712CD

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Summer Program Scheduling at the Air Force Academy

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Summer Scheduling at the United States Air Force Academy

75th MORS Symposium

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Problem Statement

- **To create a better system to schedule USAFA cadets into summer programs.**
  - Summers consist of three, 3-week periods
  - Programs include a mixture of operational tours, USAFA leadership programs, and leave
- **Previous scheduling process utilized an heuristic that left many cadets unscheduled.**

Overview

- Information about summer programs
- The old scheduling process
- Integer programming approach
- Computational results
- Future work

Summer Schedules
Rising So, Jr, Sr Cadets

2nd Summer

- Operation Non-Com
- Airmanship Program
- Global Engagement
- Leave

3rd Summer

- Operation 3rd Lt
- USAFA Leadership
- Leave

4th Summer

- Operation Brevet Lt
- USAFA Leadership
- Leave

- The order of the three (or four) courses will vary by cadet
- For rising sophomores, global engagement is always scheduled opposite airmanship program
- Airmanship programs (soaring and jump) have limited enrollment in each summer period

Summer Schedules

- More than 3,000 cadets (approx. 1,000 per class)
- Nearly 50 summer programs
  - Four major categories:
    - Airmanship
    - Leadership
    - Summer Operations (e.g., Operation Air Force)
    - Leave

Old Scheduling Process
Data Collection

- Summer programs office begins gathering data in **early October**
  - Enrollment quotas
  - “Cadre” (i.e., cadet leader) quotas
  - Pre-scheduled cadet information
    - Program staff
    - Intercollegiate athletes
    - Flying team members
    - Late graduates
  - “Must-have” leave requests
  - Cadet preferences for programs and for leave period
- Inputs are **extremely fluid** and often not received by deadline

Old Scheduling Process
The Heuristic

- Load pre-scheduled cadets into course/offerings
- Select course/offering as follows (for sophomores):
  - Leave
  - Courses with fewer than 3 offerings
  - Airmanship and Global Engagement
  - Others (fewest offerings first)
- Cadets **randomly selected**, assigned if course is preferred and cadet is available
- Cycle to next cadet until course/offering is full
- Cycle to next course/offering, continue random cadet selection

Old Scheduling Process
Results

- Nearly **6-month** process
- Heuristic had **only a 60% initial success rate** (~1,800 cadets feasibly scheduled each year)
  - Remainder incompletely or incorrectly scheduled
    - These must be completely scheduled by hand
  - Some schedules must be re-worked due to new/changing requirements or cadet circumstances
- **Little consideration given to cadet preferences** or cadet ranking (e.g., Overall Performance Average)

Toward a New Model

- **Approach:**
  - Integer programming model
    - Single IP model for the sophomores
    - Combined IP model for the juniors and seniors

- **Goals:**
  - Shorter running time, allows repeated runs and sensitivity analysis
  - Greater number of cadets scheduled to reduce the amount of manual re-work
  - Greater cadet satisfaction

Cadet Preferences

- Cadets indicate their **primary** and **alternate** choices for:
  - Leave
  - Airmanship (for sophomores)
  - Leadership (for juniors and seniors)
- **Relative value** of leave versus airmanship programs:
  - Specified by summer programs office
  - Affected by cadet's Overall Performance Average (OPA)
  - Objective function ***value*** associated with assigning a cadet to his/her primary or alternate choice given by:

	Leave	Airmanship
Primary	100*OPA	50*OPA
Alternate	10*OPA	25*OPA

Mapping Programs to Time Slots

- **Indicators (based on known data):**

$$\delta_p^t = \begin{cases} 1 \text{ if program } p \text{ is scheduled during time slot } t = 1,...,6 \\ 0 \text{ otherwise} \end{cases}$$

- **Example:**
  - MilTng 444AC -- Leave is scheduled for first period (i.e., time slots 1 and 2).

Time Slot	Delta
1	1
2	1
3	0
4	0
5	0
6	0

Decision Variables

- Let **C** be the set of cadets
- Let **P** the set of programs
  - Each program occurs once, e.g., Leave during first period is a ***different program*** from Leave during second period

- Decision Variables:

$$x_{cp} = \begin{cases} 1 \text{ if cadet } c \text{ is assigned to program } p \\ 0 \text{ otherwise} \end{cases}$$

IP Formulation

$$\max \sum_{c \in C} \sum_{p \in P} value_{cp} \cdot x_{cp}$$

Maximize overall value of assigning cadets to programs

Subject To:

$$\sum_{p \in P} \delta_p^t \cdot x_{cp} = 1 \quad \forall c \in C, t \in \{1,...,6\}$$

Each cadet has one program scheduled in each period

$$\sum_{c \in C} x_{cp} \geq \min_p \quad \forall p \in P$$

$$\sum_{c \in C} x_{cp} \leq \max_p \quad \forall p \in P$$

Number of cadets assigned to each program must lie within upper and lower enrollment limits for that program

IP Formulation

$$\sum_{p \in P_{Ops}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Ops program

$$\sum_{p \in P_{Leave}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Leave program

$$\sum_{p \in P_{Airmanship}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Airmanship program

$$\sum_{p \in P_{GE}} x_{cp} = 1 \quad \forall c \in C$$

Each cadet assigned to one Global Engagement

$$x_{cp} \in \{0,1\} \quad \forall c \in C, \forall p \in P$$

Decision variables are binary

Jr/Sr model replaces Airmanship and Global Engagement constraints with Leadership program constraints

Additional Constraints

- Incorporating double-period (six week) programs
- Handling pre-scheduled cadets
- Cadet must not enroll in a particular program
- Cadet must not enroll in a particular type of program (e.g., Ops, Leave, Leadership, or Airmanship)
- Under- or over-filling courses
  - We use slack/surplus variables and penalties to guarantee a feasible solution, but at a cost

Proof of Concept

Summer, 2004

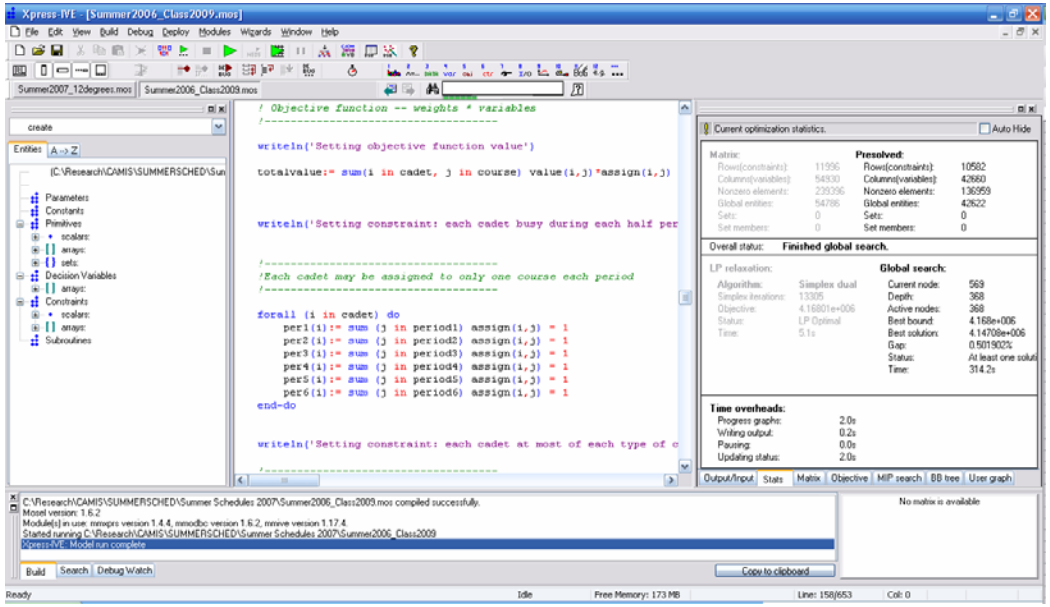
- Model tested (but not used) for summer 2004
- Tested against rising sophomore class data
- 1114 cadets to schedule
- Required programs:
  - Leave
  - Global Engagement / Airmanship
  - Combat Survival Training

Number of Cadets	Automated Heuristic	Optimization Model
Missing Leave	3	0
Missing Global Engagement	13	0
Missing Combat Survival Training	117	0
Missing Airmanship Program	174	0
Missing Required Program (Total)	308 (27%)	0
Scheduled to 1st Leave Period Preference	972 (87%)	1022 (92%)
Time to Produce Feasible Schedules	weeks	hours (including pre-processing)

** Work of Hendricks, Fear, and Perkins*

Implementation

- Coded using Xpress-MP v2004, later ported to v2006



- Data input/output via Excel, text file, and SQL interface
  - Data source is the Cadet Administrative Management Information System (CAMIS – an Oracle Database)

Implementation

- Success with 2004 test led to model development, refinement, and use for 2005, 2006, and 2007 schedules
  - Significant changes to summer program process occurred during each year
    - Required and optional programs changed
    - Program substitutes allowed to fill requirements
  - Validated model flexibility & robustness
    - Changes handled by modifying the input data

Results
Previous Years

- **Summer 2005:**
  - ~99.5% successfully scheduled
  - Only 13 of 3000+ schedules incomplete or incorrect (required re-work by hand)
    - Due primarily to conflicting requirements, (e.g. “must-have” leave and “pre-sched” program)
  - Historically, more than 1,000 re-works necessary annually
- **Summer 2006:**
  - Focused on model clean-up for long-term use
  - Same benefits to the summer programs office

Results
Summer 2007

- **Sophomore Model:**
  - 8-10 minutes (5.5 sec for LP relaxation, rest of the time in Branch and Bound)
  - LP optimality gap: 11%, reduced to less than 1% in 40 seconds
  - 12,000 rows, 55,000 columns
  - 1122 of 1138 received **first leave preference** (99%)
  - **Zero** unscheduled cadets; manual review indicated no re-scheduling required

Results
Summer 2007

- **Junior/Senior Model:**
  - 2.3 seconds (2.1 sec for LP relaxation)
  - LP optimality gap: 0%
  - 13,000 rows, 41,000 columns
  - 78% received **first preference** for leave period, while 93% received **first or second preference** for leave period
  - 13 of 2,192 cadets (1/2 %) required re-work
    - Caused by manual pre-scheduling errors

- Scheduling process for all three classes reduced from **two months** (pre-model) to **one week**

Future Work

- Develop **better methods to capture cadet program preferences** and personal trade-offs between programs
- **Implementation** into Cadet Administrative Management Information System (CAMIS)
  - Changing program requirements make this difficult
  - Anticipate a reduction in process time from one week to one day
- **Integration** with ***Operation Air Force*** scheduler
  - Summer program model provides the cadet-to-period assignments for the Ops AF program
  - Ops AF scheduler assigns cadets to specific bases

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