XTV inversion

Delta-t-V and XTV inversion assume that traces are gathered by Common Mid-Point CMP (Diebold and Stoffa 1981). Also, these inversion methods rely on the suppression of layer dip effects on apparent velocity, when sorting traces in a CMP gather by unsigned offset (Diebold and Stoffa 1981). This suppression fails at locations of strong refractor curvature. Barton and Baker (2003) try to obtain improved apparent velocities by regarding the shot direction.

To enable the realistic interpretation of sudden apparent velocity increase in CMP sorted traveltime curves, (Winkelmann 1998) proposes to extend the Delta-t-V gradient layer inversion (Gebrande 1986), with Dix inversion and Intercept Time inversion. These two additional inversion methods allow the **modeling of constant-velocity layers**.

As described by (Winkelmann 1998) and (Gawlas 2001), the XTV inversion reconstructs the 1D velocity vs. depth function v(z) below a CMP based on XTV data triples, with values X = (reduced) unsigned offset, T = (reduced) time and V = apparent velocity. These data triples sample a (reduced) CMP sorted traveltime curve. The inversion is based on the layer stripping principle. With “offset” we always mean “unsigned offset” in the following.

XTV inversion uses three separate methods, for inversion of a data triple into a model layer :

- Modified Dix inversion
- Intercept Time inversion
- Gradient layer inversion (original Delta-t-V method)

The inversion starts with the first XTV triple at the smallest offset X, as determined from the original CMP curve. Once the first layer has been determined by one of above methods, offset and time for all other triples are reduced to the bottom of this first layer. Then the XTV triple at the next smallest offset X is inverted into a second layer, and remaining triples are reduced to the bottom of this second layer. This triple inversion process is continued iteratively, until all XTV triples have been processed.

We first describe each of these three inversion methods in detail. We then describe the overall XTV algorithm, which decides what inversion method should be applied to the current XTV triple. All inversion methods are described for the two-layer case only. Since the XTV inversion is based on layer stripping, we only need to deal with two layers (current overburden, current refractor) during each iteration and triple-to-layer inversion step.

The modified **Dix inversion assumes reflection of a ray**. The layer thickness h is determined as follows :

$$h = \frac{\Delta}{2}\sqrt{\frac{Vt}{\Delta} - 1} \qquad (1)$$

Δ is the unsigned offset X between shot point and receiver.

t is the traveltime T between shot point and receiver, separated by offset Δ.

V is the measured apparent velocity, at the bottom of the layer i.e. at offset Δ.

The average layer velocity $\bar{v}$ is obtained with

$$\bar{v} = \sqrt{\frac{V\Delta}{t}} \tag{2}$$

Velocities at the top and at the bottom of the modeled layer are both set to this average velocity $\bar{v}$.

The **Intercept Time inversion assumes critical refraction of a ray**, with both overburden and basement layer having a constant velocity. Using intercept time τ as determined from the XTV triple with

$$\tau = t - \frac{\Delta}{V} \tag{3}$$

the layer thickness h is determined with

$$h = \frac{\tau}{2\sqrt{(1/v_1)^2 - (1/V)^2}} \tag{4}$$

v_1 is the direct wave velocity (for first XTV triple) or the velocity as modeled for the bottom of the previously determined layer (for reduced XTV triples).

Velocities at the top and at the bottom of the modeled layer are both set to v_1 .

The **Gradient layer inversion method or Delta-t-V method assumes a diving wave ray and a constant velocity-gradient** equal to a. So the layer's velocity-depth function is

$$v(z) = a \cdot z + v_0 \tag{5}$$

Since the velocity gradient is assumed constant, the diving first-break ray follows a circular arc, between shot point and receiver. Based on the two equations

$$\Delta(V) = \frac{2}{a}\sqrt{V^2 - {v_0}^2} \tag{6}$$

and

$$t(V) = \frac{2}{a} arch(\frac{V}{v_0}) \tag{7}$$

the velocity v_0 at the top of the modeled layer is determined numerically. Then the layer thickness h is

$$h = \frac{\Delta}{2}\sqrt{\frac{V - v_0}{V + v_0}} \tag{8}$$

and the velocity at the bottom of the modeled layer is set to the measured velocity V. v_0 can be smaller than the velocity measured at the bottom of the overlying layer. So the gradient layer inversion can recognize velocity inversions, at least in some situations. Also, the gradient layer inversion does not use the intercept time τ . Layer stripping is done using equations as described by Gibson et al. (1979).

XTV triples are sorted by unsigned offset X, for layer inversion as described here. Winkelmann (1998) proposes the following **XTV inversion algorithm** :

- Use Intercept Time inversion if the apparent velocity V increases suddenly, between adjacent XTV triples. The *Minimum velocity ratio* required for application of the Intercept Time layer inversion can be adjusted by the user. Intercept Time inversion can be disabled with XTV parameter *Enable Intercept Time layer inversion*.
- Otherwise use Dix inversion if both the average velocity $\bar{v}$ (determined with Dix inversion) and the velocity v_0 at the top of the modeled layer (determined with Gradient layer inversion) are smaller than the velocity modeled for the bottom of the previously determined layer. You may disable Dix inversion with XTV parameter *Enable Modified Dix layer inversion*.
- Otherwise use Gradient layer inversion.

A candidate XTV triple is optionally rejected if its apparent velocity V or intercept time τ are larger than average values for the next three XTV triples. This triple filtering has the aim of suppressing reflections erroneously picked as first breaks.

Intercept Time layer inversion for multiple adjacent XTV triples

v_1 as required for Intercept Time layer inversion is not clearly defined, especially if the previous layer has been obtained with Intercept Time inversion as well. You may suppress application of our Intercept Time inversion to multiple adjacent XTV triples, with XTV parameter *Allow adjacent Intercept time layer inversion*.

If the previous XTV triple was inverted with Intercept Time layer inversion as well, then the velocity v_1 for the bottom of the previous layer may be assumed to be the previous v_1, or the apparent velocity V of the previous XTV triple, or any value between these two velocities. Alternatively, v_1 can be determined by interpolating between the previous v_1 and the apparent velocity V of the current XTV triple.

You may specify how v_1 should be determined with XTV parameters *Overlying layer velocity step* and *Current layer velocity step*.

If the resulting v_1 exceeds the previous apparent velocity V, v_1 used for inversion of the current XTV triple is reset to V of the previous triple.

The XTV inversion ensures that the sum of *Overlying layer velocity step* and *Current layer velocity step* does not exceed 100%.

If you want to use apparent velocities V (from previous and current XTV triples) exclusively and disregard previous v_1, for determination of the current v_1 based on step parameters *Overlying layer velocity step* and *Current layer velocity step*, just enable XTV option *Prefer measured layer top velocity over inverted*. If this option is enabled, the apparent velocity V as obtained for the previous XTV triple and layer is taken as an estimate for the velocity at the top of the current layer. In analogy, the velocity at the top of the previous layer is estimated with the apparent velocity V of the previous-previous XTV triple.

Parameters for XTV inversion

Minimum velocity ratio

The minimum velocity ratio (between apparent velocity V of the current XTV triple and the previous triple) required for application of the Intercept time layer inversion. If the actual ratio is smaller, the Intercept Time layer inversion method will not be applied. Instead, Dix inversion or Gradient layer inversion will be applied to the current XTV triple. Valid ratio values range from 1.01 to 2.5 . This ratio is regarded if XTV parameter *Enable XTV Intercept Time layer inversion* is checked only.

Enable Intercept Time layer inversion

Check this XTV option if you want to enable XTV Intercept Time layer inversion

Enable Modified Dix layer inversion

Check this XTV option if you want to enable Dix layer inversion

Allow adjacent Intercept time layer inversion

Check this XTV option to enable application of our Intercept Time inversion method, for multiple adjacent XTV triples.

Overlying layer velocity step

This XTV parameter is used if *Allow adjacent Intercept time layer inversion* is enabled only. This step parameter may vary between values 0% and 100%. The velocity step determines how v_1 needed for Intercept Time inversion of the current XTV triple is obtained, from the previous XTV triple and by interpolation between the previous v_1 (step 0%) and the previous apparent velocity V (step 100%).

Current layer velocity step

This XTV parameter is used if *Allow adjacent Intercept time layer inversion* is enabled only. This step parameter may vary between values 0% and 99%. The velocity step determines how v_1 needed for Intercept Time inversion of the current XTV triple is obtained, by interpolation between v_1 as obtained with step parameter *Overlying layer velocity step* (current step 0%) and the current apparent velocity V (current step 100%).

Prefer measured layer top velocity over inverted

Check this XTV option to use apparent velocities V (belonging to previous and current XTV triples) exclusively and disregard the previous v_1, for determination of the current v_1, based on step parameters *Overlying layer velocity step* and *Current layer velocity step* .
Overburden velocity v_1 is needed for our Intercept Time two-layer case inversion method. If this option is enabled, the apparent velocity V as obtained for the previous XTV triple and layer is taken as an estimate for the velocity at the top of the current layer.

Suppress velocity artefacts

Enable this option to suppress the generation of processing artefacts, i.e. unrealistic velocity variations. Use best for medium and high coverage profiles. See (Winkelmann 1998), top of page 36. If enabled, a candidate ray will be used for modeling of an incremental layer if the ray specific apparent velocity and intercept time (as modeled by local regression on CMP curve, at ray specific offset) both are lower than the mean of apparent velocity and intercept time, as estimated for the next three higher CMP offsets. This triple filtering has the aim of suppressing reflections erroneously picked as first breaks. If this setting is disabled, no candidate ray selection, i.e. filtering / enforcing of *CMP traveltime curve* continuity, based on apparent velocity and intercept time will occur.

References

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