Preferred Topics: SUSTAV
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A Reinforcement Learning Approach to Conflict Resolution of Climate Optimal Trajectories

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Abstract

In light of the expansion of global air traffic, addressing the environmental responsibilities of the aviation industry has become a critical challenge. Aviation contributes to global warming by releasing CO_2 and non-CO_2 species into the atmosphere. In contrast to CO_2, the climate impact of non-CO_2 emissions depends on the atmospheric location and time of the emissions. Thus, they can be mitigated by determining more efficient maneuvers to avoid climate hotspot areas [1]. However, planning climate-friendly routes at the micro level (i.e., trajectory level) can threaten air traffic safety around climate hotspots by increasing the congestion [2]. Such degradation posed to traffic safety Climate impact, Aircraft trajectory optimization, calls for the development of an efficient strategy at the network level that, on the one hand, mitigates the climate impact of aviation by trajectory planning and, on the other, compensates for the side effects of adopting climate-optimal trajectories through a strategic resolution process.

Besides being highly time-consuming, the resolution of such a large-scale problem is challenging due to the presence of hotspot areas with non-uniform spatiotemporal distribution. The conventional resolution algorithms, such as gradient-based, mathematical programming, and meta-heuristics methods, despite showing acceptable performance to solve resolution problems, scales up the execution time with the number of aircraft involved. They also need to be performed from scratch as the scenario changes (e.g., location of climate hotspots) or new sets of trajectories are received. In this respect, having self-evolved models with fast execution time would be required when being exposed to unseen and large-scale scenarios. The application of deep reinforcement learning to this problem has been found to be promising [3].

We propose a novel multi-agent deep deterministic policy gradient (MDPG) algorithm as the resolution strategy. Airspace, including all the aircraft, can be described as a multi-agent system, with each aircraft acting as an agent. Each agent will comprehend the current traffic situation and perform decision-making to select speed advisories to avoid potential conflicts. In multi-agent environments, each agent's training progress is based only on its information. This causes instability in learning procedure and prevents the straightforward use of past experiences. This is because each agent's policy changes in the training process, and the environment becomes non-stationary from any individual agent's perspective. We address this issue by proposing centralized training and a decentralized execution scheme so that each agent is aware of other agents' information during the training.

The effectiveness of the proposed resolution algorithm in resolving conflicts is demonstrated through a case study. A scenario including one-hour traffic over Spain's airspace has been studied. For each flight, the optimization is performed in 2D airspace, considering a weighted sum of simple operating cost and average temperature response (ATR) as the flight planning objective. By varying the weight penalizing ATR, different alternative trajectories are determined. The proposed resolution model is trained based on the trajectories associated with one set of trajectories and assessed for the remaining routing options. The results indicated that obtained model is capable of solving more than 50% of conflicts for all routing options.

References

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