139-145.

6. Feng X. C., X. B. Gan, G. X. Song (2003). Wavelet Theory and Functional Analysis, Xi'an, China: Electron Technological University Press.
7. Liu G. Z. (1994). Wavelet Analysis and Applications, Xi'an Xidian University Press.
8. Lu Y. F., Y. L. Wang (2015). Multilevel Edge Detection Based on B-spine Dyadic Wavelet, Journal of Xinjiang Normal University, 34(2), 58-61.
9. Luo Z., Y. Jia (2016), MR Image Contrast Enhancement by Wavelet-based Contourlet Transform, Int J Bioautomation, 20(2), 265-278.
10. Maini R., H. Aggarwal (2009). Study and Comparison of Various Image Edge Detection Techniques, International Journal of Image Processing, 3(1), 1-11.
11. Mallat S., W. L. Wang (1992). Singularity Detection and Processing with Wavelets, IEEE Trans on Information Theory, 38(2), 617-643.
12. Marr D., E. Hidreth (1980). Theory of Edge Detection, Proceedings of the Royal Society, 207(1167), 187-217.
13. Qin Q. C., Z. K. Yang (1994). Applied Wavelet Analysis, Xi'an Xiandian University Press.
14. Shannon A., C. K. Wong (2010). Bioprocess Engineering and the Manners Gandolfi X-ray Camera, Int J Bioautomation, 14(3), 171-178.
15. Somkait U. (2004). Edge Detection in Ultrasonic Images Using Gabor Filters, IEEE Processing of Computers in Cardiology, 1, 175-178.
16. Stephane M., S. F. Zhong (1992). Characterization of Signals from Multi-scale Edges, IEEE Transactions on Pattern Analysis and Machine Intelligence, 14(7), 710-732.
17. Tao X. P., F. Yang (2014). Image Improvement Based on Sub-pixel Post-integration for a Staring Imaging System in Geostationary Orbit, Chinese Optics Letters, 12(4), 042802.
18. Wang S., X. Wu, T. Liu (2015). Multi-scale Cnut Based on Dyadic Wavelet Transform, Computer Engineering and Applications, 51(3), 9-14.
19. Wang J., G. Wang, M. Li, W. Du, W. Yu (2015). Hand Vein Images Enhancement Based on Local Gray-level Information Histogram, Int J Bioautomation, 19(2), 245-258.
20. Zhang G., Z. Xiong, S. Xia, Y. Luo, C. Xing (2016). Fingerprint Image Segmentation Algorithm Based on Contourlet Transform Technology, Int J Bioautomation, 20(3), 339-350.

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