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FastXcorr : FORTRAN Program for Fast Cross-over Error Correction of Marine Geophysical Survey Data

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FastXcorr : 해양지구물리탐사 자료의 빠른 교차점오차 보정을 위한 프로그램 개발

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해양에서 관측되는 해양지구물리 탐사자료에는 위치오차, 기기오차, 관측오차, 해상 상태 등 다양한 원인에 기인하는 오차가 포함되어 있다. 이에 의해 한 기관에서 해양지구물리 탐사 자료를 취득할 때나 여러 기관에서 취득된 해양지구물리 탐사자료를 취합할 때 많은 교차점오차가 발생하고, 이러한 교차점오차는 부적절한 해석을 야기하는 인위적인 이상대를 만든다. 교차점오차를 줄이기 위한 다양한 방법들이 제시되었지만, 이들 대부분의 방법들은 교차점을 찾기 위해 각각의 점자료(point data) 혹은 선분자료(segment data)를 모두 비교함으로써, 불필요하게 많은 계산시간을 요구하게 된다. 따라서 본 연구에서는 중복구역나눔 방법을 도입하여 빠르게 교차점을 찾고, 가중치선형내삽 방법을 이용하여 교차점오차를 보정하는 포트란(FORTRAN) 프로그램 (FastXcorr)을 개발하였다.

주요어 : 교차점오차보정, 빠른 교차점검색, 중복구역, 가중치선형내삽, 포트란

Many cross-over errors due to position errors, meter errors, observation errors, sea conditions and so on occur when marine geophysical data collected by own and other agencies are merged, and these errors can create artificial anomalies which cause an improper interpretation. Many methods have been introduced to reduce cross-over errors. However, most methods are designed to compare each point or segment data to find cross-over points, and require a long processing time. Therefore, FORTRAN program (FastXcorr) is presented to fast determine cross-over points using an overlap-sector, and to adjust cross-over errors using a weighted linear interpolation algorithm.

Keywords : Cross-over error correction, Fast finding cross-over points, Overlap-sector, Weighted linear interpolation, FORTRAN

1. INTRODUCTION

Marine geophysical data such as bathymetric, gravity and magnetic data usually show different values at the intersection of track lines (cross-over points: COPs). These discrepancies (cross-over errors: COEs) are generally caused by navigation errors, instrument drift, diurnal variation, inaccurate Eötvös correction, etc. Artifacts due to COEs need to be minimized to avoid any kinds of data misinterpretation. Many methods (Foster, 1970; Johnson, 1971; Yanger *et al.*, 1978; Sander and Mrazek, 1982; Prince and Forsyth, 1984; Mittal, 1984; Wessel and Watts, 1988; Wessel, 1989; Hsu, 1995; Catalão and Sevilla, 2004; Kang *et al.*, 2006) have been proposed, and successfully reduced COEs to make a reasonable interpretation. However, these methods do not consider how to save the processing time to find COEs. Even though modern computer technologies can partially resolve this problem, it still takes a long time to process when the amount of data is large enough to hamper the computer speed. Therefore,

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a new method called FastXcorr is introduced to optimize the processing time to find COPs. This method will divide a given dataset into several sectors and COPs will be determined in each sector, and COPs lie in the boundary of each sector can also be detected using an overlap-sector.

2. METHODS

Most methods for finding COPs compare each point or segment in a given dataset using a numerical iteration. In case of comparing all points in a given dataset, iteration number will be $(N+1)\times N/2$, where N represents the total number of data point. However, if a dataset is divided into several sectors, the iteration number is reduced to $(N/m+1)\times(N/m)\times m/2$, where m represents number of sectors. For instance, sectors in a given dataset are

Table 1. Expected iteration number when m=1 (no dividing sector) and m=2,500.

N	A : m=1	B : m=2,500	A/B
10,000	50,005,000	25,000	2,000
100,000	5,000,050,000	2,050,000	2,439
500,000	125,000,250,000	50,250,000	2,488
1,000,000	500,000,500,000	200,500,000	2,494

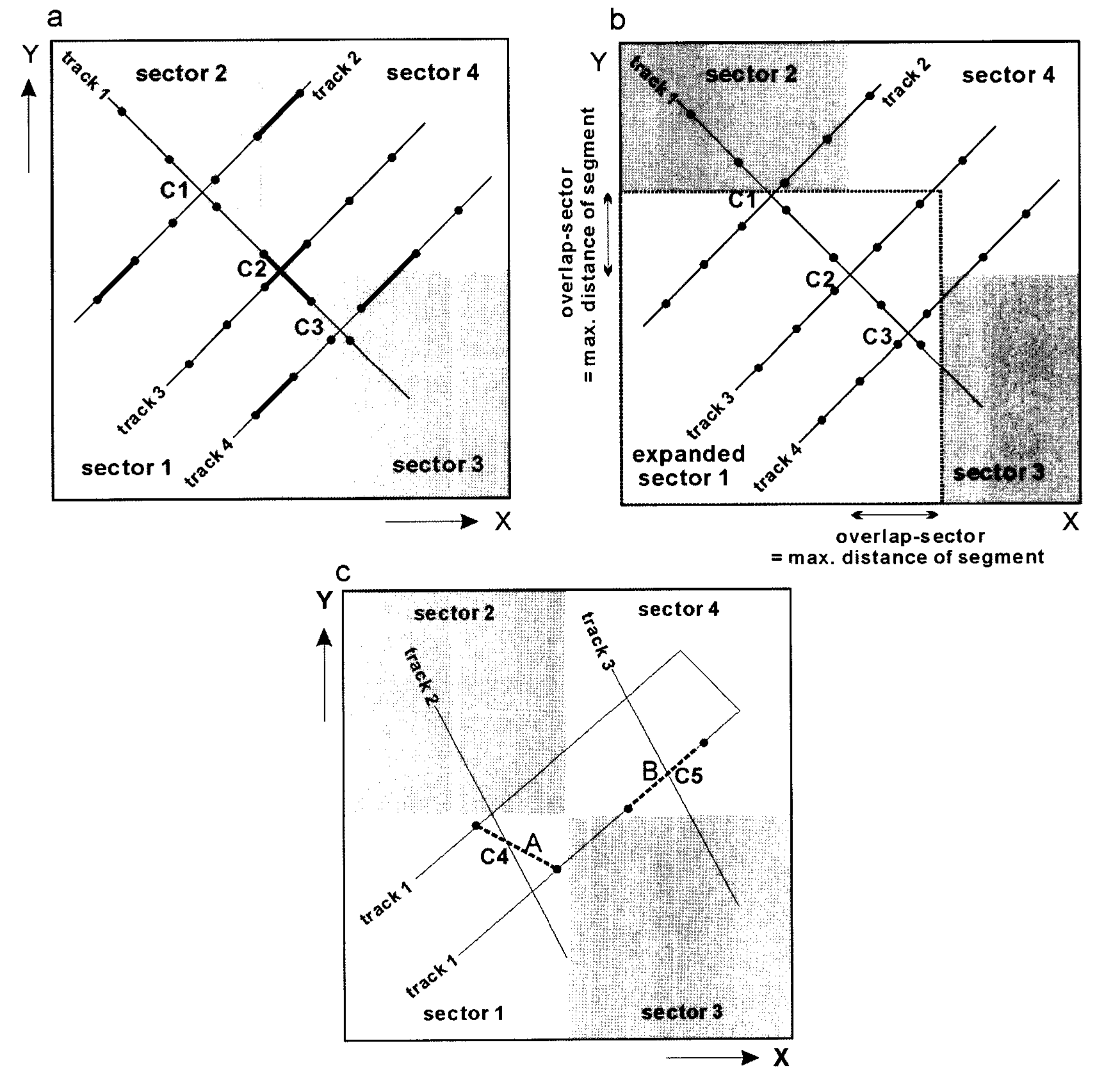

Fig. 1. Schematic diagrams showing an overlap-sector method to find COPs. (a), (b) and (c) shows missed segments (thick solid lines), overlap-sector and pseudo-segments (dotted line), respectively.

divided as many as a desired number as an input parameter within the minimum and the maximum values of x and y, and the interval of each sector (x_{int}, y_{int}) can be calculated as follows;

$$x_{int}=(x_{max}-x_{min})/m_x$$
$$y_{int}=(y_{max}-y_{min})/m_y$$

where x_{min}, x_{max}, y_{min}, and y_{max} are the minimum and the maximum values of x, y, and m_x and m_y represent the desired sector numbers. The boundary position of each sector (x_i, y_i) can be obtained from the interval of each sector; i.e.,

$$x_{i+1}=x_i+x_{int} \quad (i=1\sim m_x-1)$$
$$y_{i+1}=y_i+y_{int} \quad (i=1\sim m_y-1)$$

where x_1 and x_{m_x+1} are the minimum and the maximum values of x, and y_1 and x_{m_y+1} are the minimum and the maximum value of y. Table 1 shows the iteration number for finding COPs when $m=1$ and $m=2{,}500$, and indicates that the processing time can be reduced by dividing sector. However, if COPs lie on sector boundaries, they cannot be determined by this method. Therefore, other method also needs to be implemented.

To determine COPs at the sector boundaries, several cases need to be considered. If two points composed of one segment are separated by a different sector, this segment does not show in any sector (Fig. 1a). In this case, COP (C2 in Fig. 1a) cannot be determined. To resolve this problem, sectors need to be overlapped as much as the maximum distance of segment in a given dataset to maintain the minimum duplicated segment without missing COPs (Fig. 1b). However, COPs shown in the expanded sector (C3 in Fig. 1b) need to be deleted because they will be also determined during the process of sector 3. In case that COPs on boundaries of the expanded sectors (C1 in Fig. 1b) don't need to be considered because they will be determined during the process of sector 2. Through this process, all COPs in a given dataset will be detected. However, pseudo-COP (C4 in Fig. 1c) determined by pseudo-segment (A in Fig. 1c), which is created when the distance between two points with the same track name is shorter than the maximum distance of segment, is still included in the dataset. To avoid this kind of pseudo-COP, serial number for each data point is added when the data are read. If serial number is not in order, it will not be considered as a segment, and COPs will not be found. Other possible case to create pseudo-COP is the blanking data segment caused by instrument malfunction or other reasons (C5 in Fig 1c). In this case, COPs will be determined because the serial number is in order, and an unreasonable corrected COE value will be given. To exclude this specific case, it is assumed that no data exist when the distance between two points is 10 times longer than the average distance of segment in a given dataset (B in Fig. 1c). Therefore, all COPs in a given dataset will be determined without counting pseudo-COPs and the general procedure of overlap-sector method is introduced in Fig. 2.

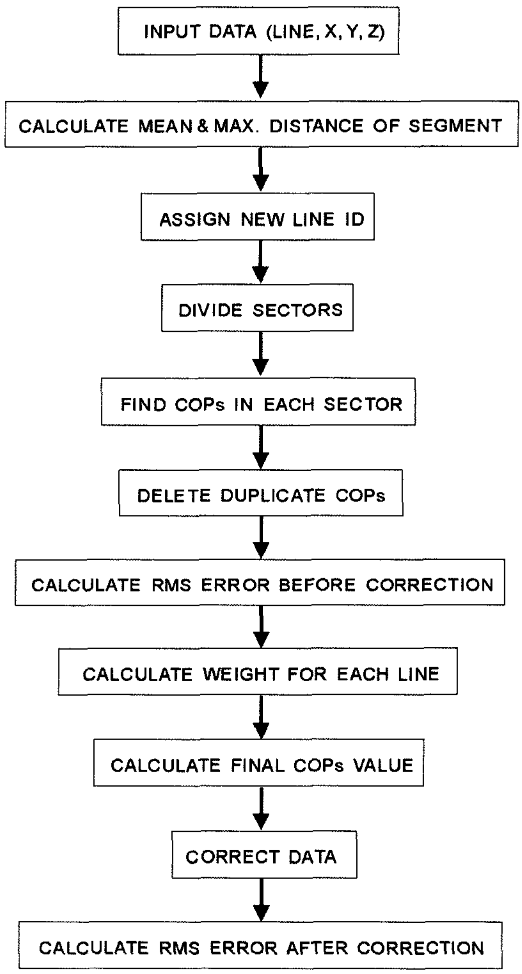

Fig. 2. Flow-chart of the FastXcorr.

3. NUMERICAL EXAMPLES and CONCLUSIONS

To verify the accuracy and the efficiency of the developed algorithm, FastXcorr was tested for three different numbers of datasets (Fig. 3). Dataset I (100,000 points), Dataset II (500,000 points), and Dataset III (1,000,000 points) were created by a simple linear interpolation based on Hsu's (1995) 102 example data points using the PC with Intel Core2 Quad 2.40GHz CPU and 3.25GB memory.

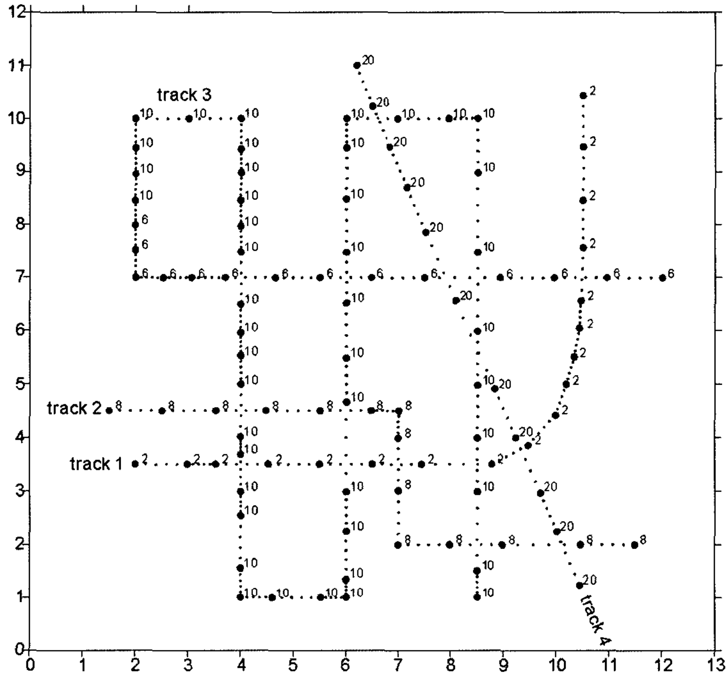

Fig. 3. Example data used for testing the efficiency of the FastXcorr. Large circles denote data used by Hsu (1995), and small circles are interpolated data.

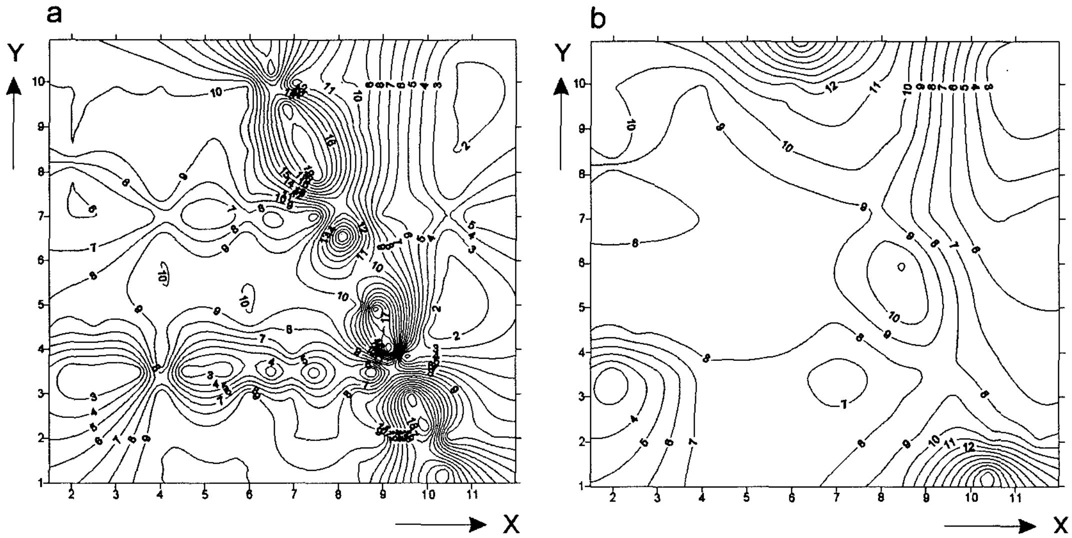

Fig. 4. COEs of example data before (a) and after (b) implementing the FastXcorr.
(a) : number of XOPs = 16, r.m.s. error = 8.544, minimum COE = -2.000, maximum COE = -18.000
(b) : number of XOPs = 16, r.m.s. error = 1.063, minimum COE = -0.117, maximum COE = -2.518

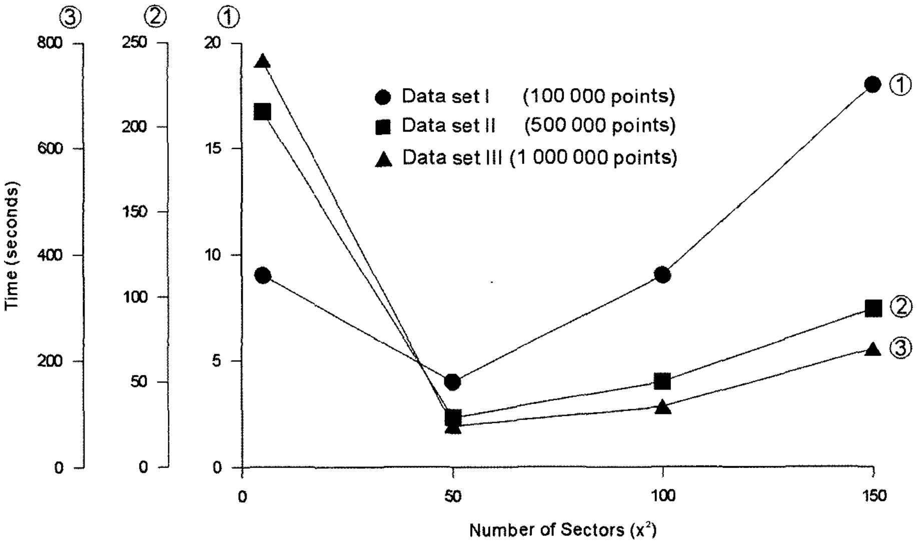

Fig. 5. Diagram showing a processing time vs. number of sectors. Circle, square and triangle represent 100,000, 500,000 and 1,000,000 points dataset, respectively.

Table 2. Comparison of compute times between the previous methods and overlap-sector method.

	Previous methods (1x1 sector)	Overlap-sector method (50x50 sectors)
Dataset I	150 sec.	4 sec.
Dataset II	3,592 sec.	29 sec.
Dataset III	15,446 sec.	77 sec.

As shown in Table 2, the overlap-sector method can significantly reduce compute time to find COPs. COEs at all identified COPs were corrected by Hsu's (1995) algorithm (Fig. 4).

To find the reasonable number of dividing sectors having the minimum computing time, three dataset was divided into 5x5, 50x50, 100x100, and 150x150, respectively. Results show that 50x 50 divided sector has the minimum compute time as shown in Fig. 5. It implies that unnecessary iteration will require more processing time if the sector is less than 2,500 and computing time for finding duplicated COPs in many overlap-sectors and for assigning data to each sector will take a time if the sector is more than 2,500.

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