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Multi-robot path planning in a dynamic environment using improved gravitational search algorithm

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Abstract

This paper proposes a new methodology to optimize trajectory of the path for multi-robots using improved gravitational search algorithm (IGSA) in a dynamic environment. GSA is improved based on memory information, social, cognitive factor of PSO (particle swarm optimization) and then, population for next generation is decided by the greedy strategy. A path planning scheme has been developed using IGSA to optimally obtain the succeeding positions of the robots from the existing position. Finally, the analytical and experimental results of the multi-robot path planning have been compared with those obtained by IGSA, GSA and PSO in a similar environment. The simulation and the Khepera environmental results outperform IGSA as compared to GSA and PSO with respect to performance matrix.

Keywords: Gravitational search algorithm; Multi-robot path planning; Average total trajectory path deviation; Average uncovered trajectory target distance; Average path length

1. Introduction

Gravitational search algorithm (GSA) is effective and efficient using an alternative approach to the multi-robot path planning. Although many algorithms (Tuncer and Yildirim, 2012; Guo and Parker, 2002) have been proposed and proven to be feasible and efficient for robot motion planning and collision avoidance, classic techniques for path planning problem (Konar, 1999; Banerjee et al., 2011) are general methods like Roadmap, Cell Decomposition, Potential Fields, Optical Tweezers and Mathematical Programming. Many authors have proposed multi-robot and the

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single robot path planning problems using different classical techniques (Kcymeulcn and Decuyper, 1994; Li et al., 2009), Neural Network (Yu and Kromov, 2001), artificial immune system (Das et al., 2012; Luh and Cheng, 2002) and heuristic optimization algorithms (Das et al., 2010, 2011; Geem et al., 2001; Yang, 2009; Regele and Levi, 2006). High time complexity in large problem spaces and trapping in local optimum are drawbacks for classic techniques and in many meta-heuristic algorithms. These drawbacks cause the classical techniques and inefficient in the various problem spaces. To improve the efficiency of classical methods, probabilistic algorithms like PRM and RRT are proposed for improving the local optimization problem, many evolutionary algorithms like Genetic Algorithms (Tuncer and Yildirim, 2012; Gong and Lincheng, 2001), PSO (Zhang et al., 2013; Masehian and Sedighizadeh, 2010), bee colony optimization (Bhattacharjee et al., 2011) and differential evolution algorithm (Chakraborty et al., 2009) are used in multi-robot path planning problem.

The gravitational search algorithm (Verma et al., 2013; Eldos and Qasim, 2013; Chatterjee et al., 2011) is a recent algorithm that has been inspired by the Newtonian's law of gravity and motion. GSA has undergone a lot of changes to the algorithm itself and has been applied in various applications. At present, there are various variants of GSA (Precup et al., 2012; Rashedi et al., 2010, 2009b; Purcaru et al., 2013) which have been developed to enhance and improve the original version. The algorithm has also been explored in many areas (Sabri et al., 2013; Eldos and Qasim, 2013).

For realization multi robot path planning problem with different goal of the respective robots with GSA (Precup et al., 2012; Tuncer and Yildirim, 2012) by the centralized approach, a fitness function is constructed to determine the next position of the robots that lie on optimal trajectories leading toward the respective goals. The fitness function of the GSA (Alba and Dorronsoro, 2005) has two main components: first one is the objective function describing the selection of next position on an optimal trajectory based on velocity, and the second one is the constraint on acceleration representing avoidance of collision with other robots and with static obstacles. The path-planning problem considered here is formulated by a centralized approach, where an iterative algorithm is invoked to determine the next position of all the robots satisfying all the constraints imposed on the multi-objective function. The algorithm is iterated until all the robots reach their destination (goal position).

The advantages of GSA are (1) easy to implement with higher computational efficiency; (2) few parameters to adjust, but the disadvantages of this algorithm are as follow (1) if premature convergence occurs, there will not be any recovery for this algorithm; (2) the algorithm loses its ability to explore and then becomes inactive only after Q6 becomes convergence. Due to above difficulties in GSA, further improvements are required for the optimal solution to the complex problem. Here, we consider the improvement of GSA which is based on the communication and memory characteristics of PSO (particle swarm optimization). Therefore, we called it improved gravitational search algorithm.

The main objective of this paper is summarized as follows: (i) we study the problem of multi-robot path planning in a clutter environment and formulated the above problem as multi-objective optimization problem with constraints; (ii) a novel method to the solution of an optimal trajectory path generation for multi robot path planning problem using IGSA is proposed in this article; (iii) the proposed algorithm has been applied for multi robot path planning in a clutter and dynamic environment and obtained results are compared to other optimization algorithms like GSA, DE; (iv) the performance of the proposed IGAS, as an optimizing tool in solving multi robot path planning problem, is applied in the simulation as well as Khepera-II environment and result is presented; (v) the performance matrix of the proposed approach is successfully validated in simulation and Khepera-II.

In this paper, the implementation of the modified gravitational search technique has been proposed to determine the trajectory path for multiple robots from predefined initial positions to predefine target positions in the environment with an objective to minimize the path length of all the robots. The result shows that the algorithm can improve the solution quality in a reasonable amount of time and also improves the convergence rate. This paper improves the gravitational search algorithm (IGSA) for improving the global path planning problem of the multi-robots by improving the convergence rate. Finally, the efficiency of the IGSA has been proved through the simulation as well as Khepera environment and a result obtained is compared with other evolutionary computing such an GSA and DE.

Q7 The rest of the paper is outlined as follows: Section 3 briefly describes the improved gravitational search algorithm. Formulation of the problem for multi-robot path planning has been elaborated in Section 4. Multi-objective optimization problem solving using improved GSA is described in details in Section 5. Section 6 demonstrates the result of path planning for multi-robot through simulation. In Section 7, the experiment has been conducted in Khepera II environment and finally, the conclusion of the work is presented in Section 8.

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