SKYTWIN: A DIGITAL TWIN OF THE NAS FOR AIR TRAFFIC

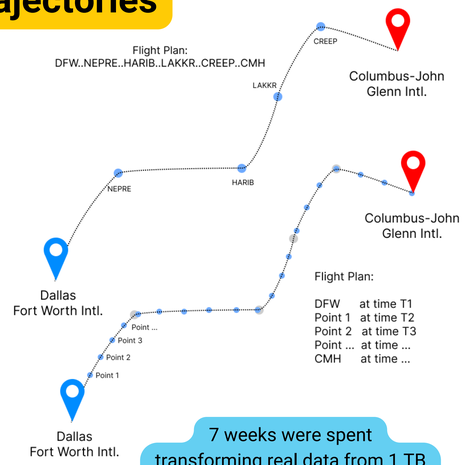
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WAYPOINTS AND TRAJECTORIES

Transitioning to Trajectories

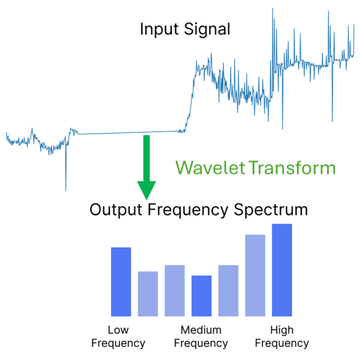
- Waypoints are more rigid than trajectories in flight planning.
- Digital Twin must work with waypoints and trajectories
- **Goal:** to predict the trajectories of flights that are using waypoint flight planning



Future data efforts may expand into the proprietary data held by aviation companies.

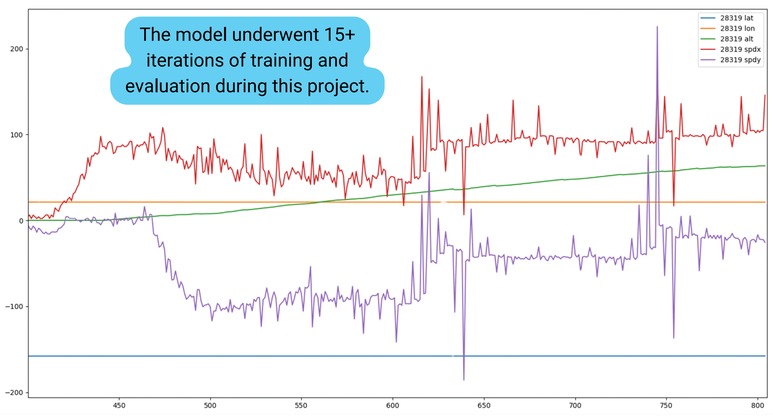
7 weeks were spent transforming real data from 1 TB of NASA's Sherlock into an interpretable form for the ML models.

Wavelet Transform



- The wavelet transform, like a Fourier transform, extracts time-frequency information from a signal
- Captures short-term and long-term movement patterns as low and high frequencies
- ML model learned to produce wavelet transform coefficients corresponding to output frequency

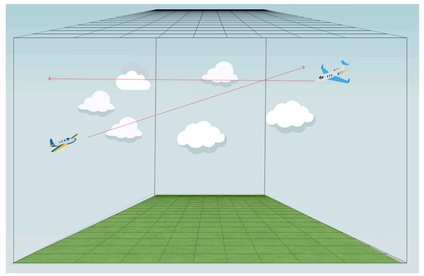
The model underwent 15+ iterations of training and evaluation during this project.

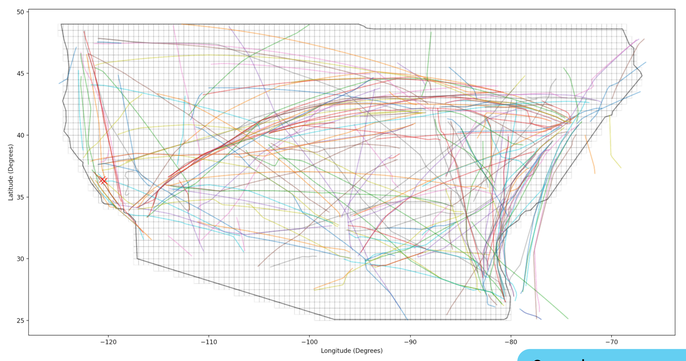


CONFLICT DETECTION

Airspace Grid

- Airspace is split into a latitudinal and longitudinal grid
- Conflicts are found by comparing aircraft only with immediately surrounding grid squares





8 weeks were spent developing the algorithm and evaluating its accuracy.

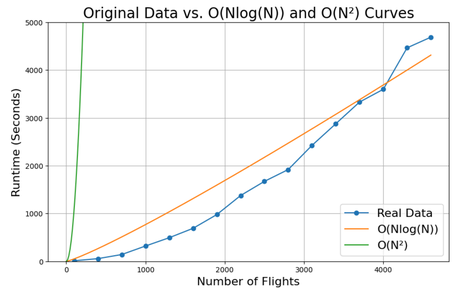
Safety

- Deterministic algorithm to guarantee adherence to separation constraints
- Separation requirements can be adjusted to accommodate error level in prediction models
- Can alert to future separation violations
  - Help Air Traffic Control Officers (ATCOs) focus on likely conflicts

Algorithm Performance

Thorough pressure testing on an increasing load of flights was conducted to determine the complexity.

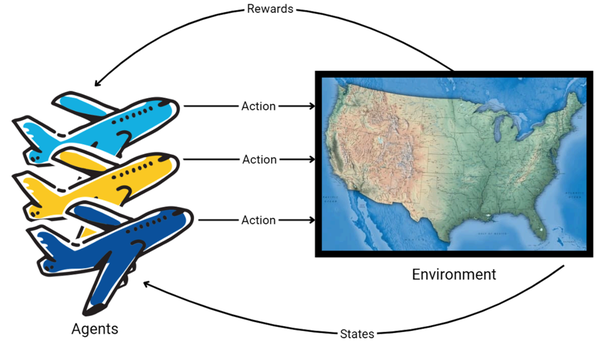
- Evaluated to have O(NLogN) performance
  - Scales very well
- Future work to increase speed by a constant amount:
  - Implementing in a compiled programming language
  - Multithreading
- Scalable and feasible for integration into the NAS



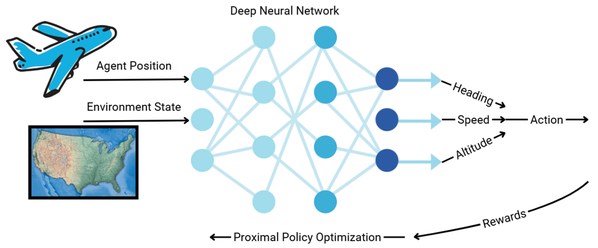
FLIGHT OPTIMIZATION

Deep Reinforcement Learning

- Proximal Policy Optimization (PPO) controls agent learning
- Multiple agents interact in the environment
- Learning an optimized approach to reaching their destination
- Complicated training -> fast and applicable usage in real world scenarios



8 weeks of training, hyperparameter tuning, and evaluation.



Optimization Factors

- Optimization is a variety of factors that can lead to faster and more fuel efficient flights
- Reinforcement learning allows for new optimization features to be trained
  - Adaptable to changing priorities

Fuel Usage
Drag estimation based on altitude and thrust

Efficiency
Time spent in flight, heading as related to the goal

Conflict Detection
Use detection algorithm to punish conflicts

2 months of research and discussions with experts to design the environment and reward structure.

Future Expansion

- Further optimization to enhance TBO
- Exploration of more trajectory prediction algorithms
- Development of a GUI optimized for ATC
- Integration with proprietary data

Estimated 2 years of development would be needed for this digital twin to be ready for certification for ATC operations.