Data Integration using the NASA Air Traffic Management Ontology

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Background:

NASA’s ATM Data Warehouse

• NASA researchers require historical ATM data
  – NASA Ames conducts research on future ATM concepts
  – Researchers require data for analysis and concept validation

• NASA Ames’ **ATM Data Warehouse** archives data collected from FAA, NASA, NOAA, DOT, industry
  – Warehouse captures:
    • live streamed data
    • published periodic data
  – Data holdings available back to 2009
A Sampling of Archived ATM Data Warehouse Holdings

- Flight plans & tracks
  - Airline Situation Display to Industry (ASDI)*
  - Air Route Traffic Control Center tracks
  - TRACON tracks
  - Center-TRACON Automation System (CTAS)
  - Exelis tracks

- Weather
  - METAR, TAF
  - Corridor Integrated Weather Service (CIWS)
  - AIREP, PIREP
  - Rapid Refresh (RR) Weather Forecast

- Traffic Management
  - Advisories & TMI
  - Time-based Flow Management (TBFM)

*SWIM conversion underway for available sources

ATM Data Warehouse: A microcosm of the NAS data environment
Problem: Non-integrated Data

- ATM Warehouse data is replicated & archived in its original format
- Data sets lack standardization
  - data formats
  - nomenclature
  - conceptual structure
- To analyze and mine data, researchers must write special-purpose code to integrate data for each new task ➔ Huge time sink!

- Possible cross-dataset mismatches:
  - terminology
  - scientific units
  - temporal alignment
  - spatial alignment
  - conceptualization organization
Proposed Solution

Relieve users of responsibility for integration!

Integrate Warehouse data sources on the server side using **Semantic Integration**
Semantic Integration Approach: Prototype System Diagram

ATM Warehouse (subset)

ASDI

METAR

TFM Advisories

Common Cross-ATM Ontology

Integrated ATM Data Store

Very large Triple Store

1

2 translators

3

Query & Access Service

Other Data Sources

Airlines, Aircraft Airport Info

ASPM

data sources
What is modeled in the NASA ATM Ontology?

- **150+ object types:** Flights, Aircraft and manufacturers, Airlines, Airports and physical infrastructure, NAS facilities, Air traffic management initiatives, Surface weather conditions and forecasts, Airspace sectors, fixes, routes, airways, Flight plans and paths.

- **150+ object properties:** actualDepartureTime, actualArrivalTime, airportArrivalRate, cloudType, dewpoint, EDCTarrivalHold, equipmentCode, groundSpeed, heading, hourlyPrecipitation, IATAcarrierCode, issuedTime, manufactureYear, maxVisibility.

- **100+ relationship types:** hasRampTower, hasRunway, operatedBy, locatedInSector, manufacturedBy, hasSurfaceWindCondition, hasLOAwith, exemptedAFP, departureScope, ADLday, adjacentSector, aircraftFix, aircraftFlown, arrivalRunway, reRouteConstraint.

- **2M+ triples in prototype** (one day of ops at one major airport)
Ontology Representation of a Flight

KATL Airport
- airport name: Hartsfield-Jackson
- FAA airport code: ATL
- ICAO airport code: KATL
- located in state: GA
- offset from UTC: -5

Delta Air Lines
- name: Delta Air Lines
- callsign: DELTA
- ICAO carrier code: DAL
- IATA carrier code: DL

Flight DAL1512
- actual arrival: 2012-09-08T20:35
- actual depart: 2012-09-08T19:03
- call sign: DAL1512
- user category: commercial
- flight route string: KATL,CADIT6...

KORD Airport
- airport name: O'Hare Intl.
- FAA airport code: ORD
- ICAO airport code: KORD
- located in state: IL
- offset from UTC: -6

Aircraft N342NB
- registrant: Delta Air Lines, Inc.
- serial number: 1746
- certificate issue: 2009-12-31
- manufacture year: 2002
- mode S code: 50742752
- registration number: N342NB

Flight Track for DAL1512
- actual arrival: 2012-09-08T20:35
- actual depart: 2012-09-08T19:03
- call sign: DAL1512
- user category: commercial
- flight route string: KATL,CADIT6...

A319-111
- AC type designator: A319
- model ID: A391-111
- number engines: 2

Airbus

Aeronautical Flight Weather Equipment Industry

KEY
Example: Mapping an ASDI Departure Message onto Ontology

<table>
<thead>
<tr>
<th>Message-Time-UTC</th>
<th>AC-ID</th>
<th>Departure-Time-UTC</th>
<th>Departure-Named-Fix</th>
<th>Arrival-Named-Fix</th>
<th>AC-Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>2012-09-08 19:02:35</td>
<td>DAL1512</td>
<td>2012-09-08 19:03:00</td>
<td>KATL</td>
<td>KORD</td>
<td>A319</td>
</tr>
</tbody>
</table>
Representative SPARQL Queries
from benchmark set of 17 queries for evaluating performance on scale-up

• Flight Demographics:
  – F1: Find Delta flights using A319s departing ZTL airports
  – F3: Find flights with rainy departures from ATL

• Sector Capacity:
  – S4: Find which sector controlled the most flights during a given hour
  – S6: Find the busiest sectors in the NAS on a given day, aggregating hourly

• FAA Advisories / TMIs
  – T1: Find flights that were subject to GDP Advisories

• Weather-Impacted Traffic Index (WITI)
  – W1: Calculate hourly (High Wind, Low Ceiling, Low Visibility) WITI values

• Flight Delay Data
  – A3: Compare hourly Airport Acceptance rate with Arrival Demand at an airport
Status

• Right now, ATM Ontology is just a prototype
  – Ontology contains integrated data corresponding to a single day of NAS operations at a major airport (9/8/12 @ ATL) using a subset of ATM sources

• Two commercial triple stores test-deployed on local server:
  – AllegroGraph (from Franz)
  – GraphDB (from OntoText)

• Within NASA Ames, triple stores can be queried via HTTP as a SPARQL endpoint
Future Plans

• Increase scale (a key challenge!)
  – 2.4M triples for one day; 36M for 30 days
  – only flights arriving/departing one airport

• Increase scope: additional data sources

• Build tools and services on top of triple store:
  – data browser
  – data query interface
  – data download service
Long Term Goal

To build the world’s largest repository of Linked Open Data describing the Global Airspace System

– A queryable resource for aviation applications, research, analysis, and public policy decision-making

Featuring interconnected data about...

- Flights
- Airports
- Airlines
- Runways/taxiways
- Terminals/Gates
- Airspace control facilities (ARTCCs, TRACONs, towers)
- Air traffic management initiatives
- Weather
- Aircraft
- Aircraft mechanical systems
- Aviation safety data
- Aircraft manufacturers
- Airspace topology (sectors, fixes, routes)
- Departure/Arrival routes