Kirchhoff Prestack Time Migration with Angle Domain Common Image Gathers

Jianhua Pan*, Robert Tilson, Gerry Schlosser, Elvis Floreani
Absolute Imaging Inc, Calgary, AB, Canada
jianhua@absoluteimaging.ca

GeoConvention 2012:Vision

Summary

This paper presents one method for constructing angle gathers within prestack Kirchhoff time migration and another method for providing accurate angle gathers from time migrated offset gathers in an isotropic medium. In the first method angle gathers are extracted at each image point by gradients of travel time from the source and the receiver to the reflector. In the second method one can calculate the angle for a certain offset and image point with the background velocity and the local dip, thus extracting angle gathers from offset gathers.

Introduction

Conventional common image gathers produced from Kirchhoff time migration are from the offset domain. The offset domain common image gathers are commonly used for migration velocity analysis and AVO studies. However, recent works show that more benefits could be obtained from seismic data by processing in common angle gathers. Instances of these benefits are amplitude-versus-angle (AVA) analysis with the specific application to fracture study and stack resolution enhancement. Angles in angle gathers refer to the reflection angle. For the acoustic case, the reflection angle is half of the opening angle which is the angle between source and receiver rays at an image point. Angle gathers collect the energy in a dataset that has been scattered over a specific reflection angle.

For Kirchhoff time migration of angle gathers, Fomel and Prucha (1999) analyzed the traveltime relations with a constant background velocity. With a constant background velocity, source-rays and receiver-rays are straight and the opening angle is obtained from the simple trigonometry of the triangle of source, receiver and image point. Although Kirchhoff time migration is a constant velocity migration procedure, and the image at any subsurface location is related only to the RMS velocity value at this location, the ray is actually curved in the case where velocities vertically above this location are not constant. Unlike amplitude distribution in the offset domain, which is only related to the RMS velocity at this location, amplitude distribution in the angle domain involves all velocities vertically above this location so that the amplitude distribution with respect to angles reflects the vertical velocity variation and is thus more reasonable.

Two methods are shown in order to provide angle gathers from prestack Kirchhoff time migration.

One calculates the reflection angle in terms of traveltime and velocity (both RMS and interval) during migration and the other transforms migrated offset gathers to angle gathers in an isotropic medium with a provided velocity field and dip field.

1. Angle calculation in prestack Kirchhoff time migration

Producing angle gathers from prestack Kirchhoff time migration can be reduced to calculating the angle between source and receiver rays. From the following figure, one can calculate the gradient of the traveltime from the source and the receiver to the image point.

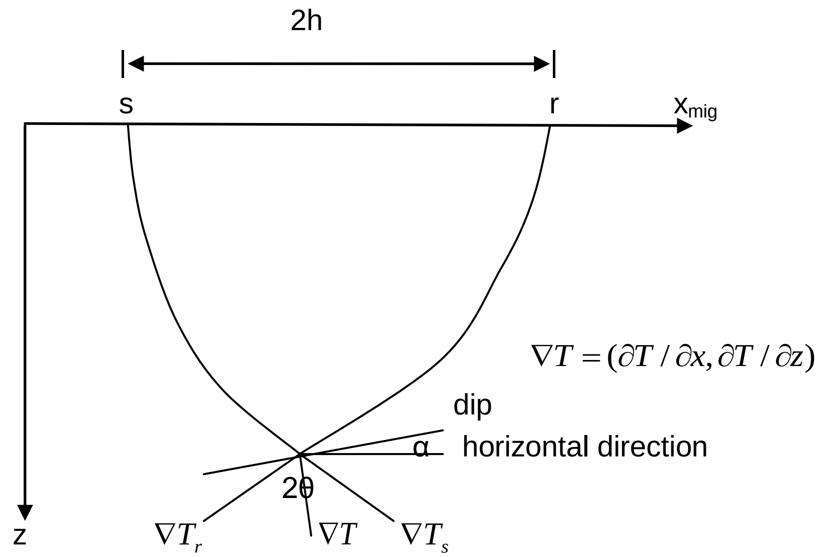

***Figure 1**: Angle in Kirchhoff migration. 2θ is the opening angle between the source and receiver rays, α is the dip angle.*

From the time to depth conversion $dz = \frac{1}{2} v_{\text{int}} d\tau$, one can see that

$$\nabla T_s = (\frac{\partial T_s}{\partial x}, \frac{\partial T_s}{\partial \tau}\frac{2}{v_{\text{int}}}) \quad \text{and} \quad \nabla T_r = (\frac{\partial T_r}{\partial x}, \frac{\partial T_r}{\partial \tau}\frac{2}{v_{\text{int}}}).$$

where τ is the two-way vertical traveltime and v_{int} is the interval velocity. Then the reflection angle can be obtained from the following equation

$$\cos(2\theta) = \frac{\nabla T_s \bullet \nabla T_r}{|\nabla T_s \| \nabla T_r|} \quad . \tag{1}$$

The above equation is valid for both isotropic and anisotropic medium. Calculating the traveltime gradient takes time and thus migration for angle gathers will be more resource intensive than for offset gathers.

2. Transformation from offset gathers to angle gathers

In an isotropic background medium, the angle between source-ray or receiver-ray and the direction of the gradient of the total travel time is half of the opening angle. In Figure 1, the total traveltime is

$$T = T_s + T_r = \sqrt{\frac{\tau^2}{4} + \frac{[(x-\xi)-h]^2}{v_{rms}^2}} + \sqrt{\frac{\tau^2}{4} + \frac{[(x-\xi)+h]^2}{v_{rms}^2}} \ ,$$

where, $x-\xi$ is the horizontal distance between the midpoint x and the reflection point ξ, and *h* is the half-offset between the source and the receiver. Since the dip direction is perpendicular to the direction of the gradient of the total travel time, one can see the relation between migration dip and derivatives of the traveltime

$$\frac{\partial T / \partial x}{\partial T / \partial z} = -\tan\alpha \ .$$

Solving the above equation for the horizontal distance $x-\xi$, one can obtain $\cos(2\theta)$ from the equation (1). Therefore, for a position (time, offset) in an offset gather at a horizontal position, and for a given associated dip, the opening angle can be uniquely calculated.

Conclusions

The method for obtaining angle gathers from Kirchhoff time migration is shown. This method can be used for both the isotropic and the anisotropic medium. Additionally, it is shown that offset gathers from Kirchhoff time migration can be transformed to angle gathers as long as the migration velocity and dip fields from the stack data are provided.

Acknowledgements

The author thanks Absolute Imaging Inc for the permission to submit this paper.

References

Sergey F.l and Marie P., 1999, Angle-gather time migration, SEP report 100, 141-151.