



Evaluating Controller Complexity Metrics: Preliminary Steps Towards an Abstraction Based Analysis

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ATC Complexity - Why is it Important?

- **Implicit relation to acceptable level of traffic**
- **Possible applications:**
 - ❑ Traffic Management Tool: (Sector Capacity)
 - ◆ Currently use Monitor Alert (count of # of aircraft).
 - ◆ Enhance relevance of alerting tool.
 - ❑ Airspace design:
 - ◆ Increase capacity while maintaining safety.



Previous Research “Dynamic Density”

- **Long tradition of assigning complexity a numerical value based on a weighted equation:**

- ◆ W_i are weights
- ◆ E_i are individual geometric relations

$$CDI = \sum_i W_i E_i$$

- **Examples:**
 - ❑ Schmidt (1976),
 - ❑ Wyndemere (1996),
 - ❑ Laudeman et al (1998) followed up by Sridhar et al (1998).
- **Use spatial and velocity distributions of aircraft in sector and try and capture complexity as a function of geometric relations between the aircraft.**
 - ⇒ E.g. counts of aircraft closure rates, altitude changes etc...



Previous Research “Entropy & Gas Models”

- **Gas Particle Model**
 - ❑ Conflict occurrence prediction by modeling aircraft as gas particles (Endoh, 1982).
- **Entropy as Measure of Disorder**
 - ❑ Modeling the problem as dynamical system, use the “Kolmogorov Entropy” as measure of disorder in the system (Delahaye and Puechmorel 2000).



Initial Observations

- **Use of geometric relations appears useful**
 - ❑ Spatial distribution of aircraft 'natural' starting point.
 - ❑ Sridar et al (1998) demonstrated high future predictability given enough intent information.
- **However, several considerations missing:**
 - ❑ Underlying Structural Characteristics
 - ◆ Effects of airways
 - ❑ Dynamic Events
 - ◆ Weather
 - ❑ Cognitive Aspects



Moving Forward: “Abstraction Analysis”

- **Working hypothesis:**
 - ❑ Controller’s use abstractions to simplify the problem,
 - ❑ Then act to impose order consistent with those abstractions.
- **Abstractions as Cognitive Techniques:**
 - ❑ Mental models / strategies such as:
 - ◆ Altitude segregation
 - ◆ Destination (Standard Routes)
 - ◆ Aircraft type
 - ◆ Stable vs. Transitioning Aircraft
- **Research Goal:**
 - ❑ How do the abstraction methods used by controllers affect complexity?



Abstractions & Organization

- **Preliminary Hypothesis**

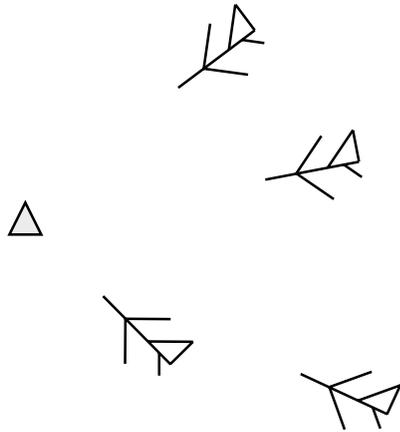
- ❑ Abstractions reduce the dimensionality of the problem.
- ❑ Use organizing structure to reduce possible system behaviors.
 - ◆ E.g. organizing traffic into flows / jet routes keeps aircraft on known paths.
- ❑ Mathematician's problem solving approach?
 - ◆ Reduce problem to one already know how to solve.

- **Sources of Organization in System**

- ❑ External
 - ◆ e.g. procedures, structure.
- ❑ Internal
 - ◆ e.g. techniques, cognitive strategies.

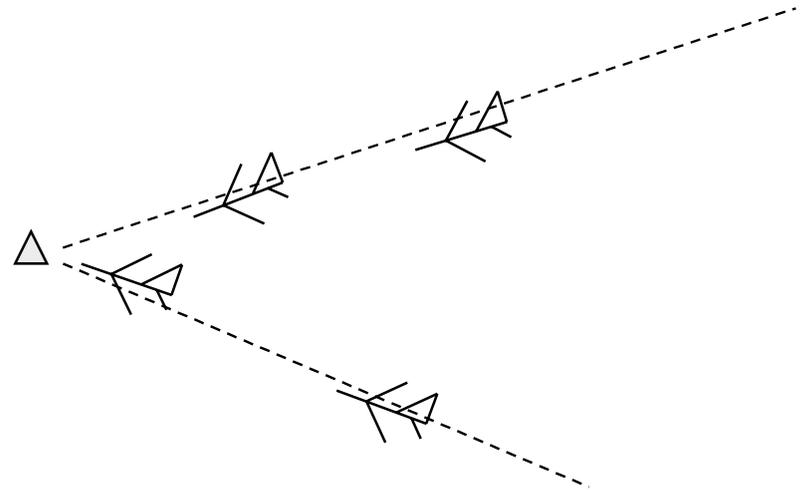
Order Reduction by Flow Organization

- Consider example of merging aircraft into single stream at a fix:



No organization:

*Potentially $\frac{1}{2}(N)(N-1)$
conflict pairs*



Organization: (2 flows to be merged)

*Potentially $2(N-1)$
conflict pairs*

- Creating organizational units reduces # of dimensions that need to be considered.



Direction of Future Work

- **Collaborative Effort with European Researchers**
 - ❑ Professor D. Delahaye at CENA.
- **Continued Literature Review**
 - ❑ Encompass other disciplines, concentrating on examples of order reduction in control problems.
- **Elicit Operational Experience from TRACON / Center Facilities**
 - ❑ Familiarization with strategies / procedures.
 - ❑ Controller interviews or surveys.
 - ◆ Identify characteristics of sectors and situations considered difficult.
 - ❑ If possible, identify sectors having elevated operational errors.
 - ◆ Data accessibility / privacy issues.



Direction of Future Work (2)

- **Identify abstraction strategies used by controllers.**
- **Develop potential models / metrics that capture cognitive strategies.**
- **Validate proposed complexity metrics.**