Path Planning for a UGV using Salp Swarm Algorithm

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Abstract

The paper researches a utilization of the Salp Swarm Algorithm (SSA), a bio-mimetic optimization technique, to improve path planning in Unmanned Ground Vehicles (UGVs). Because of the crucial role of the efficient and reliable path planning in the implementation of UGVs in such sectors as military, rescue operations, and agriculture, there is a need for algorithms that are capable of navigating complex environments. The concept of SSA, based on the natural swarming behavior of salps, represents a very promising approach that is characterized by the exploration and exploitation properties of the algorithm. This study evaluates the performance of the SSA relative to existing particle swarm optimization (PSO), in terms of path optimality, computational efficiency, and dynamic obstacle adaptability, through a number of simulated environments. Results show that the SSA has the potential to compete with the traditional algorithms in path efficiency and computational load. However, PSO shows slight superiority results compared to SSA. This study highlights the potency of bio-inspired algorithms, specifically the SSA, in enhancing the field of autonomous navigation for UGVs. It introduces new possibilities of practical application of SSA in real-life scenarios, demonstrating its scalability and resilience. The findings of this study make a contribution to the general discussion on the improvement of planning of autonomous routes and provide a possible way for more sustainable and effective UGV activities.

Keywords: Path Planning, Unmanned Ground Vehicles, Salp Swarm Algorithm, UGVs

1. Introduction

The dynamics of the autonomous navigation landscape change and the effectiveness and robustness of path planning algorithms are critical for the operational success of Unmanned Ground Vehicles (UGVs) [1-12]. These vehicles are used in various applications including military operations [13-30], disaster reliefs, as well as agricultural automation and require sophisticated navigation techniques that can allow them to navigate safely and effectively through difficult environments [31-45]. Traditional path planning methods mainly face an optimization task of path length and computational efficiency in dynamic and unpredictable terrains [46-66].

In the multitude of algorithms proposed for path planning, bio-inspired algorithms are a powerful solution since they are flexible, scalable, and capable of finding global optima in multi-dimensional spaces [67-78]. For example, the Salp Swarm Algorithm (SSA), which is based on the swarming behavior of salps in the ocean, is one of the new bio-inspired optimization techniques that have demonstrated potential in different optimization problems [79-83]. Its mode of operation, imitating the navigation pattern of the salp chain, provides an equilibrium between the stages of exploration and exploitation, and so it is an interesting candidate for UGV path planning [84-100].

This article focuses on the use of SSA in path planning of UGVs. Drawing comparisons of the salps' natural behavior and the demands of effective path navigation, the potential of SSA to improve the ability of UGVs to traverse difficult terrains is investigated. The point is to assess the performance of the algorithm in the context of path optimality, computational burden and adaptiveness to dynamic environments.

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The main contributions of this paper are threefold: Initially, we present a customized edition of the SSA, adapted specifically for the path planning issue of UGVs, emphasizing the changes to be viable in typical spatial restrictions and dynamic obstacles of UGV applications. Second, we give a differentiated comparative evaluation of the altered SSA with classical and modern path planning algorithms within a set of simulated environments, proving its success and efficiency. Lastly, we consider the implementation of SSA in actual UGVs from a practical perspective, like issues regarding computational resources and environmental uncertainty.

2. Methodology

The salp swarm algorithm (SSA) goes in the following order [81, 100]:

Initialization of n salp locations, with d dimensional search space and iteration counter (t) is set to 0.

Evaluation of the salp locations ($x_i^{j,t+1}$), and select the best fitness as the food location (F_i).

Updating the locations iteratively using the following equations:

$$x_i^{1,t+1} = F_i + c_1 \times randn \times (ub_i - lb_i) + lb_i \quad (1)$$

$$x_i^{j,t+1} = 0.5\left(x_i^{j,t} + x_i^{j-1,t}\right), n \geq j > 1 \quad (2)$$

Where c_1 is a learning coefficient that depends on the ratio between current iteration number compared to the maximum iteration number (μ), and it has a value of $2e^{-(4\mu)^2}$. ub_i and lb_i are the upper and lower bound values for the position's component (i).

Keep repeating the last two steps until the target is achieved or the maximum number of iterations is reached.

3. Results and discussion

The SSA is used to find the best road that can be used to go from the square to the star locations in Figure 1, generated using a modified code from [102]. A Monte Carlo Simulation (MCS) is conducted using 100 replications, with 150 epochs and 50 agents in each replication. The results show that SSA gives good results. SSA's results are compared to PSO results, and are illustrated for MCS in Figure 2 for shortest distance, and Figure 3 for the solution parameters. The histogram of the shortest path for both methods is illustrated in Figure 4. The MCS results in terms simulation time and convergence are shown in Figure 5 and Figure 6, respectively. The results show a slight superiority to PSO compared to SAA in terms of convergence, simulation time, and repetition of the results.

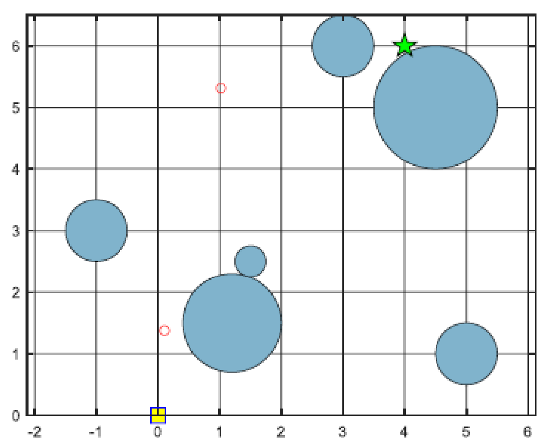

Figure 1. The environment under study

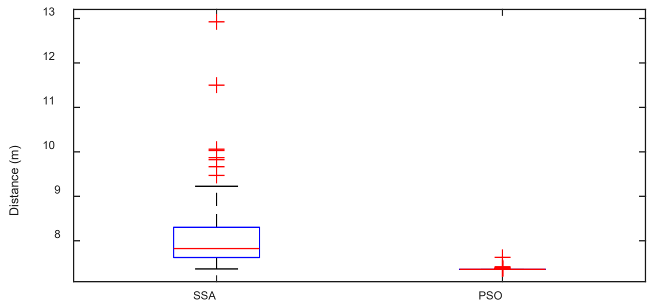

Figure 2. MCS results for the shortest distance.

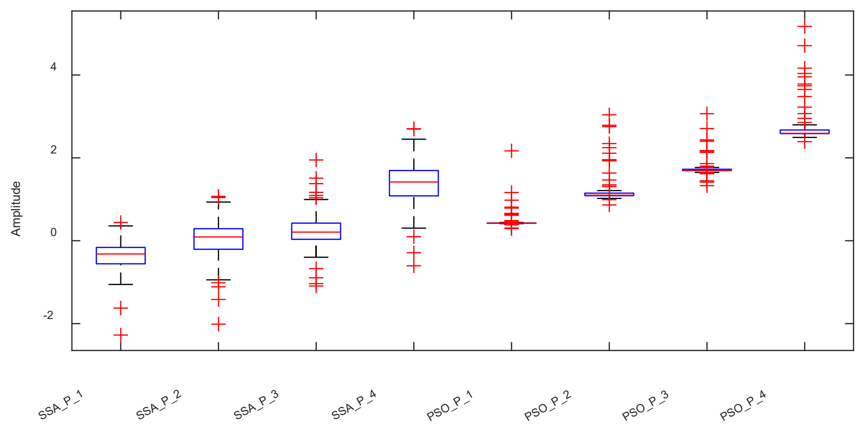

Figure 3. MCS results for the splines' parameters.

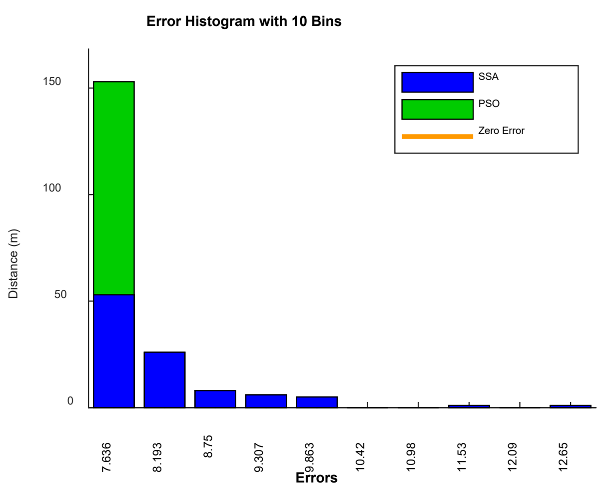

Figure 4. The histogram results of MCS for the final path's distance

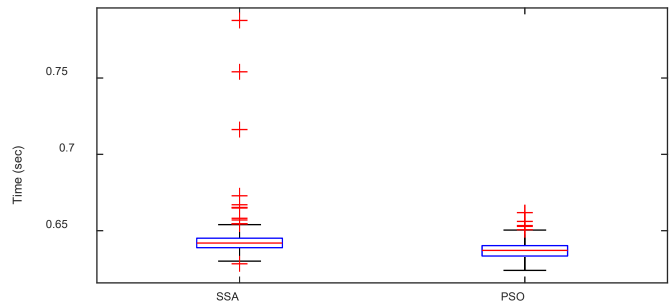

Figure 5. MCS simulation time

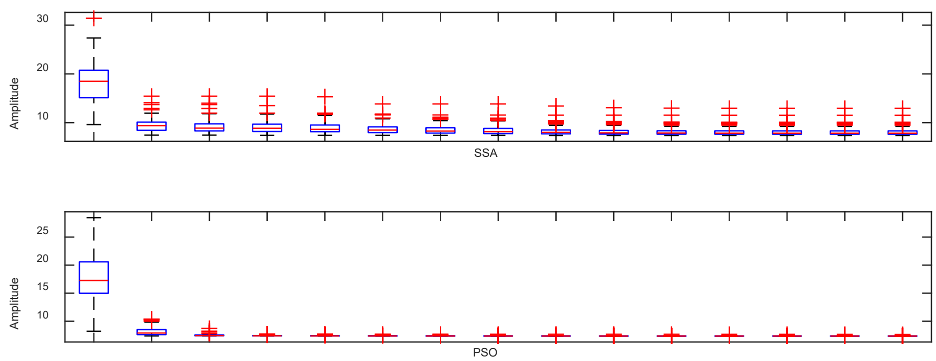

Figure 6. MCS's convergence rate for the simulations

4. Conclusion

This study investigates the use of Salp Swarm Algorithm (SSA) in path planning optimization in Unmanned Ground Vehicles (UGVs) offering an innovative method that merges the subtleties of bio-inspired optimization with real-world requirements of autonomous navigation. Our results emphasize the ability of the algorithm to greatly obtain the optimal path while maintaining the computational performance as low as other conventional approaches in various dynamic environments. Although the results show slight superiority to PSO, SSA still obtains good results, with performance matches a well-known method (PSO). Though prospective, the adaptation of SSA to UGV path planning should be investigated deeper particularly in real world testing and hybrid optimization techniques. Besides facing up a new challenge to a UGV capabilities, the above study is aiding in paving a way for future developments in autonomous vehicle navigation, showing the enormous potential of bio-inspired algorithms in complicated operational environments.

Declaration

The final draft of this research paper has undergone a rigorous proofreading process, which included the utilization of advanced artificial intelligence (AI) technology.

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