Extinction in genetic algorithms: application to receiver functions inversion

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The use of genetic algorithms in receiver functions inversion for crustal and uppermost mantle velocity-depth structure is well established (e.g. Shibutani et al., 1996). Their operation is analogous to the evolution of biological species through the use of (pseudo)random numbers to control the selection, crossover and mutation processes in their search for an optimal model(s). Despite their robustness, one drawback of the standard genetic algorithms is that towards the end of a 'run', only a few new solution ideas are explored which may lead to the stagnation of the optimization process. This can be an especially major drawback for large model dimensions, such as in the inversion of receiver functions for dipping and anisotropic structures. To mitigate this problem, this study introduces an extinction concept to genetic algorithm inversion of receiver functions for crustal shear wave velocity structure. With extinction, parts of the explored model population are regularly replaced to exploit highly fit models as well as random explorations of other domains. The concept of self-organized criticality, which has similarly been used to explain the extinction of biological species (e.g. Newman, 1996), is applied to control the size and frequency of the extinction events in the genetic algorithm following Krink et al. (2000).

Three different model replacement strategies are tested against the standard genetic algorithm of Shibutani et al. (1996) for performance comparison on both synthetic and real data problems. In random replacement, extinct models are replaced by randomly generated models. Survivor mutant replacement comprises replacing extinct models with randomly generated mutations of the surviving population. Lastly, in best-model mutant replacement, extinct models are replaced with mutations of the current best model, mutated at 2, 3 or 4 points selected at random positions. Preliminary results show that random replacement achieves the most extensive model space exploration but with the least exploitation of fitter models, consequently resulting in a less fit ‘best model’. Greater exploitation of fitter models is achieved by survivor mutant and best-model mutant replacement strategies which obtain fitter best models in fewer generations compared to the standard genetic algorithm. A combination of the three replacement strategies may offer the best balance between exploitation of 'fitter' models and exploration of the whole model space without affecting the efficiency of the algorithm as shown by the results from the synthetic tests. The difference in computational costs between the standard genetic algorithm and the genetic algorithm with extinction was insignificant during these tests. These results show that extinction in genetic algorithm inversion of receiver functions can be tuned to improve the efficiency of the optimization process in escaping local minima as well as reducing convergence time. This technique can prove very useful for optimization problems with large dimension model spaces.