Imaging primaries

~~Primary~~ and multiples simultaneously ~~imaging~~ with depth-focusing

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ABSTRACT

Seismic imaging ~~value is taken out with~~ extracted using the imaging conditions $t = 0$ and $h = 0$, where $t = 0$ means that the take-off time of the upward-coming wave is zero, and $h = 0$ means that the downward-coming and upward-coming waves meet ~~together~~ during the wavefield extrapolation. However, $h = 0$ makes no sense for ~~the~~ multiples imaging~~,~~; here h is the half-offset bewteen the source and receiver position. This imaging condition is suitable for imaging the primary, ~~imaging and~~ where the source position must be known. We ~~put forward~~ introduce an imaging condition for simultaneously imaging the primary and multiples ~~simutaneously imaging.~~ The imaging condition, in essence, is ~~composed with~~ that the take-off time of the upcoming wave equals ~~to~~ zero, and the radius of ~~the~~ curvature of the wavefront of the upcoming scattering equals ~~to~~ zero. It is known that the primary and multiple~~s~~ scattering waves will be focused during the wavefield depth extrapolation, and the primary and multiple~~s~~ scattering waves at the same depth focus at different ~~time~~ times; this is because the traveltimes from the source to the scattering point ~~is~~ are different for the primary and the multiples, even for the same scattering point ~~to the primary and multiples.~~ The focused scattering wave can be picked out, and the image is formed at the focused point. The advantages of the method ~~include that~~ are several: the primary and multiples can be imaged simutaneously, only the up-coming waves ~~need to~~ must be down-ward [one word] extrapolated, all the scattering wavefields in the different shot gathers can be added together and simutaneously extrapolated, and the source position can be unknown. Its disadvantage is that the imaging condition is much more difficult to ~~be used.~~ use.

INTRODUCTION

Up to now, the multiples in seismic data sets ~~are considered to be noises~~ have been considered as noise for the imaging of the primaries (Berkhout and Verschuur, 1997). ~~The reason is that~~ This is because it is difficult to ~~put~~ assign the multiples ~~onto its~~ to their scattering points, ~~because~~ since the common-used (ly) imaging condition (s) can not correctly and simutaneously pick up both the focused primary and its multiples.

[italics] Schuster et al. (2003) ~~put forward~~ proposed that if the source under the surface is unknown, the autocorrelation of each trace can be used to determine a suppositional source on the surface, because the autocorrelation of the direct wave is at the delaying time $t = 0$ and the direct wave is eliminated in the autocorrelogram. The autocorrelogram can be thought to be acquired with the new suppositional shot-receiver pair. Therefore, to the autocorrelogram, the conventional prestack depth migration can ~~make~~ cause the ghost wave, or the first multiple, to be focused and imaged. ~~The ghost wave imaging is the multiples imaging.~~ However, the disadvantages of the method are that the autocorrelogram does ~~not hold on~~ apply for the wave equation, and the traveltime of the direct wave can not be correctly estimated and cancelled later, ~~at some time, which makes~~ so that the travel time calculation in the integral migration does not match the travel time in the autocorrelogram. The result is imaging noise~~s~~ ~~occur~~. The crosstalk in the autocorrelogram also causes ~~cause the~~ imaging noise~~s~~. On the other hand, the ghost wave is the first multiple~~s~~, and ~~the~~ imaging of higher-order multiples is ignored.

[Is this what you mean?]

The imaging condition proposed by Claerbout (1971) should be modified if the primary and multiples are simultaneously imaged, ~~in the case of~~ whether the ~~source~~ source position is known or unknown. The imaging condition is that the radius of ~~the~~ curvature of the wavefront equals ~~to~~ zero. This is the depth-focusing imaging condition.

MacKay and Abma (1993) ~~takes~~ use ~~of the~~ depth focusing to carry out the velocity ~~nanlysis.~~ If the migration velocity is larger than the medium velocity, the focusing depth is less than the reflection depth and the imaging depth is larger than the reflection depth; On the other hand, if the migration velocity is less than the medium velocity, the focusing depth is greater than the reflection depth and the imaging depth is less than the reflection depth. The real reflection depth lies at the ~~middle~~ point ~~of~~ the focusing depth and the imaging depth. In the paper, a method for estimating the radius of the curvature of the wavefront ~~was put forward.~~ However the formula is only suitable for the primary ~~imaging~~.

[lower case (l.c.)]

For ~~the same~~ scattering point, the primary and multiples scattering ~~wavefield~~ from it ~~is~~ simultaneously focused at the same depth and at different ~~time~~ with the downward wavefield continuation. The "focusing" means that the received scattered wavefield from a scattering point is collapsed into the scattering point and the radius of ~~the~~ curvature of the wavefront diminish to zero. With the depth-focusing imaging condition, the focused imaging ~~value~~ of the primary and multiples can be simultaneously picked up from the depth extrapolated wavefield which is expressed in the time domain.

[Not clear; how can waves be focused "simultaneously" and yet "at different times?" I'm not sure what you mean here.]

~~There~~ are some ~~following~~ advantages ~~about the~~ depth-focusing imaging. The primaries and multiples (including the higher-order multiples) can be simultaneously imaged; the source position can be known (for the primaries) or unknown (for the multiples); All of the scattered wavefield can be added together and the calculation efficiency can be improved.

[l.c.]

The disadvantage is that the depth-focusing imaging condition is difficult to ~~be used,~~ especially for ~~the~~ data with a lot of noise.

PRINCIPLES OF FOCUSING

Figure 1 geometrically shows the depth-focusing process of the primary scattering wavefield and Figure 2 the same process of the multiple scattering wavefield. Comparing the two figures, it is clearly seen that the focusing process is the same for a scattering point whatever the scattering wavefield from it is primary saettering or multiple scattering.

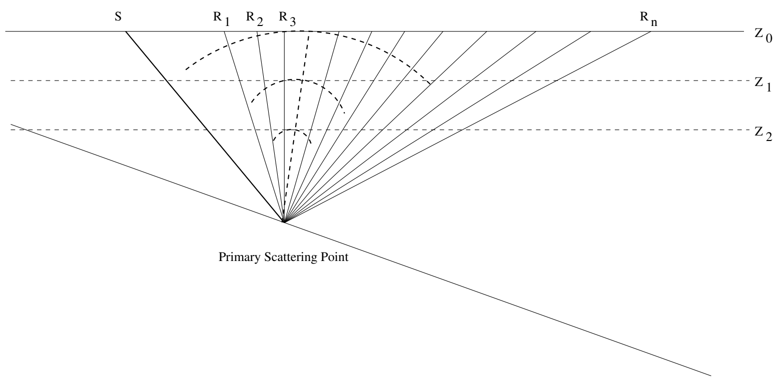

Figure 1: The depth focusing of the primary scattering wavefield with the extrapolation. The radius of the curvature of the wavefront diminsh into zero with the downward wavefield continuation. Scattering_primary [ER]

The imaging condition of prestack migration is that the arrival time of the downgoing wave equals to the take-off time of the upcoming(Claerbout, 1971). In principle, this is a prevalent imaging condition. However, conventionally, the downgoing wave means the primary downgoing wave not the multiple downgoing wave. It is difficult to determine the traveltime of the multiple downgoing wave. Therefore, with the imaging condition, it is complex to image the primaries and the mulitiples simultaneously.

The conventional imaging condition implicitly tell us that the image of a reflector appears

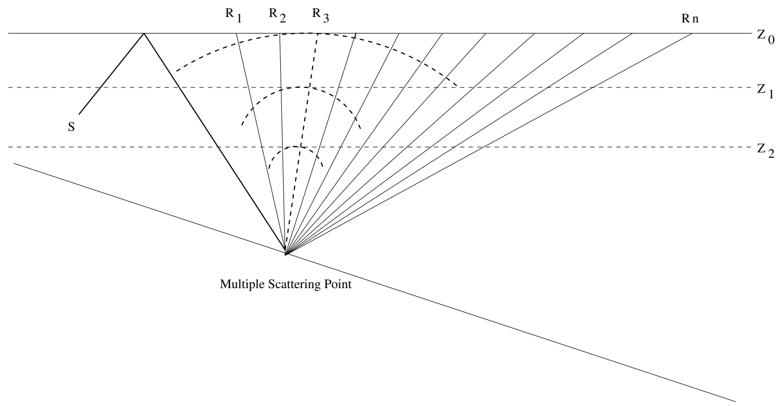

Figure 2: The depth focusing of the multiple scattering wavefield with the extrapolation. The source position can be unknown. The radius of the curvature of the wavefront diminsh into zero with the downward wavefield continuation. The higher-order multples can be focued also. Scattering_multiples [ER]

at the point where the received scattering wavefield is collapsed. At the case, the arrival time of the downgoing wave equals to the take-off time of the upcoming wave and the radius of the curvature of the scattering wavefield diminish to zero. And that the radius of the curvature of the scattering wavefield diminish to zero means the scattering wavefield is focused to the scattering point. It is different with the primary imaging that, to the multiples imaging, the offset equals to zero makes no sense. For the multiples imaging, the offset should be calculated with the "suppositional" source and the receiver position. However, it is not easy to determine the "suppositional" source position for the higher-order multiples.

In fact, the statement that the arrival time of the downgoing wave equals to the take-off time of the upcoming wave is equivalent to the one that the radius of the curvature of the scattering wavefield diminish to zero. However, the latter is much more prevalent than the former. The latter can be used to image the primaries and the multiples whatever the source position is known or unknown ~~becaues only~~ whether the scattering wavefield is focused or not ~~is concerned.~~ The latter can be called ~~as~~ the depth-focusing imaging condition. The former is a model-driven process; the latter is a hybrid-driven process wavefield extrapolation is model-driven and ~~the~~ picking the focused amplitude is data-driven.

IMPLEMENTATION OF DEPTH-FOCUSING

Estimating whether the scattering wavefield is focused or not is ~~a~~ tough work ~~about~~ primaries and multiples simultaneouskly ~~imaging~~ with depth-focusing. The wavefield extrapolation is carried out in depth domain and picking the imaging value must be implemented in time domain since the traveltime from the source to the scattering point is not necessarily ~~to be~~ known. Supposing that the ~~macro~~ velocity model is credible, the horizontal positions of the focused scattering points are correct. ~~And the~~ wavefield extrapolation depth determines the focused depth of the scattering which is also correct under the assumption. The apparent method is to ~~take~~ use ~~of~~ the amplitude of the focused scattering wavefield. When a scattering wavefield is focused, the amplitude at a focused point ~~reaches the maximum.~~

During the process of wavefield extrapolation, the amplitude of the wavefield at every point ~~are flactuating.~~ Therefore, the amplitude itself can not be used as an indication. Here, ~~I~~ suggest that the characteristic parameters ~~of~~ depicting the amplitude change should be used, such as the envelope of the amplitude change, the derivative of the envelope, ~~etc.~~ Hence, several extrapolated wavefields shoud be memorized, ~~which include~~ the current extrapolated layer and its adjacent layers. ~~All~~ of the methodology is ~~in order~~ to avoid picking the wrong focused amplitude.

Another method is to estimate the radius of the curvature of the wavefront of the scattering wave. MacKay and Abma (1993) put forward an method that, in the CMP geometry, there is a formula

$$R \approx \frac{\left(X^2 - \triangle t^2 V_r^2\right)}{2 \triangle t V_r} \tag{1}$$

where X is the offset, V_r is the medium velocity, and $\triangle t$ is the time difference between the two-way vertical traveltime and the observed traveltime. However, this formula is not suitable to be used here because the time difference is unknown. For depth-focusing imaging, the source position is not concerned and the traveltime between the source and the scattering point is not expicitly used.

We put forward the following method to estimate the radius of the curvature of the scattered wavefield. Assuming that the macro velocity is correct and with help of ray-tracing, the radius of the curvature of the scattered wavefield can be estimated with

$$R = V_r t_{scatter} \tag{2}$$

where $t_{scatter}$ is the traveltime from the scatter to the receivers, V_r is the medium velocity. And $\triangle t = t - t_s = t_{scatter}$ where t is the observed two-way traveltime and t_s is the traveltime from the source to the scatter point. t_s may include the traveltime of the multiples. According to the formula 2, the radius of the curvature of the scattered wavefield can be estimated with the extrapolated wavefield.

Some ideas in Jager et al. (2001) may give us some suggests about how to estimate the radius of the curvature of the scattered wavefield.

DISCUSSION AND CONCLUSION

We ~~put forward~~ a new imaging condition, with which, the wavefield extrapolation is carried out in depth domain and the imaging value is ~~picked out~~ from the focused scattered wavefield in the time domain if the radius of the curvature of the wavefront ~~diminsh into~~ zero. We call ~~the~~ imaging condition ~~as~~ the depth-focusing imaging condition.

We ~~think~~ that the statement that the arrival time of the downgoing wave equals to ~~the~~ take-off time of the upcoming wave is equivalent to ~~the one~~ that the radius of the curvature of the scattering wavefield ~~diminish~~ to zero.

With the imaging condition, the primaries and the multiples can be simultaneously imaged. ~~And the~~ source position can be known or unknown, therefore the passive data can be imaged with it. Some shot gathers can be added together according the receiver positions and then the new data set is imaged with the above method ~~for~~ improving the calculation efficiency. The depth-focusing imaging condition can be used for ~~the~~ imaging ~~of the~~ multicomponent seismic data.

However, since the focusing of the scattering wave is detected in the time domain, the quality of the data set will affect the use of the imaging condition. It will ~~be better for it to be used in the process of the~~ marine data set.

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