INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.
DMO on irregularly spaced seismic data

Lu, Shaoli, M.A.
Rice University, 1993

Copyright ©1992 by Lu, Shaoli. All rights reserved.
RICE UNIVERSITY

DMO ON IRREGULARLY SPACED SEISMIC DATA

by

SHAOLI LU

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

MASTER OF ARTS

APPROVED, THESIS COMMITTEE:

Gerald H. F. Gardner, Chairman
W. H. Keck Professor of Geophysics

Dale S. Sawyer
Associate Professor of Geology and Geophysics

William W. Symes
Professor of Computational and Applied Mathematics

Houston, Texas

November, 1992
Copyright

Shaoli Lu

1992
ABSTRACT

DMO ON IRREGULARLY SPACED SEISMIC DATA

by

SHAOLI LU

Irregularly spaced seismic data have uneven distribution of trace midpoint density on the half-offset \((h)\) versus common-midpoint \((y)\) space. The deviation from uniformity disrupts the cancellation and reinforcement processes of dip moveout (DMO) operators, hence artificial amplitude anomalies are produced on the DMO output. A pre-DMO weighting method is devised to weight each trace based on the trace midpoint density on the \((y,h)\) space. Using the Voronoi Diagram concept, the method is designed to calculate the Voronoi polygon areas associated with mid-points of seismic traces on the \((y,h)\) space. The area of a polygon is inversely proportional to the trace density on the \((y,h)\) space. Scaling each trace by its Voronoi polygon area prior to applying DMO, the undesirable effects caused by irregular spatial sampling can be largely overcome. The method is called the Voronoi weighting method in this thesis. It can be efficiently implemented on vector or parallel computers.
ACKNOWLEDGEMENTS

I thank Gerald Gardner, Dale Sawyer, and William Symes for their time in reading this thesis. I would like to thank M. Turhan Taner, Ozdogan Yılmaz, and Alan Levander for their support of my interest in advancing my education at a prestigious university.

I am grateful to the Geology and Geophysics Department of Rice University for giving me the opportunity to acquire higher knowledge in the field of Earth Science. I would like to acknowledge CogniSeis Development, Inc. for the computer facilities and the field data used in this thesis. My graduate study was financed by myself.

I must thank my husband Lee Lu for those intuitive discussions with him in the early stage of this research and the keen supply of papers related to this topic.

I want to thank my parents, sisters and brother for their compassion and advice when I needed guidance during the course of my study.

This master degree is just a small achievement I have accomplished. The most important thing in my life is to ensure my beloved children Dennis and Patrick grow up with love, care and proper guidance. I will have achieved my major goal when they become responsible, independent, kind and caring adults. It is the joy of having them that has given me the strength to juggle among work, school and motherhood.

This thesis is dedicated to those who believe new ideas in the scholastic world should be built on empirical or logical scientific disciplines but not on superficial terminologies.
TABLE OF CONTENTS

ABSTRACT ........................................................................................................... ii

ACKNOWLEDGEMENTS .................................................................................... iii

TABLE OF CONTENTS ....................................................................................... iv

LIST OF FIGURES ............................................................................................. vi

INTRODUCTION ................................................................................................ 1

CHAPTER 1: IRREGULARLY SPACED SEISMIC DATA

1.1 The causes .................................................................................................... 3

1.2 Offset versus common-midpoint plane ....................................................... 3

CHAPTER 2: DIP MOVEOUT

2.1 Theoretical background ............................................................................. 10

2.2 Examples of DMO application on conflicting dipping reflectors .............. 19

2.3 DMO promises in general ........................................................................... 27

CHAPTER 3: APPLY DMO ON IRREGULARLY SPACED DATA

3.1 Positioning traces using constant area cell method ................................... 29

3.2 Using point diffractor model to show the effects of irregular spatial

sampling on DMO output ............................................................................... 33
CHAPTER 4: VORONOI WEIGHTING METHOD

4.1 What is a Voronoi Diagram? ................................................................. 39
4.2 Transform trace coordinates to point set $S$ ........................................ 39
4.3 Digital construction of Voronoi Diagram on the $(y,h)$ plane .................. 44
4.4 Convert inverse problem to forward problem ....................................... 47
4.5 Application of Voronoi weighting method using forward formulation .... 48
4.6 Voronoi weighted DMO result .............................................................. 51
4.7 Run time and computer technology ...................................................... 51

CHAPTER 5: SEARCHING FOR OIL

5.1 An irregularly spaced land data .............................................................. 55
5.2 Non-uniform offset distribution in common-midpoint gathers .................. 56
5.3 Common-offset sections before and after Voronoi weighting .................... 61
5.4 DMO stack with and without Voronoi weighting .................................... 66

CONCLUSIONS ......................................................................................... 73

REFERENCES ......................................................................................... 74
LIST OF FIGURES

Figure 1.1. Stacking diagram. Each dot in this plane depicts a seismogram.

Figure 1.2. Distribution of seismograms on the $(y, h)$ plane, for regularly spaced seismic data.

Figure 1.3. Constant-offset section extracted from a regularly spaced data set.

Figure 1.4. Distribution of seismograms on the $(y, h)$ plane, for irregularly spaced seismic data.

Figure 1.5. Constant-offset section extracted from an irregularly spaced data set.

Figure 2.1. Common-midpoint gather from a flat reflector.

Figure 2.2. Common-midpoint gather from a dipping reflector.

Figure 2.3. Reflection point displacement for a single dipping reflector.

Figure 2.4. The DMO ellipse for a sample point at time $t_n$ after NMO correction.

Figure 2.5. Relationship between reflection slope measured on zero-offset data (or on the DMO ellipse) and reflector dip $\theta$.

Figure 2.6. DMO impulse response for offsets: 500, 1300 and 2200 meters.

Figure 2.7. Two planar reflectors with conflicting dips in a constant velocity medium.

Figure 2.8. Common midpoint gathers before NMO correction.

Figure 2.9. Common midpoint gathers after NMO correction. Reflections from the flat reflector are properly corrected. Reflections from the dipping reflector are over corrected.
Figure 2.10. Conventional common midpoint stack. Dipping reflector is attenuated by smearing effect.

Figure 2.11. Reflection point dispersal altered the waveform of the dipping reflector.

Figure 2.12. Common midpoint gathers after NMO+DMO correction. Reflections from both reflectors are properly corrected.

Figure 2.13. DMO stack. Smearing effect has been removed by the DMO process.

Figure 2.14. Both reflectors have the original symmetrical waveform after application of DMO.

Figure 3.1. Dividing the \((y,h)\) plane into constant area cells.

Figure 3.2. Positioning a trace at location \(P\) to regularly spaced points at 1, 2, 3, and 4.

Figure 3.3. Geometry of a point-scatterer.

Figure 3.4. DMO stack of regularly spaced seismic data. The image of a point-scatterer on a zero-offset section is a hyperbola.

Figure 3.5. DMO stack of irregularly spaced seismic data. Missing and excessive data have caused amplitude and phase distortion on the limbs of the hyperbola.

Figure 3.6. F-K migration on DMO stack of irregularly spaced seismic data. The image of the point-scatterer is distorted by artifacts on the diffraction hyperbola.

Figure 4.1. A point set \(S\).

Figure 4.2. Voronoi Diagram of \(S\), or \(\text{Vor}(S)\).
Figure 4.3. Forming Voronoi polygons by constructing Delaunay triangulation of $S$ or $DT(S)$.

Figure 4.4. Voronoi polygons of regularly spaced data. Areas of the polygons are the same.

Figure 4.5. Voronoi polygons of irregularly spaced data. Areas of the polygons are not the same.

Figure 4.6. Construction of Voronoi polygons by inverse problem approach.

Figure 4.7. Construction of Voronoi polygons by forward problem approach.

Figure 4.8. Dividing the $(y,h)$ space into finite number of discrete elements.

Figure 4.9. DMO stack of irregularly spaced seismic data, with application of Voronoi weighting method prior to the DMO process. Artifacts caused by missing and excessive data have been removed.

Figure 4.10. F-K migration on DMO stack of irregularly spaced seismic data, with Voronoi weighting method applied prior to DMO. The image of the point-scatterer is now properly focused.

Figure 5.1. CMP 650 has 24 live traces, offset interval varies from 50 to 350 meters. CMP 750 has 28 live traces, offset interval varies from 50 to 200 meters.

Figure 5.2. CMP 820 does not have offsets smaller than 275 meters. CMP 950 has 34 live traces, offset interval varies from 50 to 200 meters.

Figure 5.3. CMP 1000 has several near to middle offsets missing. CMP 1025 does not have offsets smaller than 975 meters.

Figure 5.4. CMP 1100 has 30 live traces. Offset interval varies from 50 to 350 meters. In CMP 1150 many near to middle offsets are missing.
Figure 5.5. Moderate missing data occurs along the line. Severe missing data occurs around CMPs 1000 and 1035. The syncline structure is disrupted by missing data problem.

Figure 5.6. Constant area cell method has moved a small amount of energy into the missing data zones. Voronoi weighting has improved amplitude variation along reflectors.

Figure 5.7. Severe missing data occurs around CMP 980 and around CMP 1045. Structure continuity is blurred on this section.

Figure 5.8. Voronoi weighting gives this common-offset section a better defined structure continuity.

Figure 5.9. Missing and excessive offsets in the CMP gathers disrupt the functioning of the DMO process. Bands of high and low amplitude zones occur allover the line.

Figure 5.10. Bands of high and low amplitude zones are removed by the Voronoi weighting method. A clearer image of the subsurface is obtained.

Figure 5.11. The crests of the folded layers and fold limbs are weakly defined. Low coverage around CMP 820 changes the amplitude along horizontal beds.

Figure 5.12. The boundaries of the folded sequence and the dipping fold limbs are better defined. Artificial amplitude changes along horizontal reflectors are removed.

Figure 5.13. Artificial amplitude anomalies occur after DMO processing.

Figure 5.14. Artificial amplitude anomalies are largely removed when Voronoi weighting is applied prior to DMO.
INTRODUCTION

Cost constraints and the realities of acquiring seismic data often cause the data to be sampled in an irregular fashion. However, most derivations of the DMO theories are based on regular geometry (Deregowski and Rocca, 1981; Hale, 1984) in which the irregular midpoint and offset distributions are not considered. Applying DMO to regularly sampled data will create at each spatial location a complete and balanced distribution of dip components, which interfere constructively or destructively to form the DMO-corrected wavefield. On the other hand, applying DMO on irregularly sampled data will result in a lack of dip components or overabundance of dip components at some spatial and temporal locations. This imbalance, in the components that form the DMO-corrected wavefield, hinders the process of constructive and destructive interference, as a result, artificial amplitude anomalies are produced. The objective of this research is to develop methods to compensate the distortions of reflector amplitudes on DMO processed data caused by non-uniform recording geometry.

In chapter 2, we will see that the DMO operator is derived along a constant shot-receiver azimuth, however variations in shot-receiver azimuth do occur in seismic data acquisition. To avoid complication, this research assumes a constant shot-receiver azimuth.

Different facts of irregularly spaced seismic data have been discussed by various authors. Ronen (1987) attempted to interpolate missing data by finding the inversion of huge data matrices. Black and Schleicher (1989) attempted to comprehend the artifact problem by designing correction filters and edit the data after processed by DMO. Beasley and Klotz (1992) attempted to equalize the dip components at each DMO output location. While the problem is caused by uneven distribution of midpoints on the \((y,h)\) plane, approaching the problem by seeking a method that can counter-balance the imbalance mid-point density on the \((y,h)\) plane is probably the
right direction.

The concept of Voronoi regions has been applied in a variety of scientific disciplines. For example, in defining the domains of action of crystals and in formulating the Thiessen polygons of meteorological data. The Voronoi regions have also been applied in statistics, geography, interpolation, physical chemistry, and many other fields. The straight-line dual of the Voronoi Diagram is called Delaunay triangulation, which has been widely applied in 3D seismic data processing for area interpolation. In this thesis, I applied the concept to find the region that is closest to a trace on the offset versus common-midpoint space. The region represents the weight of influence of the trace on the recorded data set.

Two big questions exist, 1. how to apply the DMO process on irregularly spaced seismic data, 2. how to construct the Voronoi Diagram on the (y,h) plane. The first question leads to the development of constant area cell method, which is explained in chapter 3. The second leads to the development of Voronoi weighting method, which is explained in chapter 4.
CHAPTER 1

IRREGULARLY SPACED SEISMIC DATA

1.1 THE CAUSES

In seismic data acquisition, we would like to place the sources and receivers in a manner that offset increment is constant within a shot and the intervals between shots are constant along a line. However, many uncontrollable situations often cause the shots and the receivers being placed at locations to deviate from the regular manner. On land, because of physical obstructions and environmental objectives, sources or receivers can not always be placed at the desired locations; wherever possible, extra shots or receivers are deployed, resulting in sparse coverage at some locations and perhaps an overabundance of traces at other locations. For marine data, marine-cable feathering and swath or patch shooting can produce sparse or irregular distribution in one or more of offset, azimuth, and fold. Other factors contributing to irregular sampling include asymmetrical shooting geometries and editing of noisy data.

1.2 OFFSET VERSUS COMMON-MIDPOINT PLANE

The geometry layout of a survey can be visualized on a diagram, normally called stacking diagram as shown in Figure 1.1 (Claerbout, 1985). On this diagram, is defined as the midpoint between the shot location \( s \), and the geophone location \( g \), \( h \) is defined as half the horizontal offset between the shot and geophone:

\[
y = \frac{g + s}{2},
\]

\[
h = \frac{g - s}{2}.
\]
Figure 1.1. Stacking diagram. Each dot in this plane depicts a seismogram.
These equations represent a change of coordinates from the space of \((s, y)\) to the space of \((y, h)\). Each dot on the diagram depicts a seismogram or trace. Rotating the stacking diagram by 45 degrees, we will obtain a coordinate space where the ordinates are the half-offsets \(h\) and the abscissas are the midpoints \(y\). Figure 1.2 shows the distribution of seismograms recorded with regularly spaced shots and receivers on a \((y, h)\) plane. Since the data is also a function of the travel time \(t\), the full dataset lies in a volume. Let \((y, h=\text{const}, t)\) represent a constant-offset section. If we select constant-offset sections at fixed increment along the \(h\) axis, we can extract a fix number of constant-offset slices from the regularly spaced data volume. On each extracted \((y, h=\text{const}, t)\) section, a seismogram is situated at constant increment of \(y\) coordinates (Figure 1.3). All the recorded traces of the seismic line will be included and evenly distributed on each of the \((y, h=\text{constant}, t)\) sections.

Figure 1.4 shows the distribution of seismograms recorded with irregularly spaced shots and receivers. If we select constant-offset sections at a fixed interval from the irregularly spaced data volume, we will see that many of the recorded traces will not be included on the sections selected. Furthermore, if we sample the \(y\) axis at a constant space sampling rate, we will see that the seismograms are not spaced at equal distance along the \(y\) axis, some regions on the \(y\) axis may have more traces than the other regions, and many of the traces may be situated in the neighborhoods of regularly spaced sample points but not on the sample points themselves as shown in Figure 1.5. This raises the questions of how to apply DMO on this type of data and what effects this data will have on the DMO output.
Figure 1.2. Distribution of seismograms on the $(y, h)$ plane, for regularly spaced seismic data.
dcx = constant

( y, h=const, t ) section

Figure 1.3. Constant-offset section extracted from a regularly spaced data set.
Irregularly spaced seismic data

Figure 1.4. Distribution of seismograms on the \((y, h)\) plane, for irregularly spaced seismic data.
\text{dcx} \neq \text{constant}

(\text{y, h=const, t}) \text{ section}

Figure 1.5. Constant-offset section extracted from an irregularly spaced data set.
CHAPTER 2

DIP MOVEOUT

2.1 THEORETICAL BACKGROUND

DMO is the acronym for dip moveout (Hale, 1984). It is a partial migration process which transforms a pre-stack data set so that each common midpoint gather of traces actually contains events from the same reflection point (Deregowski, 1986). It is well known that common midpoint gathers do not contain reflections with common reflection points when reflectors are dipping. Figure 2.1 is a CMP gather consists of traces reflected from a flat reflector. Figure 2.2 is a CMP gather consists of traces reflected from a dipping reflector. It is apparent that the larger the offset the further the reflection point moves in the up dip direction.

For a single dipping planar reflector and a single-receiver offset, as shown by Levin (1971), the reflection point displacement, \( L \), measured along the reflector with dip \( \theta \), is given by

\[
L = \frac{h^2}{D \cos \theta \sin \theta} , \tag{1}
\]

where \( h \) is half the source-receiver offset and \( D \) is the shortest distance from the source-receiver midpoint to the reflector (Figure 2.3). To compensate for this reflection point displacement, DMO must move the reflection recorded at non-zero offset in this common midpoint gather a distance \( X \) away from the midpoint, where \( X \) is given by

\[
X = -\frac{h^2}{D \sin \theta} . \tag{2}
\]
Figure 2.1. Common-midpoint gather from a flat reflector.
Figure 2.2. Common-midpoint gather from a dipping reflector.
Figure 2.3. Reflection point displacement for a single dipping reflector.
In other words, DMO must move the non-zero offset reflection in the up dip direction so that it will be stacked with a zero-offset reflection having the same reflection point. The zero-offset reflection time \( t_0 \) after DMO is related to the distance \( D \) by

\[
D = \frac{V t_0}{2} + X \sin \theta ,
\]

where \( V \) is the seismic wave velocity. This expression may be used to replace \( D \) in equation (2) and we get

\[
X^2 - \frac{V t_0}{2 \sin \theta} X - h^2 = 0 .
\]

The DMO impulse response shaped like an ellipse is shown in Figure 2.4 and is described by the equation

\[
\left( \frac{t_0}{t_n} \right)^2 + \left( \frac{X}{h} \right)^2 = 1 ,
\]

where

\[
t_n = (t_r^2 - \frac{4h^2}{V^2})^{\frac{1}{2}} ,
\]

\( t_n \) is the normal moveout time and \( t_r \) is the travel time of a non-zero-offset raypath from the source to the reflector to the geophone.

This DMO ellipse describes the mapping to zero-offset of a single sample of seismic data, recorded at some non-zero offset. Unlike pre-stack migration ellipse, the DMO ellipse does not depend on velocity. Each point along the DMO ellipse corresponds to a particular reflector dip. In particular, the bottom of the ellipse, where its slope is zero, corresponds to horizontal reflectors. The steeper slopes along the DMO ellipse
Figure 2.4. The DMO ellipse for a sample point at time $t_n$ after NMO correction.
correspond to steeper reflector dips. Differentiating $t_0$ with respect to $X$ in equation (5) we get

$$\frac{dt_0}{dX} = -\frac{t_n}{t_n h^2}X = -\frac{t_0 X}{h^2 - X^2}.$$  \hspace{1cm} (7)

Since the general relationship between reflection slope measured on the DMO ellipse and reflector dip is given by the relation

$$\frac{dt_0}{dX} = \frac{2\sin\theta}{V},$$  \hspace{1cm} (8)

as shown in Figure 2.5.

Substitute equation (8) into equation (7) we get

$$X^2 - \frac{V t_0}{2 \sin\theta} X - h^2 = 0,$$  \hspace{1cm} (9)

which is exactly the same as equation (4). Therefore, the DMO ellipse provides just the right amount of lateral movement $X$ for each dip to correct for reflection point smear.

It can be shown that (Hale, 1988):

$$|X| \leq \frac{|h|}{(1 + \frac{V^2 t_0^2}{4h^2})^{\frac{1}{2}}}.$$  \hspace{1cm} (10)

This inequality shows that the total width of the DMO impulse response never exceeds the total source-receiver offset, $2h$. Furthermore, the DMO impulse response is widest for large $h$ and small times $t_r$ or $t_n$ (Figure 2.6). In practice, $X$ never equals $h$, because early times are typically muted.
Figure 2.5. Relationship between reflection slope measured on zero-offset data (or on the DMO ellipse) and reflector dip $\theta$. 

\[
\frac{v dt_0}{2} = dx \sin \theta
\]
Figure 2.6. DMO impulse response for offsets: 500, 1300 and 2200 meters.
2.2 EXAMPLES OF DMO APPLICATION ON CONFLICTING DIPPING REFLECTORS

To demonstrate the usefulness of DMO application on seismic data processing, a model, as shown in Figure 2.7, consisting of two planar reflectors in a constant velocity medium is generated. One reflector is flat the other has a dip of 30 degrees. The reflectivities are represented by zero phase wavelets bandlimited with a lowcut of 8 Hz and a highcut of 35 Hz. Figure 2.8 shows three common midpoint gathers picked from the model before applying NMO correction. The results after NMO correction are shown in Figure 2.9. Since the NMO equation is:

\[ t^2 = t_0^2 + \frac{h^2}{v^2}, \]

and the stacking velocity for a dipping reflector is

\[ \frac{v}{\cos \theta}, \]

where \( v \) is the medium velocity, and \( \theta \) is the reflector dip, the travel times for the dipping reflector are over corrected. The conventional CMP stack of the model is shown in Figure 2.10. Because of reflection point dispersal, the dipping reflector is attenuated. The smearing effect or reflection point dispersal is clearly depicted in Figure 2.11, here the stacked traces of CDPs 60, 100 and 140 are shown. We can see that the wavelets of the flat reflector remain symmetrical but reflection point smearing has changed the wavelets of the dipping reflector. After applying DMO on the normal moveout corrected common-midpoint gathers, the dip dependency of stacking velocities has been removed. As shown in Figure 2.12, both reflectors can now be corrected to zero-offset travel times with the same velocity. The dip moveout corrected CMP stack of the model is shown in Figure 2.13. Now the image of the
Figure 2.7. Two planar reflectors with conflicting dips in a constant velocity medium.
Figure 2.8. Common midpoint gathers before NMO correction.
Figure 2.9. Common midpoint gathers after NMO correction. Reflections from the flat reflector are properly corrected. Reflections from the dipping reflector are over corrected.
Figure 2.10. Conventional common midpoint stack. Dipping reflector is attenuated by smearing effect.
Figure 2.11. Reflection point dispersal altered the waveform of the dipping reflector.
Figure 2.12. Common midpoint gathers after NMO+DMO correction. Reflections from both reflectors are properly corrected.
Figure 2.13. DMO stack. Smearing effect has been removed by the DMO process.
dip reflector has significantly enhanced by the DMO process. The DMO stack traces for CDPs 60, 100 and 140 are displayed in Figure 2.14, comparing to Figure 2.11, we see reflectivities from both the flat and the dip reflectors are now having the same zero-phase wavelets after DMO application.

2.3 DMO PROMISES IN GENERAL

The above example shows that DMO is a powerful process to image subsurface structures with conflicting dips. In general the DMO process can provide the following promises (Deregowski, 1986):

1. Migrate each trace to zero offset so that each common-offset section becomes identical to zero-offset section. Reflector point dispersal for non-zero offset traces is removed.

2. Coherent noise with impossibly steep dip is removed, and at the same time steeply dipping fault planes are better imaged alongside horizons with smaller dips.

3. Stacking velocities become independent of dip, so that correct stacking of simultaneous events with conflicting dips is made possible.

4. Diffractions are preserved so as to give improved definition of discontinuities after post-stack migration. Post-stack time migration when applied on DMO stack becomes equivalent to pre-stack time migration, but at considerably less expense.
Figure 2.14. Both reflectors have the original symmetrical waveform after application of DMO.
CHAPTER 3

APPLY DMO ON IRREGULARLY SPACED DATA

3.1 POSITIONING TRACES USING CONSTANT AREA CELL METHOD

As mentioned earlier the DMO ellipse is described by equation (5):

$$\left(\frac{t_0}{t_n}\right)^2 + \left(\frac{X}{h}\right)^2 = 1,$$

where \( h \) is the half-offset. Fix \( h \) as a constant parameter, and vary \( X \) at a known interval, a simple relationship can then be established between \( t_0 \) and \( t_n \). That is why DMO is usually applied on common-offset sections in which the spacing between any two traces is constant. However, if the data are irregularly spaced on the \((y, h)\) space, there will be no finite panel of constant-offset sections. In order to apply the constant-offset DMO process, it is necessary to devise a method to group the irregularly spaced data to the regular grid points.

The common practice in forming common-offset sections is normally carried out by first selecting a constant common-midpoint interval for the survey line, those traces with mid-point coordinates closer to the coordinates of a CMP are grouped into one CMP gather; a constant offset interval is then selected in the CMPs for the whole line, each non-zero offset is NMO corrected and grouped to the closest offset location. To make up even fold count in each CMP, dead traces are normally inserted to replace missing offsets, and excessive offsets are either rejected or combined. Doing this way has the disadvantage that many holes may exist in the data and the available information are not fully used.

The method used in this paper is illustrated in Figure 3.1: the diagram shows
Figure 3.1. Dividing the $(y,h)$ plane into constant area cells.
a half-offset versus common-midpoint space, the offset axis has \( n \) offsets with an increment of \( df_s \), the CMP axis has \( m \) common-midpoints with an increment of \( dcx \), the \((y, h)\) plane is divided into \( m \times n \) constant area cells, each cell has an area of \( df_s \times dcx \) and is bounded by four grid points at its corners. A recorded trace is stacked to the regularly spaced grid points based on its position inside a cell. As shown in Figure 3.2 a trace at location \( P \) with coordinates \((y_p, h_p)\) is placed at point 1 after its amplitudes are scaled by area \( A_3 \). It is placed at point 2 after scaled by area \( A_4 \), at point 3 after scaled by \( A_1 \), and at point 4 after scaled by \( A_2 \). If \( W_1, W_2, W_3 \) and \( W_4 \) represent the normalized weights applied to the trace for points 1, 2, 3 and 4 respectively, then their values are:

\[
W_1 = \frac{(dcx - cm1) \times (df_s - sf1)}{dcx \times df_s},
\]

\[
W_2 = \frac{(dcx - cm1) \times sf1}{dcx \times df_s},
\]

\[
W_3 = \frac{cm1 \times sf1}{dcx \times df_s},
\]

\[
W_4 = \frac{cm1 \times (df_s - sf1)}{dcx \times df_s}.
\]

where

\[
cm1 = |cx1 - y_p|,
\]

\[
sf1 = |fs1 - h_p|.
\]
Figure 3.2. Positioning a trace at location $P$ to regularly spaced points at 1, 2, 3, and 4.
and \((x_1, y_1)\) are the coordinates of point 1.

This method ensures that the closer the mid-point of a trace to a regular grid point the heavier its weight of contribution. It also has the advantages that less holes will exist in the regularly grouped data and no wastage of available data information.

3.2 USING POINT-DIFFRACTOR MODEL TO SHOW THE EFFECTS OF IRREGULAR SPATIAL SAMPLING ON DMO OUTPUT

Wave theory states that a wave incident on a point within the earth reflects waves in all directions. Any model is a superposition of point-scatterers (Claerbout, 1985). One important goal in seismic data processing is to be able to accurately image a point-diffractor in the subsurface. In order to achieve that, in the processing sequence, the multi-channel seismic data are first corrected to zero-offset data by the NMO + DMO processes; a zero-offset migration process is then applied on the zero-offset data for positioning to the true subsurface reflection point. The image of a point-diffractor on a zero-offset section should be a hyperbola, when the zero-offset migration process is applied on the hyperbola, the hyperbola will collapse into a single point, which is the true image of the point-scatterer in the subsurface.

In analyzing the effects of irregular spatial sampling on the DMO result, a point-diffractor model appears to be an ideal choice. As what happened to a point can be generalized to the whole structure.

The point-scatterer geometry for a point located at \((x, z)\) is shown in Figure 3.3, where \(x\) is the horizontal distance from a selected origin and \(z\) is the depth. The equation for travel time \(t\) from the source location \(s\) to the receiver location \(g\) at the surface is the sum of the two travel paths

\[
tv = \sqrt{z^2 + (s - x)^2} + \sqrt{z^2 + (g - x)^2},
\]
Figure 3.3. Geometry of a point-scatterer.
where \( v \) is the medium velocity. To demonstrate the effects of irregular spatial sampling on the DMO result, a 24 fold synthetic data derived from a constant velocity point-diffractor model is designed. The model is first generated with regularly spaced data having 200 CDPS and a fold count of 24 in each CDP. The CMP interval along the CMP axis is 25 meters, the offset interval along the offset axis is 100 meters. Figure 3.4 shows the stack of the DMO result on the regularly spaced data. The model is then generated with data having varied offsets and CMP intervals such that around CDPs 35 to 55 some offsets are missing and around CDPs 145 to 165 abundant or excessive data existed. The traces in this irregularly spaced data set are distributed to the regular grid points using the constant area cell method described above and followed by the application of common-offset DMO process. The DMO stack of irregularly spaced data is shown in Figure 3.5. Comparing to Figure 3.4, we see that missing and excessive data have caused amplitude and phase distortion on the limbs of the hyperbola. To get back the true image of the point-scatterer, a zero-offset F-K migration process is applied to the DMO stack of irregularly spaced data, and the result after F-K migration is shown in Figure 3.6. It is clear that the artifacts caused by missing and excessive data have impaired the imaging ability of the migration process, and the point-scatterer is not properly imaged.

This example shows that the quality of DMO output depends on the uniformity of trace distribution on the offset versus common-midpoint space. As shown in Figure 2.6, the DMO operators are not limited to the CMP boundaries. The process maps each amplitude to a suite of output traces that fall on a line between the source and receiver. The mapped amplitudes are then summed with other traces that fall in the same output CMP. Hence the amplitudes of DMO output are influenced by the distribution of trace density on the \((y, h)\) space. This leads to the idea of balancing the DMO output by weighting the input traces based on the density distribution of trace mid-points on the \((y, h)\) plane.
Figure 3.4. DMO stack of regularly spaced seismic data. The image of a point-scatterer on a zero-offset section is a hyperbola.
Figure 3.5. DMO stack of irregularly spaced seismic data. Missing and excessive data have caused amplitude and phase distortion on the limbs of the hyperbola.
Figure 3.6. F-K migration on DMO stack of irregularly spaced seismic data. The image of the point-scatterer is distorted by artifacts on the diffraction hyperbola.
CHAPTER 4

VORONOI WEIGHTING METHOD

4.1 WHAT IS A VORONOI DIAGRAM?

Consider the following problem, known as the post office problem: We are given a set $S$ of $N$ points in the plane (considered as post offices or sites). When an arbitrary new point $(x,y)$ (say, a residence) is given, we must find out which post office is closest to $(x,y)$. For each post office $P$, the locus of points $(x,y)$ that are closer to $P$ than to any other post office in $S$ is a convex region $V(P)$, called the Voronoi region or Voronoi polygon associated with $P$. The $N$ polygons $V(P)$ form a partition of the plane, called the Voronoi Diagram (Aurenhammer, 1988) of $S$, denoted by $Vor(S)$. Figure 4.1 shows a point set $S$ and Figure 4.2 shows $Vor(S)$. The Voronoi polygons can be formed by first constructing the Delaunay triangulation $DT(S)$ of the point set $S$ and followed by finding the perpendicular bisectors at the edges of the triangles, connecting the intersections of the perpendicular bisectors then form the Voronoi polygons as shown in Figure 4.3.

4.2 TRANSFORM TRACE COORDINATES TO POINT SET $S$

The post office problem can be transformed to the problem of uneven trace distribution on the $(y,h)$ space. The point set $S$ is analogous to the $N$ mid-points of the seismic traces in the $(y,h)$ plane. Since the distance between any point in the Voronoi polygon of a trace is shorter than the distance from the point to any other traces on the $(y,h)$ plane, the area enclosed in a Voronoi polygon associated with a trace $P$ varies with the trace density distribution on the $(y,h)$ plane. If the density distribution is uniform, the area of the Voronoi polygon of every trace will be the same, an example is shown in Figure 4.4. Whereas if the density distribution is not uniform then the higher the trace density the smaller the Voronoi polygon of a trace, the lower the trace
Figure 4.1. A point set S.
Figure 4.2. Voronoi Diagram of $S$, or $\text{Vor}(S)$. 
Figure 4.3. Forming Voronoi polygons by constructing Delaunay triangulation of $S$ or $DT(S)$. 
Figure 4.4. Voronoi polygons of regularly spaced data. Areas of the polygons are the same.
density the larger the Voronoi polygon of a trace (Figure 4.5). Thus weighting each trace by the area of its Voronoi polygon will give each trace a weight which is inversely proportional to the trace density in the offset-CMP space. This method is termed Voronoi weighting method in this paper.

4.3 DIGITAL CONSTRUCTION OF VORONOI DIAGRAM ON THE \((y,h)\) PLANE

Digital computers have become the most widely used computers in seismic data processing, although Voronoi Diagram can be constructed geometrically using Delaunay triangulation, it requires many complex programming steps on a digital computer. Using the concept of digital bits a seemingly less complex method is investigated to form the Voronoi Diagram on the \((y,h)\) space. The method is to divide the \((y,h)\) space into small discrete elements similar to the pixels on a television screen. Assuming all the pixels are turned off at time equals to zero second, and at that time all the traces start to radiate out one radii increment in all directions from their mid-points, those pixels reached by the radius are turned on. The circles centered at the mid-points slowly expand as time increments. At each time step only those pixels which were off and are reached by the radius are turned on and the amount of pixels that are turned on for a trace are counted. When all the pixels on the \((y,h)\) space are turned on, the boundaries between the Voronoi polygon of each trace will be formed digitally and the Voronoi weights for all the traces are also automatically obtained. An example for a point set \(S\) of 4 points is illustrated in Figure 4.6. This method may be easier to grasp visually, but for thousands of seismic traces with random mid-point coordinates, keeping track of the pixels that should be turned on by each trace at each time step is an extremely difficult programming task.
Figure 4.5. *Voronoi polygons* of irregularly spaced data. Areas of the polygons are not the same.
Figure 4.6. Construction of Voronoi polygons by inverse problem approach.
4.4 CONVERT INVERSE PROBLEM TO FORWARD PROBLEM

The method just described is like an inverse problem: knowing the coordinates of each trace, we want to find the pixels that are closer to a trace than to any other traces. The definition of inversion is that given the data we would like to find the model from the observed data (Menke, 1984). In seismic data processing the migration process is like an inverse problem: given the data recorded, migration tries to find the true positions of the subsurface structures that give rise to the data. If we look at the mid-points of the traces on the \((y, h)\) space as data, and the pixels or small discrete elements as the model parameters, the models we wish to find are the Voronoi polygons on the \((y, h)\) plane. If we have \(N\) measurements of trace coordinates, we can form a vector \(d\) of length \(N\), such that

\[
data : d = [d_1, d_2, d_3, d_4, \ldots, d_N]^T,
\]

where \(d_i\) are the mid-point coordinates of trace \(i\).

There are \(N\) models we wish to find. Suppose the mid-points expand through \(M\) elements at each time step, then, for each model, the model parameters can be represented as the elements of a vector \(m\), which, is of length \(M\),

\[
\text{model parameters : } m = [m_1, m_2, m_3, m_4, \ldots, m_M]^T,
\]

where the elements \(m_j\) are the coordinates of the pixels. In general an inverse problem is more difficult to solve than a forward problem. This is because in forward modeling the model is known and data are derived from the known model whereas in inverse theory the model is determined from the data and estimates of model parameters. Having this in mind, if we can convert the problem of finding the Voronoi polygons from an inverse problem to a forward problem, may be it will be easier to find the Voronoi
To formulate a forward problem we need the input data and the model, we can assume each small discrete element on the \((y, h)\) space is a model, and the coordinates of the mid-points of all the traces are the input, then the data we want to find is the trace whose mid-point has the shortest distance to the model among all the traces. After the data of a model is found the program then increment to the next model and perform the same computation. When all the elements (models) on the \((y, h)\) space are used and their corresponding data are derived, the shape of the Voronoi polygon for each trace is then automatically defined and the number of elements in each polygon or Voronoi weight is also automatically accumulated. An example for 4 input points is illustrated in Figure 4.7.

4.5 APPLICATION OF VORONOI WEIGHTING METHOD USING FORWARD FORMULATION

To demonstrate the effectiveness of the Voronoi weighting method, I applied the method on the irregularly spaced data set of the point-diffractor model. The procedure is carried out by first selecting a regularly spaced offset versus common-midpoint grid. In this case the interval along the \(h\) axis is 100 meters and along the \(y\) axis is 25 meters. The regular grid is then divided into tiny fine grids along the offset and the common-midpoint axes. We can imagine the \((y, h)\) space covered by fish net with small holes as shown in Figure 4.8. In this example the size of the hole is \(10 \times 2.5\) square meters. Each knot on the net represents a discrete element on the \((y, h)\) space and its coordinates are calculated. The mid-point coordinates of each trace are then input to the program. In searching the trace which is closest to an element, the distances between the element and the mid-points of all the traces are computed, and stored in an array. The distance array is then sorted to find the smallest value which is the the trace having the smallest distance to the element. The element is then marked
Figure 4.7. Construction of *Voronoi* *polygons* by forward problem approach.
Figure 4.8. Dividing the \((y, \lambda)\) space into finite number of discrete elements.
with the trace number and the program then moves to the next element and performs
the same search. After moving through all the fine elements on the \((y, h)\) space, the
amount of elements marked for a trace is tabulated and its value is the same as the
area of the Voronoi polygon associated with the trace. This information is stored in a
file in the computer for later access.

4.6 VORONOI WEIGHTED DMO RESULT

Prior to applying the DMO process, each input trace of the point diffractor model
is first NMO corrected. The file which contains the Voronoi weights of the traces is
read in, each trace is then scaled by its Voronoi weight and distributed to the regularly
spaced grid using the constant area cell method described earlier in this paper. The
DMO process is then applied on each constant-offset section and followed by common-
midpoint stacking.

The DMO stack after application of the Voronoi weighting method is shown in Figure
4.9. Comparing to Figure 3.5, it is apparent that the artifacts due to irregular spatial
sampling have been removed. To get back the original image of the point-scatterer, a
zero-offset F-K migration process is applied on the Voronoi weighted DMO stack data
and the result is shown in Figure 4.10. The difference between Figure 4.10 and Figure
3.6 shows that the Voronoi weighting method has successfully removed the damaging
effects of artificial amplitude anomalies on the imaging ability of the migration process,
and the point-scatterer is now properly imaged.

4.7 RUN TIME AND COMPUTER TECHNOLOGY

The computation time required in calculating the Voronoi weights is directly pro-
portional to the total number of discrete elements defined on the \((y, h)\) space and
the size of the data set. In the era of vector computers and parallel processing, this
Figure 4.9. DMO stack of irregularly spaced seismic data, with application of Voronoi weighting method prior to the DMO process. Artifacts caused by missing and excessive data have been removed.
Figure 4.10. F-K migration on DMO stack of irregularly spaced seismic data, with Voronoi weighting method applied prior to DMO. The image of the point-scatterer is now properly focused.
method not only is straightforward to implement, it also has the great advantage that it can use the vector and parallel processing facilities provided by the latest computer technology. Since the method treats each element independently, separate arrays can be formed for each element and distributed to different parallel nodes for computation. The sorting process can also benefit from the available vector library routines on most of the vector computers.
CHAPTER 5

SEARCHING FOR OIL

5.1 AN IRREGULARLY SPACED LAND DATA

I find an extremely valuable piece of land data, because of physical obstructions at the field, the dynamites and the receivers were unable to be placed at regular intervals. Thus, not only the shot intervals vary along the line, but the receiver intervals also vary along the line. Furthermore, due to malfunction of equipments and lithology of the area many dead traces, and noisy traces exist in the data. Obviously, like many other data acquired elsewhere, due to economic and environmental reasons it will be too costly to reacquire the data. So, to get a reliable and accurate picture of the subsurface, we can only resort to sophisticated seismic data processing techniques and experienced data processing knowledge.

The data is in SEGY exchange format with a data length of 6 seconds sampled at 1 millisecond. The number of channels per shot is 120. The recording pattern is split-spread. The desired regular channel interval is 50 meters, and the desired regular common-midpoint interval is 25 meters. A total of 240 shots were collected along the line.

As the zone of interest lies above 4 seconds, I have only used up to 4 seconds of data for all the displays shown in here.

The initial processing sequences include: demultiplexing, gain recovery, resampling to 4 milliseconds, deconvolution, velocity study, uphole corrections, datum static corrections, editing of noisy traces and common-midpoint sorting. After CMP sorting, those traces with mid-point coordinates closer to a CMP station are grouped into one CMP gather. There are 1100 common-midpoint stations for this line. Since the line is long, only 501 of them are shown in this thesis.
5.2 NON-UNIFORM OFFSET DISTRIBUTION IN COMMON-MIDPOINT GATHERS

To exam the offset distribution and fold coverage in the common-midpoint gathers, I have selected some CMP gathers along the line and displayed them in here:

Figure 5.1 shows CMP 650 and CMP 750: In CMP 650 the smallest offset is 25 meters, the largest is 2825 meters, and the offset interval varies from 50 to 350 meters. There are 24 live traces in this CMP gather. In CMP 750, the smallest offset is 25 meters, the largest is 2975 meters, offset interval varies from 50 to 200 meters, there are 29 live traces in this CMP.

Figure 5.2 shows CMP 820 and CMP 950: In CMP 820 the smallest offset is 275 meters, offsets smaller than 275 meters do not exist at all, the largest is 2925 meters, offset interval varies from 50 to 250 meters, there are 26 live traces in this CMP. In CMP 950, the smallest offset is 25 meters and the largest is 2975 meters. The offset interval varies from 50 to 200 meters. There are 34 live traces in this CMP.

Figure 5.3 shows CMP 1000 and CMP 1025: In CMP 1000 the smallest offset is 25 meters, the largest offset is 2925 meters, and the offset interval varies from 50 to 200 meters. Many dead traces exist in this CMP. The fold count is 37, but the live trace count is 30. In CMP 1025, the smallest offset is 975 meters, the largest is 2875 meters, and all of the near offsets are missing in this CMP. The fold count is 38, and there are 32 live traces.

Figure 5.4 shows CMP 1100 and 1150: In CMP 1100 the smallest offset is 75 meters, the largest is 2925 meters, and the offset interval varies from 50 to 350 meters. The fold count is 35, and there are 30 live traces. In CMP 1150 the smallest offset is 25 meters, the largest is 2825 meters, and the offset interval varies from 100 meters to 225 meters, many near and middle offsets are missing in this CMP. The fold count is 27, there are 25 live traces.

Each CMP gather shown in here is formed by traces whose midpoint coordinates
Figure 5.1. CMP 050 has 24 live traces, offset interval varies from 50 to 350 meters. CMP 750 has 28 live traces, offset interval varies from 50 to 200 meters.
Figure 5.2. CMP 820 does not have offsets smaller than 275 meters. CMP 850 has 34 live traces, offset interval varies from 50 to 300 meters.
Figure 5.3. CMP 1000 has several near to middle offsets missing. CMP 1025 does not have offsets smaller than 975 meters.
Figure 5.4. CMP 1100 has 30 live traces, offset interval varies from 50 to 350 meters. In CMP 1150 many near to middle offsets are missing.
are closer to the CMP station than to other CMP stations. Common-midpoint gathers, like the examples shown in here, are all over the line, most of them do not have uniform offset distribution and adequate fold coverage.

5.3 COMMON-OFFSET SECTIONS BEFORE AND AFTER VORONOI WEIGHTING

Before applying the common-offset DMO process on common-offset sections, it is interesting to see how the data look like on the common-offset sections with and without the Voronoi weighting. To form the common-offset sections, I have selected a regular offset versus CMP grid for the line: The regular offset interval I selected is 125 meters, and the regular CMP interval selected is 25 meters. The smallest offset is 75 meters, the largest is 2950 meters. The common-offset plots labeled with NO VORONOI WEIGHTS are formed by the conventional way of forming common-offset sections and is described in section 3.1. Those labeled with VORONOI WEIGHTED are formed using the Voronoi weighting and the constant area cell methods which are described in detailed in chapter 3 and 4.

Figure 5.5 is the common-offset section of offset 825 meters, we can see this offset is missing in some CMP gathers. The missing data problem is relatively severe around CMP 1000, and CMP 1035. The folded structure is poorly defined on the section, particularly the syncline structure is disrupted due to missing data around the hinge zone. Figure 5.6 shows the same offset after applying the Voronoi weights, we can see the Voronoi weighting method has improved amplitude variation along the reflectors. The folded structure is better defined, and the syncline structure can be identified more easily.

Figure 5.7 shows the common-offset section of offset 1375 meters before Voronoi weighting. Severe missing occurs around CMP 985. Relatively severe occurs around CMP 1045 and CMP 1055. Moderate missing of this offset occurs everywhere along the line. It is hard to see if there is a structure on this section. Figure 5.8 shows the
Figure 5.5. Moderate missing data occurs along the line. Severe missing data occurs around CMPs 1000 and 1035. The syncline structure is disrupted by missing data problem.
Figure 5.6. Constant area cell method has moved a small amount of energy into the missing data zones. Voronoi weighting has improved amplitude variation along reflectors.
Figure 5.7. Severe missing data occurs around CMP 980 and around CMP 1045. Structure continuity is blurred on this section.
VORONOI WEIGHTED COMMON-OFFSET 1575 METERS

Figure 5.8. Voronoi weighting gives this common-offset section a better defined structure continuity.
common-offset section after Voronoi weighting. The folded structure is clearer on this section.

Since the Voronoi weights are calculated based on the density distribution of midpoint coordinates on the $(y, h)$ space, the common-offset sections with Voronoi weighting have more balanced amplitude along the line and clearer structure definition.

5.4 DMO STACK WITH AND WITHOUT VORONOI WEIGHTING

Figure 5.9 is the DMO stack section without application of Voronoi weighting method. It is very clear that missing and excessive offsets in CMPs have caused the DMO output to have some zones with high amplitudes, and some zones with weak amplitudes along the line. The imbalance in amplitude contributions also degrades the continuity of the subsurface structure. Figure 5.10 is the DMO stack with application of Voronoi weighting method. Comparing to Figure 5.9, we see the amplitude variation is much smoother along the line. The anticline and syncline structures are significantly enhanced on the VORONOI WEIGHTED DMO stack section, particularly on the continuity of the dipping fold limbs.

To get a closer look of the enhancements produced by the Voronoi weighting method, the zone between CMP 690 and 890, inbetween 1 and 3 seconds is highlighted and shown in Figure 5.11 and Figure 5.12. Obviously, the boundaries between the subsurface reflectors are much clearer defined in Figure 5.12 than in Figure 5.11. Another highlighted zone is between CMP 930 and 1130; the time range is inbetween 1.5 and 3.5 seconds. In Figure 5.13, we can see alternating strong and weak amplitude bands along the section. The weak amplitude band is especially noticeable around CMP 1020, where data is severely missing. In Figure 5.14, the alternating strong and weak amplitude bands along the section are largely removed. The slightly concave reflections around 1.8 second under CMP 1020 are significantly enhanced by applying the Voronoi weighting method prior to the DMO process.
Figure 5.9. Missing and excessive offsets in the CMP gathers disrupt the functioning of the DMO process. Bands of high and low amplitude zones occur all over the line.
Figure 5.10. Bands of high and low amplitude noise are removed by the Voronoi weighting method. A clearer image of the subsurface is obtained.
Figure 5.11. The crests of the folded layers and fold limbs are weakly defined. Low coverage around CMP 820 changes the amplitude along horizontal beds.
Figure 5.12. The boundaries of the folded sequence and the dipping fold limbs are better defined. Artificial amplitude changes along horizontal reflectors are removed.
Figure 5.13. Artificial amplitude anomalies occur after DMO processing.

HIGHLIGHT (NO VORONOI WEIGHTS)
Figure 5.14. Artificial amplitude anomalies are largely removed when Voronoi weighting is applied prior to DMO.
CONCLUSIONS

Irregularly spaced seismic data is an unavoidable situation commonly occurring in seismic data acquisition. When the recording geometry of an irregularly spaced seismic line is viewed on the offset versus common-midpoint \((y,h)\) plane, some regions on this plane will have a dense distribution of trace mid-points and some will have sparse distribution. It is shown in this thesis that the unbalanced trace density can damage the DMO process by causing artifacts on the DMO output. The concept of Voronoi Diagram is utilized in this research to balance the uneven trace density on the \((y,h)\) space. I have designed a method to construct the Voronoi polygons from the mid-point coordinates of seismic traces on the \((y,h)\) plane and compute the area of each Voronoi polygon. The area of the Voronoi polygon associated with a trace is then used to weight the trace prior to DMO application. The process is called Voronoi weighting method in this research. It is feasible to implement the method in the production oriented environment and is particularly suitable to implement it on vector or parallel computers. In this thesis the Voronoi weighting method has been applied on synthetic and real data sets and it has demonstrated to be effective in overcoming the undesirable effects of irregular spatial sampling on DMO output. Although Voronoi weighting can be used to compensate positioning variations prior to DMO processing, however, for severe missing data it is necessary to infill or reshoot the data before the method can be applied.
REFERENCES


