Application of median filtering in Kirchhoff migration of noisy data

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INTRODUCTION

Random noise and abnormally strong coherent noise have been presenting difficulties in seismic migration and imaging. Although noise level should have been reduced dramatically by signal processing such as CMP stacking and multichannel-based poststack noise reduction, the remaining noise may still be too strong for migration and imaging. A feasible way is to perform noise reduction during migration. Kirchhoff migration by weighted hyperbolic summation is a method on which a multichannel based noise reduction technique can be easily applied, since each sample in a migrated section corresponds to a horizontal amplitude series. Median filtering is often effective in removing random noise and strong abnormal amplitudes within a time series and it is often applied in the spatial direction to reduce spatial inconsistency. We applied a median filter before the summation in Kirchhoff migration, and some preliminary results are presented.

KIRCHHOFF MIGRATION ON NOISY DATA

Kirchhoff migration is one of the most popular migration algorithms used in the industry. It is implemented by summing along diffraction curves since we look upon every point in the subsurface as a diffractor.

Often we assume that the noise in a seismic section is random and it can be attenuated by multi-trace stacking. However, for a limited migration aperture, the noise along the diffraction curve is not necessarily random, so that it might not cancel out by stacking. Thereby the stack sections remain contaminated by random noise.

Strong abnormal amplitude spikes can be another problem in Kirchhoff migration, and often the migration quality is degraded even with correct velocities. Although threshold amplitude filter can remove the exceptionally large spikes before migration, it is often set to be slightly smaller than the large wild values to ensure that no signal is removed. This method can not deal with any noise that is only slightly stronger than the coherent signal.

MEDIAN FILTER AS A TOOL OF NOISE REDUCTION

A median is the middle point of an ascending -value sequence. For example,

(5, 1000, 6, -1, -2, 7, 10),

when ordered, becomes

(-1, -2, 5, 6, 7, 10, 1000).

The median is 6.

The most significant property of a median is that wild values (such as 1000 in the above example) do not affect the median at all. A mean, however, will be dominated by such wild values. A median is the value in a sequence that has a minimal 'distance' from all other points, which means that the median value minimizes the absolute value of the sum of differences between it and other points of the sequence. A schematic diagram (figure 1) shows the median filtering operation (after Stewart, R.R., 1985).

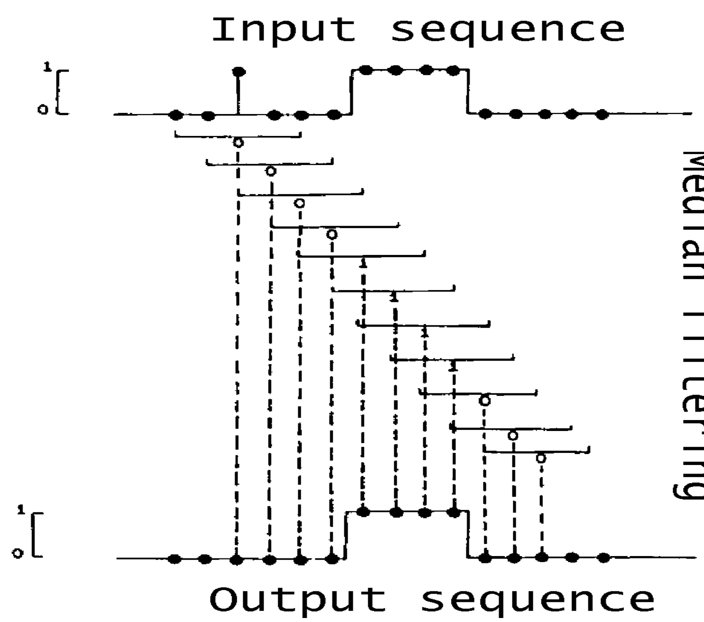


Figure 1. A schematic diagram of median filtering operation (after Stewart, 1985). Wild values can be easily removed, while the step function is untouched.

Besides wild value removal, median filtering is also used in F-K domain for random noise reduction. This has been well demonstrated by several authors. Stewart (1985) showed that F-K domain median filters can tremendously reduced random noise in VSP data. Duncan and Beresford (1995) applied F-K median filtering to surface seismic data and obtained very good results. However, we won't discuss this method here since it is beyond the content of this paper.

MEDIAN FILTER IN KIRCHHOFF MIGRATION

We applied median filtering before the hyperbolic summation in Kirchhoff migration. Some preliminary results are presented in this section.

Figure 2 shows a noise-free zero-offset data and the migrated sections by traditional Kirchhoff migration, 10-point median filter Kirchhoff migration and 20-point median filter Kirchhoff migration. The aliasing noise in the upper part of the section has been dramatically reduced. However, median filter tends to reduce the length of a horizontal reflection. This is demonstrated in figure 2 (d) by the horizontal reflection at the bottom of the input data. The length of a median filter should be carefully selected. In our case, we will use the 10-point median filter for the rest of the testing.

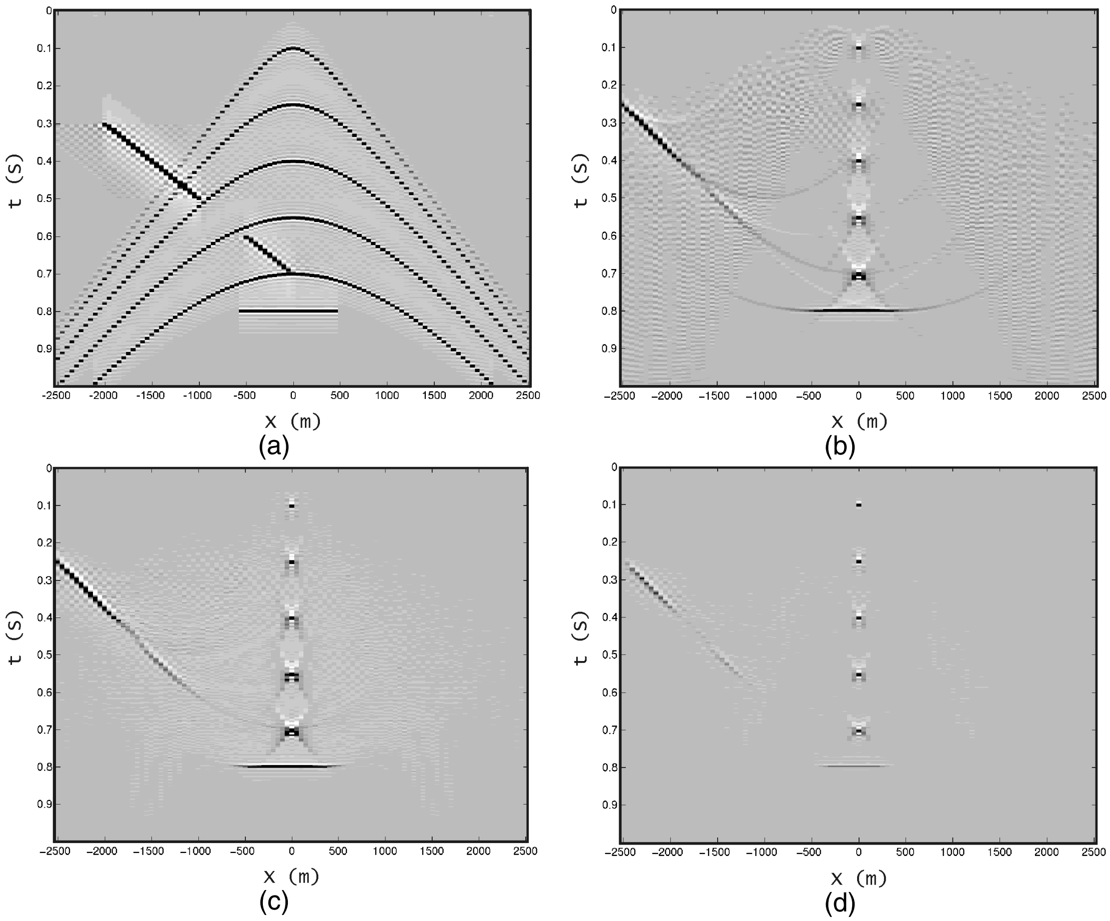
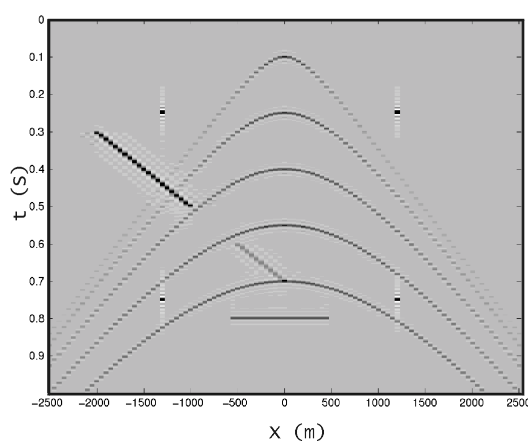


Figure 2. Input noise-free zero offset section and the migration results, (a) input zero-offset data, (b) traditional Kirchhoff migration, (c) 10-point median filter Kirchhoff migration, (d) 20-point median filter Kirchhoff migration.

Figure 3 shows the effect of median filtering when large noise spikes are present. Large noise spikes can be easily removed by median filtering.



(a)

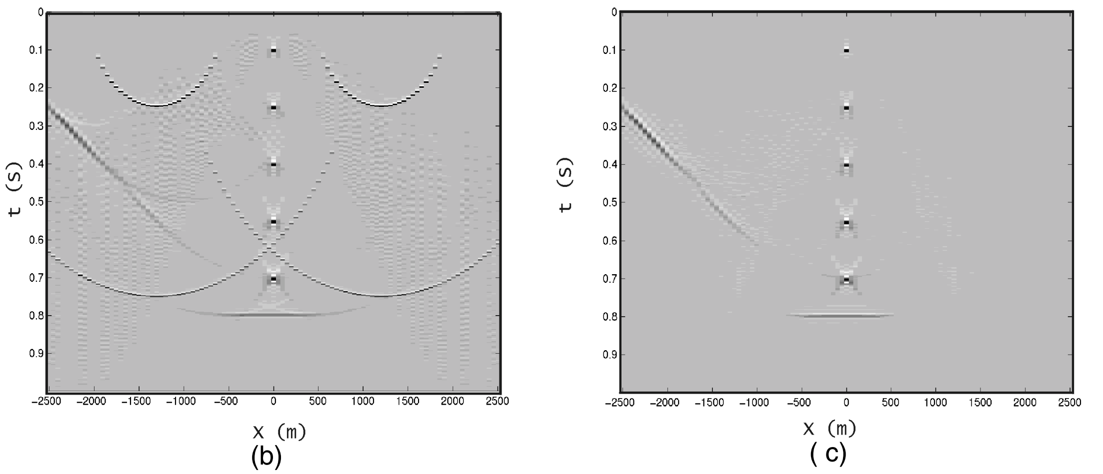


Figure 3. Migration of data with large noise spikes, (a) input zero-offset data with four large noisy spikes, (b) Kirchhoff migration, (c) 10-point median filter Kirchhoff migration.

Figure 4 shows the migration of the input data in figure 3, with 50% random noise. the median-filter Kirchhoff migration has removed the effect of spikes and the noise level is comparable with that of Kirchhoff migration.

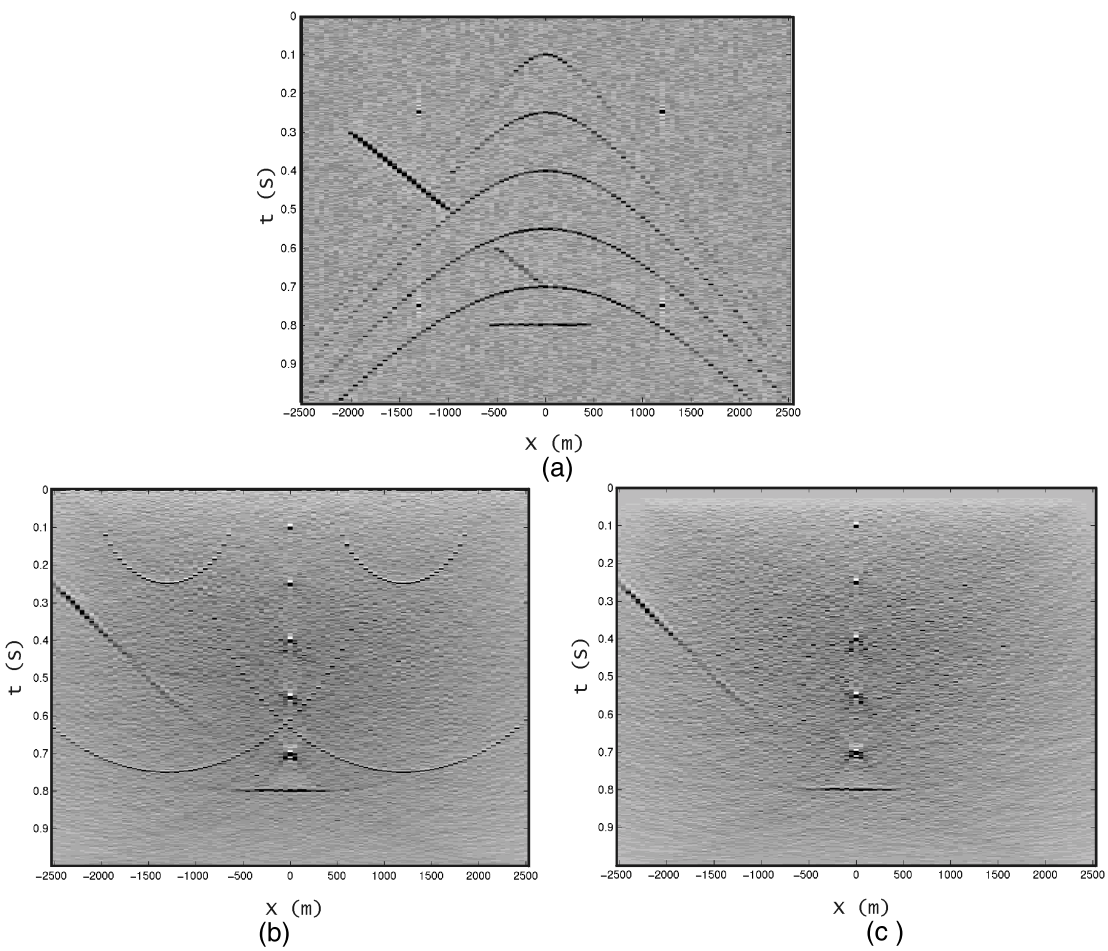


Figure 4. Migration of the input data of figure 3 with 50% random noise, (a) input data, (b) Kirchhoff migration, (c) 10-point median filter Kirchhoff migration. The noise level of median-filter migration seems slightly lower than that of the Kirchhoff migration.

FUTURE WORK

The median filter we have applied before the hyperbolic summation in Kirchhoff migration is the simplest median filtering. Kirchhoff migration itself is already a slow process. Adding median filter before summation increases the computing time. The larger the migration aperture is, the longer the computing time is. For example, for a small dataset with 101 500-sample traces, it takes about 1.5 minutes for Kirchhoff migration under a Matlab environment running on a Sun Ultra-10, while about 30 minutes to complete the migration for median-filter migration. We need to seek a way to speed up the process. Also, there are still other noise-reduction methods, which can be applied in the noise reduction before summation.

ACKNOWLEDGEMENT

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REFERENCE

Duncan, G. and Beresford, G., 1995, Some analyses of 2-D median F-K filters, Geophysics, 60, no. 04, 1157-1168.

Stewart, R.R., 1985, Median filtering-Review and a new f/k analogue design, Can. J. Expl. Geophys., 21, no. 01, 54-63.