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Comparison of Diffraction Imaging Using Plane-Wave Destruction, Image Segmentation, and Multi-Domain Diffraction Identification by Deep Learning

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Conventional processing does not utilise the diffraction energy, choosing instead to focus on enhancing the reflection energy. As such, considerable information from the diffracted portion of the wavefield is wasted. Diffraction imaging is a technique which aims to exploit the diffractions and is used to identify small-scale scattering features in the subsurface, which relate to geologically significant structures and stratigraphies. Several methods for diffraction imaging exist which aim to separate the diffracted portion of the wavefield either through separating or suppressing the reflections. Here we compare a popular method of suppression, plane-wave destruction, with two machine learning methods of separation, image-segmentation and multi-domain diffraction identification.

Plane-wave destruction works to suppress reflections by first estimating the local slope of the reflection energy. Any energy which conforms to this slope is regarded as a reflection and is muted, whilst the remainder of the wavefield is left untouched. However, there are some issues with this method. Firstly, while this method does effectively remove the reflections from the wavefield, noise also does not conform to the local slope and thus the remnant wavefield contains not only diffractions but noise also. Secondly, in areas where there is a non-continuous slope the method breaks down.

Image segmentation is a technique which involves separating an image into different components based on the image qualities. As diffractions appear different to reflections and noise in shape, amplitude, and sharpness, these can be used for separation. A simple machine learning classifier is used to account for variations in the image properties and for variations along the length of diffractions and reflections. While this method does separate diffractions, reflections, and noise, the overlapping wavefields and complex nature of the problem mean this method does not suit more complex dataset examples.

As diffractions and reflections have overlapping wavefields, a domain must be found in which these can be separated to allow for the maximum reflection energy to be removed while maintaining the diffraction energy. Multi-domain diffraction identification is a novel diffraction imaging technique which involves converting the data into multiple domains in which diffractions may be easier separated. This is achieved here by using a convolutional neural network for automated classification and separation of the wavefields. While the processing time is increased due to the multiple transformations and use of the neural network, the quality of the separation far offsets this.

When comparing the three methods, multi-domain classification outperforms the other two methods in almost every aspect. Plane-wave destruction remains an effective method for separation due to its simplicity and analytical approach, however, the influence of noise and the breakdown of the method in the presence of a variable slope remain drawbacks of this technique. Image segmentation had initial promise due to the ability to separate noise, however, broke down in complex real-world scenarios due to overlapping wavefields. Multi-domain diffraction identification allowed for the highest quality results and effectively separated diffractions, reflections, and noise, at the cost of increased processing time.