# Analysis of Seismic Event Confusion via Trees

R. Phillip Bording* S. Padina†

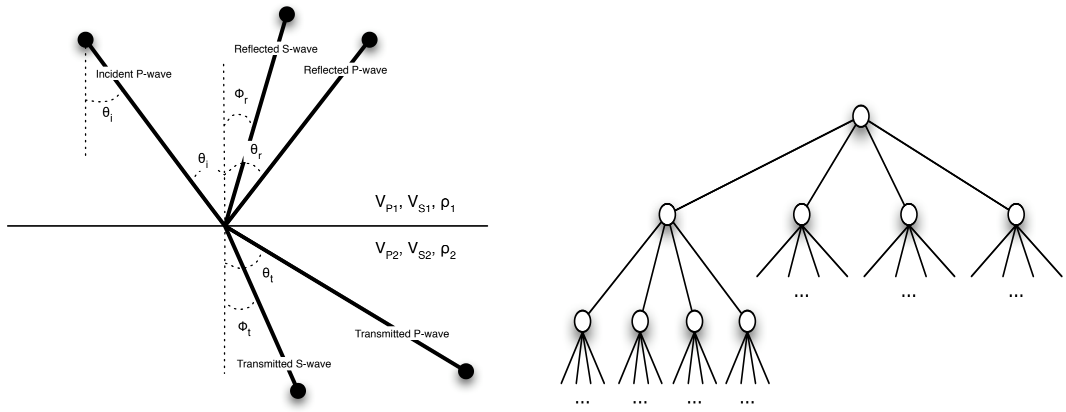
Seismic modeling methods that rely on finite difference approximations are used to compute wiggle traces from known models. The complete wave equation methods are the most robust for seismic modeling, as they generate all possible wave events. These include all inter layer multiples, head waves, and surface waves consistent with the selected wave equation. The acoustic wave equation only models compressional waves while the general isotropic elastic wave equation can model compressional waves (P-waves) and shear waves (S-waves).

The rich variety of waves recorded at the receiver location include the important P-wave data known to come from principal reflectors. Many other wave types also are recorded including the important shear waves and converted shear waves. However, many smaller amplitude waves are also recorded; so many in fact that we have a hard time understanding their root cause. This phenomenon is so complex, we call it *event confusion*.

We can explain reflection events if we use ray theory because we can track the ray paths and explicitly determine/make the event to occur. To do this, ray tracing is performed on the model to trace the paths and determine the distances traveled. In the general case of solid-solid interfaces, at every interface a ray will split into four different rays: two transmitted waves and two reflected waves, one each for a P-wave and an S-wave. The current computational techniques typically discard the S-waves, and as such their effect on the final wiggle becomes noise, driving down accuracy.

The term event confusion refers to the fact that we cannot exactly explain from the actual data trace what mix of waves is responsible for the wiggle. In addition, the current algorithms cannot associate specific reflection or refraction points with their corresponding contribution to the wiggle. To improve on this, we propose a new seismic method that employs 4-way trees to store relevant wave parameter information from each layer. The use of trees presents the advantage of allowing for a clear representation of the relationship that exists between different waves according to the ray tracing algorithms.

*Husky Energy Chair in Oil and Gas Research, Memorial University of Newfoundland
†Graduate Student, Computational Science Program, Memorial University of Newfoundland




(a) (b)

Figure 1: Snell's law for an incident P-wave at a solid-solid interface (a), a typical 4-way tree (b)

The 4-way trees is a type of rooted tree where every node can have between zero and four children but no more. Although four might seem like an arbitrary choice, this is motivated by the underlying geophysical phenomenon of wave splitting upon reaching a layer interface which we briefly mentioned in the previous section. Figure 1(a) shows a visual representation of a P-wave splitting into four different waves: two reflected and transmitted P-waves, and two transmitted and reflected S-waves. Although the figure shows a P-wave as the incident wave, the same situation holds for an incident S-wave. Thus if we were to represent a wave as a node, its parent would be the wave it previously split from, while its children will be the resulting waves upon reaching the interface – which can be at most four.

The tree structure allows us to understand *the number* of waves that contributed to the final wiggle and their relationships. Figure 1(b) illustrates a 4-way tree, similar to the ones discussed here. By storing wave parameters within each node, the tree will also allow us to draw conclusions on *how much* of the amplitude of the wiggle the individual waves are responsible for. Such parameters include the angle of incidence/reflection, the amplitude of the wave and the total distance travelled. To compute these values the tree generating code will employ Snell's law and Zoeppritz's equations for horizontal surfaces.

After the tree is constructed, we will perform a pruning process in which we will eliminate any nodes corresponding to waves that have decreased in amplitude past an arbitrary threshold. We will the use the remaining nodes to compute the wiggle and evaluate the results compared to finite difference codes.

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