Data driven automatic aperture optimization for Kirchhoff migration

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Summary

The migration aperture is a parameter often difficult to set in Kirchhoff PSDM. It may take a lot of tests to determine the best possible aperture for a given dataset. We propose here a method to avoid migration tests and to optimize the aperture with a spatially variable function of data.

Our workflow consists first in migrating the data with an aperture class Kirchhoff PSDM algorithm. We obtain a migrated image for each aperture class which we can weight before stacking them. We have developed an algorithm which automatically picks coherent events on the different aperture classes and uses these picks to interpolate, for each depth point, weights for the different aperture classes.

This automatic data driven aperture optimization algorithm has been successfully tested on real marine and land datasets. With almost no human interaction it was possible to improve the quality of the migrated images, in some cases in a very significant way.

Introduction

The migration aperture is a critical parameter in Kirchhoff PSDM to obtain the best image quality from a given dataset. Reducing the migration aperture generally enhances the signal/noise ratio and reduces computation time but to the detriment of dipping events imaging. Aperture is the result of a compromise. Moreover a constant aperture can never be optimal in complex media. We must use a spatially variable aperture to optimize the image quality in complex media.

In a standard PSDM workflow, the aperture is often selected after several migration tests. We propose here a method to avoid migration tests and to optimize aperture thanks to a data driven post-migration processing.

Theory and Method

1. *Aperture class migration*

1.1. What is migration aperture?
The Kirchhoff migration algorithm basically consists in spreading out each trace sample amplitude on the isochron surface related to the trace sample time, and the trace source and receiver positions. If we repeat this process for all traces, the sum of all single trace migration images constructs the total reflectivity image. However, in practice, we only spread out the amplitudes on a part of the isochron centered on the trace CMPs. This is the aperture (figure 1).

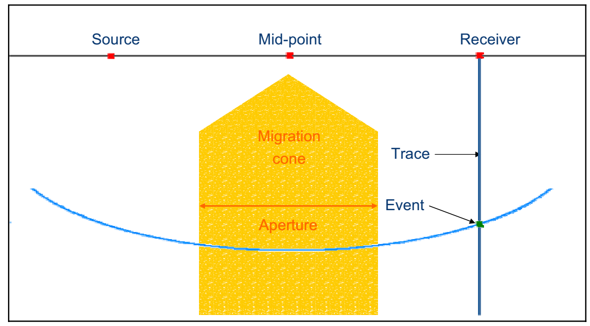

Figure 1: Migration aperture definition

1.2. How do we choose migration aperture?
The first obvious criterion is that Kirchhoff migration computation cost is directly related to the aperture size.

The second criterion is dipping events imaging.

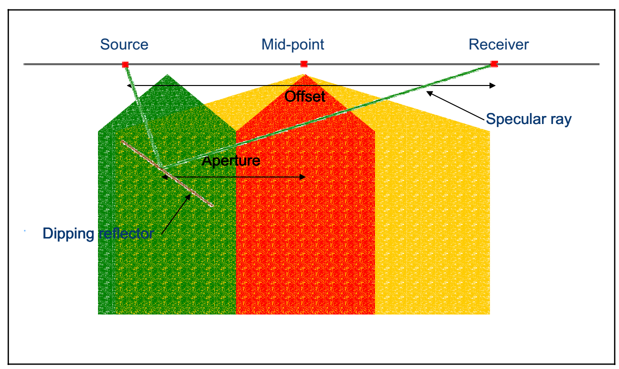

Figure 2: Dipping events imaging

Using the red aperture cone we cannot image the dipping reflector (figure 2). With the yellow aperture cone, we image the reflector but we add noise to the image. Ideally, we would like to use the green cone.

Finally, the third criterion for aperture selection is the signal/noise ratio. The larger the aperture is, the more noise we add to the image. Ideally, aperture should be limited to the Fresnel zone around the specular reflection.

The only problem is that the specular reflection position is related to the geological dips which are unknown before migration.

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The adopted strategy consists in splitting the total aperture in aperture classes (figure 3) and in selecting the appropriate aperture for each depth point in a post migration processing. We actually realize a time to depth mapping and the imaging is postponed to the aperture class selection and stack. This process is completely reversible: by stacking the aperture class images, we obtain the total aperture image.

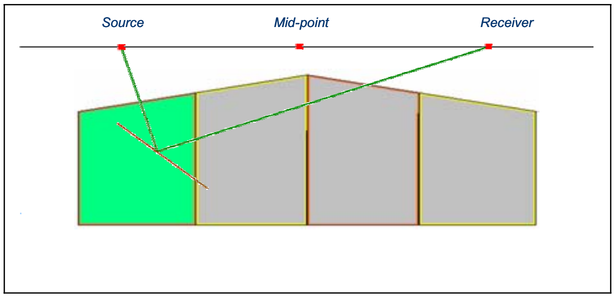

Figure 3: Aperture class migration

2. *Aperture optimization*

After migrating a given dataset with aperture classes, it is possible to optimize migration aperture.

2.1. Maximum useful aperture

Aperture classes can first be used on some test inlines to determine the maximum useful total aperture for the migration. We migrate the image with a large aperture sub-divided in aperture classes and analyze the signal for each aperture class. We can determine the maximum useful migration cone. This strategy helps us avoid doing several migration tests and reduce the computation time. The use of aperture classes is also optimized by having narrower classes.

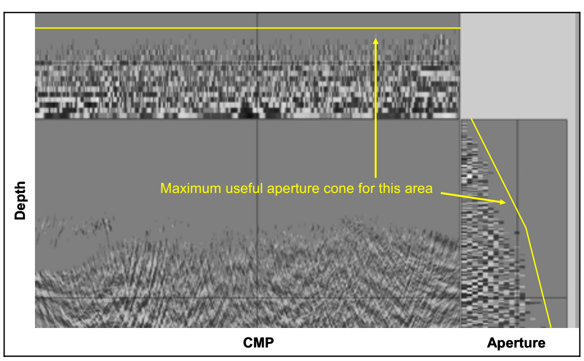

Figure 4: Maximum useful aperture selection

2.2. Manual aperture optimization

The next thing to do is to optimize aperture by selecting, for each depth point, which aperture classes to stack. In this way, we have a spatially variable aperture.

The first basic use of aperture classes consists of a manual selection of the aperture classes we want to stack. This can be done in order to enhance the signal/noise ratio in noisy parts of the image. We have therefore developed the following workflow:

- Picking of the best aperture class for the parts of the image we wish to improve (top of figure 5).
- Running an algorithm which interpolates weights for the aperture classes from the picks positions and values.
- Stacking the aperture classes (bottom of figure 5).

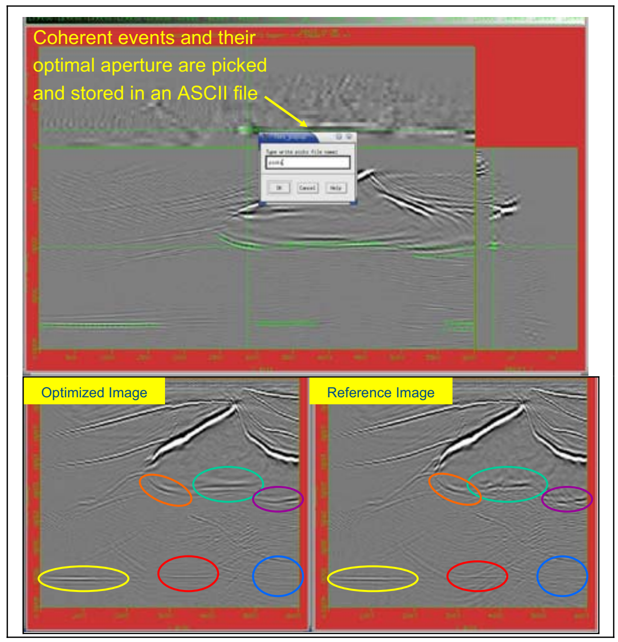

Figure 5: Aperture classes manual picking and aperture optimization

2.3. Automatic aperture optimization

The next goal is to make the aperture optimization automatic. For this purpose, we simply need to make the aperture classes picking of the workflow described above automatic. We then have a completely automatic aperture optimization algorithm, which enables us to process larger datasets.

Our automatic aperture class picking is based on the article published by H. Tabti in First Break in March 2004.

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3. *Multi-arrivals*

Our picking can pick several aperture values for the same depth point if there are coherent events in several aperture classes. As we do not interpolate aperture but weights for the different aperture classes, we avoid the issues related to multi-valued functions. The weighting interpolation algorithm naturally integrates multiple paths in migration.

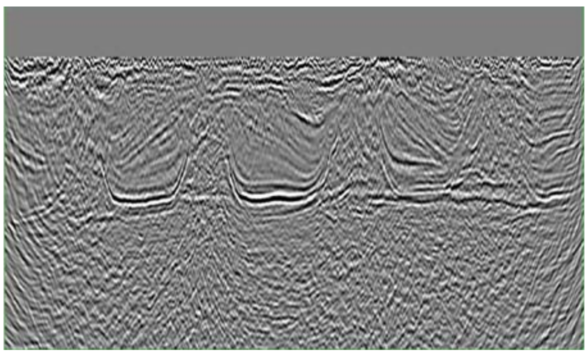
This technique is able to deal with multiple arrival migration and with complex geologic structures.

4. *Cost*

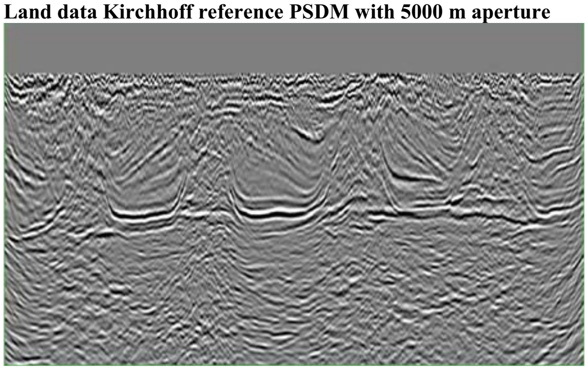
The cost of the aperture class migration is marginal in term of computation time but is very important in terms of computer memory. We have to store in memory an image which size is multiplied by the number of aperture classes.

Real Data Examples

Example 1: Automatic migration aperture optimization on real 2D land data.

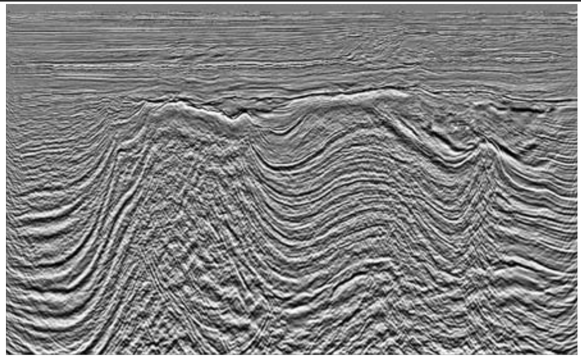


Land data Kirchhoff reference PSDM with 5000 m aperture

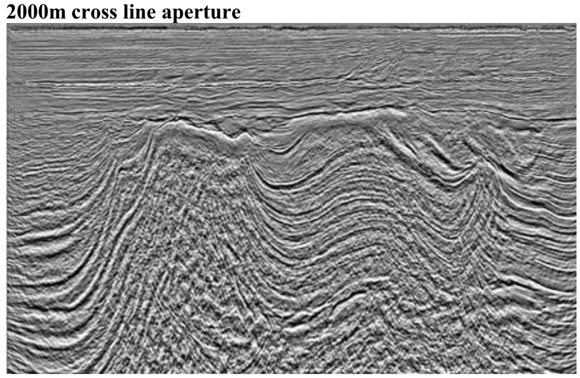


Same PSDM result with 5000 m aperture subdivided in 25 classes and automatically optimized

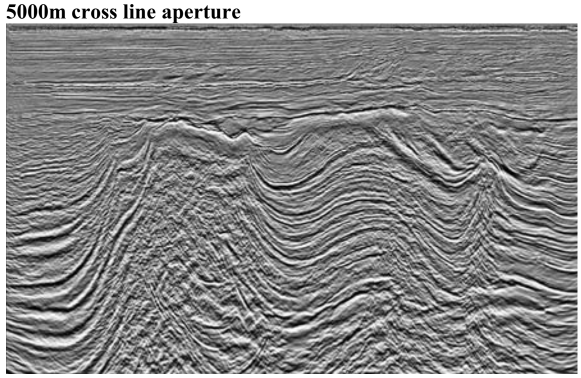
Example 2: Automatic migration aperture optimization on real 3D marine data.



Kirchhoff production PSDM with 3000m inline aperture and 2000m cross line aperture



Kirchhoff production PSDM with 8000m inline aperture and 5000m cross line aperture



Kirchhoff aperture optimized PSDM with 8000m inline aperture and 5000m cross line aperture

In the 3000m inline 2000m cross line aperture standard production image we did not image correctly the steep dips. With 8000m inline and 5000m cross line aperture we recover the steep dips but the image becomes very noisy. Using 25 aperture classes with the automatic aperture optimization algorithm, we obtain an image with the same dips as the big aperture image and the same or lower noise level as the small aperture image.

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Conclusions

Migration aperture in the traditional Kirchhoff implementations has always been a difficult parameter to choose but on which can rely the quality of the final migrated image, especially with noisy data. It is normally set after several migration tests, which can be time consuming and still lead to some bad surprises if the strongest dips are not present on the tested areas.

We have proposed here a realistic cost effective way to deal with the aperture problems in Kirchoff migration. The current limitations are due to the huge memory sizes which are needed to run migrations with aperture classes. We have to use shared memory schemes of parallelization on full 3D blocks.

The automatic aperture optimization was successfully tested on several datasets. It drastically improved the signal/noise ratio on noisy images. Some strong dipping events were sometimes partially attenuated.

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EDITED REFERENCES

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