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Multi-Aircraft Trajectory Prediction Using Bayesian Spatio-Temporal Graph Transformer Network

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-The escalation of civil aviation operations has led to the concept of the next generation air traffic management system (NextGen), which aims to efficiently and safely accommodate the growing air traffic flow within the U.S. airspace. Air Traffic Controller (ATC) workload is one of the main limitations to the capacity of the air traffic management system. The ATC workload increase urges the advancement of air traffic decision-support tools (DSTs) for NextGen, which includes flight plan (FP) change, dynamic weather rerouting (DWR), trajectory prediction (TP), and conflict detection and resolution (CDR). Furthermore, in NextGen, surveillance information sharing is greatly enhanced among the controllers and the pilots. In such a way, the aircraft itself can take over a portion of air traffic management tasks from ground ATCs. And this leads to the prediction of multi-aircraft trajectories, which is beneficial in the relevantly congested, near-terminal air space.

In practice, a deterministic TP model is insufficient when dealing with increasingly congested airspace and is not suitable for safety-related applications due to the inability to consider the uncertainty. The uncertainty comes from a variety of sources. The environmental factor is one of the major contributors to the TP uncertainty, which usually develops expeditiously and randomly. Human factors such as the pilot's intent or decision preference when dealing with an aviation event also contribute to the TP uncertainty. Other factors such as aircraft performance and the pilot's physical condition can lead to an unreliable deterministic model prediction. The development of TP models is of fundamental importance to various advanced engineering application domains, e.g., autonomous systems and warning systems in the automotive and defense industry. Many currently used TP models consider only one agent; however, predicting multi-aircraft trajectories is a multi-agent TP problem. Thus, there is a need for an air traffic control model that is an uncertainty-aware multi-agent TP model.

A researcher at Arizona State University has developed an air traffic control system for predicting trajectories of multiple aircraft simultaneously using a Bayesian spatio-temporal graph transformer network. This system was tested on the ETH and UCY pedestrian benchmark datasets and achieved state-of-the-art performance. Real-world flight recording data was also used to demonstrate and validate this system for multi-aircraft interactions in the near-terminal area. Additionally, the system refines recent advancement in deep predictive modeling and adapts to the air transportation domain by encoding aviation regulations and physics knowledge into a deep learning model.

Related publication: Bayesian Spatio-Temporal grAph tRansformer network (B-STAR) for multi-aircraft trajectory prediction

Potential Applications:

- Air traffic management systems
- Autonomous vehicle systems
- Early collision warning systems

Benefits and Advantages:

- Interactively forecasts future location of multiple agents with a user-defined prediction time interval
- Handles an arbitrary number of agents
- Achieves state-of-the-art mean prediction performance on the ETH and UCY pedestrian datasets
- Provides reliable uncertainty estimates without sacrificing prediction performance