An Immune Genetic Algorithm for AUV Local Path Planning

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ABSTRACT

This paper proposes a new immune genetic algorithm and applies it to generate local paths for an autonomous underwater vehicle (AUV) when it fails to avoid abrupt obstacles by reactive behaviors. The algorithm mixes both immune algorithm and genetic algorithm through introducing niche technology based on path segment number, maintaining population’s diversity by population clustering, enhancing local search capability and convergence velocity through cell clone operation and immune memory mechanisms. The simulation results verify that the proposed algorithm is not only more efficient than immune algorithm and genetic algorithm, but also feasible and effective in a typical semi-closed obstacle scenario.

KEY WORDS: AUV; path planning; immune genetic algorithm; obstacle avoidance.

INTRODUCTION

Obstacle avoidance and path planning are two necessary capabilities for an autonomous underwater vehicle (AUV) to operate in an unknown complex environment without human’s intervention. The objective of obstacle avoidance is to generate a series of actions on the basis of sensorial information. Path planning is mainly to find an optimal or hypo-optimal safety path from start point to goal point according to performance criteria (Zu, 2007). They are different but correlative each other. Obstacle avoidance is usually implemented by a reactive control law in the lower level of control system and may get into local extremes in the absence of apriori information and global map. But path planning can find an optimal obstacle-free path even in an entrapment and then direct AUV to break the deadlock of local extremes. We have presented a real-time obstacle avoidance method based on fuzzy control in the reference (Xu, 2008). And this paper mainly discusses the local path planning problem.

In recent years, researches on AUV local path planning are focused on modified virtual field force algorithms (Jiao, 2007), evolutionary algorithms (Alvarez, 2004), mixed integer linear programming methods (Yilmaz, 2005) and numerical nonlinear programming techniques (Petillot, 2001). It is widely accepted that evolutionary algorithms, especially genetic algorithms are more applicable to solve complex multi-objective optimization problems such as path planning (Chang, 2005). Genetic algorithm originates from the Darwinian theories of natural selection and survival. It is categorized as global search heuristics used to find exact or approximate solutions to optimization problems. Its computational complexity has been proved to increase linearly with the dimension of the solution space (Kanakakis, 2007). In the case of AUV real-time path planning, environments are space- and time-varying, and its solution space is a four-dimensional space. Then traditional genetic algorithm can not guarantee convergence to an optimal solution in limited time.

This paper introduces immunological theories into genetic algorithm and proposes a new immune genetic algorithm, which inherits all advantages from them. There are three main improvements. Firstly a niche technology based on path segment number is presented to reduce solution space of search. Then we apply antibody population clustering to maintain population’s diversity. At last local search capability and convergence velocity are enhanced through cell clone operation and immune memory mechanisms. The simulation results verify these improvements finally.

THE NICHE GENETIC ALGORITHM

In Ecology niche is named as a habitat supplying the factors necessary for the existence of an organism. It means that an organism strongly inclines to live with ones that have the same characters and behaviors. In this paper we introduce the niche concept to reduce solution space of search.

During searching an optimal path connecting a start point with a goal point, the segment number of the optimal path is unsure in advance, that may be one at least and may be infinite at most in theory. But in practice the shortest length of a path segment is limited by the AUV’s maneuverability and mission requirements, so that the path segment number is finite for a specific planning task. For this reason, the paths having the same segment number may form a niche. We can determine the number of niches as \( M(M > 2) \). Then the population \( P(t) \) will be divided into \( M \) son-populations.

\[
P(t) = [P_1(t), \ldots, P_m(t), \ldots, P_M(t)] , \quad m = 1, 2, \ldots, M
\]

In every son-population \( P_m(t) \) each path comprises of \( m \) path segments. A path corresponds to a chromosome \( P_{\text{opt}} \) and a point is