Automated Scenario Generation for Meeting Human-in-the-Loop Simulation Requirements

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Air Traffic Management Testbed (ATMTB)

- NASA building testbed to accelerate deployment of ATM concepts into NAS
- Goal of providing access to community
- Provides infrastructure and some applications
- Scenario generation is one of the capabilities of testbed
Motivation

• Manual creation of realistic scenarios for generating traffic for Human-in-the-Loop (HITL) simulation is difficult
  – Missing and erroneous data
  – Manual process is time consuming
  – Difficulties cause studies to be limited to few scenarios

• Automated scenario generation has potential for overcoming limitations
  – Use real air traffic data to create scenario
  – Remove flights with erroneous data
  – Select flights to achieve the desired short-haul to long-haul ratio
  – Alter landing times to shape scenarios
Background: Aviation 2018 Paper

Input Data for Scenario Generation

Automated Scenario Generation

Seed-scenario

Manual Refinement
Input Data for Scenario Generation

Automated Scenario Generation

Seed-scenario

Manual Refinement

HITL-scenario

- Simulations can be run with ATM Testbed created seed-scenario
- Seed-scenario found to be a good starting point for creating HITL-scenario
- Experience showed that many of the manual adjustments can be automated to directly create the HITL-scenario
Outline

- Step 1: Automated scenario generation using ATM Testbed
- Step 2: Automated scenario refinement
- Traffic scenario selection
- Results
- Conclusions
Input Data Source for Scenario Generation

- System-Wide Information Management (SWIM) data processed into files, and stored in Sherlock data-warehouse

- Reduced Record (RD)
  - Single record for each flight
    - Beacon-code, flight-plan, takeoff/landing runway, departure/arrival time, sector/center transition list

- Event Data (EV)
  - Multiple records related to events for each flight
    - Event time and type- landing, crossing (sector, center, TRACON)

- Integrated Flight Format (IFF)
  - Multiple records for each flight
    - All flight plans including amended flight plans & position data

- RD and EV useful for filtering and IFF for data augmentation
Multi-Aircraft Control System (MACS) Scenario Generation

- MACS is a distributed system with multiple-pseudo pilot and air traffic controller stations
- It is frequently used at NASA for HITL evaluations of ATM concepts
- MACS traffic scenario consists of
  - Flight route
  - Initial conditions
ATMTB Scenario Generation Steps

- Load & filter input data
ATMTB Scenario Generation Steps

- Load & filter input data
- Preprocess flight data
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes
     - Find entry track data
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes
     - Find entry track data
     - Find last flight-plan prior to entry track time
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes: Find entry track data
     - Find last flight-plan prior to entry track time
     - Process flight-plan data
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes
     3.1 Find entry track data
     3.2 Find last flight-plan prior to entry track time
     3.3 Process flight-plan data
     3.4 Compute entry state data
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes
     3.1 Find entry track data
     3.2 Find last flight-plan prior to entry track time
     3.3 Process flight-plan data
     3.4 Compute entry state data
4. Update comment fields
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Find entry track data
4. Find last flight-plan prior to entry track time
5. Assign values to data fields
6. Process flight-plan data
7. Update comment fields
8. Compute entry state data
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
4. Yes
   - Find entry track data
   - Find last flight-plan prior to entry track time
5. Assign values to data fields
6. Process flight-plan data
7. Compute entry state data
8. Update comment fields
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes: Find entry track data
     - Find last flight-plan prior to entry track time
     - Process flight-plan data
     - Compute entry state data
     - Update comment fields
   - No: Assign values to data fields
4. Output scenario data
ATMTB Scenario Generation Steps

1. Load & filter input data
2. Preprocess flight data
3. Flights remaining?
   - Yes:
     3.1. Find entry track data
     3.2. Find last flight-plan prior to entry track time
     3.3. Process flight-plan data
     3.4. Compute entry state data
     3.5. Update comment fields
     3.6. Assign values to data fields
     3.7. Repeat from step 3
   - No: Output scenario data
     - Stop
New Automated Scenario Generation Process

ATMTB generated scenario
New Automated Scenario Generation Process

ATMTB generated scenario

1. Route length filter
New Automated Scenario Generation Process

ATMTB generated scenario

1. Route length filter

2. Cruise speed filter
New Automated Scenario Generation Process

1. Route length filter
2. Cruise speed filter
3. Cruise altitude filter
New Automated Scenario Generation Process

ATMTB generated scenario

1. Route length filter

2. Cruise speed filter

3. Cruise altitude filter

4. Entry time filter
New Automated Scenario Generation Process

1. Route length filter
2. Cruise speed filter
3. Cruise altitude filter
4. Entry time filter
5. Short to long-haul ratio filter
New Automated Scenario Generation Process

1. Route length filter
2. Cruise speed filter
3. Cruise altitude filter
4. Entry time filter
5. Short to long-haul ratio filter
6. Schedule arrivals
New Automated Scenario Generation Process

- ATMTB generated scenario
  1. Route length filter
  2. Cruise speed filter
  3. Cruise altitude filter
  4. Entry time filter
  5. Short to long-haul ratio filter
  6. Schedule arrivals
     Final MACS scenario
Northeast Region Traffic Scenario

• Obtained JFK, EWR, LGA and TEB runway configuration data from FAA’s Aviation System Performance Metrics (ASPM) database

• Examined hourly JFK, EWR, LGA and TEB runway configuration data every day of 2017 to identify
  – Most frequently used configurations individually
  – Most frequently used configurations together
  – Hours with the most operations taken together
  – Selected 5/23/2017 for traffic scenario
  – Chose six-hours from 18 UTC (14 local) to 23 UTC (19 local)
5/23/2017 Traffic Scenario

Landing rate (# aircraft/hour)

- Arrival
- Departure
- Sum

Local time (hour)

0 5 10 15 20 25

18 UTC
23 UTC
# Filtering Results

<table>
<thead>
<tr>
<th>Filter</th>
<th>Criteria</th>
<th># Aircraft</th>
</tr>
</thead>
<tbody>
<tr>
<td>ASPM</td>
<td>None</td>
<td>865</td>
</tr>
<tr>
<td>ATMTB</td>
<td>MACS scenario generation</td>
<td>808</td>
</tr>
<tr>
<td>Route length</td>
<td>&lt; 20 nautical-miles</td>
<td>791</td>
</tr>
<tr>
<td>Cruise speed</td>
<td>&lt; 120 knots</td>
<td>791</td>
</tr>
<tr>
<td>Cruise altitude</td>
<td>&lt; 600 feet</td>
<td>769</td>
</tr>
<tr>
<td>Entry time</td>
<td>&lt; 30 minutes w.r.t start time</td>
<td>769</td>
</tr>
</tbody>
</table>
Short-haul to Long-haul Ratio

\[ \frac{x_{2s}}{x_{1s}} = r \]

- \( x_1 \) = \# long-hauls
- \( x_2 \) = \# short-hauls
- \( x_{1s} \) = \# selected long-hauls
- \( x_{2s} \) = \# selected short-hauls
- \( r \) = desired ratio

\[
x_{1s} = x_1 \text{ and } x_{2s} = \left\lfloor rx_1 \right\rfloor \text{ if } r \leq \frac{x_2}{x_1}
\]

\[
x_{1s} = \left\lceil \frac{x_2}{r} \right\rceil \text{ and } x_{2s} = x_2 \text{ if } r > \frac{x_2}{x_1}
\]

<table>
<thead>
<tr>
<th>#</th>
<th>r</th>
<th>Short-haul</th>
<th>Long-haul</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>0</td>
<td>531</td>
</tr>
<tr>
<td>2</td>
<td>0.25</td>
<td>132</td>
<td>531</td>
</tr>
<tr>
<td>3</td>
<td>0.5</td>
<td>238</td>
<td>476</td>
</tr>
<tr>
<td>4</td>
<td>0.75</td>
<td>238</td>
<td>317</td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>238</td>
<td>238</td>
</tr>
<tr>
<td>6</td>
<td>300</td>
<td>238</td>
<td>0</td>
</tr>
</tbody>
</table>
Scenario Landing Rate

\[ \hat{t}_L = t_E + \frac{l_R}{\bar{V}_{CR}} \]

- \( \hat{t}_L \) – Expected landing time
- \( t_E \) – Entry time
- \( l_R \) – Route length
- \( \bar{V}_{CR} \) – Average cruise speed
Scheduling Arrivals

\[ \Delta t = \frac{60}{n} \text{ minutes} \]

\[ t_s(i) = t_s(i-1) + \max(\Delta t, t_p(i) - t_s(i-1)) \]

\[ \delta(i) = (\Delta t - t_p(i) + t_s(i-1)) \left[ t_p(i) - t_s(i-1) < \Delta t \right] \]

\[ t_f = t_p - t_E \]

\[ t_{sE} = t_s - t_f \]

\[ t_s(i) = t_s(i-1) + \Delta t \]

- \( t_p \) – Proposed landing time
- \( t_E \) – Entry time
- \( t_f \) – Flight time
- \( t_s \) – Scheduled landing time
- \( t_{sE} \) – Scheduled entry time
Results of Scheduling Arrivals

Landing rate
(# aircraft/hour)

Landing time (hours past 12 UTC)
Histograms of Entry Times

Original entry times

Scheduled entry times
Conclusions

• New automated scenario generation process can create MACS scenarios for meeting HITL simulation requirements
  – Selecting flights to achieve the desired short-haul to long-haul ratio
  – Altering landing times

• The two-step process is
  – Less error prone
  – Faster and efficient
  – Repeatable

• New process will be added to enhance ATMTB scenario generation capability