Clustering radar tracks to evaluate efficiency indicators

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1. Introduction
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3. KPI: Idealized Flight Time
Key Performance Indicators for inbound traffic

- The Airport Sequencing and Metering Area (ASMA) contains the TMA and roughly the airspace needed for separation of aircraft.
- The ASMA is realized as simple as possible as a 100NM radius circle around the ARP.
- Key Performance Indicators (KPIs) for measuring the performance of handling inbound traffic:
  - ASMA-flight time median
  - ASMA-flight time variance
  - Relative variance and
  - idealized flight time (virtual optimal flight time)
Data base for this analysis

- The data consists of a set of Airport locations and a set of flight tracks
- Each flight track consists of a series of points which in turn hold several information:
  - 3D-Location
  - Time
  - Velocity
  - Starting Airport, Destination Airport
  - etc.
- More than 1000 Airports involved, 65 of which with more than 500 total approaches within time frame
- NOT in Data base:
  - Airport layout of any kind
  - TMA layout
Data examples

- typical flight tracks
- flight tracks with errors
Current Section

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Motivation for Clustering

- ASMA Flight time depends on the combination of entrance direction and landing direction
- Aircraft approaching an airport from different directions or landing on different runways are not comparable
- First task: find groups of aircraft that use similar routes (clustering)
- For each approach cluster (group of routes of similar routed aircraft), cluster dependent KPIs are calculated
- The final KPI is calculated as a weighted sum of the cluster dependent KPIs with the fraction of total flights as weight
- Two different clustering approaches are proposed
First approach: Clustering ASMA entrance and landing locations

- Two steps of clustering are required: ASMA-Entrance Point and landing point
- For the ASMA-entrance point clustering, the first recorded radar point inside the ASMA is used
- Filter routes out where the first recorded radar point is lonely or too far in the centre
- Calculate the location of the aircraft at 6NM from the ARP and use this position for a second clustering step
- Each combination of entrance cluster and runway cluster forms an approach cluster
- Example: approach cluster 1 = [4, 1]
Clustering entrance points

unclustered entrance points

clustered entrance points
Modified Fuzzy c-Means for clustering

- Clustering landing points and entrance points is very similar
- Each approach route is assigned with a degree of membership for each cluster
- Use the highest degree of membership to determine the cluster affiliation
- Problem: number of clusters must be known in advance for Fuzzy c-Means
- Use a modified version of the algorithm that requires the diameter of the clusters instead
Clustered flight tracks
Second approach: Clustering flight tracks by flight track similarity

- Define a distance (dissimilarity) function for flight tracks. Possible simple distances:
  - Area in between the flight tracks
  - Maximal distance of flight tracks
- Used Distance function: weighted point-wise distance to increase the influence of flight track difference near the ARP
- The DBScan algorithm is used to cluster the aircraft with the defined distance measure
Data set, clustered by flight track similarity
Comparing clustering methods

- Noise data objects are data objects that seemingly belong to no particular group
- Noise clusters are quite different for both approaches
- Removing noise data objects acts like a filter as these data objects are removed
- Clustering by flight track similarity filters rare approach routes
- Clustering by entrance and landing points filters infrequent used entrance points
Noise data from clustering

entrance/landing point

flight track similarity
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3 KPI: Idealized Flight Time
Idealized approach route and time

- With the approach clusters, the KPIs Flight time median, variance and relative variance are easy to calculate.
- The KPI idealized flight time is more difficult.
- For each approach cluster, a fuzzy overflight frequency map (OFM) is generated.
- For each OFM, an idealized approach route is calculated.
- It should be short, smooth, flyable and it should represent the data.
- The idealized approach route can be used for simulations without knowing the exact airspace structure.
- The idealized flight time is calculated, using the idealized approach route and the median of velocity.
Idealized approach route example
Conclusions

- Clustering provides insight into airspace usage
- Different queueing strategies are analysable and comparable
- Clustering provides the tools to calculate the idealized flight time
- Results are usable for simulations and performance monitoring
Thank You for your attention