# Reliability-Aware Multi-UAV Coverage Path Planning using a Genetic Algorithm

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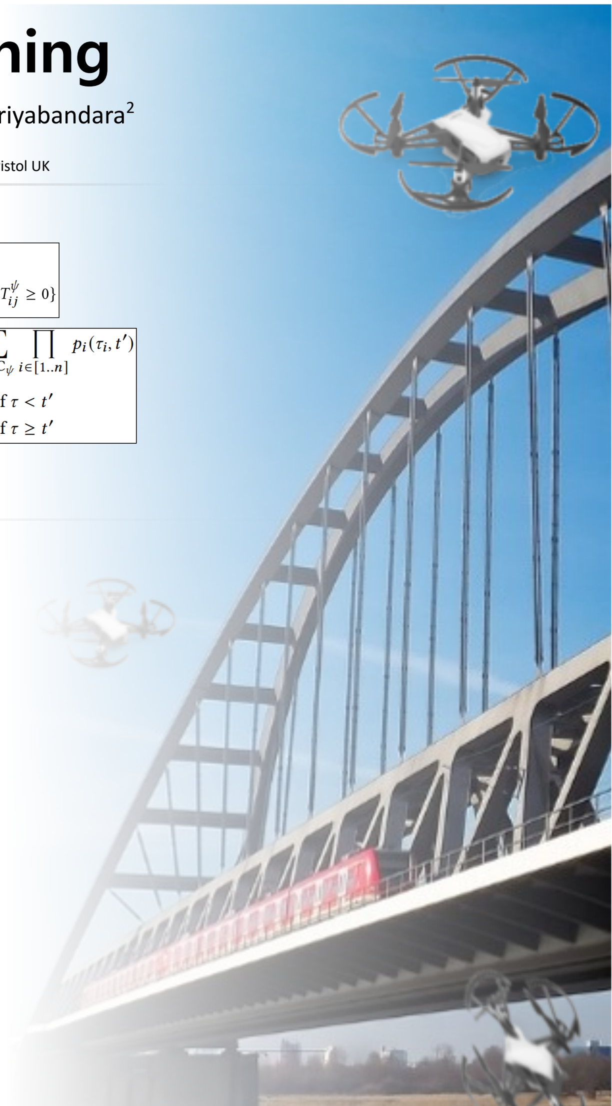

## Introduction

Multi-agent systems have the potential to be more reliable than single agents. Especially for failure prone aerial robots or UAVs. [1]

Most existing multi-agent Coverage (mCPP) methods either assume no failures, or are reactive. Neither give any performance guarantees to the user if failures occur.

The **Reliability-Aware Multi-Agent Coverage Path Planning Problem** (RA-MCPP) seeks to find coverage paths for each failure-prone UAV which a-priori maximises the probability of mission completion by a deadline.

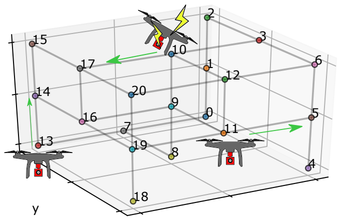

Figure 1: If drones are failure prone, what routes maximise the probability of mission completion?

## Reliability Evaluation

This work uses the metric of Probability of Completion (PoC) to evaluate the reliability of any given multi-agent path plan.

Let state $x = (\tau_1, ..., \tau_n)$ represent the amount of work an agent has done. The environment is a unit graph G(J, E) of connected tasks $J = (j_1, ..., j_m)$.

A strategy Ψ is a set of finite connected tasks for each agent. For a given strategy, at each state either all tasks have been visited or not. These *completion states* together form the **Completion Region** $\mathbf{C}_\Psi$.

$$C_\psi = \{x \in S \mid \forall j \; \exists i \; \tau_i \geq T^{\psi}_{ij}\}$$
$$= \{x \in S \mid \min_{j \in [1..m]} \max_{i \in [1..n]} \tau_i - T^{\psi}_{ij} \geq 0\}$$

$$PoC(\psi, t') = \sum_{x \in C_\psi} p(x, t') = \sum_{x \in C_\psi} \prod_{i \in [1..n]} p_i(\tau_i, t')$$

$$p_i(\tau, t') = \begin{cases} f_i(\tau), & \text{if } \tau < t' \\ R_i(\tau), & \text{if } \tau \geq t' \end{cases}$$

Given agent failure distributions, the **Probability of Completion** for strategy Ψ at time t' is then the sum of the probability of surviving to a completion state.

## Path Based Genetic Algorithm

This paper proposes a Genetic Algorithm (GA) for solving the RA-MCPP problem through the simultaneous optimisation of all agent's paths.

The GA chromosome encodes a strategy allocation $T^\Psi$ which describes the first visit to each task for each agent. Two fitness functions are defined: (i) only PoC, and (ii) a weighted sum of PoC and the time taken to completion with no failures (PoC+Time).

For reproduction 4 Mutation and 2 Crossover operations are implemented. At the end of each iteration, tournament selection is used for constructing the next generation.

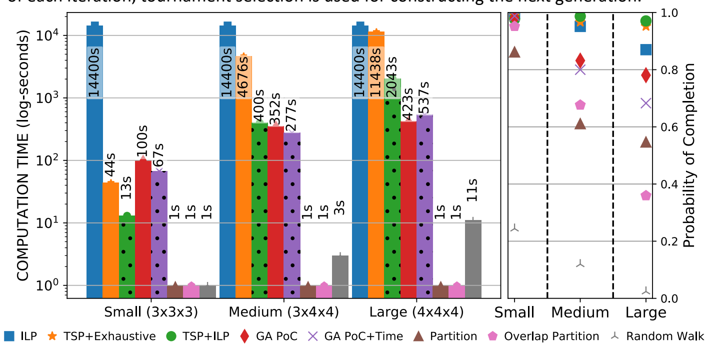


Figure 2: Performance and computation time comparison of RA-MCPP methods on different sized environments

## Results and Conclusion

The proposed method finds more reliable strategies compared to existing mCPP and heuristic methods (Partition, R.Walk), while being more computationally scalable than existing methods of an ILP [2] and 'TSP phasing'. Both GAs provide good solutions and are an order of magnitude faster for larger environments, *trading off highly reliable strategies for computation time*.

Future work focuses on applying RA-MCPP to real Inspection scenarios which will require solving the problem in continuous space and time.

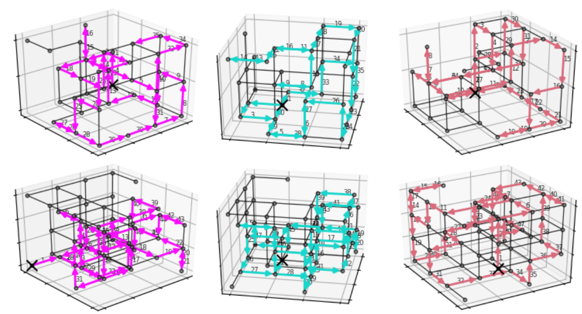

Figure 3: Example GA PoC Agent Paths for Medium and Large Environments

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