Migration of Uniformly Interpolated West Texas Data

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ABSTRACT

The West Texas field data have been interpolated onto an uniform grid and then migrated. Results show that the uniform grid traces yields a noticeably worse migrated image than that migrated from traces interpolated onto a quasi-Monte Carlo grid. The uniform grid image is even worse than the migrated image obtained from data interpolated onto a regular grid where there is fine sampling in at least one direction.

INTRODUCTION

To test the efficiency of quasi-Monte Carlo migration (QM), Zhou and Schuster (1995) interpolated field data traces onto either regularly-spaced grid points or quasi-randomly spaced grid points. A Halton distribution was used for the quasi-random grid points. The method to generate a regularly-spaced subset of data is to subsample the interpolated traces along the geophone
line. For example, 1/4 regular subsampling uses every 4th geophone along the interpolated geophone line. Then the number of subsampled traces is 1/4 of the total number of traces. Their results show that quasi-Monte Carlo distributions of sources and receivers produce better quality migrated images and higher computational efficiency than the regular distributions of sources and receivers.

In this report the field data are interpolated to traces on a uniform grid (X- or Y- spacings are the same) and these interpolated traces are migrated. The uniform migrated images are compared to the QM images.

**WEST TEXAS DATA GEOMETRY**

The West Texas field data contain 334,659 traces, which were generated by 530 shots and recorded by up to 1793 geophones. The source inline spacing is approximately 330 ft and the crossline spacing is approximately 1,320 ft. The inline and cross line spacings for geophones are approximately 220 ft and 1,320 ft, respectively. See Table 1, where \((dx_s, dy_s)\) and \((dx_r, dy_r)\) are the source and geophone sampling intervals, respectively. The source lines are roughly perpendicular to the geophone lines such that there is a fine sampling (i.e., either 330 ft or 220 ft) in either the X or the Y directions.

<table>
<thead>
<tr>
<th>dx_s</th>
<th>dy_s</th>
<th>dx_r</th>
<th>dy_r</th>
<th>Number of traces</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,320 ft</td>
<td>330 ft</td>
<td>220 ft</td>
<td>1,320 ft</td>
<td>334,659</td>
</tr>
</tbody>
</table>

Figure 1 displays the source and receiver distributions after coordinate rotation. It shows that the source distribution is well
sampled along the Y direction and coarsely sampled along the X direction. In contrast, the geophone distribution is well sampled along the X direction and coarsely sampled along the Y direction. For the 4-D sampling space \((X_s, Y_s, X_r, Y_r)\), two of the variables are finely sampled.

![Shot & Receiver Distributions After Coordinate Rotation](image)

**Figure 1:** The shot and receiver distribution after the coordinate rotation. The crosses represent shot positions and the dots represent receiver positions. The shot inline direction and the receiver inline direction are perpendicular to one another.

Figure 2 shows the shot and geophone distributions for shot No. 400 and Figure 3 is the associated shot gather. It indicates
that just a portion of the geophones was turned on (701 out of a total of 1793). The period of the wavelet in the seismograms ranges from 16\text{ms} to 30\text{ms}, with an average period of 20\text{ms}. Thus the average wavelength for a velocity of 15,000 \text{ft/s} is 300 \text{ft}.

Figure 2: The shot and receiver locations for the No. 400 shot gather. The star is the location of the shot. The dots represent the geophones activated for shot No. 400. Note that only 701 receivers were activated for this shot.

Figures 4 and 5, respectively, show the shooting geometry and seismograms for shot No. 600.
Figure 3: The common shot gather for shot No. 400.
Figure 4: The shot and receiver locations for the No. 600 shot gather. The star is the location of the shot and the dots represent the geophones activated for shot No. 600. Note that only 773 receivers were activated for this shot.
Figure 5: The common shot gather for shot No. 600.
UNIFORM INTERPOLATION OF TRACES

There are 3 steps for the operations of uniform interpolation and migration of West Texas traces.

(1) Identify a source-receiver pair on the uniform grid. Find the nearest 4 regular grid shot points that surround this uniform source point. Then find the four traces of each regular shot point that most closely surround the uniform receiver point. A total of 16 regular-grid traces will be associated with each uniform source-receiver pair.

(2) Use linear interpolation to interpolate these 16 regular-grid traces to obtain a trace at the uniform source-receiver point. This procedure will be repeated for all source-receiver pairs on the uniform grid.

(3) Finally the interpolated traces are migrated to obtain the images.

TEST 1: INTERPOLATE FIELD DATA TRACES TO AN UNIFORM GRID

For the uniform sampling where \(dx_s = dx_r = dy_s = dy_r = 550 \text{ ft}\), there are 339,314 uniformly spaced traces. For this sampling interval, the total number of traces interpolated is roughly the same as the number of traces in the West Texas field data. Table 2 shows the the spatial sampling intervals for the interpolated traces.

Table 2. Survey parameters of the uniformly distributed traces

<table>
<thead>
<tr>
<th>(dx_s)</th>
<th>(dy_s)</th>
<th>(dx_r)</th>
<th>(dy_r)</th>
<th>Number of traces</th>
</tr>
</thead>
<tbody>
<tr>
<td>550 ft</td>
<td>550 ft</td>
<td>550 ft</td>
<td>550 ft</td>
<td>339,314</td>
</tr>
</tbody>
</table>
Figures 6 and 7 show the distributions of shots and geophones for the uniformly spaced traces. Both the shot points and geophone points have a spatial sampling interval of 550 ft in either the X or the Y directions. In Figures 8 and 9, both the original and interpolated shot points and geophone points are plotted together to show how the uniformly spaced shot points and geophone points are interpolated from the surrounding regular grid shot points and geophone points, respectively. Figures 10 and 11 are blowups of Figures 8 and 9, respectively. They show that
Figure 7: The uniform receiver distribution for a receiver spacing of 550 ft.
traces from some regular grid points have the same contribution to two or three uniformly spaced traces, while traces from some other regular grid points make no contribution to the trace interpolation at any of the uniformly spaced shot or geophone points.

Figure 8: The uniform shot distribution compared with the regular-grid shot distribution of the W. Texas data. The crosses are the shot positions of interpolated traces and the dots are those of the regular-grid traces.

Figure 12 shows the image obtained by migrating the uniform distribution of interpolated traces. And Figure 13 displays the image obtained by migrating the original West Texas data.
Figure 9: The uniform receiver distribution compared with the original receiver distribution. The crosses are the receiver positions of the interpolated traces and the dots are those of the original traces.
Figure 10: Blowup of Figure 8. Notice that some regular grid shot points contribute to more than one uniform shot point while other regular grid shot points make no contributions to any uniform shot point.
Figure 11: Blowup of Figure 9. Notice that some regular grid receiver points contribute to more than one uniform receiver point while other regular grid receiver points make no contribution to any uniform receiver point.
Comparison of these two images show that the uniform migration image is worse than the migration image of original field data. The partial reason may be that, as mentioned above, the average wavelength of the source wavelet is about 300 ft, while the spatial sampling interval for the uniformly spaced data is 550 ft. So the interpolated data are spatially aliased in both the X and Y directions.

**TEST 2: 1/2 UNIFORM INTERPOLATION**

For the uniform sampling where \( dx_s = dx_r = dy_s = dy_r = 650 \text{ ft} \), there are 167,216 uniformly spaced traces. For this sampling interval, the total number of interpolated traces is roughly 1/2 the number of traces in the West Texas field data. Table 3 shows the spatial sampling intervals for the interpolated traces.

Table 3. Survey parameters for the 1/2 uniform grid.

<table>
<thead>
<tr>
<th>( dx_s )</th>
<th>( dy_s )</th>
<th>( dx_r )</th>
<th>( dy_r )</th>
<th>Number of traces</th>
</tr>
</thead>
<tbody>
<tr>
<td>650 ft</td>
<td>650 ft</td>
<td>650 ft</td>
<td>650 ft</td>
<td>167,216</td>
</tr>
</tbody>
</table>

Figures 14 and 15 show the shotpoint and geophone distributions of the original and the interpolated traces. Both the shot points and geophone points have a spatial sampling interval of 650 ft in either the X or Y directions. Figures 16 and 17 are blowups of Figures 14 and 15, respectively and show that traces from some regular grid shot points or geophone points have the same contribution to interpolated traces at two or three uniformly spaced shot points or geophone points, while traces from some other regular grid points make no contribution to the trace interpolation at any of the uniformly spaced shot or geophone points.
Figure 12: Image obtained by migrating the uniform distribution of interpolated data. The data consists of 339,314 traces with an uniform sampling interval of 550 ft.
Figure 13: Image obtained by migrating the original West Texas data which consists of 334,659 traces.
Figure 14: The uniform shot distribution compared with the original shot distribution. The crosses are the shot positions of interpolated traces and the dots are those of the original traces. The uniform spatial sampling interval is 650 ft.
Figure 15: The uniform receiver distribution compared with the original receiver distribution. The crosses are the receiver positions of the interpolated traces and the dots are those of the original traces. The uniform spatial sampling interval is 650 ft.
Figure 16: Blowup of Figure 14. Notice that some regular grid shot points contribute to more than one uniform shot point while other regular grid shot points make no contributions to any uniform shot point.
Figure 17: Blowup of Figure 15. Notice that some regular grid receiver points contribute to more than one uniform receiver point while other regular grid receiver points make no contribution to any uniform receiver point.
Figure 18 shows the image obtained by migrating the uniformly interpolated traces. It looks even worse than Figure 12 because the data are more aliased.

**TEST 3: 1/4 UNIFORM INTERPOLATION**

For the uniform sampling where \( dx_s = dx_r = dy_s = dy_r = 800 \text{ ft} \), there are 74,448 uniformly spaced traces. For this sampling interval, the total number of interpolated traces is roughly 1/4 the number of traces in the West Texas field data. Table 4 shows the spatial sampling intervals for the interpolated traces.

<table>
<thead>
<tr>
<th>( dx_s )</th>
<th>( dy_s )</th>
<th>( dx_r )</th>
<th>( dy_r )</th>
<th>Number of traces</th>
</tr>
</thead>
<tbody>
<tr>
<td>800 ft</td>
<td>800 ft</td>
<td>800 ft</td>
<td>800 ft</td>
<td>74,448</td>
</tr>
</tbody>
</table>

Figures 19 and 20 show the shotpoint and geophone distributions of the original and the interpolated traces. Both the shot points and geophone points have a spatial sampling interval of 800 ft in either the X or Y directions. Figures 21 and 22 are blowups of Figures 19 and 20, respectively and show that traces from some regular grid shot points or geophone points make the same contribution to interpolated traces at two or three uniformly spaced shot points or geophone points, while traces from some other regular points make no contribution to the trace interpolated at any of the uniformly spaced shot or geophone points.

Figures 23, 24, and 25 show the 1/4 UM, the 1/4 RM and the 1/4 QM images, respectively. Comparison of these three images show that, at 1/4 subsampling, QM migration produces the best
Figure 18: Image obtained by migrating the uniform distribution of interpolated data. The data consist of 167,216 traces with an uniform sampling interval of 650 ft. The trace number is roughly 1/2 of the original West Texas field data.
Figure 19: The uniform shot distribution compared with the original shot distribution. The crosses are the shot positions of interpolated traces and the dots are those of the original traces. The uniform spatial sampling interval is 800 ft.
Figure 20: The uniform receiver distribution compared with the original receiver distribution. The crosses are the receiver positions of the interpolated traces and the dots are those of the original traces. The uniform spatial sampling interval is 800 ft.
Figure 21: Blowup of Figure 19. Notice that some regular grid shot points contribute to more than one uniform shot point while other regular grid shot points make no contribution to any uniform shot point.
Figure 22: Blowup of Figure 20. Notice that some regular grid receiver points contribute to more than one uniform receiver point while other regular grid receiver points make no contribution to any uniform receiver point.
quality image and RM migration produces a medium quality image, while the UM migration produces the worst quality image.

**TEST 4: 1/8 UNIFORM INTERPOLATION**

For the uniform sampling where $dx_s = dx_r = dy_s = dy_r = 900 \text{ ft}$, there are 48,384 uniformly spaced traces. For this sampling interval, the total number of interpolated traces is roughly $1/8$ the number of traces in the West Texas field data. Table 5 presents the spatial sampling intervals for the interpolated traces.

Table 5. Survey parameters for the 1/8 uniform grid.

<table>
<thead>
<tr>
<th>$dx_s$</th>
<th>$dy_s$</th>
<th>$dx_r$</th>
<th>$dy_r$</th>
<th>Number of traces</th>
</tr>
</thead>
<tbody>
<tr>
<td>900 ft</td>
<td>900 ft</td>
<td>900 ft</td>
<td>900 ft</td>
<td>48,384</td>
</tr>
</tbody>
</table>

Figures 26 and 27 show the shotpoint and geophone distributions of the original and the interpolated traces. Both the shot points and geophone points of the interpolated traces have a uniform spatial sampling interval of 900 ft in either the X or Y directions. Figures 28 and 29 are blowups of Figures 26 and 27, respectively. They also show that traces from some regular grid shot points or geophone points have the same contribution to interpolated traces at two or three uniformly spaced shot points or geophone points, while traces from some other regular grid points make no contribution to the trace interpolation at any of the uniformly spaced shot or geophone points.

Figure 30 shows the image obtained by migrating the 1/8 uniformly interpolated traces. Figure 31 shows the 1/8 RM image and Figure 32 shows the 1/8 QM image. Comparison of these three images show that, at 1/8 subsampling, the QM migration produces the best quality image and the RM migration produces
Figure 23: Image obtained by migrating the 1/4 subsampled uniform distribution of data. The data consist of 74,448 traces with an uniform sampling interval of 800 ft. The trace number is roughly 1/4 the number of traces in the original West Texas field data.
Figure 24: 1/4 RM image.
Figure 25: 1/4 QM image.
Figure 26: The uniform shot distribution compared with the original shot distribution. The crosses are the uniform shot positions and the dots are the original shot positions. The uniform spatial sampling interval is 900 ft.
Figure 27: The uniform receiver distribution compared with the original receiver distribution. The crosses are the uniform receiver positions and the dots are the original receiver positions. The uniform spatial sampling interval is 900 ft.
Figure 28: Blowup of Figure 26. Notice that some regular grid shot points contribute to more than one uniform shot point while other regular grid shot points make no contribution to any uniform shot point.
Figure 29: Blowup of Figure 27. Notice that some regular grid receiver points contribute to more than one uniform receiver point while other regular grid receiver points make no contribution to any uniform receiver point.
a medium quality image, while the UM migration produce the worst quality image.

**DISCUSSION**

The field data tests in this report show that interpolating traces from a regular grid to a uniform grid produces worse migrated images than interpolating traces to a quasi-Monte Carlo grid or even a regular grid.

Why are the uniform images the worst compared with the RM and QM images? There might be two possible reasons. The first reason is the spatial aliasing caused by the coarse discrete spatial sampling and the second reason is that the trace may not be properly interpolated. These two factors are difficult to isolate. The point scatterer migration response tests show (Chen, 1997) that the likely major cause is the coarse spatial sampling rather than the interpolation problem.

**ACKNOWLEDGEMENTS**

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**REFERENCES**

Figure 30: Image obtained by migrating the 1/8 subsampled uniform distribution of data. The data consists of 74,448 traces with an uniform sampling interval of 900 ft. The trace number is roughly 1/8 the number of the traces in the West Texas field data.
RM Image of 1/8 Interpolated Data

Figure 31: 1/8 RM image.
QM Image of 1/8 Interpolated Data

Figure 32: 1/8 QM image.