Dynamic Aircraft Routing Services: Complexity, Scalability, Efficiency, and Software Design

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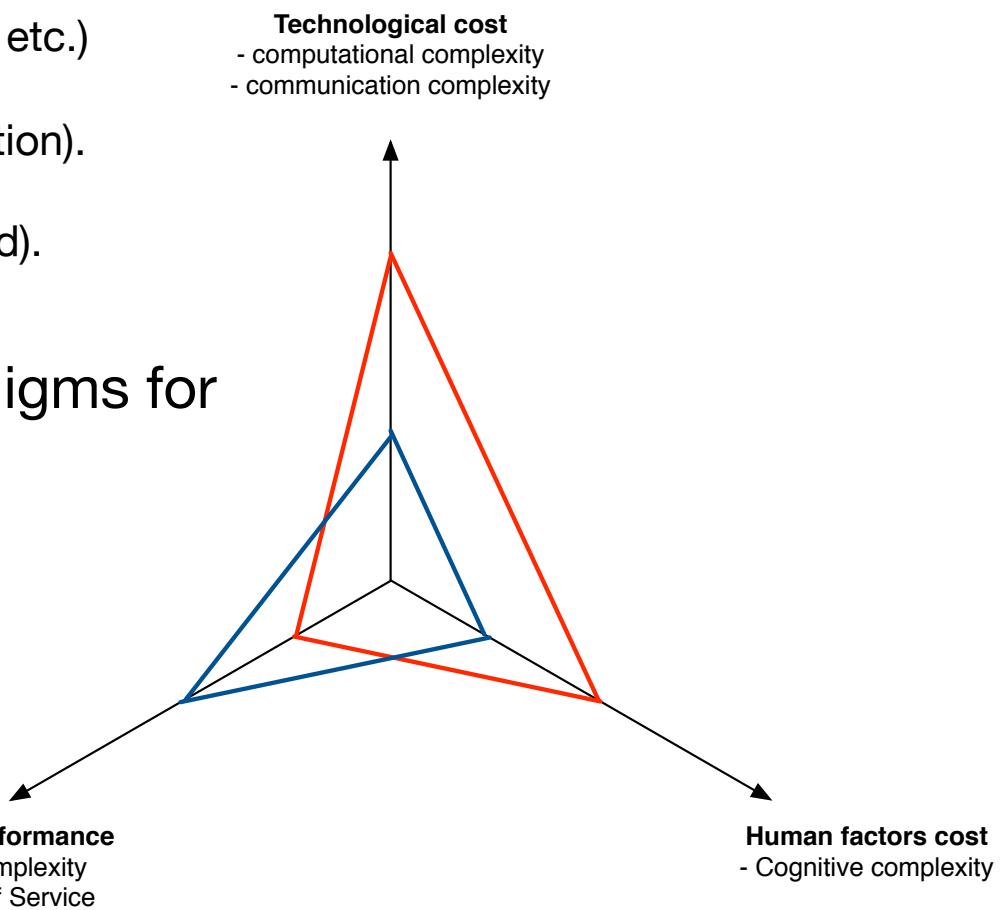
Scalability and complexity of aviation software

- Current software design/analysis paradigms:
  - Most research on safety/correctness of automation software.
  - Some concern on scalability/computational complexity of proposed **algorithms**.
  - ***For what range of inputs/problem parameters will an embedded system maintain the safety/correctness properties? To what extent shall we be able to verify these properties?***
- Little or no systematic investigation of the **problem complexity**, as a function of system parameters (e.g., traffic volume, network size):
  - Computational complexity (comp. time, space, etc.)
  - Verification complexity
  - "Physical" time complexity (e.g., traffic congestion).
  - Communication complexity (network load)
  - Cognitive complexity (human operator workload).
- Search for tradeoffs/(co)design paradigms for **cyber-physical systems**.
  - Algorithm design
  - Information flow protocols
  - Human interfaces
  - Infrastructure design

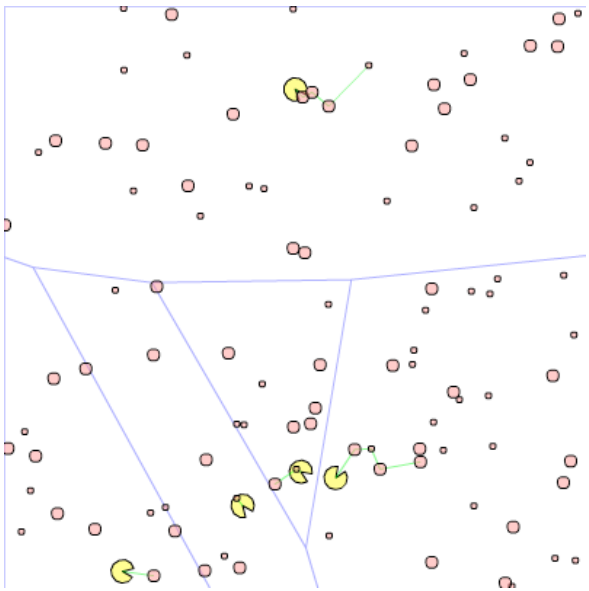


Dynamic Aircraft Routing Services

- Application domains:
  - Air Traffic Management
  - UAV autonomy
  - Command and Control interfaces

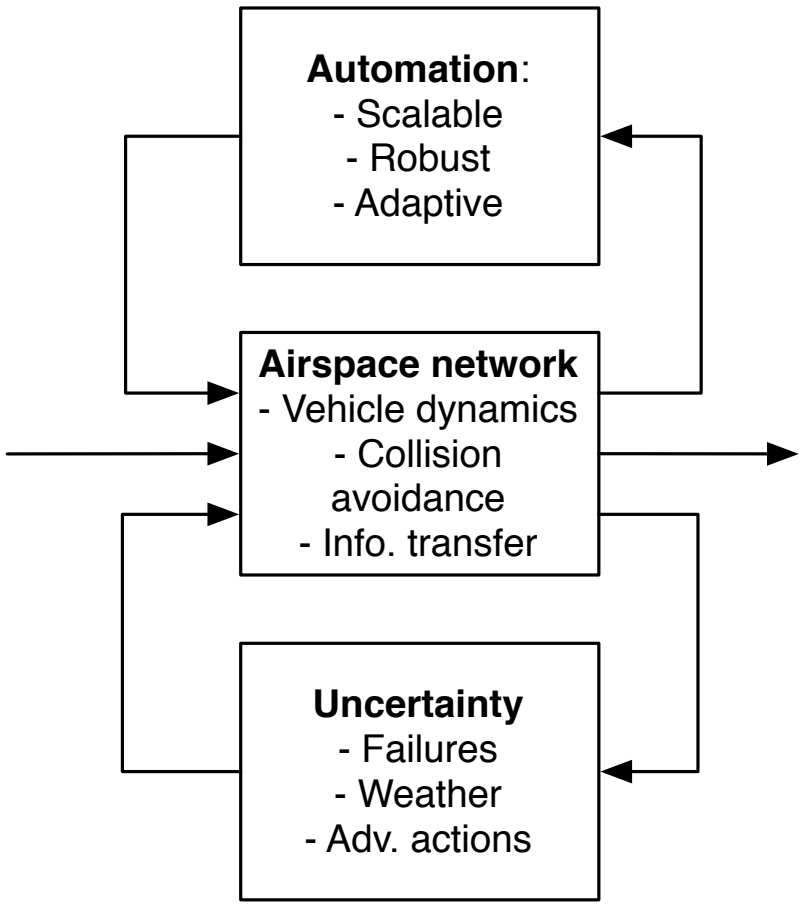
- Models:
  - Large-scale heterogeneous networks of mobile and stationary agents (e.g., aircraft and ground operators) as a shared resource.
  - Dynamically-generated tasks and/or constraints; task specifications have a **discrete/combinatorial nature**.
  - Aircraft dynamics, environmental interaction, sensing/communication add a **(differential) geometric aspect**.

- Performance criteria:
  - Quality of service (average, worst-case delays, etc.)
  - Acceptable guarantees of safety
  - Robustness to off-nominal conditions, adversarial actions.



An input-output view

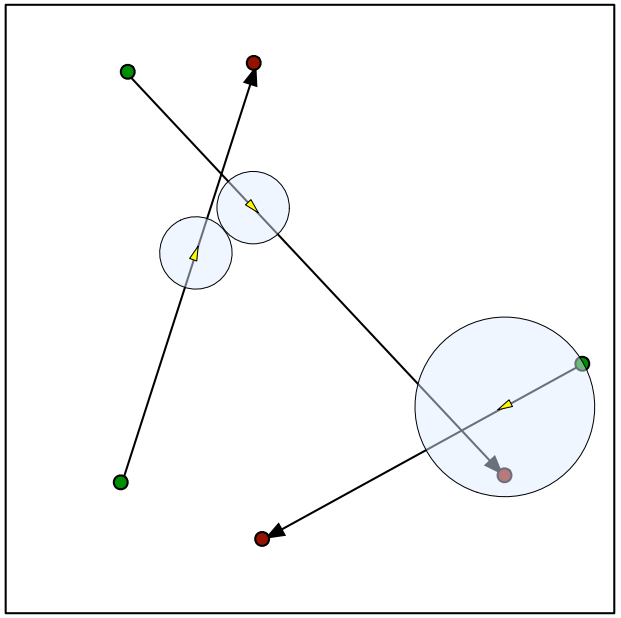
Routing Service requests:
Tasks generated over time
by a dynamic process, e.g.:
- human operators
- airline schedules
- adversarial actions



Quality of Service:
- Average/worst-case delay
- Reliability (task completion ratio)
- Total number of tasks completed over the system's lifetime

Example: Traffic volume/congestion tradeoffs

- **Problem:** What is the minimum time required to **safely** transfer *n* mobile agents from their source to their destination point?
  Source and destination randomly sampled from a given distribution



Comm	Distribution	Time	Avg. speed
No	Singular	$\Theta(n)$	$\Theta(1/n)$
No	Abs. Cont.	$\Theta(n^{1/2})$	$\Theta(n^{-1/2})$
Yes	Abs. Cont.	$O(\log n)$	$\Omega(1/\log n)$