Timetabling Math Courses at USNA

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14Apr MORS 2010

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Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
14 APR 2010		**00-00-2010 to 00-00-2010**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Timetabling Math Courses at USNA	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **U.S. Naval Academy,121 Blake Road,Annapolis,MD,21402**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES
Education and Professional Development Colloquium: "Operations Research, A Global Solution Methodology" 14-15 April 2010, Army Logistics University (ALU), Ft. Lee, Virginia.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**16**	

Overview

- Problem Description
- Project Goals
- GLPK
- Data/Variables/Constraints
- Remaining issues
- Questions?

The Problem

- USNA math courses currently scheduled by hand
  - extremely cumbersome
  - Large number of variables (200+ sections, 80+ instructors, etc.)
  - Many constraints: professor and room availability, course meeting times (three times a week, four times, etc.)
  - Results in several days of work by some faculty member

Objectives

- Use Integer Programming to provide Math department with a feasible schedule
  - Solve using GLPK
  - Ideally, produce a decision tool to simplify future scheduling
- Gain experience in large-scale IP scheduling problems
  - Preparation for internships and postgraduate work

GLPK

- GLPK = free integer programming software for solution
  - Potentially not powerful enough to solve problem of this magnitude

Given Data

- Course-teacher assignments already completed by Department Chair
  - Number of sections for each course already determined
  - Course structure defined (e.g. MWF, TR, etc.)
- Rooms available
  - roughly 85 rooms (4 computer labs)
- Period construction preset
  - Monday-Friday, 6 periods each

Decision Variables

- X_{ijk} = 1 if course i *starts* during period j in room k
- X_{ijk} = 0 o.w.
- "Course i" represents some number (1,2,3) of consecutive sections of the same course
  - Ex. Professor Miller teaches 2 sections of course Math101 beginning in period 2 in room 001

Constraint #1

- "Every course i must start during some period j in some room k"
- AMPL:

tells GLPK which set to input

constraint name

```
subject to req{i in COURSES}: sum{j in PERIODS, k in ROOMS}
x[i,j,k] = 1;
```

- Algebraic Notation:

For every course i:

$$\sum_{j,k} X_{i,j,k} = 1 \text{ ,}$$ summing over

j in Periods, k in Rooms

Constraint #2

- "5 period Calculus courses must take place during MTWRF periods"
- One constraint for each type of class
- subject to *calc5*{i in CALC5PER}:

sum{j in MWF, k in ROOMS} x[i,j,k] +

sum{u in MTWF, k in ROOMS} x[i,u,k] +

sum{v in MWRF, k in ROOMS} x[i,v,k] = 0;

- Slightly more complicated constraint:
  - Indices change to 'u' and 'v'
  - Sum = 0; make objective true with a constraint making the inverse false

Constraint #3

- “Cannot begin teaching a 2-section block in periods 4 or 6”
- subject to lunch1{j in PERIODST3, k in ROOMS}:
  - sum{i in TWOCOURSES} x[i,j,k] = 0;
    - PERIODST3 = *periods type three*, periods with no immediately following period
    - TWOCOURSES = back-to-back courses, i.e. two periods of Multivariable Calculus taught consecutively

Constraint #4

- "Only one course may occupy a room during any period"
- subject to overlap3{j in PERIODST4, k in ROOMS}:

  sum{i in COURSES} x[i,j,k] +
  sum{i in TWOCOURSES, v in TWOCONF[j]} x[i,v,k] +
  sum{i in THREECOURSES, u in THREECONF[j]} x[i,u,k]
  <= 1;
  - PERIODST4 = periods with two preceding periods (3rd and 4th)
  - TWOCONF[i] = period preceding period j
  - THREECONF[j] = one and two periods preceding period j

Other Constraints Implemented

- “Teachers can only teach one course at a time”
- “Computer courses must take place in computer rooms”
- “Instructor Miller can only teach in the mornings”
- “Courses of the same instructor must be taught consecutively”

***

- No objective, simply looking for feasible solution

AMPL Code

```
set THURSDAY[4] := MWRF4 MTWRF4;
set THURSDAY[5] := MWRF5 MTWRF5;
set THURSDAY[6] := MWRF6 MTWRF6;
set TWOPERIODNO := MWF6 MTWF6 MWRF6 MTWRF6;
set THREEPERIODNO := MWF5 MTWF5 MWRF5 MTWRF5 MWF6 MTWF6 MWRF6 MTWRF6;
set THIRDPERIOD := MWF3 MTWF3 MWRF3 MTWRF3;
set FOURTHPERIOD := MWF4 MTWF4 MWRF4 MTWRF4;
set FIFTHPERIOD := MWF5 MTWF5 MWRF5 MTWRF5;


set COURSES := 401A 401T 402 421M 421S 121C 121N 121V 121S 122A 122B 1
122J 122K 122L 122M 122N 122O 122P 123C 123H 123J 123L 123O 123P 123Y
212E 212F 212G 212H 212I 212J 212K 212L 212M 212N 213A 213B 213L 213N
221C 221D 221E 220A 220B 222 230A 230D 230E 261 279A 279B;
#TWOCOURSES represents a pair of the same courses taught consecutively
#THREECOURSES represents a triplet of the same courses taught consecut
set ONECOURSE := 402 421S 421M 121N  122C 122D 122E 122F 122G 122J 122
212C 212D 212E 212H 212I 212L 212M 212N 213B 213L 213N 219A 219B 221A
set TWOCOURSES := 401A 401T 121V 121S 122A 122B 122H 122I 122K 122L 12
212K 213A 219D 219E 221C 221D 222 279A 230B 230C;
set THREECOURSES := 121C 122M 122P 219C 221E 220A 230D;
set CALC5PER := 123C 123H 123J 123L 123O 123P 123Y 121C 121N 121V 121S
set CALC4PER := 122A 122B 122C 122D 122E 122F 122G 122H 122I 122J 122F
212E 212F 212G 212H 212I 212J 212K 212L 212M 212N 213A 213B 213L 213N
set COURSES3PER := 401A 401T 402 421M 421S 219A 219B 219C 219D 219E 26
#set COURSES2PER := 230B 230C;
```

AMPL Code (cont.)

```
#Only one course may occupy a room during any given period
#[2 constraints to ensure that consecutive duplicates don't overlap during e
subject to overlap1{j in PERIODST1, k in ROOMS}: sum{i in COURSES} x[i,j,k]
subject to overlap2{j in PERIODST2, k in ROOMS}: sum{i in COURSES} x[i,j,k]
subject to overlap3{j in PERIODST4, k in ROOMS}: sum{i in COURSES} x[i,j,k]
sum{i in THREECOURSES, u in THREECONF[j]} x[i,u,k] <= 1;

#Cannot begin teaching a 2 period course in periods 4 or 6
subject to lunch1{j in PERIODST3, k in ROOMS}: sum{i in TWOCOURSES} x[i,j,k]

#Cannot begin teaching a 3 period course in periods 3,4,5,6
subject to exist{j in PERIODST5, k in ROOMS}: sum{i in THREECOURSES} x[i,j,k

#4 period Calculus courses must take place during MTWF or MWRF periods [by m
subject to calc4{i in CALC4PER}: sum{j in MWF, k in ROOMS} x[i,j,k] + sum{u

#5 period Calculus courses must take place during MTWRF periods
subject to calc5{i in CALC5PER}: sum{j in MWF, k in ROOMS} x[i,j,k] + sum{u

#3 period courses will not take place during MTWF/MWRF/MTWRF periods
subject to course3{i in COURSES3PER}: sum{j in MTWF, k in ROOMS} x[i,j,k] +

#MTWF/MTWRF/TR/MWRF cannot overlap on Tuesday and Thursday
#subject to tuesday{u in SIX, k in ROOMS}: sum{i in COURSES, j in TUESDAY[u]
```

Remaining Issues

- GLPK running for >48 hours, 700mb memory, no solution
  - CPLEX?
  - GUROBI?
- Add constraints to reflect graduation requirements and teacher preferences
- Alter decision tool to ensure it is more user-friendly

Questions???