

THESIS TITLE

THESIS

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AFIT-ENS-MS-20-M-tbd

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Predicting Weather conditions utlizing artificial neural networks for c-17 mission planning

THESIS

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# Abstract

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Predicting Weather conditions utlizing artificial neural networks for c-17 mission planning

I. Introduction

1.1 Background

The Department of Defense (DoD) has an obligation to the American people to be stewards of their tax dollars in all defense related spending. As such, the DoD is always searching for ways to minimize spending while also increasing combat capabilities, military readiness, and operational effectiveness. Aircraft are an integral part of the United States Air Force (USAF) and by its very nature, fulfilling these goals incurs a substantial cost for procuring and consuming fuel. From the 2019 fiscal year budget for the DoD, $24 billion was requested for fuel consumption with $6.6 billion going to operations and $4.5 billion going to transportation [1]. The USAF consumes around half of this budget for aviation fuel with majority of it being used by Air Mobility Command (AMC), a major command (MAJCOM) within the USAF structure [2]. Of the many aircraft within the AMC inventory, the C-17 fleet represents the primary aircraft responsible for global transportation and cargo, and as such consumes the largest amount of the aviation fuel [3]. Increasing efficiency in fuel consumption within this fleet can have an immense impact on cost savings for the USAF, and the DoD as a whole.

1.2 Overview

There are a multitude of ways to address increasing efficiency in fuel consumption among C-17s. This study focuses particularly on headwind and temperature predictions in the upper atmosphere relating to mission planning for C-17 operations. Reduction in fuel usage will come from predicting the most fuel-efficient route from point A to point B given accurate predictions for the aforementioned factors. Optimizing speed and altitude will be given consideration since they are natural parameters to consider when constructing a fuel-efficient route [4].

There are two distinct classes of weather models to look at, which are deterministic and ensemble. While a deterministic model will be comprised of a single model, an ensemble model will be comprised of multiple deterministic models [5]. In an ensemble model, each of its members is initialized with slightly different values for their parameters. This will generate a forecast giving a variety of results, which provides keener insights into accurate forecast predictions.

Temperatures and wind speeds are known to follow a nonlinear behavior when modeled over time. Their discontinuous and stochastic nature makes it difficult to provide accurate predictions utilizing linear approximation techniques. Artificial neural networks (ANN) can learn the underlying structure of datasets and provide accurate predictions for seemingly complex weather problems [16]. This ability has generated a huge research surge in investigating the application of ANNs to varying different weather related problems [].

The following section will discuss background literature relating to the methodologies being deployed within this work, including the difference in weather model types, ANNs, and shortest path problems (SPP).

II. Literature Review

2.1 Overview

This section will discuss the difference between the deterministic and ensemble weather models. Next, the basic concepts of artificial neural networks (ANN), and their application to weather modeling will be overviewed. Finally, the shortest path problem (SPP) formulation will be examined, along with its relation to flight planning for C-17s.

2.2 Weather Models

The weather data for this study comes from the Global Data Assimilation System (GDAS), which is run by NOAA. The GDAS takes in all available global satellite, conventional (rawinsonde, aircraft, surface), and radar observations to report weather conditions across the globe every six hours. This report details conditions for every latitude and longitude coordinate across 31 different pressure layers. The system is responsible for providing the initial conditions for the deterministic and ensemble weather models produced by the global forecast system (GFS).

Ensemble modeling for weather is the current method employed by large organizations, such as the National Oceanic and Atmospheric Administration (NOAA). It has been shown to be better at forecasting than deterministic models in a myriad of applications [6]. For example, Keith and Leyton displayed how weather models were better predictors of adverse where conditions, which would require aircrafts to consume more fuel than originally expected [7]. Ensemble forecasting is not always superior in every instance though. An incident in Venice showcased this, where the accuracy for predicting flooding due to storms more than four days out with a deterministic model was comparable to the ensemble model [8]. In another instance, Leonardo and Colle found that a deterministic model gave the lowest total track error when predicting North Atlantic tropical cyclones, even when compared against several different ensemble models [9]. In general, though, it is noted by the World Meteorological Organization that ensemble forecast produce more reliable results than deterministic forecast, especially when the forecast is for more than 1-3 days out [10].

2.3 Artificial Neural Networks

An ANN is a set of algorithms designed to recognize patterns, modeled loosely after the human brain. They use a form of machine perception to interpret sensory data, and label or cluster raw input. The patterns recognized are numerical and contained in vectors, in which all real-world data is translated [11]. This technique has been shown to have a high degree of accuracy when predicting weather forecasts, especially when modeling temperature, and wind speed [12].

2.4 Shortest Path Problem

In examining the mission planning problem, a network for potential flight routes can be created and treated as a SPP. This technique solves the problem of finding the path between two nodes such that the sum of its weights is minimized [13]. Recent studies looked at using stochastic SPP with correlated arcs for finding the optimal path through a future instance of the network [14]. Others have explored time-optimal paths for the solution of aircraft routing [15].

II. Methodology

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