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Optimal Acoustic Search Path Planning for Sonar System Based on Genetic Algorithm

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The design of an efficient search path to maximize Cumulative Detection Probability (CDP) is mainly dependent on experience and intuition when a searcher detects an ocean target using sonar. Recently, with the advance of modeling and simulation methods, it has become possible to access the optimization problem more systematically. In this paper, a method for the optimal search path calculation is developed by combining the genetic algorithm (GA) with a detection algorithm. We consider the continuous system for the search path, space and time, and use the sonar movement direction as the GA gene. Lagrangian and Eulerian approaches are used to model a moving target. The developed algorithm, Optimal Acoustic Search Path Planning (OASPP), is shown to be effective, via a simulation, in finding the optimal search path for the case where the intuitive solution exists.

INTRODUCTION

When a searcher detects the target using sonar in complicated ocean environments, the calculation of the optimal sonar search track is an important influence on the effectiveness of sonar and human resources. In addition, because the ladder search method in general use is intuitively not the optimal search method, the development of a search path planning method with improved performance and reduced search time is an important research focus.

The optimal search path problem can be treated as a search-effort-allocation problem (Stone, 1992), which assumes that the effort can be allocated arbitrarily over the search space within the achievable path by the sonar platform. The search path can be modeled by either the discrete-search-path problem (Washburn, 1967, 1996, 1998), which assumes the searcher and target move in discrete space and time, or the continuous-search-path problem, which assumes they must follow realizable paths in continuous space and time. Recently, DelBalzo (Kierstead and DelBalzo, 2003; DelBalzo and Hemsteter, 2002; DelBalzo et al., 2001) developed a calculation method for the continuous-search-path problem based on the combination of the genetic algorithm (GA) and the detection range.

In this study, GA is used in nonhomogeneous and anisotropic environments to nearly optimize the sonar search track (Hemsteter and DelBalzo, 2002), and Bayesian statistics allow amalgamation of the individual detection probability into a Cumulative Detection Probability (CDP, P_{cd}) for the search path, which is the Measure Of Effectiveness (MOE) for that path against a Monte Carlo distribution of targets obeying realistic motion models (DelBalzo et al., 2002; Matthiesen, 2002; Zumwalt et al., 2000). The optimization metric for the search path is the target CDP during a fixed time period (Hemsteter and DelBalzo, 2002; Zumwalt et al., 2000).

As for the path, the continuous-search-path is employed, but the search step is fixed in length and time. The movement direction of the searcher is used as the gene of GA, which means that each gene is only composed of one set of real numbers, θ, representing the direction of movement, so that $0 \leq \theta < 360$. In addition, due to the process of evolution, the offspring of each generation contain a wide variety of candidate paths for perturbing some aspects of the trial solution. Crossover is accomplished by exchanging the genes between the initial and final segments of the 2 parents. The perturbation and elimination of the nodes are implemented as part of the mutation. In addition to crossover and mutation, a bank of genes representing segments of various search movements is used as a part of the process of evolution. Lagrangian and Eulerian approaches are used to describe the particle motion for the modeling of the moving target distribution.

We present a simple example to illustrate, via a simulation, that the developed algorithm, OASPP (Optimal Acoustic Search Path Planning), produces the optimal search path for the case where the intuitive solution exists.

THEORY AND CODING

Inspired by Darwin's theory, GA is an approach for solving otherwise intractable problems by mimicking the process of evolution (Hemsteter and DelBalzo, 2002; Goldberg, 1989; Winter et al., 1996; Michalewicz, 1998; Mitchell, 1998). It was invented by John Holland and described in detail in the reference *Adaptation in Natural and Artificial Systems*, published in 1975 (Moon, 2003).

GA is applicable to the global optimization problem where the search space is too big to employ an exhaustive search. The objective of using GA is not to find the best and unique solution, but rather a reasonably acceptable solution with good performance within a limited computation time. In order to treat the search

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