Sensors & Transducers, Vol. 182, Issue 11, November 2014, pp. 203-206

Sensors & Transducers

A New Waveform Mosaic Algorithm in the Vectorization of Paper Seismograms

[1, 2, *] **Maofa Wang,** [1] **Qigang Jiang,** [2] **Jilin Feng,** [1] **Xueqin Yu,** [1] **Nan Lin,** [2] **Shichen Feng,** [2] **Cong Liu**

[1] College of Geoexploration Science and Technology, Jilin University
Jilin, Changchun, China, 130026
[2] Department of Disaster Information Engineering, Institute of Disaster Prevention,
Hebei, Sanhe, China, 065201
[*] E-mail: wangmaofa2008@126.com

Received: 23 August 2014 /Accepted: 30 October 2014 /Published: 30 November 2014

Abstract: History paper seismograms are very important information for earthquake monitoring and prediction, and the vectorization of paper seismograms is a very import problem to be resolved. In this paper, a new waveform mosaic algorithm in the vectorization of paper seismograms is presented. We also give out the technological process to waveform mosaic, and a waveform mosaic system used to vectorize analog seismic record has been accomplished independently. Using it, we can precisely and speedy accomplish waveform mosaic for vectorizing analog seismic records. *Copyright © 2014 IFSA Publishing, S. L.*

Keywords: Analog seismic record, Digital image processing, vectorization, Time coordinates mosaic, Waveform coordinates mosaic.

1. Introduction

Historical paper earthquake records are important information for earthquake monitoring and prediction [1-2]. Although the construction of digital seismic stations has been undertaken in many countries at present, those massive saved simulated seismogram records over the past decades still have a great value, which is important original information associated with the earthquake-generating process for analyzing and studying earthquake [3-9].

In our previous work, we have found that the analog seismic record will lose its precious historical value without digitized and vectorized, and it is an important and urgent task for vectorizing paper analog seismic records [3-9]. We have also present one new tracing algorithm for simulated seismogram curves based on visual filed feature (VFF), given out the whole technological process to vectorizing simulated seismograms, and an analog seismic records vectorization system has been accomplished independently [4]. In this paper, A new waveform mosaic algorithm based on local feature in the vectorization of paper seismograms was put forward, using it, we can precisely and speedy accomplish waveform mosaic for vectorizing analog seismic records.

2. Key Algorithms Analysis and Discussion

2.1. The Whole Technological Process to Vectorizing Simulated Seismograms [4]

We want to vectorize paper simulated seismograms with digital image processing technique. Fig. 1 is original image of simulated seismogram.

Fig. 2 is the whole technological process to vectorizing simulated seismograms system, throughout it, there are six approaches: loading images, preprocessing, vectorizing image, and waveform mosaic, warehousing waveform and time coordinate, waveform inversion [4]. In the paper, we give the detailed discuss and depict of waveform mosaic, which mainly includes of waveform coordinate mosaic, time coordinate mosaic and waveform inversion.

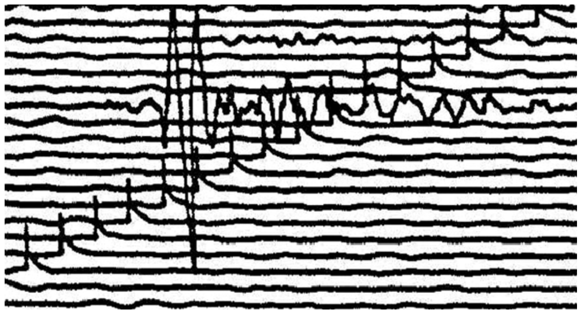

Fig. 1. One original image of simulated seismogram.

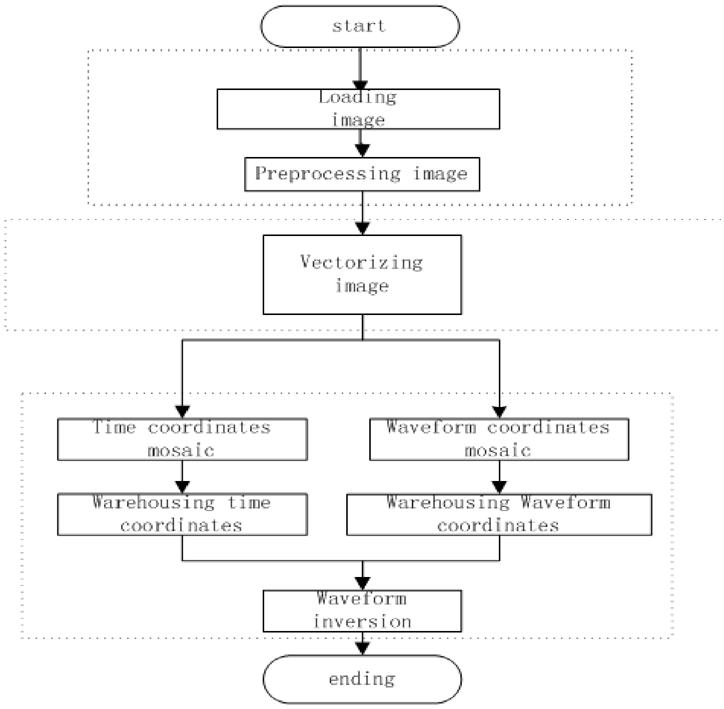

Fig. 2. Technological process to vectorizing simulated seismograms.

2.2. Waveform Coordinate Mosaic

The whole waveform coordinate mosaic algorithm is derived as the following:

After vectorization of paper seismograms, all the points on the waveform curves are saved into many arrays with two dimensional *a*[i] (i=1, 2, n), and all the points on the same one curve are stored in the same one array.

Fig. 3 is the sketch map of waveform coordinate mosaic Principle, from it, we can find that the last point on *a* [0] curve coincides with the first point on *a*[1] curve, and the last point on *a*[1] curve coincides with the first point on *a* [2] curve, and so on.

$$\therefore\ \triangle x_0 = a[1].\mathrm{first.x} - \mathrm{a}[0].\mathrm{last.x}$$

$$\triangle \mathrm{y}_0 = a[1].\mathrm{first.y} - \mathrm{a}[0].\mathrm{last.y}$$

$$a[1].x' = a[1].x - \triangle x_0$$

$$a[1].y' = a[1].y - \triangle y_0$$

$$\therefore\ a[2].x' = \mathrm{a}[2].x - \triangle x_0 - \triangle x_1$$

$$a[2].y' = \mathrm{a}[2].y - \triangle y_0 - \triangle y_1$$

....

$$\therefore a[i].x' = \mathrm{a}[i].x - \sum_{n=0}^{i-1} \triangle x_n\,, \tag{1}$$

$$\therefore a[i].y' = \mathrm{a}[i].y - \sum_{n=0}^{i-1} \triangle y_n\,, \tag{2}$$

where $\triangle x_n$ is the x coordinate difference between the first point on the nth curve and the last point on (n-1)th curve. And $\triangle y_n$ is the y coordinate difference between the first point on the nth curve and the last point on (n-1) th curve.

After vectorization of paper seismograms, all points on all the curves can be normalized onto one curve with continuous coordinates by Eq. (1-2).

Fig. 3. The sketch map of waveform coordinate mosaic principle.

2.3. Time Coordinate Mosaic

The whole time coordinate mosaic algorithm is derived as the following:

On the paper seismograms, there are some hand-painted key time coordinate points, using which, we can map out time value of all the points on the paper seismograms. How to compute out corresponding coordinate's value on the normalized curve for every one hand-painted key time coordinate points is key problem.

For every one hand-painted key time coordinate point *b*[j] (j=0, 1, …. , m), we can compute out one waveform wave *a*[i] (i=0, 1, n) which has minimum distance to the hand-painted key time coordinate point as described by Eq. (3)

$$\min = \left| a[i].y - b[i].y \right| , \qquad (3)$$

And we can get the mosaic coordinate of corresponding hand-painted key time coordinate point b[j] (j=0, 1, …. , m) as Eq. (4-5).

$$b[j].x' = b[j].x - \sum_{n=0}^{i-1} \Delta x_n , \qquad (4)$$

$$b[j].y' = b[j].y - \sum_{n=0}^{i-1} \Delta y_n , \qquad (5)$$

2.4. Waveform Inversion

The inversion algorithm of waveform whose time range from h_a to h_b (h_a and h_b may be decimal) can be described as following:

1) Select two time axis points: $T_{floor}((x_f, y_f), h_f)$, $T_{ceil}((x_c, y_c), h_c)$ from the time axis points *set* $T_i((x, y), h)$ $(i = 0, 1, ..., 24)$ by bubble sorting method, and these two points satisfies Eq. (6):

$$h_f = \text{floor}(h_a), \quad h_c = \text{ceil}(h_b), \qquad (6)$$

2) Select two time axis points: $P_f(x_f, y_f)$, $P_c(x_c, y_c)$ from the mosaic waveform points *set* by bubble sorting method, and these two points satisfies Eq. (7).

$$x_f = \text{floor}(x_f), \quad x_c = \text{ceil}(x_c), \qquad (7)$$

3) Compute out two corresponding x coordinate values for time h_a and h_b by Eq.(8-9).

$$x(h_a) = x_f + \frac{h_a - h_f}{h_c - h_f}, \qquad (8)$$

$$x(h_b) = x_f + \frac{h_b - h_f}{h_c - h_f}, \qquad (9)$$

4) Finally, we fit these points within $[x(h_a), x(h_b)]$ on the mosaic waveform points set to one curve using the least square method [10, 11], and the final result of mosaic is shown as Fig. 4.

Fig. 4. Simulating seismogram inversion.

3. Conclusions

The paper focuses on a new waveform mosaic algorithm in the vectorization of paper seismograms. From the detected results of smooth and complicated waveforms as shown in Fig. 4 we can see that the topology of the mosaic result is consistent with original curves.

We also write the correlative software with c# codes, which applying the above digital image processing algorithms (including mosaic algorithm). The analogue seismogram records which come from Chengde [in 1991 and excess of 10 G have been vectorized using the software.

Acknowledgment

Two of Authors (Maofa Wang, Jilin Feng) thank the financial support from Special Fund of

Fundamental Scientific Research Business Expense for Higher School of Central Government (Projects for creation teams) (Research on the Acquisition and rapid Processing of earthquake disaster information ZY20120104).

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