# Trajectory Prediction of a Fixed-Wing UAV using Sequence-to-Sequence RNNs

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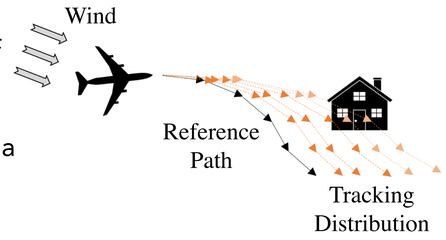
## Introduction

- UAVs operating in populated areas require safe contingency planners in forced landing situations
- Most planners operate by scoring the **risk** of a proposed **reference path**
- A fundamental measure of risk is the **tracking distribution** – the distribution of trajectories a UAV would realize by following a reference path

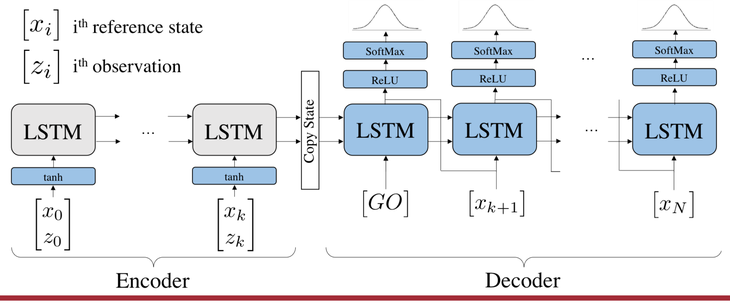



## Motivation and Objectives

- Problems with current methods:
  - Inflexible, **parametric** models
  - Strong, often Gaussian, **assumptions**
  - Simplistic **approximations** of tracking distribution
- Objectives:
  - **Data-driven, model-free** method
  - **Offline** computation to encode tracking distribution, and **online** observation reasoning
  - **No assumptions** on tracking distribution

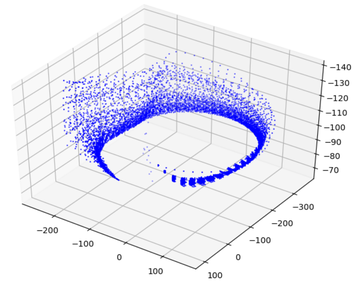
## Approach

- In a Sequence-to-Sequence model, an **encoder RNN** inputs a sequence of real-time observations of the UAV relative to the current path
  - Encoder builds an indirect notion of the current dynamics of the UAV
- Then, a **decoder RNN** uses the internal state to predict the tracking distribution, relative to a candidate reference path




## Experiments and Results

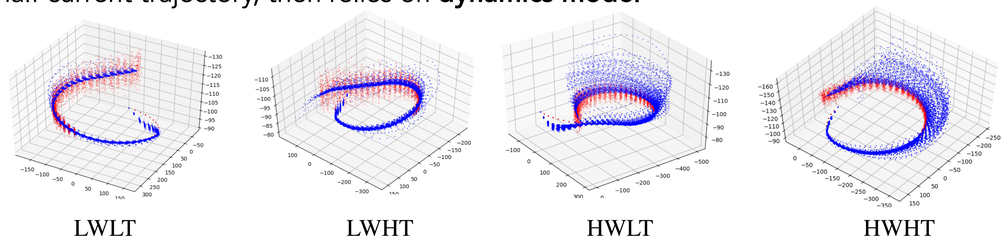
- Data Generation
  - Full 12-state, 6-degrees-of-freedom nonlinear model with Gaussian distributed **constant wind** in a random direction, and Dryden modeled **turbulence**
  - Conditions are a combination of **Low Wind** or **High Wind** and **Low Turbulence** or **High Turbulence:** (LWLT, LWHT, HWLT, HWHT)
  - 4000 reference paths, 200 simulated paths each, using a custom UAV simulator
  - Tracking distribution discretized as a sequence of histograms



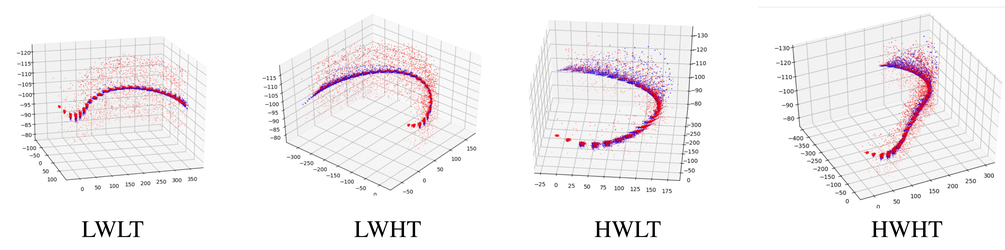
Example of HWHT Tracking Distribution

- Unscented Kalman Filter (UKF) Baseline
  - Provided observations of the half current trajectory, then relies on **dynamics model** to predict the rest

Sampled distributions of UKF predictions (red) and true tracking distributions (blue)




- Sequence-to-Sequence
  - Only provided **observations** of the half current trajectory




| | Average KL-Divergence (bits) | | | |
|---|---|---|---|---|
| | LWLT | LWHT | HWLT | HWHT |
| UKF | 21.260 | 22.437 | 24.950 | 25.029 |
| Seq-to-Seq | **10.120** | **11.585** | **12.055** | **13.558** |

(Above) sampled distributions of Sequence-to-Sequence predictions (red) and true tracking distributions (blue).
(Left) Comparison of average KL-Divergence between predicted and true distributions

## Conclusion and Future Work

- The Sequence-to-Sequence model produces a l**ower difference in distribution**
- Better prediction without an explicitly defined model
- For the future:
  - Compare to Gaussian Processes
  - Evaluation with Wasserstein metric
  - Spline fitting instead of histograms
  - Test on data with control failures

## Acknowledgements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