NormStad Flight Analysis: Visualizing Air Traffic Patterns over the United States

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ABSTRACT

In this paper, we describe the NormSTAD Flight Analysis system, a novel visualization application that enables interactive visualization of air traffic patterns using Aircraft Situations Display to Industry (ASDI) data. A web-based visualization is demonstrated which allows users to analyze flight data and make discoveries pertaining to their 4D trajectories which include their time, distance, altitude, and speed. Unique patterns discovered in this application could result in less fuel consumption and more efficient management of departure and arrivals by air traffic controllers.

The application consumes ASDI data then normalizes flight attributes including distance, speed, altitude, and time along the flight path. This information is then displayed on a line chart which can be customized through filtering, coloring and selection. Attributes pertaining to selected flights can be viewed in a details on demand fashion. The result is a both intuitive and visually appealling visualization with the goals of revealing flight paths, spotting trends and revealing outliers.

Categories and Subject Descriptors

H.3.3 [**Information Storage and Retrieval**]: Information Search and Retrieval—*Information filtering*;
H.3.5 [**Information Storage and Retrieval**]: Online Information Services—*Web-based services*;
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces

General Terms

Design, Human Factors, Performance

1. INTRODUCTION

The National Airspace System (NAS) is a complex nondeterministic system that is impacted continually by both major and minor variables including aircraft delays and human decisions that largely cannot be accurately forecasted. The system has developed to offer feedback and response at all levels from gate agents to the Command Center with the intent of restoring the desired efficient state. The result is a self-ordering system that is broadly similar, but has different daily operations. An important point to note is that a seemingly insignificant event such as a delay in obtaining a wheel chair can have large impacts in delays as *slots* are missed and reassigned. At every stage decisions are being made to recover the system and keep it as close to optimal given its current state. However, there is currently no method of quantifying the effects of a decision or comparing them to an alternate decision. NAS operations are recorded concurrently across different systems in different formats. If this information was collated and catalogued, it would be possible to analyze the NAS operations to identify inefficiencies, disruptive events and poor decisions along with the resulting impacts on airspace users.

In 1992 the Federal Aviation Administration (FAA), started a program to provide real-time flight plan and track information for the NAS to airlines and other oganizations. The feed known as Aircraft Situation Display to Industry (ASDI) is a product of the Enhanced Traffic Management System (ETMS). It originates from the Traffic Flow Management (TFM) Production Center located at the William J. Hughes Technical Center in Atlantic City, New Jersey. Figure 1a shows the number of ASDI messages for a single random day while Figure 1b shows the number of supporting records for the main message set.

A novel visualization system is needed to aggregate this data in order for users to detect anomalies and discover unique patterns. To be able to compare flights of varying distance or time, the data values are normalized to create a standardized display of time series allowing direct comparison between flights.

The rest of this paper is organized as follows. Section 2 discusses related work. Section 3 explains the ASDI data and its attributes. Section 4 describes the overall architecture and the interface is described in Section 5. Section 6 provides the expert reviews and feedbacks of the implementation. Section 7 discusses future work, while our conclusions are outlined in Section 8.

2. RELATED WORK

There has been a great amount of research in flights pertaining to algorithms for optimal trajectories, anomaly detection and conflict resolution [1, 2, 3, 4, 5, 6]. Liu et al. [4] study departure and arrival delays and how these delays can propagate to future flight delays and cancellations. Our

Message	Total Messages
Arrival Information	46,000
Boundary Crossing Update	84,000
Departure Information	54,000
Flight Management Information	522,000
Flight Plan Amendment	303,000
Flight Plan Cancellation	121,000
Flight Plan	120,000
Oceanic Report	9,000
Track Information	6,259,000
Total Messages	**7,518,000**

(a)

Supporting Record	Total Records
Aircraft Spec	558,000
Airways	1,732,000
Centers	1,692,000
Computer Id	5,551,000
Fixes	6,200,000
Oceanic Planned Position	18,000
Oceanic Reported Position	9,000
Qualified Aircraft Id	532,000
Route Of Flight	721,000
Sectors	1,773,000
Waypoints	7,667,000
Total Messages	**26,413,000**

(b)

Figure 1: (a) Caption for Figure 1a – SAMET (b) Caption for Figure 1b – SAMET

system instead focuses on in-air flight data to help study why these delays may be happening with respect to time of day, flight number, airline or flight trajectory. Chu et al. similarly attempt to detect anomalies in aircraft cruise data by using time, location, altitude and speed. They also normalized their data as was done in the NormSTAD system. However, the NormSTAD system utilizes only historical data while Liu et al. only studied the results of a simulation. While the study of such algorithms for detection of anomalies and conflict resolution is vitally important to the field of aviation, the goal of the NormSTAD Flight Analysis Tool is to allow easy and timely analysis of large amounts of flight data without the need for such algorithms.

3. ASDI DATA

In this section, we introduce ASDI data and its attributes, overall. In addition, data normalization process is described.

ASDI subsystem of the Traffic Flow Management System (TFMS) allows near real-time air traffic data to be disseminated to members of the aviation industry. The data stream is made available through the U.S. Department of Transportation's Volpe Transportation Center. The data stream consists of data elements which show the position and flight plans of all aircraft in U.S. Elements include the location, altitude, airspeed, destination, estimated time of arrival and tail number or designated identifier of air carrier and general aviation aircraft operating on IFR flight plans within U.S. airspace.

Due to the projectâĂŹs requirements, only a subset of historical ASDI data was used. The data set included Delta and Delta Connection, Atlantic Southeast AirlinesâĂŹ flights departing from Seattle Tacoma Airport (KSEA) for the duration of July and August 2012.

Flights pertaining to Delta Airlines consisted of the following flight numbers: âĂć DAL842, departing from Seattle Tacoma and arriving to New York JFK âĂć DAL1043, departing from Seattle Tacoma and arriving to New York JFK Airport âĂć DAL2410, departing from Seattle Tacoma and arriving to Detroit Metropolitan Wayne County Airport

Flights pertaining to Delta Connection, Atlantic Southeast Airlines consisted of the following flight numbers: âĂć ASA24, departing from Seattle Tacoma and arriving to Boston Logan International Airport âĂć ASA678, departing from Seattle Tacoma and arriving to Denver International Airport

Dataset was generated by merging a subset of various message types including: âĂć Departure Information âĂć Track Information and âĂć Flight Management Information

The process yielded the following fields: âĂć Source Date âĂć Source Time âĂć Aircraft Id âĂć Flight Key âĂć Speed âĂć Altitude Type âĂć Altitude Format âĂć Altitude âĂć Latitude âĂć Longitude

In addition, certain values were normalized so that various flights or time series of same flights could be overlaid on the same line chart. Normalized values for interactive visualization included: âĂć Altitude âĂć Speed âĂć Distance âĂć Planned Flight Time and âĂć Actual Flight Time

All normalized values range between 0 and 1 with an exception that Actual Flight Time may well go over 1 or remain under 1 due to fact that non on-time flights usually take less or more than Planned Flight Time.

4. ARCHITECTURE

5. INTERFACE

The NormSTAD Flight Analysis user interface initially shows four panels of display as seen in FIG labeled Filters, Line Chart, Map and Details on Demand. Each panel allows for direct interaction or display of the data and can be minimized to give more room to the other panels by selecting the arrow in the upper right corner of the specific panel.

When the application is first opened, the Line Chart panel of NormSTAD Flight Analysis is shown in the top center of the browser displaying two graphs with all flights displayed for the loaded dataset. A noticeable issue is that lines are often close together and hard to distinguish. To combat this issue, the bottom graph allows for selection of a range of the horizontal axis. By selecting a range along the horizontal axis, the coordinate system of the top graph is redrawn to have only values contained within the selected subset creating a zoom-in effect. This range can be expanded or contracted and even moved by clicking, holding, and dragging the range window. A mouse hover or mouse click on a line turns the line red and thicker making it easier to see. A mouse click on a line has the effect of updating the Details on Demand to display flight information and removing this information on the second click of the line. If the "Show Flight Path" checkbox is checked in the Filters panel, then a mouse click on a line also displays the flight path in the Map panel on a Google Maps map for the sampled latitude and longitude points along with a label containg the airport code at the departure and arrival airports. The Details on Demand panel displays the flight number, the departure and arrival airports, the date, the arrival time and the duration of the flight in minutes for the flights selected in the Line Graph.

The Filters panel allows the user to limit the results that they see on the Line Chart. The first section, "Choose Airlines", is for selection of airlines to display in the Line Chart which is set to all airlines by default. Upon selection of an airline, the Line Chart is updated accordingly and the "Choose Flights" section is populated with all flights for the selected airline(s). Note that a user can select multiple adjacent rows for both the Choose Airlines and the Choose Flights sections by holding the Shift key and selecting rows or multiple rows by holding the Control key (Apple key on Apple computers) and selecting rows. Selection of row(s) in the Choose Flights section allows for updating of the Line Chart by the flight number. The flights can be further filtered by limiting the flight data using the "Start Date" and "End Date" drop down calendar menus. The data displayed in the Line Chart can be changed by changing the "Line chart type" value which subsequently changes the axis or both of the axes where all values are normalized. By default, this value is set to "Distance vs. Actual Flight Time", but it can be changed to "Distance vs. Planned Flight Time", "Altitude vs. Actual Flight Time", or "Speed vs. Actual Flight Time". The lines can be colored by their airline or by their flight number using the "Color by" drop-down menu.

6. EXPERT REVIEWS AND FEEDBACK

7. FUTURE WORK

8. CONCLUSION

9. ACKNOWLEDGEMENTS

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