MVO-BASED PATH PLANNING SCHEME WITH COORDINATION OF UAVs IN 3-D ENVIRONMENT

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Outline

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- Research Gaps
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- MVO algorithm for path optimization
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- Experimental Simulation Results
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Overview

- The path planning of UAV deals with the process of figuring the most optimal path from source to the destination while avoiding obstacles on course
- The ability of the UAVs can be enhanced if there is coordination between them to find the best cost-effective target dynamically.
- Such UAVs can be used in various applications like rescue operations and combat zone.

Overview (contd)

Path planning problem is NP-Hard and solution given by deterministic algorithms have high time complexity. So probabilistic algorithms can be used to obtain solution in less time complexity.

- A new Multiverse Optimizer based algorithm is applied.
- It's performance is compared with other meta-heuristic optimization techniques
- The Munkres algorithm is applied for the coordination of UAVs in case of multiple targets

Need for a 'Meta-Heuristic' approach

- There exist different methods for path planning(Online and Offline)
- Conventional Methods are not efficient(Local Minima trapping and High time complexity)
- Meta-heuristic approaches give the sub optimal paths in a complex domain
- Lesser execution times when compared to deterministic approaches

Existing Literature Review

Author(s)	Paper Title	Year	Remarks
Kumar, P. et al,	Mvo-based two-dimensional path planning scheme for providing quality of service in uav environment [1]	2018	Several recently proposed meta-heuristic optimization schemes were explored while designing a UAV path planning problem using multiverse optimizer (MVO).
YongBo,C., YueSong, M., JianQiao,Y., XiaoLong,S. and Nuo, X.	Three-dimensional unmanned aerial vehicle path planning using modified wolf pack search algorithm [2]	2017	Mutation and crossover operators of the Genetic Algorithm were used. The cubic B-spline curve was used for the process of path smoothing.
Phung, M. D., Quach, C. H., Dinh, T. H. and Ha, Q.:	Enhanced discrete particle swarm optimization path planning for uav vision-based surface inspection [3]	2017	Performance improvement was obtained by using deterministic initialization, random mutation, and edge exchange

Existing Literature Review

Author(s)	Paper Title	Year	Remarks
Zhang, B. and Duan, H	Three-dimensional path planning for uninhabited combat aerial vehicle based on - predator prey pigeon inspired optimization in dynamic environment [4]	2017	The comparative simulation results showed greater efficiency than PIO, PSO, and different evolution DE.
Zhang, S., Zhou, Y., Li, Z. and Pan, W	Grey wolf optimizer for unmanned combat aerial vehicle path planning [5]	2016	Showed that the proposed method was more competent than other state-of-the-art evolutionary algorithms.
Chen, Y., Yu, J., Mei, Y., Wang, Y. and Su, X	Modified central force optimization (mcfo) algorithm for 3D uav path planning [6]	2016	The GA and PSO algorithms were applied to improve the original method for optimization of central force.

Existing Literature Review

Author(s)	Paper Title	Year	Remarks
Mirjalili, S., Mirjalili, S. M. and Hatamlou, A.:	Multi-verse optimizer:a nature-inspired algorithm for global optimization [7]	2016	The mathematical models of white holes,black holes and wormholes were developed to perform exploration,exploitation, and local search
Zhang, B. and Duan, H.	Predator-prey pigeon-inspired optimization for uav three-dimensional path planning [8]	2014	Comparisons were made with the PSO and PIO algorithms

Research Gaps

- **Extension of MVO for 3-D path planning**
  - The MVO algorithm has previously been used for path planning in a 2D environment and good results were obtained.
  - This inspired it's selection for 3D UAV path planning
- **Munkres coordination**
  - Optimal assignment of UAVs to targets in polynomial time in order to improve efficiency

Problem Formulation

- **Terrain Construction**
  - The purpose of the algorithm for path planning is to find a collection of points that connect S(source) to T(destination). The design of the environment takes place in 3-Dimensional space.
  - There are several areas in the environment where there is a prohibition of movement. These are known as obstacles. The UAVs are required to stay away from these obstacles during its movement.
  - Obstacles are cuboidal in shape.

Problem Formulation

- Three maps are used for running the algorithm and performing the simulation experiments.Their visual representation is given below

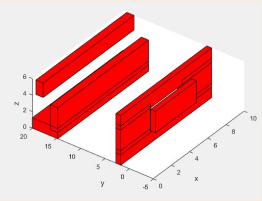


Figure: **Map 1**

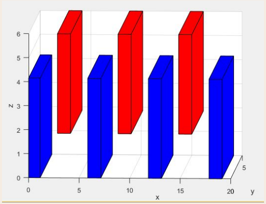


Figure: **Map 2**

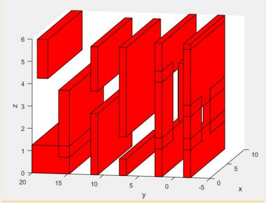


Figure: **Map 3**

Problem Formulation

- **Cost Function Definition:-** Various factors are used to decide the cost of potential solutions.
  - C_{fuel}**:-** It is the cost because of the path covered from the source to the destination.
  - $C_{divergence}$**:-** It is the cost due to the sharp divergences occurring on course.
  - C_{end}**:-** It is summed in the total cost in case the resultant path fails to reach the destination node because a principal obstacle lies in its path

The total cost function is the sum total of all the cost functions. It helps in determining the most optimum path among the path set. The total cost of the solution of path planning is:

$$C_{Total} = \alpha_1 * C_{fuel} + \alpha_2 * C_{divergence} + \alpha_3 * C_{end} \tag{1}$$

Multiverse Optimizer

It is a meta-heuristic algorithm which takes inspiration from the theory of multi-verse.The process of optimization begins by first creating a set of universes randomly

Rules applied on Universes

- If a universe has a greater rate of inflation , then there is a greater probability of the presence of a white hole and a tendency to send objects via them
- If a universe has a greater rate of inflation , then there is a lesser probability of black holes.A lower rate of inflation implies a greater likeness of receiving objects via them
- The presence of wormholes can cause random movement of objects towards the best universe obtained so far

Multiverse Optimizer

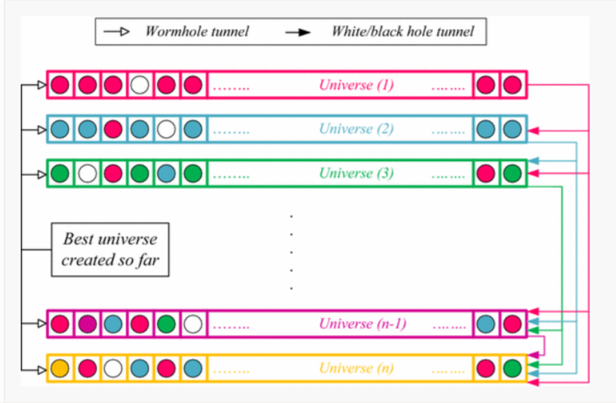


Figure: **Conceptual Model of MVO**

Multiverse Optimizer

Phases in MVO

- Random Universe Initialization
- Objects exchange through white/black hole tunnel

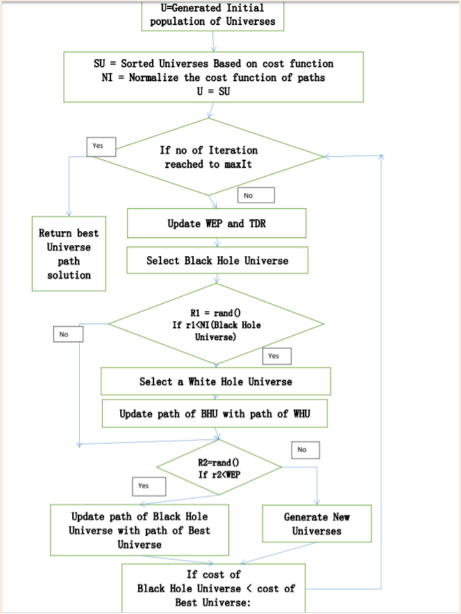
$$x_i^j = \begin{cases} x_k^j & r1 < NI(U_i) \\ x_i^j & r1 \geq NI(U_i) \end{cases} \tag{2}$$

- Objects teleportation through wormhole passage

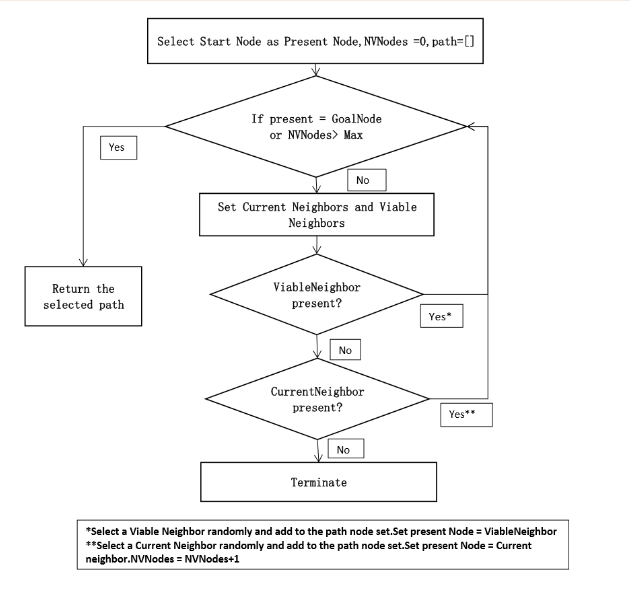
$$x_i^j = \begin{cases} \begin{cases} X_j + TDR \times ((ub_j - lb_j) \times r4 + lb_j) & r3 < 0.5 \\ X_j - TDR \times ((ub_j - lb_j) \times r4 + lb_j) & r3 \geq 0.5 \end{cases} & r2 < WEP \\ x_i^j & r2 \geq WEP \end{cases} \tag{3}$$

- WEP and TDR updation phase:- WEP increase should be in a linear fashion with the iterations so that the focus is on exploitation in the optimization process.The traveling distance rate (TDR) is increased as the iteration number increases so that a more accurate local search/exploitation can be done around the best universe obtained so far

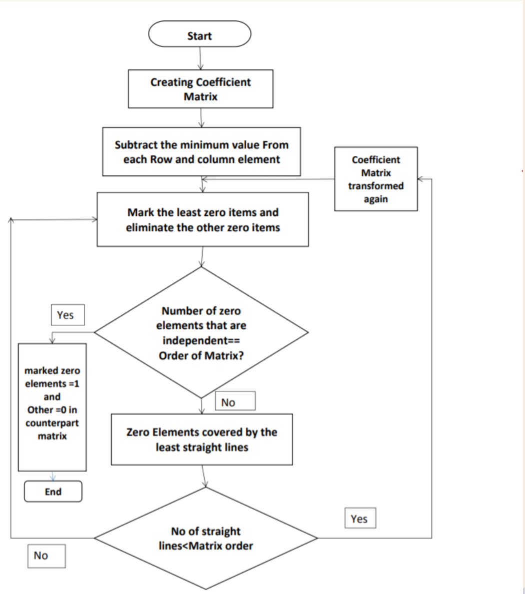
MVO algorithm for path optimization



Path Generation of Universes



Munkres Algorithm



Path planning for Single UAV

- The trajectories obtained by executing the MVO algorithm on the three maps are shown below.

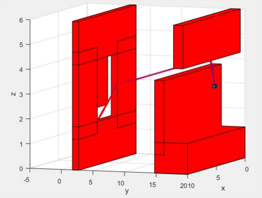


Figure: **Map 1**

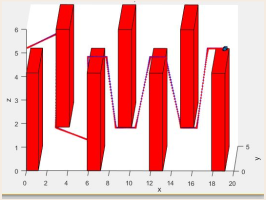


Figure: **Map 2**

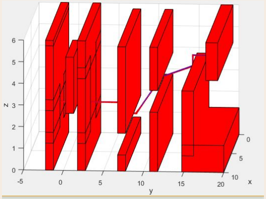
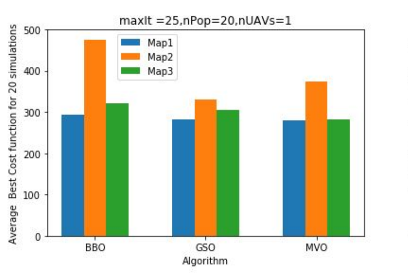
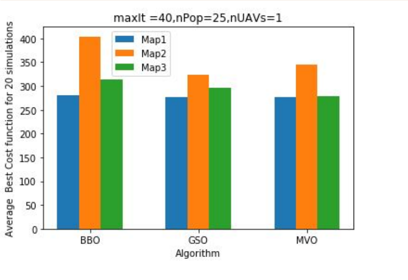


Figure: **Map 3**

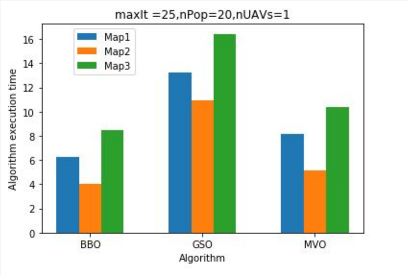
Experimental Simulation Results

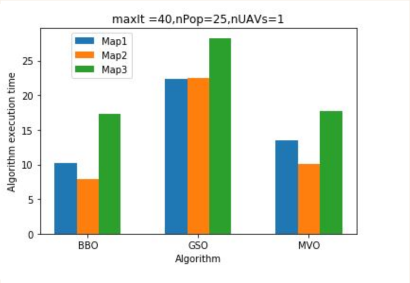
- **Analysis of Average Best cost**





- **Analysis of Execution Time**





Experimental Simulation Results

- **Convergence Analysis of Average Best cost with variation in Iterations**

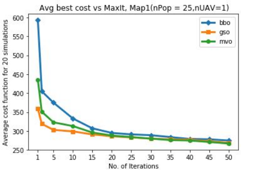


Figure: **Map 1**

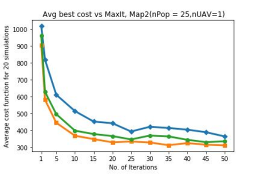


Figure: **Map 2**

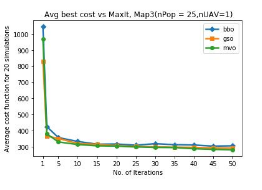


Figure: **Map 3**

Experimental Simulation Results

- **Distribution Analysis of Minimum Best Cost**

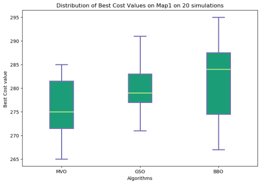


Figure: **Map 1**

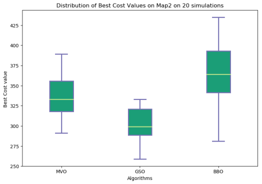


Figure: **Map 2**

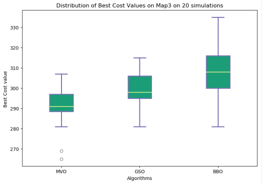


Figure: **Map 3**

Experimental Simulation Results

- **Analysis of Algorithm Execution Time with variation in Population size(maxIt = 25)**

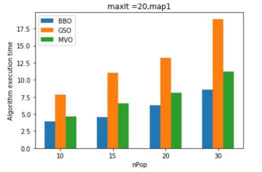


Figure: Map 1

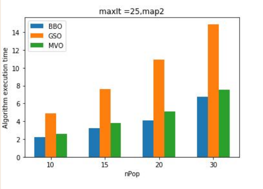


Figure: Map 2

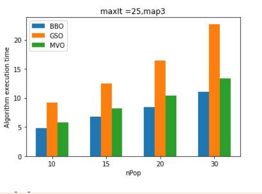


Figure: Map 3

Experimental Simulation Results

- **Analysis of Algorithm Execution Time with variation in Population size(maxIt = 40)**

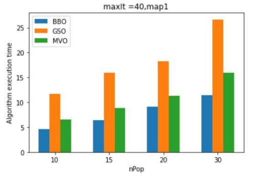


Figure: Map 1

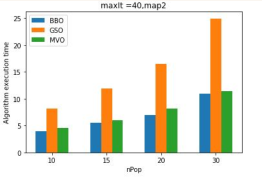


Figure: Map 2

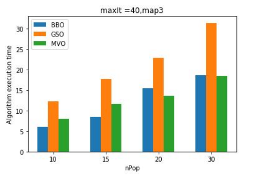


Figure: Map 3

- **Multiple UAV path planning**

Coordination between UAVs becomes an important factor here.Trajectories generated with and without coordination are shown.

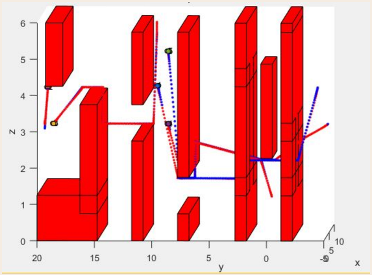


Figure: Trajectory generated for 5 UAVS on MAP 3 with Munkres

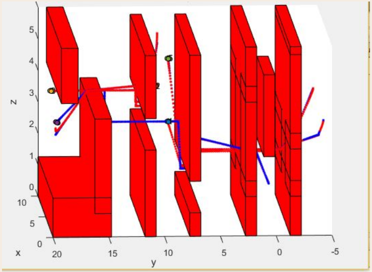


Figure: Trajectory generated for 5 UAVS on MAP 3 without Munkres

Experimental Simulation Results

- **Effect of the coordination of UAVs on Average Best Cost**

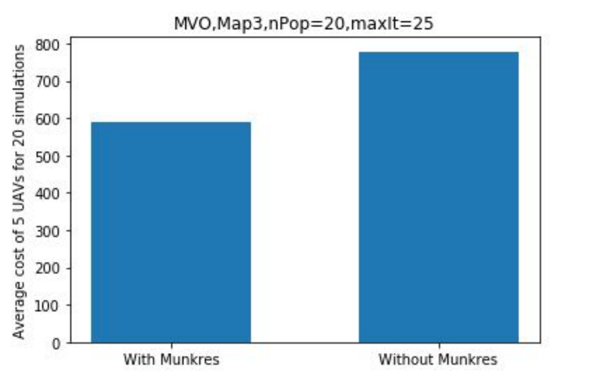


Figure: Comparision of Avg. Total Best cost of 5 UAVS on MAP 3

- **Effect of Number of UAVs on Overall Run Time**

Since using Munkres algorithm shows good results, therefore, readings are taken with coordination case only, but for all three different algorithms on Map, 2.

Table: **Overall time variation with Number of UAVs (Map 2)**

Overall time variation with Number of UAVs						
No. of UAVs	**iterations= 25 Pop size =20**			**iterations= 40 Pop size =25**		
	MVO	**GSO**	**BBO**	**MVO**	**GSO**	**BBO**
2	28.18	43.95	20.88	42.02	72.11	27.88
3	36.12	57.93	25.81	57.85	91.16	34.73
4	45.50	70.96	30.24	63.95	116.33	40.06
5	49.5	80.85	34.06	73.03	133.20	44.80

- **Convergence Analysis of Average of Total Best Costs with variation in Iteration**

Variation of total best cost with number of iterations is observed on map 1, map 2and map 3 with all three MVO,GSO and BBO when five UAVs were present in the environment.

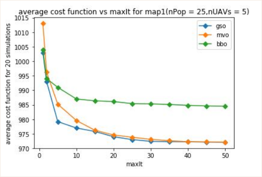


Figure: Map 1

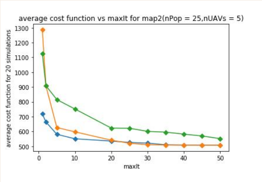


Figure: Map 2

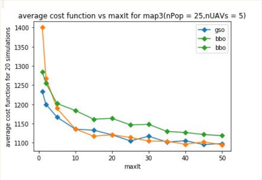


Figure: Map 3

Experimental Simulation Results

- **Variation in Algorithm performance with change in parameters**
  - **Influence of size of Population:-** For the creation of optimal solutions, the number of iterations and the size of the population help each other for the creation of the most optimal solutions
  - **Effect of the number and arrangement of obstacles:-** The number and arrangement of the obstacles in the map play a key role in deciding the number of iterations it takes to obtain an optimal solution
  - **Impact of the cost function parameters and constants:-** The constant values appended to the cost functions depend on the importance assigned to its differing parts.

Concluding Remarks

- The MVO algorithm successfully generates optimal paths and viable trajectories from source to destination for each UAV while avoiding the obstacles.
- The performance of the MVO algorithm was compared with the Glowworm Swarm Optimization(GSO) and Biogeography-Based Optimization(BBO) algorithms and the results were satisfactory
- The Munkres algorithm was also used to optimally assign UAVs to targets in polynomial time and its usage provided good results.

Future Scope

- Extension of the above work to an environment consisting of dynamic obstacles
- Modifications to the proposed MVO algorithm to further improve its performance
- The use of hybrid algorithms based on MVO for applications to this problem.

DEMONSTRATION

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Publication

- This work has been submitted in Jounal of Computational Science Elsevier.

Thank You