Particle Swarm Optimization in Interferometer Array Designs for Radio Astronomy Applications

Nanbo Jin and Yahya Rahmat-Samii
Department of Electrical Engineering, University of California, Los Angeles
Los Angeles, CA 90095
jnnb@ee.ucla.edu rahmat@ee.ucla.edu

The design of interferometer arrays for radio astronomy applications is a challenging engineering problem. Limited by the ground constraints at the site of observatory, the array configuration must provide a good u-v plane coverage, a high maximum-minimum baseline ratio and a low peak sidelobe level (SLL). Much effort has been expanded on designing an "optimum" array configuration by applying conventional methodologies such as steepest descent method and simulated annealing (T. Cornwell, MMA Memo No. 38, 1987; L. Kogan, MMA Memo No. 171, 1997; F. Boone, ALMA Memo No. 400, 2001); however, an efficient global optimization technique is still desired for designing an array configuration that meets multiple criteria aforementioned to retrieve a reliable image.

The problem is addressed in this paper using particle swarm optimization (PSO). PSO is a novel evolutionary algorithm that exploits the optimizing feature in the swarm behavior to search for the global optima. The algorithm has been proven to be suitable for both linear and nonlinear problems in multi-dimensional, multimodal complex solution spaces. Each particle in the swarm represents a candidate design, with its performance denoted by a fitness function. For instance, in order to achieve the array configuration that has the most uniform u-v coverage, the fitness function can be defined as the minimum separation between u-v samples. After a large number of iterations, all the particles get converged to the optimum configuration that fits the design criterion best. The PSO algorithm is also able to handle multiple-objective optimizations using multiple fitness functions (MOPSO). The optimization gives a set of array configurations that trade off different design criteria (such as u-v coverage versus max-min baseline ratio) in an optimum manner.

We test the methodology by designing interferometric arrays with up to 12 elements. To achieve a uniform u-v coverage, the array configuration converges to be ring-like, and the max-min baseline ratio varies with the relative positions of the elements. A testing algorithm is also developed to validate the optimized array configurations. Given an array configuration, the sampled visability of a fictitious source is calculated and an image of the source is retrieved by applying inverse fourier transformation. The algorithm accommodates both snapshot and earth-rotation observations. It is shown that the optimized array configurations can be used to observe more reliable images than conventional, periodic ring-like arrays. A detailed implementation of the algorithm will be discussed in the presentation.