Automated Flight Scheduling for Training

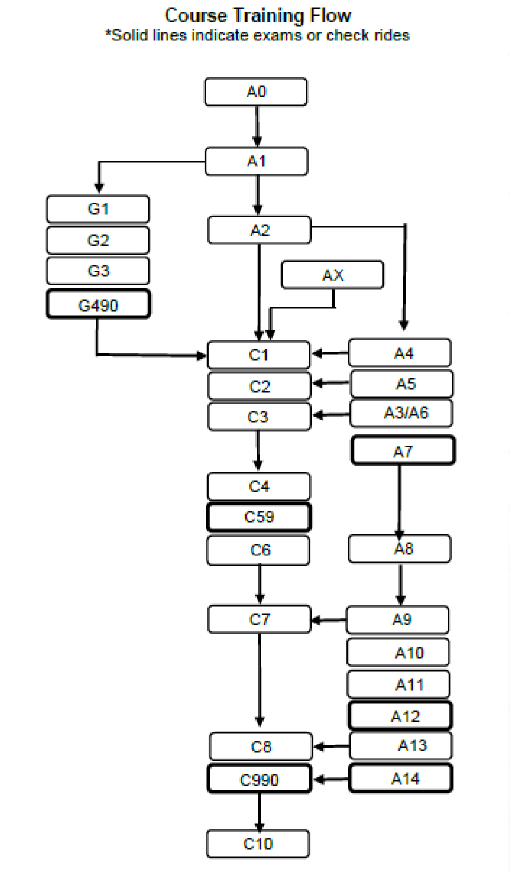
Peter Barkley

Overview

- Problem description
- Modeling approach and solution
- Results and future work

The Naval Academy Flight Program

- 3 blocks of 4 weeks each
- ~90 students and 20 instructors per block
- 14 classes/written exams
- 14 practical events in aircraft
- ~15 aircraft of 3 types
- Ends with a solo, if student makes it



Terminology

- *Flight schedule*: mapping of aircraft availability to specific students and instructors for a specific set of events
- *Onwing*: A student’s primary instructor
- *Partner*: One of a pair of students who are flown together
- *Event*: One of the 14 required training sessions on the aircraft
- *Wave*: A time period for aircraft operation

Typical military flight scheduling

- Manual flight schedule construction
- Looks only one day ahead
- Fails to account for the weather
- Last minute changes are difficult
- Complexity leads to errors

The flight training scheduling problem

- The real problem: find a set of feasible flight schedules for all days from tomorrow until the end of the block which minimizes $\sum h(C_s)$ where *h* is an increasing penalty function with a large increase at the end of the block and C_s is the completion time of student *s*
- *But …*
  - Stochastic process: flights frequently do not result in completion and progression to the next event due to weather, student failures, mechanical problems, etc.
  - Intractability: operations team needs to compute schedules in minutes, not hours

The flight training scheduling problem

- The heuristics:
  - Solve only the next *n* days
  - Prioritize students based on their “spare days” [days remaining - events remaining] and completion-probability
  - Break plane availability into discrete “waves”, pre-compute overlap restrictions
  - Maximize priority and completion-probability weighted student events

Formulation: Variables and Objective

5.4. Variables

$X_{s,p,d,w,e}$ 1 if student s is scheduled on plane p on day d in wave w for event e, 0 otherwise

$X_{i,p,d,w}$ 1 if instructor i is scheduled on plane p on day d in wave w, 0 otherwise

5.5. Objective Function

maximize

$$\sum_{d \in D} \sum_{w \in W} \sum_{s \in S} \sum_{p \in P_s \cap P_{d,w}} \sum_{e \in E_{s,d}} R_w R_d R_s X_{s,p,d,w,e} - \alpha \sum_{d \in D} \sum_{w \in W} \sum_{i \in I} \sum_{p \in P_i \cap P_{d,w}} R_{i,d,w} X_{i,p,d,w}$$

Formulation: Variables and Objective

where:

- R_d is the weight given to day d
- R_w is the weight given to wave w
- R_s is the weight given to student s
- $R_{i,d,w}$ is the cost of wave w for instructor i
- α is a scaling constant making instructor utilization a secondary objective

Formulation: Constraints

Physical constraints:

- Instructors and students can be in only one plane at a time
- No more than two students should be in each plane per wave
- The total weight of instructor and students should not exceed the max useful load of the aircraft

Formulation: Constraints

Maintenance constraints:

- Aircraft must be inspected every 100 flight hours
- Inspections typically take 3 days
- Ground events do not require flight-ready aircraft

Formulation: Constraints

Availability constraints:

- Variables are only generated for waves in which plane p is available and events which are possible
- Students should not be scheduled when unavailable
- Instructors should not be scheduled when unavailable
- Inactive students should not be scheduled

Formulation: Constraints

Syllabus constraints:

- Only one event (except C10) should be scheduled each day
- Ground events should be scheduled with any instructor
- Events C1-C4, C6-C8, and C10 should be scheduled with a student’s onwing instructor
- Event C590 should be scheduled with a non-onwing instructor
- Event C990 should be scheduled with a non-onwing check instructor

Formulation: Constraints

Syllabus constraints:

- Student pairs should be scheduled together if they are on the same event
- The order of scheduled events must adhere to event precedence rules
- Each event should only be scheduled once
- Instructors shall fly $\leq$ 8 hours daily
- Students shall have $\geq$ 12 hours unscheduled overnight
- Students shall fly no more than 6 days in a row

Implementation

- Initial:
  - AMPL / GLPK / Google Sheets / Google Forms / Javascript
- Final:
  - Python / Gurobi / MySQL / Web Application / PHP

USNA Powered Flight Program

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Student	Callsign	Status	Last Flight	G1	G2	G3	G490	C1	C2	C3	C4	C590	C6	C7	C8	C990	C10
MIDN Chow, Raymond		active	Jul 25	P	P	P	P	P	S	D	D	D					
MIDN Cinq Mars, Alexander		active	Jul 25	P	P	P	P	P	C D	D D							
MIDN Clanton, Mark		active		P	P	P	P	C D	D	D							
MIDN Coffin, Thomas		active	Jul 25	P	P	P	P	P	S	D	D	D					
MIDN Colceri, Bryce		active	Jul 25	P	P	P	P	P	C D	D	D						
MIDN Conn, Andrew		active	Jul 25	P	P	P	P	P	S	D		D					
MIDN Corbett, Dean		active	Jul 25	P	P	P	P	P	C D D								
MIDN Coyle, Connor		active	Jul 25	P	P	P	P	P	C D	D D							
MIDN Crockett, Samuel		active	Jul 25	P	P	P	P	P	S	D		D					
MIDN Davis, John		active	Jul 25	P	P	P	P	P	C D	D D							
MIDN Delmonte, Brenden		active		P	P	P	P	S	D	D	D						
MIDN Doan, Kristine		active	Jul 25	P	P	P	P	P	S	D	D	D					
MIDN Doyle, Molly		active		P	P	P	P	S	D	D	D						

Human Systems Integration

- Make it easier to change inputs and re-run optimization than make a manual change
  - Incorporates latest information
  - Applies new conditions to all events
- Start summer with new system
- Make it easy for instructors / operations team to input information
  - Mobile-friendly, pre-filled forms, automated prompting
- Irreducible infeasible subset highlights “reasons” student was not scheduled

Results

- Less than 2 minutes per schedule looking out 3 days
- Scheduling work load dropped from 12 hours to 3 hours each day
- Increased solo rate from 51% to 79%
- Saved over $890,000 in 36 weeks

Literature

- J. F. Raffensperger, S. Swords, Scheduling Prowler training, Naval Research Logistics (NRL) 50 (2003) 289-305.
- R. Hohzaki, T. Morimoto, S. Omi, Flight scheduling for the SH-60J military helicopter, Military Operations Research 16 (2011) 5-17.
- R. A. Hahn, A. M. Newman, Scheduling United States Coast Guard helicopter deployment and maintenance at Clearwater Air Station, Florida, Comput. Oper. Res. 35 (2008) 1829-1843.

Future Work

- Completion-probability: historical data rather than expert evaluation
  - Weather
  - Time between flights
  - Past success/failure
- Formation flights
- Predictive weighting for various event types (aerobatics/night/instrument)
- Day-of changes

Questions?