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Optimized Experimental Network Design for Earthquake Location Problems: applications to geothermal fields seismic networks

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We propose a network optimization scheme for augmenting and qualifying local and regional microseismic monitoring arrays. Our optimization routine is based on the traditional minimization of the volume error ellipsoid of the linearized earthquake location problem (*D-criterion*) but with the twist of a sequential design procedure. Seismic stations are added one by one at each step for multiple hypothetic earthquake locations with varying attenuation levels. The sequential design approach significantly reduces computation efforts and allows the analysis for benefit/cost relations. Cost curves are computed for all hypothetic events and reveal the minimum optimal number of stations needed for a design experiment. In addition sequential design allows for easier *on the field* seismic station deployment as one can quickly compute one by one the next position and account for the latest placement variations had it not been possible to place a seismometer precisely at a suggested point.

The developed routine was first tested on three theoretical design experiments obtaining resulting network geometries similar to those of the classical simulated annealing approach. Later we used the routine to augment an existing seismic network for monitoring microseismicity in a geothermal field in NE Iceland (Theistareykir). The resulting 23 station network would become the backbone of a 3-year study of the reservoir behavior. Hypothetic event locations and magnitude relations were taken from a previous regional seismicity study and coincide with known injection and production areas. Sensitivities were calculated from a known 1D velocity model profile using a finite-difference back-ray tracer, and body wave amplitudes were computed from known local magnitude relations. Finally expected earthquake location accuracies were obtained via multiple Monte-Carlo experiments. Areas around the regions of interest present accuracies of approximately 0.5 km at a depth of 2.5km.

On a similar note, the same principles were used to qualify an existing dataset and seismic network of SW Iceland (Reykjanes). We explored the possibility of adding few picks of strategic stations with benefits and accuracies considerably enhanced. Similarly, the seismic array was selectively reduced and benefit and expected accuracies quantified to observe whether costs could have been optimized had a previous network design experiment been performed.

Overall the technique hereby explored proves a quick tool for designing and qualifying networks for many applications at various scales.