Interactive Analysis of Aviation Data

Behrooz Omidvar-Tehrani, Arnab Nandi,
Nicholas Meyer, Dalton Flangan
Department of Computer Science
The Ohio State University
{omidvar-tehrani.1,nandi.9,meyer.1089,flanagan.166}@osu.edu

Seth Young
Center of Aviation Studies
The Ohio State University
young.1460@osu.edu

***Abstract*—To date, flight data has remained unanalyzed to a great extent due to its large volume. In this paper, we propose SpaceTime, an interactive visualization framework for flight data analysis. A combination of back-end and front-end techniques enables our framework to provide immediate aviation- oriented insights. By providing scenarios validated by avia- tion experts, we illustrate different utilities of our framework such as planning, prediction and fuel consumption.**

I. Introduction

Understanding the behavior of flights traveling through the National Airspace System (NAS) is a highly challenging activity, primarily due to the *vast volume*, types, and missions of aircraft flying through the system and complexity of the air traffic network through which these aircrafts travel. At any given period of time upwards 5,000 aircraft are flying within the system, totaling more than 50,000 flights daily. To date, this gigantic data has been largely untapped for analysis due to the *inefficiency of analysis tools*. Although current approaches (such as TABLEAU[1]) manages to visualize millions of flight records as a single-shot, flight analysis in practice occurs in *query-response* interactive sessions: aviation experts wants to interact with flight data by implementing various filters and verifying diverse hypotheses.

Aviation experts analyze planned flight route and actual flight track data through visualization environments like GOOGLE EARTH[2] and TABLEAU. Most often, the application of data is performed in a static environment, with significant effort placed on the input and process of data in a relevant database and querying interface, for illustration and analysis in a visual format. Such processing may take minutes or hours of analysis per visualization. This, then, creates a limitation on the ability to *interactively* visualize multiple views, whether it be to compare different flights, or to look at a time series of events, and as such. Lack of interactivity limits the analysis power of an aviation expert.

In this paper, we present SPACETIME, an interactive visualization framework for flight data analysis. One principle of interactivity is responsiveness [7], [5], [1]. Although there exists various visualization frameworks for spatiotemporal data [2], [4], none scales to the volume of flight data. Moreover, an aviation expert is not only interested in a one-shot visualization, but a series of iterative visualizations (i.e., interactive analysis) to investigate different aspects of data.

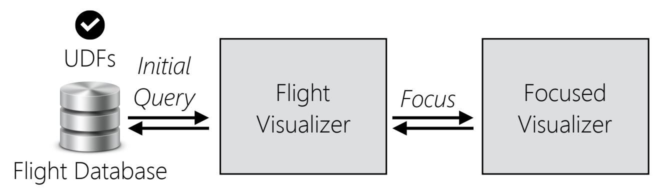

Fig. 1. SPACETIME Framework

SPACETIME provides a fluid dialog between the expert and the flight data where she observes different sections of data and tests different metrics without delay. Although traffic visualization tools like FLIGHTAWARE[3] and FLIGHTRADAR24[4] show actual air traffic, SPACETIME enables experts to analyze historical data and make comparisons time-wise and location-wise.

An aviation expert may have different analytical needs. For example, an airline may desire to learn more about schedule variability on deviated flights on a daily schedule, whereas corporate flight departments and charters may be more concerned with the positioning of aircraft based on a non-scheduled, on-demand flight routing policy. Air traffic or airport analysis, on the other hand, may desire metrics based on the volume of traffic in a particular airspace sector or airport environment. For this aim, SPACETIME support efficient integration of of UDFs (User-Defined Functions) to satisfy specific needs of experts and providing the capability to create customizable views, summaries, and metrics based on the needs of the user.

Visualizing planned flight routes and actual flight tracks provide insights for the aviation experts. However, expends tend to desire additional analytical tools, in the form of performance metrics, to provide guidance and recommendations towards seeking solutions towards optimizing air traffic efficiencies. SPACETIME provides a series of such metrics of great potential benefit for the aviation analysis. Metrics developed include:

Volatility Index. A measure of the deviation of the actual flight track of an aircraft from its planned route of flight, or great circle route.

Altitude and Speed Metrics. Measures of average, maximum, and distribution of aircraft altitude and ground speeds along a path of flight for a given flight and/or given airspace sector.

Volume Metrics. Measures of the volume of aircraft traversing along a given route, airspace sector, or single geographic point.

[1] *http://www.tableau.com*
[2] *https://www.google.com/earth/*
[3] *https://flightaware.com*
[4] *https://www.flightradar24.com*

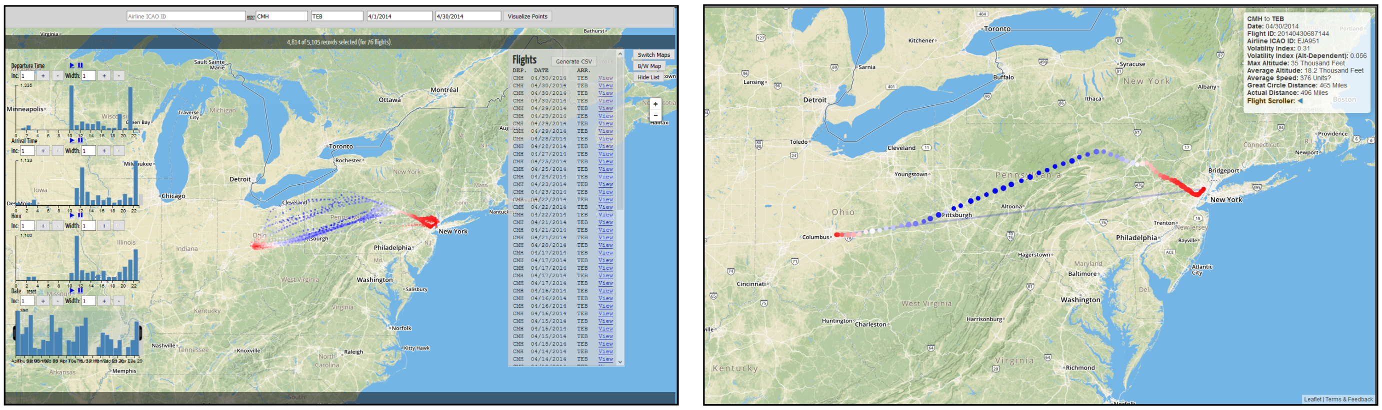

Fig. 2. SPACETIME Screenshot

II. FRAMEWORK

Figure 2 plots a screen-shot of SPACETIME framework. The main components of the framework are as follows.

Query Form. The expert defines a subset of flights for her analysis using the form on top. She may specify airline, departure or arrival airport and date interval. Note that any field can remains blank to obtain more general results. Regular expressions can also be exploited to obtain tailored results.

Geographical Map. A full screen geographical map shows points for queried flights. The zoom-level is automatically chosen in a way to cover all points. Altitude is color-coded where blueness shows higher altitude and redness shows being on the ground. Clicking each point provides complementary information like time of occurrence, altitude and speed. Clicking the button "switch maps" on top-right, shows a heat-map instead, where the analyst can focus on dense regions.

Crossfilter Charts. They exhibit aggregated number of points for departure time, arrival time, hour of occurrence and date of occurrence. Crossfilter charts [6] enable *coordinated views*, i.e., a technique that a brush on any visual component (any chart or the geographical map) will immediately update all other components. Normally this task needs a query execution per brush and per visual component, which is time-consuming. By exploiting the notion of *incremental queries*, the task evolves to sub-second execution. The analyst can also make an animation on each chart to observe flight evolutions.

Flight Table. It shows the list of queried flights. If one chart is brushed (e.g., the interval 8-10 is selected in departure time chart), then the flight table shows an updated reduced list for flights whose departure is between 8:00 and 10:00.

SPACETIME is designed in a way to satisfy all expert's needs in one screen so she doesn't need to reload or switch between pages during the analysis. Once a query is made in the form, a connection is made to the flight database to obtain results. Then SPACETIME won't require a connection to the database and all other filters and brushes will be done online without re-querying. We also consider a *sampling* strategy to guarantee a visualization in less than a second independent from the query result size.

SPACETIME contains two interactive dashboards which correspond to two major analysis needs of an aviation expert. First dashboards is FLIGHT VISUALIZER (as in Figure 2 left) which provides an environment to observe several flights in one place. If the analyst wants to focus on one flight to have more detailed analysis, she switches to FOCUSED VISUALIZER (Figure 2 right). This dashboard is employed to see detailed information about each precise moment of a flight and compare flights in the same itinerary using different metrics such as volatitliy index, altitude, speed and volume metrics.

SPACETIME is implemented in Python 2.7.10 as computation engine and PostgreSQL 9.3.11 as database engine (with proper *hash* indexes on airport names and *B-Tree* index on dates and times). The front-end is a web-based application in JavaScript (JS). We use D3 library[5] for all our visualizations and LeafletJS[6] for geographical and heat maps. As SPACETIME is simply a web-application, it has no requisite and can be executed on any platform.

III. DEMP PLANS

Data. We employ a subset of flight data provided by NetJets[7] aviation service provider and FAA for all operated flights from January 2012 to December 2014 inclusive. The data contains information about aircrafts, departure/arrival locations and times. It also contains detailed information about the location of flights in 3D space (latitude, longitude and altitude) by the precision of minutes. The data has 49,652,101 records for 623,906 flights.

Scenario 1. A business aviation company is interested in understanding the average and maximum speeds flown on various routes with the goal of further understanding flight route efficiencies with respect to total travel time and overall fuel burn. We show how SPACETIME can quickly provide information on traveling speeds by aircraft type, route, and portion of route.

Scenario 2. We show how our framework helps an airline to perform an analysis of how its flights are being routed as compared to another competing airline flying the same route.

Scenario 3. We also show how SPACETIME contributes to airport analysis [3] to get a better understanding of the flow of inbound and outbound traffic, by time of day, day of week, or season. The airport may also desire a metric that measures

[5] *https://d3js.org*
[6] *http://leafletjs.com*
[7] *https://www.netjets.com*

the volatility of flight routes flown by aircraft to and from its airport.

References

[1] N. Kamat, P. Jayachandran, K. Tunga, and A. Nandi. Distributed and interactive cube exploration. In *ICDE*, pages 472–483, 2014.

[2] D. A. Keim. Designing pixel-oriented visualization techniques: Theory and applications. *Visualization and Computer Graphics, IEEE Transactions on*, 6(1):59–78, 2000.

[3] V. Kumar and L. Sherry. Airport troughput capacity limits for demand management planning. In *Integrated Communications, Navigation and Surveillance Conference, 2009. ICNS'09.*, pages 1–10. IEEE, 2009.

[4] L. Lins, J. T. Klosowski, and C. Scheidegger. Nanocubes for real-time exploration of spatiotemporal datasets. *Visualization and Computer Graphics, IEEE Transactions on*, 19(12):2456–2465, 2013.

[5] A. Nandi and H. Jagadish. Guided interaction: Rethinking the query-result paradigm. *VLDB*, 4(12):1466–1469, 2011.

[6] I. Square. Crossfilter: Fast multidimensional filtering for coordinated views. 2013.

[7] B. O. Tehrani, S. Amer-Yahia, and A. Termier. Interactive user group analysis. In *CIKM*, 2015.