Identifying the Requirements and Design Variables for New Aircraft Considering Fleet-Level Objectives Under Uncertainties

Satadru Roy, William A. Crossley, Navin Davendralingam, Parithi Govindaraju
School of Aeronautics and Astronautics, Purdue University

Research Task / Overview

- Can we identify a quantitative approach to determine the “right requirements” for a new system?
- Can we concurrently optimize multiple systems?
- Can this approach address multi-domain uncertainties?

Goals & Objectives

Develop decision support framework that:
- Assists decision-maker or acquisition practitioner to identify new system requirements that improve (maximize) system-level objective
- Allows new system to operate along with the existing system
- Addresses multi-domain uncertainties and uncertainty propagation

Data & Analysis

Case - Study
- A notional 31-route network airline with hub at Memphis
- Airline has 7 different aircraft types currently in its fleet (blue bars)
- User-determined 5 new aircraft to be acquired (red bar)

Objective

Maximize fleet level expected profit

Variables

New aircraft requirements (design range, seat capacity)
New aircraft design variables (NLP: Nonlinear Programming)
- Aspect ratio, taper ratio, wing sweep, engine thrust etc.
Allocation variables (MIP: Mixed integer programming)
- Trips, passengers carried on a particular route

Constraints

- Passenger demand
- Aircraft performance (takeoff distance, landing distance etc.)
- Fleet operations (maximum operational hours, number of each aircraft types etc.)

Addressing Uncertainty

- Reliability-based design optimization (RBDO) formulation to handle uncertainty in new system design
- Descriptive sampling approach to handle uncertainty in passenger demand
- Propagation of uncertainty from aircraft sizing to subspace
- Performance of new aircraft is uncertain
- Coefficients in allocation problem have distributions
- Used a ‘Robust Optimization’ approach
- Interval Robust Counterpart (IRC) formulation: Optimize considering the nominal and worst-case values of uncertain parameters within a predefined tolerance limit

Preliminary Results I: Expected Fleet Profit

- Green bar denotes baseline fleet with no new aircraft type-X in use
- 75 seats has higher expected profit
- 75 seats with 1200nm design range leads to highest fleet expected profit

Preliminary Results II: Design-Allocation Subspace

- Alternate approach to address multi-domain problems as Mixed-Integer Non-Linear Programming (MINLP) problem
- Requires a new MINLP solving approach to address complex tightly coupled systems
- AMIGO (A Mixed Integer Efficient Global Optimizer) - A MINLP solver to address Aircraft design and Airline allocation as MINLP problem (under development)
- Would enable to integrate other complex systems
- For example, an integrated Revenue Management System
- Future Research

Methodology

- Top level
- Aircraft Design
- Sequential Decomposition Approach

Future Research

- Alternate approach to address multi-domain problems as Mixed-Integer Non-Linear Programming (MINLP) problem
- Requires a new MINLP solving approach to address complex tightly coupled systems
- AMIGO (A Mixed Integer Efficient Global Optimizer) - A MINLP solver to address Aircraft design and Airline allocation as MINLP problem (under development)
- Would enable to integrate other complex systems
- For example, an integrated Revenue Management System
- System will enable to decide the ticket prices under uncertainty in passenger demand

Contacts/References

1. Satadru Roy, Ph.D. Candidate (email: roy10@purdue.edu)
2. William A. Crossley, Professor (email: crossley@purdue.edu)
Address: 701 W. Stadium Ave., School of Aeronautics & Astronautics, Purdue University, West Lafayette, IN 47907

This work has been partially funded by:
* Naval Postgraduate School Acquisition Research Program through the grant number N0014-15-1-0063
* NASA through grant number NNX14AC73A as a part of the LEARN project: “Scalable Multi-Fidelity Design Optimization: Next Generation Aircraft and their Impact on the Air Transportation System”

SERC Sponsor Research Review, November 17, 2016