Evaluation of the PhD thesis

"Joint Detection, Location and Source Mechanism Determination of Microseismic Events"

submitted by
Denis V. Anikiev
Saint Petersburg State University, Russia
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The PhD thesis of Denis Anikiev is devoted to a new fully automated imaging method for microseismic monitoring. Microseismic imaging is mainly used in the oil and gas industry for passive seismic monitoring of reservoirs, specifically for observation of fracture growth during hydraulic fracturing, evaluation of well stimulation efficiency and estimation of potential reserves. Key challenge of the industrial application consists in automating the processing and analysis stage and removing the human bias. Method proposed in this thesis completely eliminates labour-intensive picking process and replaces it with multi-step automatic procedure that allows automatically detecting, validating and locating microseismic events while simultaneously evaluating their radiation patterns. One of the key elements of this approach is to conduct on-the-fly estimation of the seismic moment tensor, and then to perform summation along the diffraction curves with the coefficients derived from this tensor that correct for change in polarity. It was known that microseismic events possess complex radiation pattern, but author found an efficient way to perform an estimate of the seismic moment tensor for each time sample thus correcting diffraction stacking.

Primary effect of such proper summation based on actual estimated source mechanism results in improved detection of weak microseismic events especially on the real data with low signal-to-noise ratio. This enhancement is critical for practical application especially when observation arrays are located on the noisy surface of the earth.

Secondary benefit of this approach is delivery of seismic moment tensors and orientations of associated nodal planes for each event. Statistical analysis of this information should allow industrial users not only locate stimulated parts of the reservoir, but also understand exact nature of each swarm of events thus providing information about orientation of induced microfractures. While previously such information could be obtained only in some averaged sense for each swarm in non-automated way, delivering it in a consistent and automated way for all detected events should aid reservoir engineers in better understanding stimulation mechanisms.

Author also suggested original ways to automatically detect events and validate them in particular distinguishing from strong noise outbursts.

The proposed method has been applied to a real dataset recorded during stimulation of a shale gas reservoir. Results demonstrate that the method is able to automatically detect and locate a large number of real microseismic events while reliably estimating source mechanisms. The developed imaging method is fully automated and appears feasible for industry applications in real-time microseismic monitoring. Benchmarking analysis of locations and source mechanisms shows good agreement with standard techniques that involve manual picking. However, picking-based techniques can only reliably locate strongest events, whereas automatic stacking method can detect events with lower magnitude and perform better on noisier data.

I recommend the submitted thesis to be accepted. I have several comments that mainly should be considered as recommendation for future work and as a way to better contrast new approach presented in the thesis to existing best industry practices:

1. I would recommend more apple-to-apple comparison of new approach with current industry approaches. Specifically trying to replicate current approach as much as possible (based on publically available information) and then comparing fidelity and location capabilities of current and new approach. I find comparison with manual picking for strongest events a sufficient demonstration, but perhaps not the most impressive.
2. Same comments applied to estimated source mechanisms. It would be best to see a comparison with current result for averaged source mechanisms and what can be provided by a proposed method.
3. I would recommend revealing more practical details on decimation steps for initial detection as well as moment tensor inversion. Source mechanism for a single event of a finite duration can be additionally constrained to be the same (which makes physical sense) rather than allowing it to vary from one time sample to another. This may be an additional regularization step to provide better accuracy of the estimated source mechanisms.

Dr. Andrey Bakulin
Geophysics Technology, EXPEC Advanced Research Center, Saudi Aramco