Velocity model building and arrival classification using expectation-maximization

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Inversion of seismic traveltime data for velocity model inference is a technique commonly employed across a broad range of subsurface imaging applications (e.g. crustal transects, earthquake location, vertical seismic profiling). In all applications, model inference given the seismic traveltime data is reliant on the ability to appropriately identify ray theoretical arrivals and assign a travel time. Generating these traveltime datasets can be a time consuming and often iterative task, requiring (1) identification and (2) picking of arrivals as well as (3) classification of the arrival type or phase. Moreover, arrival identification, picking, and classification is typically carried out independently of inversion of the traveltime data. This sequential approach can be potentially detrimental, as it is well understood that uncertainties associated with the identification of individual arrivals and the determination of traveltime contribute to overall model uncertainty. As a source of uncertainty, the arrival classification is often overlooked or ignored in these sequential approaches and potential misclassification of arrivals can lead to erroneous velocity models.

To appropriately address and handle these aspects of uncertainty within a unified framework, we propose an approach that treats arrival classification and velocity model building as a joint problem using the expectation-maximization (EM) algorithm (Dempster et al., 1977). We introduce the use of an autopicker (Saragiotis et al., 2013) to identify potential arrivals and, via the EM algorithm, select ray theoretical ones for use in the traveltime inversion. In the expectation step the likely class of arrival is estimated and in the subsequent maximization step the velocity model is updated. We demonstrate the feasibility of the method through a synthetic example which yields promising results that show arrival classification can be successfully treated as a free parameter within inversion. We conclude by illustrating and discussing the potential applicability of the method to active source shot gathers.
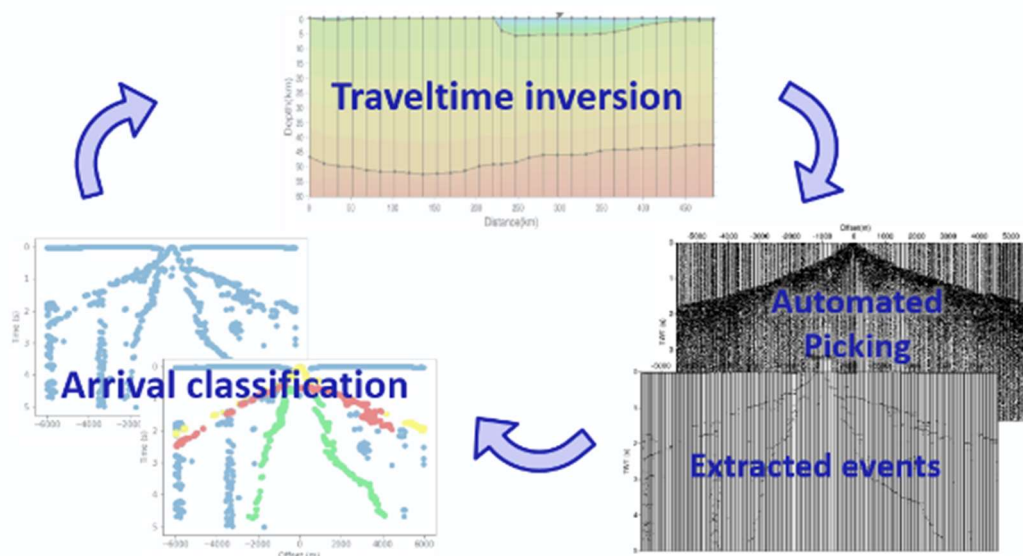

Figure 1. Joint approach to arrival classification and velocity model building

References
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Saragiotis, C., Alkhalifah, T., Fomel, S., 2013, Automatic traveltime picking using instantaneous traveltime. Geophysics, 78(2), T53–T58.