Minimizing Schedule Changes

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Introduction

Our project had 2 parts:

- Build a course schedule for the UMass Amherst Mathematics and Statistics Department that maximizes the faculty members' course preference and time availability
- 2. Take changes that need to be made to the schedule, and minimize how many other changes are made as a result

Goals

- We want to find what course schedule maximizes faculty preferences of course and time, while leaving only as many lower-level and large lecture courses as necessary unassigned to an instructor
- ► From the course schedule we want to minimize changes made to the original schedule, while satisfying issues coming up after the first schedule has been made
- Examples of this are a faculty member no longer being able to teach at the given time or the given course, or going suddenly on leave

The first portion of our project was constructing a linear program that creates a schedule maximizing the instructor preferences.

We will use this schedule as the starting point for changes that need to be made later.

Basic Information:

- ➤ 70 instructors (18 VAPs, 14 lecturers, 38 tenure-track professors)
- ▶ 133 total sections of 61 total courses to be taught
- ▶ 14 time slots (MWF 8-8:50 considered 1 time slot)

Decisions

We want to decide who is teaching what class and when, and which constraints to fully satisfy

Variables

Assignment Variables: these are all binary variables that equal 0 if person i isn't teaching class j (at section level, not course) at time h, and 1 if they are.

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x_{ijh} = \mathsf{VAP}\ i \in \{1, \dots, n_1\} teaching class j \in \{1, \dots, m\} at time h \in \{1, \dots, l\}
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y_{ijh} = \text{lecturer } i \in \{1, \dots, n_2\} \text{ teaching class } j \text{ at time } h
z_{ijh} = \text{tenure-track professor } i \in \{1, \dots, n_3\} \text{ teaching class } j
at time h
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➤ Softness Variables: these are binary and non-negative integer variables added in to allow some constraints to not be fully satisfied

Goal

We want to find what schedule maximizes instructor time and course preferences

Objective Function

Let $a_{ij} =$ preference weight for person i teaching course j, and $b_{ih} =$ preference weight for person i teaching at time h. Then the objective is to:

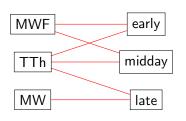
$$\max \sum_{i=1}^{n_1} \sum_{j=1}^m \sum_{h=1}^l f(a_{ij}, b_{ih}) x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=1}^m \sum_{h=1}^l f(a_{ij}, b_{ih}) y_{ijh} + \sum_{i=1}^{n_3} \sum_{j=1}^m \sum_{h=1}^l f(a_{ij}, b_{ih}) z_{ijh} - \text{softness variables}$$

Where $f(a_{ij}, b_{ih})$ is some function of the preferences. We tested f(a, b) = ab and f(a, b) = a + b

Determining a

- ► A weight of 0 is given to any course an instructor explicitly said they did not want to teach
- ► A weight of 0.25 is given to any course an instructor did not mention in the spreadsheet
- ▶ In general, a weight of 1 is given to a person and course if it was their top choice when ranking upper/lower/lecture courses.
- ➤ Similarly, a weight of 0.75 is given to second choices, and 0.5 to third choices
- ▶ However, if a person did not volunteer to teach large lectures, their preferences for those were reduced to 0.3, 0.2, and 0.1 respectively.

Determining b



- 1. Rank MWF/TTh/MW 1-3 (1 best)
- 2. Rank early/midday/late 1-3 (1 best)
- 3. Multiply the values as shown in the image
- 4. Assign the following preferences by the product:
 - 1 = 1
 - **▶** 2 = 0.8
 - **▶** 3 = 0.6
 - **▶** 4 = 0.4
 - ightharpoonup 6 = 0.2
 - **▶** 9 = 0

Constraints

1. Each course should be assigned exactly one time slot and one instructor, with the exception of some lower-level courses or large lectures which may be filled in by new instructors later.

$$\sum_{i=1}^{n_1} \sum_{h=1}^{l} x_{ijh} + \sum_{i=1}^{n_2} \sum_{h=1}^{l} y_{ijh} + \sum_{i=1}^{n_3} \sum_{h=1}^{l} z_{ijh} = 1 - p_j \qquad \forall j \quad (1)$$

$$p_j = 0 \quad \forall j \in \{\text{upper-level or grad class}\}$$
 (2)

2. Each person teaches at most one class during any time-slot.

$$\sum_{i=1}^{m} x_{ijh} \le 1 \qquad \forall i \in \{1, \dots, n_1\}, h$$
 (3)

$$\sum_{j=1}^{m} y_{ijh} \leq 1 \qquad \forall i \in \{1, \dots, n_2\}, h \tag{4}$$

$$\sum_{j=1}^{m} z_{ijh} \leq 1 \qquad \forall i \in \{1, \dots, n_3\}, h$$
 (5)

3. Pre-assigned course-instructor c, i pairings are upheld. Let $C = \{j : j \text{ is a section of course } c\}$

$$\sum_{i \in C} \sum_{h=1}^{l} x_{ijh} = r_{ic} \tag{6}$$

if the instructor is a VAP,

$$\sum_{j\in\mathcal{C}}\sum_{h=1}^{l}y_{ijh}=r_{ic}\tag{7}$$

if the instructor is a lecturer, and

$$\sum_{i\in\mathcal{C}}\sum_{h=1}^{l}z_{ijh}=r_{ic}\tag{8}$$

if the instructor is a tenure-track professor, where r_{ic} = the number of sections of course c instructor i is teaching.

4. Instructors that cannot teach certain classes should not be assigned to teach those classes.

For fixed i^* and j^* being the instructor-course pair that cannot be assigned:

$$\sum_{h=1}^{l} x_{i^*j^*h} = 0 (9)$$

if the instructor is a VAP,

$$\sum_{h=1}^{l} y_{i^*j^*h} = 0 (10)$$

if the instructor is a lecturer, and

$$\sum_{h=1}^{I} z_{i*j*h} = 0 (11)$$

if the instructor is a tenure-track professor.

Instructors that cannot teach at certain times should not be assigned to teach during those times.

For fixed i^* and h^* being the instructor-time pair that cannot be assigned:

$$\sum_{j=1}^{m} x_{i^*jh^*} = 0 (12)$$

if the instructor is a VAP,

$$\sum_{j=1}^{m} y_{i^*jh^*} = 0 (13)$$

if the instructor is a lecturer, and

$$\sum_{i=1}^{m} z_{i^*jh^*} = 0 \tag{14}$$

if the instructor is a tenure-track professor.

6. Lecturers cannot teach upper-level classes.

$$\sum_{h=1}^{l} x_{ijh} = 0 \qquad \forall i \in \{1, \dots, n_1\}, j \in \{\text{upper-level}\}$$
 (15)

7. Each instructor teaches the correct number of courses. As this number cannot be generalized for everyone, we will assign each person a parameter L_{xi} , L_{yi} , or L_{zi} accordingly that represents the load or number of classes that person is able to teach. (SOFT, may teach 1 less course)

$$\sum_{j=1}^{m} \sum_{h=1}^{l} x_{ijh} = L_{xi} \qquad \forall i \in \{0, \dots, n_1\}$$
 (16)

$$\sum_{i=1}^{m} \sum_{h=1}^{l} y_{ijh} = L_{yi} \qquad \forall i \in \{0, \dots, n_2\}$$
 (17)

$$\sum_{i=1}^{m} \sum_{k=1}^{l} z_{ijh} = L_{zi} \qquad \forall i \in \{0, \dots, n_3\}$$
 (18)

8. Instructors should not be assigned to teach both MWF/MW and TTh.

$$\sum_{j=1}^{m} x_{ijh'} + \sum_{j=1}^{m} x_{ijh''} \le 1 + q_{xi} \qquad \forall i, h', h''$$
 (19)

$$\sum_{j=1}^{m} y_{ijh'} + \sum_{j=1}^{m} y_{ijh''} \le 1 + q_{yi} \qquad \forall i, h', h''$$
 (20)

$$\sum_{j=1}^{m} z_{ijh'} + \sum_{j=1}^{m} z_{ijh''} \le 1 \qquad \forall i, h', h''$$
 (21)

Where $h' = \{1, ..., 8\}$, $h'' = \{9, ..., 14\}$, and $q_{xi}, q_{yi} = 1$ if a VAP or lecturer respectively would like to teach all 5 days, 0 otherwise.

Instructors should not be assigned to teach both early MWF and late MW. (SOFT for lecturers)

$$\sum_{j=1}^{m} x_{ij1} + \sum_{j=1}^{m} x_{ijw} \le 1 \qquad \forall i$$
 (22)

$$\sum_{j=1}^{m} y_{ij1} + \sum_{j=1}^{m} y_{ijw} \le 1 \qquad \forall i$$
 (23)

$$\sum_{j=1}^{m} z_{ij1} + \sum_{j=1}^{m} z_{ijw} \le 1 \qquad \forall i$$
 (24)

Where w = the last MW time slot.

 Instructors should not be assigned to teach both early and late TTh. (SOFT for lecturers)

$$\sum_{j=1}^{m} x_{ij(w+1)} + \sum_{j=1}^{m} x_{ijl} \le 1 \qquad \forall i$$
 (25)

$$\sum_{j=1}^{m} y_{ij(w+1)} + \sum_{j=1}^{m} y_{ijl} \le 1 \qquad \forall i$$
 (26)

$$\sum_{j=1}^{m} z_{ij(w+1)} + \sum_{j=1}^{m} z_{ijl} \le 1 \qquad \forall i$$
 (27)

Where w = the last MW time slot, I = the last TTh time slot.

11. For each time slot, there should be an appropriate number of lower- and upper-level courses being taught so we can assign classes to rooms. (SOFT with large penalty)

$$\left\lfloor \frac{\alpha}{\beta} \right\rfloor \leq \sum_{i=1}^{n_1} \sum_{j=1}^{\alpha} x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=1}^{\alpha} y_{ijh} + \sum_{i=1}^{n_3} \sum_{j=1}^{\alpha} z_{ijh} \leq \left\lceil \frac{\alpha}{\beta} \right\rceil$$

$$\forall h \in \{ \text{not first or last of the day} \}$$
(28)

$$\left\lfloor \frac{m - \alpha}{\beta} \right\rfloor \leq \sum_{i=1}^{n_1} \sum_{j=\alpha+1}^m x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=\alpha+1}^m y_{ijh}$$

$$+ \sum_{i=1}^{n_3} \sum_{j=\alpha+1}^m z_{ijh} \leq \left\lceil \frac{m - \alpha}{\beta} \right\rceil \quad \forall h \in \{ \text{not first or last of the day} \}$$
(29)

Where $\alpha=$ the number of lower-level and large lecture sections being taught, and $\beta=$ the number of time slots that are not the first or last of the day.

11. For less-popular time slots, we don't need to lower-bound the number of classes.

$$\sum_{i=1}^{n_1} \sum_{j=1}^{\alpha} x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=1}^{\alpha} y_{ijh} + \sum_{i=1}^{n_3} \sum_{j=1}^{\alpha} z_{ijh} \le \left\lceil \frac{\alpha}{\beta} \right\rceil$$

$$\forall h \in \{ \text{first or last of the day} \}$$
(30)

$$\sum_{i=1}^{n_1} \sum_{j=\alpha+1}^m x_{ijh} + \sum_{i=1}^{n_2} \sum_{j=\alpha+1}^m y_{ijh} + \sum_{i=1}^{n_3} \sum_{j=\alpha+1}^m z_{ijh} \le \left\lceil \frac{m-\alpha}{\beta} \right\rceil$$

$$\forall h \in \{ \text{first or last of the day} \}$$
(31)

12. We do not want sections of core courses (lower-level, large lecture) to overlap too much. The number of sections of a given course that can overlap will depend on how many sections of that class there are, so we assign a parameter: s_c = max number of sections of core course c that can be taught during a time-slot.

Let $C = \{j : j \text{ is a section of course } c\}$

$$\sum_{j \in C} \sum_{i=1}^{n_1} x_{ijh} + \sum_{j \in C} \sum_{i=1}^{n_2} y_{ijh} + \sum_{j \in C} \sum_{i=1}^{n_3} z_{ijh} \le s_j \quad \forall h, c \in \{\text{core courses}\}$$
(32)

13. We want courses that are commonly taken together to have little overlap so that students are able to fit all of those courses in their schedule. For some courses that have many sections, there can be some overlap between that class and another, but for upper-level courses that have only one or two sections, we want these sections to be at different times. Take sets D_1, D_2, \ldots to be sets of j that belong to lower-level courses often taken together.

$$\sum_{j \in D_k} \left(\sum_{i=1}^{n_1} x_{ijh} + \sum_{i=1}^{n_2} y_{ijh} + \sum_{i=1}^{n_3} z_{ijh} \right) \le 2 \qquad \forall h, k$$
 (33)

Take sets $F_1, F_2,...$ to be sets of j that belong to upper level courses often taken together.

$$\sum_{i \in F_k} \left(\sum_{j=1}^{n_1} x_{ijh} + \sum_{i=1}^{n_2} y_{ijh} + \sum_{j=1}^{n_3} z_{ijh} \right) \le 1 \qquad \forall h, k \qquad (34)$$

14. If someone is up for promotion but has not taught a variety of courses yet, we want them to teach at least one new course during this semester.

Let

 $\alpha_i = \{c : \text{person } i \text{ has taught course } c \text{ before}\}\$ $C_{\alpha_i} = \{j : j \text{ is a section of a course in } \alpha_i\}$

$$\sum_{j \in C_{\alpha_i}} \sum_{h=1}^{l} x_{ijh} + 1 \le \sum_{j=1}^{m} \sum_{h=1}^{l} x_{ijh}$$
 (35)

 $\forall i \in \{VAPs \text{ to be promoted and needs new courses}\}\$

$$\sum_{j \in C_{\alpha_i}} \sum_{h=1}^{l} y_{ijh} + 1 \le \sum_{j=1}^{m} \sum_{h=1}^{l} y_{ijh}$$
 (36)

 $\forall i \in \{ \text{lecturers to be promoted and needs new courses} \}$

15. To ensure that courses for which some sections are left open still have a qualified chair, we want at least one of the sections to be taught by a tenure-track professor or permanent lecturer. (SOFT, and forced to not need to hold if a VAP is pre-assigned to a course)

$$\sum_{i=1}^{n_3} \sum_{j \in C} \sum_{h=1}^{l} z_{ijh} + \sum_{i=1}^{n_2} \sum_{j \in C} \sum_{h=1}^{l} y_{ijh} \ge 1$$
 (37)

 $\forall c \in \{\text{lower-level or big lecture}\}\$

Monday	Tuesday	Wednesday	Thursday	Friday
3.00-3:50	8:38-9:45 337 2 - more 27 337 3 - more 28 337 43 - more 28 Perlose 2 - more 40 Perlose 2 - more 20 Perlose 2 - more 20	8.00-8.50	B:20-5-45 MF2 : more 27 MF3 - more 35 MF4 : more 36 Professor 1 - more 40 Professor 31 - more 20 Professor 31 - more 20	8.60.8.69
9.05-9.55 VAP 4: convey 21 VAP 5: convey 28 VAP 5: convey 28 Letters 2 - convex 41 Letters 2 - convex 6 Letters 2 - convex 6 Letters 1 - convex 6 Letters 1 - convex 6 Professor 6 - convex 6 Professor 7 - convex 6 Professor 7 - convex 6 Professor 2 - convex 6 Professor 3 - convex 6 Professor 4 - convex 6 Professor 5 - convex 6 Professor 6 - convex 6 Professor 6 - convex 6 Professor 7 - convex 6 Professor 8 - convex 6 Professor 9 - convex 6	BB:564-11:15 A322-course fit A322-course fit A322-course fit A322-course fit A322-course fit Lateure L-amount fit Lateure L-amount fit Lateure L-amount fit Februar 3-course fit Februar 3-course fit Februar 13-course fit Februar 13-course fit Februar 13-course fit Februar 13-course fit	9,65.49.55 NAP 8: course 23 NAP 9: course 24 NAP 9: course 24 Lestiner 2 - course 4 Lestiner 2 - course 4 Lestiner 1 - course 16 Lestiner 12 - course 6 Lestiner 12 - course 6 Perdoner 23 - course 6 Probase 23 - course 62	10:40-11:15 VAP 2 - courte El Latteur 4 - courte El Latteur 5 - courte El Prodoux 1 - courte El	9.605-9.55 NOT # course 21 NOT # course 21 LOST * course 21 LOST * course 24 Lostour 3 * course 4 Lostour 7 * course 6 Lostour 1 * course 15 Lostour 1 * course 15 Professor 4 * course 57 Professor 7 * course 67 Professor 7 * course 67 Professor 20 * course 62
He/H-11:00 VEXT - comm 2) VEXT - comm 2) VEXT - comm 3) ANT 6 - comm 36 Lemmer 2 - comm 4 Lemmer 3 - comm 6 Lemmer 3 - comm 6 Lemmer 3 - comm 6 Lemmer 10 - comm 6 Lemmer 10 - comm 6 Professor 6 - comm 6 Professor 5 - comm 67		He/9-III-00 VLF 8 - memo 31 AAP 9 - memo 36 AAP 10 - memo 36 AAP 10 - memo 36 AAP 10 - memo 36 Lentwer 2 - memo 4 Lentwer 3 - memo 4 Lentwer 3 - memo 4 Professor 31 - memo 46 Professor 31 - memo 46 Professor 31 - memo 46		H=18-31-00 VAF 1 - commo 30 VAF 1 - commo 30 VAF 1 - commo 34 VAF 1 - commo 34 Lemener 2 - commo 4 Lemener 3 - commo 4 Lemener 3 - commo 4 Lemener 4 - commo 4 Lemener 4 - commo 4 Lemener 4 - commo 4 Findacar 5 - commo 4 Findacar 5 - commo 4 Findacar 5 - commo 47
10:15-12:05 VEP 1 - control 27 VEP 15 - control 36 Levinew 2 - control 36 Levinew 3 - control 13 Levinew 10 - control 13 Levinew 10 - control 14 Levinew 10 - control 2 Levinew 10 - control 3 Levinew 10 - control 3 Pediator 10 - control 3 Pediator 10 - control 5 Pediator 10 - control 51	11:39-12:45 MAP - course 29 MER - course 29 Lantoure 1 - course 30 Lantoure 10 - course 30 Problems 27 - course 37 Problems 28 - course 30 Problems 29 - course 30 Problems 29 - course 30	H : 05-12-05 ANP 1 - course 27 ANP 25 - course 25 Lostover 2 : course 3. Lostover 3 : course 3. Lostover 10 - course 3. Lostover 10 - course 3. Lostover 12 - course 3. Lostover 12 - course 3. Professor 24 - course 4. Professor 24 - course 5.9 Professor 24 - course 5.9	11:50-12:45 AVE 3 - come 28 AVE 4 - come 28 Learner 1 - come 28 Learner 1 - come 18 Learner 1 - come 18 Learner 10 - come 18 Professor 17 - come 18 Professor 17 - come 19 Professor 18 - come 11	H188.12.00 VM 1 - serrer 27 VM 1 - serrer 38 Lesteur 2 - serrer 38 Lesteur 3 - serrer 13 Lesteur 4 - serrer 14 Lesteur 6 - serrer 14 Lesteur 6 - serrer 14 Lesteur 7 - serrer 14 Lesteur 7 - serrer 16 Probass 14 - serrer 18 Probass 17 - serrer 18 Probass 18 - serrer 19 Probass 18 - serrer 19
E128-1.18 NJ 13 - convex in Lettions 7 - convex in Lettions 7 - convex is Lettions 7 - convex is Lettions 18 - convex is Lettions 18 - convex is Lettions 18 - convex is Professor 15 - convex is Professor 15 - convex is Professor 25 - convex is Professor 25 - convex is	1:80-2:15 33.75 course 20 33.75 course 21 33.75 course 21 Lainer 1 course 31 Lainer 1 course 31 Fachers 31 course 31 Fachers 31 course 31 Fachers 31 course 31 Fachers 32 course 32 Fachers 32 course 32 Fachers 32 course 33	12:08-1:09 NOT 11: moure 61 Lottory 7-cores 13 Lottory 7-cores 13 Lottory 12: moure 62 Lottory 13: cores 14 Lottory 14: cores 16 Lottory 14: cores 16 Probase 23: cores 26 Probase 23: cores 28 Probase 23: cores 28	1300-2:15 VAD 3 - more 20 VAD 4 - consent 21 VAD 4 - consent 21 VAD 4 - consent 21 Lecture 1 - more 20 Lecture 1 - more 20 Producer 11 - more 20 Producer 11 - more 20 Producer 11 - more 20 Producer 21 - more 20 Producer	12:03-12:03 AN III content to Lestower 3 - content to Lestower 4 - content to Lestower 1 - content to Producer 1 - content to Producer 2 - content to Producer 3 - content to Producer 3 - content to Residence 3 - content to
1-25-2-15 VAP 1 - conven 27 VAP 5 - conven 2 VAP 5 - conven 2 Lottower 10 - conven 10 Polloner 10 - conven 10		1/25/2/18 NPT 1 - outers 27 NPT 5 - outers 46 Lotturer 4 - outers 18 Lotturer 18 - outers 18 Lotturer 11 - outers 18 Lotturer 13 - outers 18 Professor 5 - contex 25 Professor 5 - contex 25 Professor 12 - souter 18 Professor 12 - souter 18 Professor 13 - souter 18 Professor 11 - souter 18		1-25-2-15 NAT 1- course 27 NAT 1- Course 4. NAT 1- Course 4. Lattery 11- course 1. Lattery 11- course 16 Lattery 11- course 16 Lattery 11- course 16 Perious 21- course 2. Prious 11- course 2. Prious 21- course 3.
2,304.3/45 Volt 4 comment 17 Volt 4 comment 26 Volt 30 comment 26 Volt 30 comment 26 Volt 30 comment 27 Professor 1 comment 27 Professor 1 comment 28 Professor 1 comment 28 Professor 10 comment 28 Professor 20 comment 28	2,08-3/45 MAF is more 26 MAF is more 28 Landown 1 - more 21 Landown 1 - more 21 Landown 2 - more 30 Landown 3 - more 30 Landown 3 - more 30 Landown 3 - more 30 Problem 21 - more 30 Problem 21 - more 30 Problem 21 - more 40	2,50,3,48 Volt 4, marco 17 Volt 5 marco 18 Volt 5 marco 18 Volt 5 marco 18 Volt 4 marco 18 Lecture 18 marco 18 Periose 1 marco 48 Periose 4 marco 38 Periose 14 marco 38 Periose 14 marco 38 Periose 14 marco 38	2.30-3/45 ADF 6. commer 26 ADF 9. commer 26 Lorenter 1 - commer 27 Lorenter 1 - commer 27 Lorenter 2 - commer 20 Lorenter 3 - commer 30 Lorenter 3 - commer 30 Lorenter 3 - commer 40 Pendener 31 - commer 30 Pendener 31 - commer 40 Pendener 31 - commer 40 Pendener 31 - commer 40	2:30-3+45
4:90-5:15 VSF 4:-manua 24 VSF 13manua 23 VSF 14manua 23	4:00-5:15 SSERIC remove IP Leature 6 - years IB Leature 7 - years IB Leature 12 - years IB Professor IP - common IB	4:00-5:15 NAF i: more 28 NAF D - more 20 NAF H - more 20	4:90-5:15 VAP No conserve Pr Learners 1- conserve Pr Learners 1- conserve Rr Learners 2- conserve Rr Fredman Pr - conserve Rr	4:89-5:15
5:30-6:45	5:30-6:45	5:30-6:45	5:30-4:45	5:30-6:45

Figure 1: Optimal Schedule 1 (a * b)

Monday	Tuesday	Wednesday	Thursday	Friday
1.004.50	\$136-9-45 NAF 2 merce 27 NAF 3 merce 28 NAF 43 merce 28 Professor 7 merce 41 Professor 8 merce 27 Professor 8 merce 28	E00450	\$136-9:45 337 2 more 27 337 7 more 28 337 10 more 28 Professor 3 more 28 Professor 8 more 27 Professor 8 more 28	800-850
9,05-9,55 NSF1 comme 11 NSF1 comme 13 NSF1 comme 13 NSF1 comme 13 Lattice 2 comme 6 Lattice 2 comme 6 Lattice 2 comme 11 Lattice 2 comme 11 Professor 10 comme 16 Professor 10 comme 16 Professor 10 comme 16 Professor 10 comme 17 Professor 20 comme 17	18:90-11:15 AVE2 - comic E AVE2 - comic E AVE2 - comic E AVE2 - comic E Leafment > comic E Leafment > comic E Leafment > comic E Pendemar 1- comic E	9:05-9:05 ***TAP***: create 21 ***TAP***: create 23 ***TAP***: create 24 ***TAP***: create 27	16:00-11:15 M22 - control 27 M22 - control 28 M22 - control 29 M22 - control 20 Lockson 4 - control 20 Probaso 21 - control 20 Probaso 21 - control 30 Probaso 21 - control 30 Probaso 31 - control 30	9:85-9:55 VOFE comme II VOFE comme II VOFE comme II VOFE comme II Excises II
10:10-11:00 NEF 0-cours 32 NEF 0-cours 36 NEF 10: news 36 NEF 10: news 36 Lameur 2-cours 5 Lameur 2-cours 6 Lameur 3-cours 6 Lameur 3-cours 6 Lameur 6: news 11 Lameur 11: news 12 Professer 1-cours 23 Professer 3-cours 23		10:18-11:90 VAF4 - contex 52 VAF4 - contex 52 VAF14 - contex 52 VAF14 - contex 52 Loctore 3 - contex 5 Loctore 3 - contex 6 Loctore 3 - contex 6 Loctore 5 - contex 6 Loctore 7 -		10 c 16 c 11 c 10
H: 65-12-95 ANT 1 - comme 27 Lenteure 2 - comme 37 Lenteure 3 - comme 15 Lenteure 4 - comme 15 Lenteure 4 - comme 15 Lenteure 7 - comme 16 Lenteure 10 - comme 20 Lenteure 10 - comme 20 Lenteure 10 - comme 20 Professor 15 - comme 50 Professor 15 - comme 50 Professor 12 - comme 50	11:38-12:45 Volt 4: comm 17: Latinut 1 - comm 17: Latinut 1 - comm 17: Latinut 2: comm 18: Latinut 2: comm 18: Latinut 18: comm 18: Professor 11: comm 18: Professor 18: comm 18:	H155-42-95 VAF 1 - contex 25 Lecture 2 - contex 5 Lecture 2 - contex 5 Lecture 2 - contex 5 Lecture 2 - contex 1 Lecture 2 - contex 6 Lecture 10 - contex 1 Lecture 10 - contex 1 Lecture 10 - contex 1 Professor 2 - contex 5 Professor 2 - contex 5 Professor 2 - contex 5	11:38-12:45 MJ 4: conver 17 Latinus 1 - conver 17 Latinus 1 - conver 17 Latinus 2 - conver 17 Latinus 3 - conver 17 Latinus 18: conver 18 Fradewar 18: conver 18 Fradewar 18: conver 28	H:15-12:05 VFT - comment 2 Lecture 2 - comment 5 Lecture 3 - comment 5 Lecture 4 - comment 5 Lecture 5 - comment 10 Lecture 5 - comment 10 Lecture 10 - comment 10 Lecture 10 - comment 10 Professor 25 - comment 40 Professor 25 - comment 30 Professor 25 - comment 30
12:38:438 NF 5 - once 46 NF 16 - once 30 Leziner 1- once 21 Leziner 18 - once 22 Leziner 18 - once 34 Pridose 7 - once 36 Pridose 7 - once 37 Pridose 14 - once 48 Pridose 14 - once 48 Pridose 15 - once 38	1.66-2:15 1.06-2:15 1.07 in comme (F) Learner (F) Learner (F) Learner (F) Learner (F) Learner (F) Politics (F)	12:20:1:10 VAPE 1- common in VAPE 1- common in VAPE 1- common in Ladaurer 1- common il Locturer III - common il Locturer III - common il Professor 1- common il Professor 1- common il Professor 1- common il Professor 2- common il Professor 2- common il Professor 24 - common il Professor 25 - comm	E-60-2-15 VAP is conver in Lance II conver in Lance II conver in Lance II conver il Lance II conver il Probase II conver il Probase III conver il Probase III conver il Probase III conver il Probase II conver il Probase	12-20-1-18 VFS - serion 8 VFF - serion 8 Lecture 1-mone 2 Lecture 21-mone 14 Lecture 21-mone 14 Lecture 21-mone 14 Professor 1-mone 2 Professor 1-mone 2 Professor 1-mone 2 Professor 2-mone 2 Professor 2-mone 2 Professor 21-mone 4 Professor 21-mone 4 Professor 21-mone 4 Professor 21-mone 4
1.25-2.65 VAP 1 - owner 27 VAP 5 - owner 25 VAP 15 - owner 25 VAP 15 - owner 25 Lemmer 18 - owner 14 Lemmer 18 - owner 14 Lemmer 13 - owner 25 Professor 12 - owner 25 Professor 12 - owner 28		1125-2115 VAF 1 - come 27 VAF 2 - come 25 VAF 25 - come 36 VAF 25 - come 46 Lecture 10 - come 14 Lecture 11 - come 14 Lecture 13 - come 5 Federate 13 - come 5 Federate 12 - come 5		1.25-2.15 V.F.1 - commo 27 V.F.2 - commo 27 V.F.3 - commo 28 V.F.2 - commo 28 V.F.2 - commo 28 Lecture 18 - commo 14 Lecture 18 - commo 14 Lecture 19 - commo 14 Lecture 19 - commo 14 Lecture 19 - commo 14 Performe 17 - commo 29 Professor 17 - commo 21 Professor 27 - commo 28
2:30-30-65 VSF 4: manue 77 VSF 4: manue 78 VSF 11: manue 30 VSF 31: manue 30 VSF 31: manue 40 Lorstow 14: manue 40 Lorstow 14: manue 40 Fradmow 14: manue 44 Fradmow 14: manue 45 Fradmow 16: manue 36 Fradmow 16: manue 36	2.36-3.465 VAF 3. manue 24 VAF 3. manue 24 VAF 25. manue 24 VAF 25. manue 34 VAF 25. manue 34 Explainer 16. manue 38 Professor 17. manue 38 Professor 33. manue 38 Professor 34. manue 38	2:38-30-45 VAF 4: comes 17 VAF 4: comes 18 VAF 5: comes 18 VAF 5: comes 28	2.38-3.45 13.23 - comp 29 13.25 - comp 20 14.25 - comp 20 15.25 - comp 20 15.2	238-3-45
4/00.5(15 Val U - marc 21 Professor 6 - marc 28	4.00.5(15) Vall 3. comme 28 Vall 16. comme 28 Larenum 7. comme 18 Larenum 19. comme 18 Larenum 19. comme 19. Larenum 19. comme 19. Larenum 19. comme 19. Larenum 19. comme 19. Produces 23. comme 48 Produces 23. comme 48	4:00-5;25 33F33-course 33 Professor 4:course 28	4.00-5:15 13.23 - come 28 13.24 is, come 28 13.25 is, come 28 14.25 is, come 28 15.25 is, come 28 15.25 is come 15 15.25 is c	489-5:15
538445	539.445	539445	538448	5,08445

Figure 2: Optimal Schedule 2 (a + b)

A Closer Look at Some Instructors

Professor 8

- 2 classes
- ▶ Upper-level preferences: 37, (41,34), (28,39)
- Does not volunteer for large lectures
- Lower-level preferences: 18, 13
- No classes they prefer not to teach
- Time preferences: Early (not 8am MWF), midday, late
- Day preferences: TTh, MW, MWF
- ► Has reasons to only teach 2 days a week (didn't implement)
- No specific time they can't teach
- ➤ **Schedule 1:** teaching 37 (TTh 8:30-9:45) and 18 (TTh 10-11:15)
- ➤ **Schedule 2:** teaching 37 (TTh 8:30-9:45) and 38 (TTh 10-11:15)

A Closer Look at Some Instructors

Lecturer 11

- 3 classes
- Does not want to teach upper-level courses
- ► Large lecture preferences: (4,8), (9,1,2), (11,6,7) (volunteers)
- Lower-level preferences: 10, 40 (not lower-level), 14
- ▶ Time preferences: Early, midday, late
- Day preferences: TTh, MWF, MW
- No specific time they can't teach
- Schedule 1: teaching 14 (MWF 9:05-9:55), 14 (MWF 10:10-11), 16 (MWF 1:25-2:15)
- Schedule 2: teaching 16 (MWF 10:10-11), 14 (MWF 12:20-1:10), 14 (MWF 1:25-2:15)

A Closer Look at Some Instructors

VAP 2

- 2 classes
- ▶ Upper-level preferences: (28,39,41,36,23,37), (30,27), (34,26)
- Does not volunteer for large lectures
- ► Lower-level preferences: (18,13), (17,16), 14
- No classes they prefer not to teach
- Time preferences: Early, midday, late
- Day preferences: TTh, MW, MWF
- Can't teach Tuesdays 4-5pm
- **Schedule 1:** teaching 27 (MW 4-5:15), 27 (TTh 10-11:25)
- **Schedule 2:** teaching 27 (TTh 8:30-9:45), 27 (TTh 10-11:25)

Change Minimizer

Decisions

We want to decide who is teaching what class and when in the new schedule, and what has changes

Variables

- Assignment Variables: We will have the same x_{ijh} , y_{ijh} , z_{ijh} , and p_j variables in this program as in the schedule builder.
- ► Change Variables: We have binary variables (1 = yes, changed, 0 = no, stayed the same):
 - $\hat{x}_{ijh} =$ whether the status of VAP i teaching class j at time h has changed
 - \hat{y}_{ijh} = whether the status of lecturer i teaching class j at time h has changed
 - $\hat{z}_{ijh} =$ whether the status of tenure-track professor i teaching class j at time h has changed
- ➤ Softness Variables: more variables to allow some constraints to not be fully satisfied if necessary

Change Minimizer

Goal

We want to find the schedule the minimizes changes made to an original schedule.

Objective Function

min
$$\sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{h=1}^{l} \hat{x}_{ijh} + \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{h=1}^{l} \hat{y}_{ijh} + \sum_{i=1}^{n} \sum_{j=1}^{m} \sum_{h=1}^{l} \hat{z}_{ijh} + \text{ softness variables}$$
(38)

Change Minimizer

Constraints:

1. We will take an already-created schedule, and assign the following binary (1 = yes, 0 = no) parameters from that: $\overline{x}_{ijh} = \text{lecturer } i \text{ teaches class } j \text{ at time } h \text{ in original schedule}$ $\overline{y}_{ijh} = \text{VAP } i \text{ teaches class } j \text{ at time } h \text{ in original schedule}$ $\overline{z}_{ijh} = \text{tenure-track professor } i \text{ teaches class } j \text{ at time } h \text{ in original schedule}$

Then we want the $\hat{x}, \hat{y}, \hat{z}$ variables to take on the right values, so we have:

$$\hat{x}_{ijh} = x_{ijh} + \overline{x}_{ijh} - 2\overline{x}_{ijh}x_{ijh} \qquad \forall i, j, h$$
 (39)

$$\hat{y}_{ijh} = y_{ijh} + \overline{y}_{ijh} - 2\overline{y}_{ijh}y_{ijh} \qquad \forall i, j, h \tag{40}$$

$$\hat{z}_{ijh} = z_{ijh} + \overline{z}_{ijh} - 2\overline{z}_{ijh} x_{ijh} \qquad \forall i, j, h$$
 (41)

Change Minimizer Constraints

- 2. All constraints from the schedule builder will apply for this program as well.
- 3. For instructor i^* who has an issue with teaching class j^* , we add a constraint as in (4) of the schedule builder.
- 4. For instructor i^* who has an issue with teaching at time h^* , we add a constraint as in (5) of the schedule builder.

Change Minimizer Constraints

 For an instructor i* who is suddenly on leave, we add a constraint

$$\sum_{i=1}^{m} \sum_{h=1}^{l} x_{i*jh} = 0, (42)$$

$$\sum_{j=1}^{m} \sum_{h=1}^{l} y_{i^*jh} = 0, \text{ or}$$
 (43)

$$\sum_{j=1}^{m} \sum_{h=1}^{l} z_{i^*jh} = 0 \tag{44}$$

to match the level of instructor they are.

Change Minimizer Constraints

6. If pre-registration, all courses c should keep its original instructor i^* and have the time changed. (SOFT) Where $C = \{j : j \text{ is a section of course type } c\}$,

$$\sum_{i \in C} \sum_{h=1}^{I} x_{i*jh} = 1 \qquad \forall c \tag{45}$$

$$\sum_{i \in C} \sum_{h=1}^{l} y_{i*jh} = 1 \qquad \forall c \tag{46}$$

$$\sum_{j\in\mathcal{C}}\sum_{h=1}^{l}z_{i*jh}=1 \qquad \forall c \tag{47}$$

7. If post-registration, a course c should keep its time-slot h^* and have the instructor changed. (SOFT)

$$\sum_{j \in C} \sum_{i=1}^{n_1} x_{ijh^*} + \sum_{j \in C} \sum_{i=1}^{n_2} y_{ijh^*} + \sum_{j \in C} \sum_{i=1}^{n_3} z_{ijh^*} = 1 \qquad \forall c \quad (48)$$

Changes Made to Schedule 1 (a * b):

- 1. VAP 5 teaching course 26
- 2. VAP 14 teaching at time 7
- 3. Lecturer 11 teaching at time 3
- 4. Professor 14 teaching at time 11
- 5. Professor 2 on leave

Monday	Tuesday	Wednesday	Thursday	Friday
160 May 1 160 A 50 march B Vol 11 - march B Vol 12 - march B Letter II - centre I I Pridone I - centre I I Pridone I - centre I I Pridone I - centre II Pridone I - centre II	National State of the Control of the	1600-501 VAP 9 - course 28 VAP 9 - course 28 VAP 9 - course 30 Lecture 11 - course 14 Performe 1 - course 40 Performe 1 - course 40 Performe 15 - course 40 Performe 15 - course 40 Performe 15 - course 40 Performe 15 - course 40 Performe 27 - course 32 Performe 29 - course 32	## 100 - 5 (m) 1 (m) 2 (500-455 500-45
9,65-9;55 NOF7-course 23 NOF7-course 38 Leatinum 5-course 16 Leatinum 6-course 17	16:00-11:15 Vel 1-course 24 Vel 1-course 24 Vel 1-course 24 Vel 1-course 24 Follows 1-course 42 Follows 1-course 40 Follows 1-course 40 Follows 11-course 40 Follows 11-course 21	\$165.9155 NAP 1- comme 25 NAP 1- comme 85 NAP 1- comme 86 Lentwer 6 - comme 84 Lentwer 6 - comme 87	10-00-11:15 VM1 - mone M VM2 - mone M VM2 - mone M VM2 - mone M Part of the mone M Part o	9.05.5/55 NAT: comm 23 NAT: comm 33 Learner 1: comm 84 Learner 1: comm 87
10:20-11:00 NAP 13 - course 32 Lecture 4 - course 2 Lecture 9 - course 11		20: 20: 21: 60 VAP 13 - course 32 Lecturer 6 - course 2 Lecturer 9 - course 11		10:10-11:00 NAP 13 - overne 32 Lestener 6 - overne 2 Lestener 9 - overne 11
11:15-12:05 NOF 4 - more 24 Lenter 22 - more 5 Lenter 22 - more 4 Lenter 13 - more 8 Profesor 13 - more 44	11:30-12:45 Profesor 31 - seare 31	11:15-12:85 33P4 - course 24 Lecture 2 - course 5 Lecture 12 - course 5 Lecture 12 - course 8 Professor U - course 4	11:30-12:45 Profesor 31 - reserv 31	11:15-12:95 NAP 4 : marro-24 Entriere 7 : course 5 Leatmor 12 - course 4 Leatmor 13 - course 6 Professor 13 - course 44
12:20-0:19 NOP 5-corns 26 Lettiner II - corns 14 Professor 26 - corns 88	1:90-2:15 VMH - control III Lecture III - control IZ Fedinari III - control IZ Fedinari III - control IZ	12:00:0:10 VAPS - course 5 Lettave II - course 14 Professor 28 - course 48	1:00-2:15 Vol 14-auro 36 Lesters III centra 27 Federal III centra 27 Federal 27-centra 48	12:28-1:18 NOP 9 - course 26 Lestinos 61 - course 11 Professor 28 - course 48
1:25-2:15 NOT 2: course 41 NOT 12: course 46 Professor 30: course 21 Professor 20: course 47 Professor 30: course 49		1:25-2:15 33P 2 - more 41 33P 12 - more 45 Professor 84 - more 27 Professor 24 - more 49 Professor 28 - more 48		1:25-2:15 NAP 2: control 81 NAP 12: control 81 Professor 81: control 27 Professor 81: control 47 Professor 81: control 47
2 (30-3)45 VAF 2 - more 28 VAF 3 - more 27 VAF 13 - more 27 VAF 13 - more 28 Lecture 1 - more 6 Professor 26 - more 26 Professor 26 - more 28	2:30-3:45	2 (34)-3/45 MAP 1 - course 20 MAP 1 - course 20 MAP 13 - course 20 MAP 13 - course 20 Lecture 1 - course 30 Fredomor 21 - course 40 Fredomor 22 - course 40	2:39-3:45	2:30-3+45
4,00-5;15 VOM-Lorenz S VOM-Lorenz S Lottens H-rome S Lottens H-rome S Professor 21—rome S Professor 21—rome S	d. disk-d. 15 Voll 1 - morary 20 Voll 2 - morary 20 Voll 3 - morary 20 Voll 4 - morary 20 Voll 4 - morary 20 Lances 2 - morary 30 Lances 2 - morary 30 Padeson 4 - morary 30 Padeson 4 - morary 31 Padeson 4 - morary 31 Padeson 31	4.00-5.15 VM 4. come 28 Latinot 7. come 28 Latinot 7. come 10 Parkers 14 Parkers 14 Parkers 15 Park	4:00-5:15 VOF 1- source 31 VOF 1- source 32 VOF 1- source 32 VOF 16- source 32 VOF 16- source 32 Letture 1- cource 33 Letture 1- cource 34 Pendance 1- cource 32 Pendance 1- cource 32 Pendance 1- cource 32 Pendance 21- cource 34 Pendance 31- cource 34 Pendance 31- cource 35 Pendance 31- cource 36 Pendance 31- cource 36 Pendance 31- cource 36 Pendance 31- cource 36 Pendance 31- cource 35 Pendance 31- cource 35 Pendance 31- cource 35	400-515
5:30-4:45	5:38-4:45	5:38-4:45	5:30-4:45	5:384:45

Figure 3: New Schedule 1 - Pre Registration

Monday	Tuesday	Wednesday	Thursday	Friday
8.00-8.50	B.39-5-45 Ver 3-monty 29 Ver 4-monty 20 Ver 4-monty 20 Ver 4-monty 20 Ver 12-monty 20 Ver 12-monty 20 Ver 13-monty 20 Leviner 3-monty 20 Leviner 3-monty 20 Leviner 3-monty 20 Leviner 4-monty 20	8.00.8.50	8:38-9:45 VAF 1-manus 25 VAF 4-manus 45 VAF 1-manus 41 VAF 21-manus 27 VAF 31-manus 27 Lecture 21-manus 30 Lecture 21-manus 30 Endowed 21-manus 30 Pauloued 31-manus 37	2,00-2,50
9:05-9:55 YEF 4 course 80 YEF 6 course 82 YEF 6 course 82 YEF 10-course 82 YEF 10-course 82 Earthurs 9-course 81 Lexthorn 81 course 81 Lexthorn 81 course 84 Frederick 9-course 87 Frederick 9-course 87 Frederick 9-course 87	10:99-11:15 YER 4-month 27 YOF 1-month 51 YOF 2-month 51 Locket 1-month 61 Locket 1-month 61 Locket 1-month 61 Locket 1-month 61 Particul 12-month 62 Particul 12-month 63 Particul 12-month 64 Particul 12-month 64 Particul 13-month	9,65-9;55 NAF 4 course 40 NAF 6 course 40 NAF 6 course 41 NAF 15 course 41 NAF 15 course 11 Lentwer 11 course 11 Lentwer 12 course 4 Pridous 5 course 57 Pridous 5 course 57 Pridous 5 course 57	19-90-11:15 VX7 4 - mone 27 VX7 1 - mone 15 Letture 1 - mone 15 Letture 2 - mone 17 Letture 1 - mone 17 Letture 11 - mone 17 Letture 17 - mone 17 Letture 17 - mone 17 Perfora 17 - mone 28 Perfora 17 - mone 28 Perfora 17 - mone 28	9 (05-0) (SC NF 4 - 10 - 10 - 10 - 10 - 10 - 10 - 10 -
10(18-11)00 VSF 3 - course 36 VSF 16 - course 67 VSF 16 - course 67 Lenters 2 - course 17 Lenters 2 - course 17 Lenters 4 - course 17 Professor 5 - course 18 Professor 6 - course 18 Professor 6 - course 18 Professor 6 - course 19 Professor 5 - course 27 Professor 5 - course 27 Professor 5 - course 28 Professor 5 - course 28 Professor 5 - course 28		H1.00-11.00 ANT 5 - course 36 ANT 5 - course 46 Lorent 2 - course 17 Lorent 2 - course 17 Lorent 2 - course 18 Lorent 2 - course 19 Lorent 2 - course 19 Pridous 7 - course 21 Pridous 7 - course 21 Pridous 6 - course 14 Pridous 10 - course 21		High-Light NFT comma In NFT comma In NFT incomma In NFT Incomma In Light 2 - grown IT Light 2 - grown IT Light 2 - grown IT Fridam 1 - grown IT Fridam 1 - grown II Fridam 2 - grown II Fridam II Fr
III.75-12.96 Levisure 2 - memor 14 Levisure 3 - memor 14 Levisure 3 - memor 15 Levisure 10 - memor 3 Levisure 10 - memor 3 Levisure 10 - memor 3 Professor 7 - course 27 Professor 7 - course 37 Professor 21 - memor 30 Professor 21 - memor 31 Professor 21 - memor 31 Professor 27 - memor 17	H1590-12-45 Y023-control P Y023-control P Y023-control P XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX	III.15-12.65 Lenters 2 i. outre 14 Lenters 2 i. outre 14 Lenters 18 course 13 Lenters 19 course 3 Lenters 19 course 3 Lenters 19 course 5 Professor 7 - course 27 Professor 7 - course 40 Professor 24 course 40 Professor 24 course 40 Professor 27 course 50 Professor 27 course 57	11:30-12:45 Produce M. conce M. VOT - conce M. VOT - conce M. VOT - conce M. VOT - conce M. Letters 1 conce M. Letters 1 conce M. Produce M. conce M.	Hald Edge Lentere 7 - course 16 Lentere 8 - course 16 Lentere 8 - course 16 Lentere 8 - course 18 Lentere 18 - course 20 Lentere 18 - course 20 Pridere 7 - course 27 Pridere 18 - course 27 Pridere 18 - course 20 Pridere 27 - course 20 Pridere 28 - course 20
Eligible (1) VMT commer 20 VMT 2 commer 20 VMT 2 commer 60 Earthough 4 commer 2 Earthough 6 commer 1 Earthough 10 commer 6 Earthough 10 commer 6 Earthough 10 commer 6 Earthough 10 commer 6 Erithough 10 commer 6 Erithough 10 commer 6 Erithough 10 commer 6 Erithough 10 commer 50	1:90-2:15 Vall II. manul II Letters 2 - manul II Letters 2 - manul II Letters 3 - manul II Letters 3 - manul II Letters 3 - manul II Patients 4 - manul II Patients II. manul II Patients III. manul II Patients III. manul II Patients III. manul II Patients II. manul II Patients II. manul II Patients II. manul II Patients III. manul II	12-08-1000 NPT 1-mome 28 NPT 2-control 68 NPT 2-control 60 Lectures 4 control 2 Lectures 10-mome 2 Lectures 10-mome 4 Lectures 10-mome 6 Perform 10-control 60 Perform 10-control 60 Perform 11-control 60 Perform 12-control 60 Perform 12-control 60 Perform 12-control 60 Perform 13-control 60 Perform 13-control 60 Perform 13-control 60	1:00-2:15 VAF II. manu II Leber 2: manu II Leber 2: manu II Leber 3: manu II Leber 3: manu II Pation II Pa	12(28) 1/18 VAT 1: mores 20 VAT 2: contex 30 Lantanes 4: marca 21 Lantanes 4: marca 21 Lantanes 10: mores 4: Lantanes 10: mores 6: Lantanes 10: mores 6: Lantanes 10: mores 6: Produces 21: contex 9: Produces 21: contex 9: Produces 21: contex 9:
135-2:15 VXF 1 - comma 27 VXF 2 - comma 29 VXF 2 - comma 40 Levisore 4 - comma 40 Levisore 11 - comma 14 Lexisore 12 - comma 14 Lexisore 12 - comma 18 Lexisore 13 - comma 18 Profices 13 - comma 18 Profices 15 - comma 18		1:25-2:15 NAF 1-course 27 NAF 2-course 46 Lecture 4 : course 46 Lecture 1 : course 14 Lecture 11 : course 14 Lecture 12 : course 16 Lecture 12 : course 18 Lecture 12 : course 18 Parloan 12 : course 2 Parloan 13 : course 2 Parloan 13 : course 2 Parloan 13 : course 20		1.25-2.25 VAF 2 - control 27 VAF 2 - control 28 VAF 2 - control 28 Levineur 1 - control 2 Levineur 1 - control 14 Levineur 1 - control 14 Levineur 10 - control 14 Levineur 10 - control 14 Professor 3 - control 23
2:38-3-045 VXF - sente 18 VXF 10 - mane 24 VXF 10 - mane 24 VXF 10 - mane 24 VXF 10 - mane 25 Lentwer 1 - mane 18 Lentwer 1 - mane 18 Professor 37 - sente 38	2.39-3-45 VOF Homester IS Lenterer Lomester IB Lenterer Lomester IB Lenterer Lomester IB Lenterer II- control IB Parliment IB- control IB	2:30-3:45 VAF - contact 25 VAF 10: contact 26 VAF 10: contact 24 VAF 10: contact 2 VAF 10: contact 2 VAF 10: contact 2 Lecture 1: contact 15 Lecture 10: contact 27 Findance 26: - contact 26	2:38-3:45 VEP H- memo 15 Lenteure 1 comme II Lenteure 1 comme II Lenteure 2 comme II Lenteure 3 comme II Lenteure 3 comme II Lenteure 4 comme II Professor II comme II Professor II comme II Professor II comme II Professor II comme II Professor III comme III Professor III comme III	2:39-3:45
4:00.5:15 VSF4: remon 23 Fridon 15 - contra 25 Fridon 28 - remon 26	4:50-5:15 VXF H - mount H VXF H - mount H VXF H - mount H Laborated H Laborated H Laborated H Parliamed H	4:90-5:15 VAF c. meno 23 Findame 13 - sentre 23 Findame 28 - sentre 28	4:86-5:15 Val Homeno H Val Homeno H Val Homeno H Lather I - control H Lather I - control H Police H - control H	4:80-5:15
539.645	539445	530445	539-645	53646

Figure 4: New Schedule 1 - Post Registration

Changes Made to Schedule 2 (a + b):

- 1. VAP 5 teaching course 24
- 2. VAP 14 teaching at time 7
- 3. Lecturer 11 teaching at time 3
- 4. Professor 13 teaching at time 10
- 5. Professor 2 on leave

Monday	Tuesday	Wednesday	Thursday	Friday
\$400-8:50 VAFI - course 24 VAFI - course di Lecture 6 - course 15 Lecture 14 - course 1 Professor 3 - course 44	8 (30)-0-16 SAR DESTRUCTION OF S	NOR-8-56 VAP I - course 54 VAP II - course 66 Lecturer 6 - course 16 Lecturer 14 - course 1 Professor 8 - course 64	\$1,30.49,45 VAP 13. conver 28 VAP 14. conver 28 VAP 14. conver 28 VAP 26. conver 28 Latine 11. conver 28 Problem 14. conver 14 Problem 14. conver 14 Problem 15. conver 28 Problem 16. conver 28 Problem 16. conver 38 Problem 16. conver 38 Problem 16. conver 38	E00-8-59 VAF 2 - course 24 VAF 3 - course 66 Lecturer 6 - course 66 Lecturer 8 - course 61 Professor 14 - course 61 Professor 8 - course 64
9.05-9:55 NPT r corner II NPT I d corner II Lorner I corner II Professor II corner II Professor II corner II Professor II corner II	16:98-11:15 NPT - count-off NPT 2: count-off NPT 2: count-off Professor 4 - count-15 Professor 4 - count-16	9:05-0:05 NAPT: comer 31 VAPT: 14: comer 36 Lotter 1: come 16 Lotter 1: come 16 Lotter 2: come 16 Lotter 2: come 16 Position 21: comer 30 Position 21: comer 30 Position 21: comer 27	10-50-11:15 NAT - counts 48 NAT 12 - counts 38 Latieur 1 - count 17 Professor 4 - counts 36	9:05-9:55 NAF7 - course IR NAF II - course IR Locture 1 - course IR Locture 2 - course IR Locture 2 - course III Federate II Professor II - course II Professor II - course II Professor II - course II
HEID-11390 NAT I course 46 NAT I course 46 NAT I course 45 NAT T course 27 NAT IT course 21 NAT IT course 21 NAT IT course 21 NAT IT course 21 NAT IT course 31 Learner 2 course 64 Learner 3 course 67 Learner 6 course 7 Professor 6 course 67 Professor 6 course 67 Professor 6 course 67		10(10-11:00 YASF 1 comme 40 YASF 2 comme 27 YASF 2 comme 27 YASF 2 comme 22 YASF 2 comme 22 YASF 2 comme 23 Loctory 2 comme 16 Loctory 2 comme 17 Loctory 3 comme 17 Posterior 1 comme 37 Posterior 1 comme 37 Posterior 1 comme 39		Helli-Hi.20 VASP 1 comme file VASP 2 comme file VASP 3 comme file VASP 4 comme file
11:15-12:85 NOFE - course 33 Lenterer 2 - course 9 Professor 31 - course 55	11:58-12:45 Net 4 - cores 25 Leature 12: - cores 4 Professor 12: - cores 6 Professor 11: - cores 60 Professor 11: - cores 60	11:15-12:85 VAFR: conner 33 Lecturer 2: conner 5 Professor 31 - conner 55	11:50-12:45 NP 4 - cores (2) Letters 12 - cores 4 Professor 11 - cores 4 Professor 21 - cores 60 Professor 21 - cores 61	H105-12-05 NAPA - course 33 Louiseve 3 - course 9 Professor 31 - course 55
12:29-0:19 Lenterer II - course III Professor II - course III Professor III - course III Professor III - course 24 Professor 25 - course 26	1:90-2:15 NATH control & fortune 3 - control ?? Professor H - control & Professor H - control &	12:20-1:10 Lecture 1 - course 13 Professor 7 - course 24 Professor 27 - course 24 Professor 28 - course 24 Professor 28 - course 30	1:98-2:15 Vol III concre di formere il concre III Professe III concre III Professe III concre III	12:28-1:38 Lentere 3 course 33 Professor 7 course 48 Professor 21 course 24 Professor 22 course 39
1-25-2-18 NOP 1 - course 34 NOP 2 - course 34 NOP 3 - course 34 NOP 3 - course 36 NOP 3 - course 35 Lottours 35 - course 35 Lottours 35 - course 36 Lottours 16 - course 36 Professor 6 - course 36 Professor 31 - course 38 Professor 31 - course 38 Professor 34 - course 36		1/25-2/15 VAP 1 - commo 34 VAP 2 - commo 34 VAP 2 - commo 34 VAP 3 - commo 29 VAP 4 - commo 29 Lottorr 13 - commo 29 Lottorr 13 - commo 39 Federare 14 - commo 39 Federare 14 - commo 39 Federare 15 - commo 35		ECS-2-85 NMT 1 - commo 34 NMT 2 - commo 34 NMT 2 - commo 29 NMT 2 - commo 29 NMT 2 - commo 20 Lecturer 13 - commo 35 Lecturer 13 - commo 35 Professor 31 - commo 35 Professor 32 - commo 35 Professor 31 - commo 35 Professor 31 - commo 35
2.10-3.45 NAP 4: comme 28 NAP 8: comme 18 NAP 8: comme 18 Letters 19 Letters 7: comme 28 Letters 10: comme 28 Profuse 11: comme 28 Profuse 11: comme 28 Profuse 11: comme 28 Profuse 21: comme 28 Profuse 21: comme 29 Profuse 21: comme 29	2.50-3.45 AND - count 25 AND 11 count 15 AND 12 count 15 Latter 15 count 16 Latter 15 count 16 Latter 15 count 16 Latter 15 count 16 Polisses 11 count 17 Polisses 11 count 27 Polisses 11 count 27 Polisses 13 count 28	2.36-3.45 MAY 4: course 26 MAY 1: course 18 MAY 1: course 18 Eastward 4: course 10 Eastward 4: course 10 Eastward 4: course 10 Eastward 4: course 10 Eastward 7: course 20 Eastward 10: course 10 Frederic 11: course 20 Frederic 11: course 20 Frederic 11: course 20 Frederic 21: course 20	2.180-3-165 AM2 - come IS AM2 I come II AM2 II come II II II come II II come II II come II I come II	2:59-3:45
4:00-5:15 VVF1 - more 6: Leview 11 - cours 15 Leview 12 - cours 15 Professor 20 - cours 4: Professor 21 - cours 25 Professor 21 - cours 4:	4:00-5:15 Levinor 4: course 2 Fredouer 9: course 21 Fredouer 20: course 52 Fredouer 20: course 57	4.60-Sc15 MF I: many iii Ledwar I : many II Ledwar I : many II Ledwar I : many II Privace II	4:00-5:15 Letters 4: conv 2 Fradour 9: conv 2 Fradour 18: conv 51 Fradour 19: conv 51 Fradour 29: conv 51	4:99-5:15
539-645	526-645	5.20-6-45	526-645	539645

Figure 5: New Schedule 2 - Pre Registration

Monday	Tuesday	Wednesday	Thursday	Friday
\$.00-5:50 Professor 26 - course 26	E-30-5-45 VOFF - context 27 VOFF 14 - context 28 VOFF 15 - context 28 VOFF 25 - context 28 Lackness 10 - context 30 Lackness 10 - context 40 Problems 2 - context 41 Problems 3 - context 41 Problems 3 - context 41 Problems 3 - context 31	X-90-31-50 Professor 36 - ownso 26	B.50-5-45 VAF - comm 17 VAF - comm 28 VAF H - comm 28 VAF H - comm 28 Latinus 1 - comm 38 Latinus 1 - comm 18 Latinus 18 Latinus 18 Priderus 2 - comm 48 Priderus 3 - comm 41 Priderus 3 - comm 41 Priderus 3 - comm 23	R.00-R.50 Professor 36 - course 26
9:05-9:55 Lariano 2 - ourse 6 Lariano 2 - ourse 6 Lariano 4 - ourse 18 Lariano 19 Lariano 14 - ourse 19 Pridose 72 - ourse 6 Pridose 12 - ourse 19 Pridose 12 - ourse 19 Pridose 15 - ourse 20 Pridose 25 - ourse 21 Pridose 25 - ourse 21	16;00:41;155 VAP7-connect of VAPT-connect of VAPT-connect of Interview is connected in Levieure is connected in Levieure is connected in Produce in Co	5:05-9:25 Latters 2 - come 4 Latters 3 - come 8 Latters 4 - come 10 Latters 14 - come 10 Latters 14 - come 10 Latters 14 - come 10 Professor 11 - come 10 Professor 11 - come 10 Professor 12 - come 10 Professor 13 - come 10 Professor 24 - come 20 Professor 25 - come 20	10:00-11:15 ANT - comm of ANT - comm of ANT - comm of Lestone 1: comm of Lestone 1: comm of Produce	9:65-9:25 Lobrary 2- come 4 Lotter 4- come 18 Lotter 4- come 18 Lotter 16- come 18 Lotter 16- come 19 Probase 17- come 6 Probase 12- come 19 Probase 12- come 19 Probase 21- come 20
16:18-11:09 NVF 9 - course 32 NVF 2 - course 36 NVF 12 - course 36 NVF 13 - course 36 Lecture 2 - course 15 Lecture 2 - course 17 Lecture 4 - course 47 Professor 6 - course 47 Professor 5 - course 47 Professor 7 - course 37		10: 10-11: 00 3.379 - manue 22 3.07 12 - manue 23 3.07 12 - manue 36 3.07 12 - manue 36 Lostrary 2 - manue 15 Lostrary 2 - manue 12 Lostrary 3 - manue 12 Fandaman 4 - manue 42 Fandaman 4 - manue 42 Fandaman 27 - manue 28		18:00-11:00 YAFF - course 21 YAFF 12 - course 36 YAFF 12 - course 36 YAFF 13 - course 36 Location 2 - course 31 Location 2 - course 32 Location 4 - course 42 Produces 4 - course 42 Produces 21 - course 24
HillS-1236 VOFT - course IP VOFT - course IP VOFT - course IB Lestoner 2 - course IS Lestoner 4 - course IS Lestoner 4 - course IS Lestoner 5 - course IS Lestoner 2 - course IS Lestoner 2 - course IS Performer IS - course IS Performer IS - course IS Performer IS - course IS	11 (36:12) 45 Vall 4. ment 24 Vall 5. ment 24 Vall 7. omine 25 Vall 7. omine 25 Vall 7. omine 27 Vall 7. omine 27 Letwer 18. control 17 Enforce 25. control 25 Enforce 26. control 25 Enforce 26. control 25 Enforce 26. control 25 Enforce 26. control 26 Enforce 26. control 26 Enforce 26. control 27 Enforce 26. control 27	III.15-12:85 MM 1 - control 21 VM II : control 48 Lotters 2 - control 48 Lotters 2 - control 31 Lotters 4 - control 31 Lotters 4 - control 31 Lotters 7 - control 31 Lotters 2 - control 31 Profiless 231 - control 30 Profiless 231 - control 30	H (36-12-45 VAF 4 comme 24 VAF 7 comme 25 VAF 7 comme 16 VAF 1 comme 17 F comme 17 Letture 18 comme 17 Fradmar 28 comme 25 Fradmar 28 comme 25 Fradmar 28 comme 28 Fradmar 28 comme 28	H:15-12:85 VM21 - come 27 VM21 - come 28 Lecture 2 - come 18 Lecture 3 - come 18 Lecture 4 - come 18 Lecture 4 - come 2 Lecture 4 - come 2 Lecture 5 - come 2 Lecture 7 - come 8 Parkew 22 - come 8 Parkew 22 - come 8 Parkew 23 - come 50
12-28-1:10 NO2 - owner 65 NO2 - owner 65 NO2 - owner 64 Lestoner 5 - owner 18 Lestoner 5 - owner 18 Lestoner 5 - owner 18 Professor 9 - owner 18 Professor 9 - owner 20 Professor 18 - owner 66 Professor 14 - owner 61	1790-2115 VOIT - count 27 VOIT - count 27 VOIT - count 27 VOIT - count 28 VOIT - count 29 VOIT - count 20 Lecture 10 - count 20 Lecture 10 - count 4 Lecture 10 - count 4 Lecture 11 - count 4 Particular 11 - count 4 Particular 11 - count 4 Particular 11 - count 41 Particular 11 - count 41	12:38-1:16 SSE 1 - count di SSE 2 - count di SSE 2 - count di Lottore 4 - counc di Lottore 7 - contro li Lottore 7 - contro li Parlemen 9 - commo di Professor 9 - contro di	1:90-2:15 AND - comme 2: AND - comme 2: AND - comme 2: AND - comme 2: AND 1: comme 3: AND 1:	12-20-8-20 SO2 - course of SO2 - course of SO2 - course of Leature 4 - course of Leature 5 - course of Leature 7 - course of Parkers 9 - course of Parkers 15 - course of
1/25-2/25 VVF 1 - outer 45 VVF 2 - outer 45 VVF 4 - outer 25 VVF 14 - outer 25 Levinor 3 - outer 2 Levinor 31 - outer 2 Levinor 31 - outer 4 Levinor 31 - outer 4 Federat 32 - outer 5 Pridinat 32 - outer 32 Pridinat 32 - outer 38		1/25-2/15 NAP 1 - control 46 NAP 4 - control 25 NAP 14 - control 25 NAP 14 - control 22 Leaturer 8 - control 24 Leaturer 8 - control 24 Leaturer 13 - control 34 Leaturer 13 - control 35 Professor 10 - control 37 Professor 10 - control 38		1.26-5.28 VAP 1 - course 66 VAP 4 - course 23 VAP 14 - course 23 VAP 14 - course 23 Leature 3 - course 2 Leature 11 - course 14 Leature 13 - course 3 Parlower 10 - course 8 Parlower 10 - course 8 Parlower 21 - course 30
2:30-3:45 Visit 1 - memor M Visit 2 - memor M Visit 2 - memor M Lockers 2 - commo M Lockers 2 - commo M Lockers 2 - commo M Lockers 10 - commo M Findows 10 - commo M Findows 10 - memor M Findows 20 - memor M Findows 20 - memor M	23(0.3) 45 Vall 3. counte 24 Vall 3. counte 24 Vall 1. counte 40 Letterer 5. counte 40 Entition 10. counte 40 Producer 11. counte 54 Producer 11. counte 54 Producer 21. counte 54 Producer 23. counte 54	2:36:3045 NAP 2: comme 26 NAP 3: comme 26 Lantoner 2: comme 28 Lantoner 2: comme 20 Lantoner 2: comme 27 Lantoner 3: comme 27 Lantoner 3: comme 36 Professor 31: comme 36	2.30-3/45 Vall 3-counte 29 Vall 10-counte 40 Lantener 3-counte 40 Lantener 3-counte 40 Printener 11-counte 54 Printener 11-counte 54 Printener 11-counte 54 Printener 33-counte 43	2,59-3+45
4:00-5:15 YSFH - memor 28 Professor 12 - memor 33	4.50-5c15 VSF 6. mene 26 VSF 10. mene 26 VSF 10. mene 36 VSF 10. mene 36 VSF 10. mene 37 Earlies 10. mene 38 Earlies 10. mene 38 Earlies 10. mene 38 Earlies 10. mene 20 Findous 10. mene 20 Findous 10. mene 30 Findous 10. mene 31	4:06-5:15 NAF III - conver 20 Professor 12 - conver 20	4:00-5:15 VM 4: mene 26 VM 12: mene 26 VM 12: mene 28 VM 10: mene 28 VM 10: mene 20 VM 10: mene 20 Extract 1: mene 18 Extract 12: mene 18 Fridam 14: mene 20 Fridam 14: mene 20 Fridam 14: mene 31	4:00-5:15
536.645	539445	509445	539445	5,38445

Figure 6: New Schedule 2 - Post Registration

Comparing Change Minimizers

	a * b	a+b	
Pre-	5 exact	5 exact	
Reg.	16 same unassigned	17 same unassigned	
reg.	49 same instructor	46 same instructor	
Post-	33 exact	39 exact	
Reg.	15 same unassigned	16 same unassigned	
iveg.	108 at same time	108 at same time	

- Much better post-registration
- ▶ 133 sections total, so over 90% of assigned classes stay at same time post-registration
- a + b leads to slightly better results, but more analysis needed to see if it is significant

A Closer Look at Some Instructors

Lecturer 11

- ► Forced Change: No teaching MWF 10:10-11
- ➤ **Schedule 1:** teaching 14 (MWF 9:05-9:55), 14 (MWF 10:10-11), 16 (MWF 1:25-2:15)
- ► **Schedule 1 PRE:** teaching 14 (MWF 8-8:50), 14 (12:20-1:10)
- ► **Schedule 1 POST:** teaching 14 (MWF 9:05-9:55), 3 (MWF 11:15-12:05), 14 (MWF 1:25-2:15)
- Schedule 2: teaching 16 (MWF 10:10-11), 14 (MWF 12:20-1:10), 14 (MWF 1:25-2:15)
- ► **Schedule 2 PRE:** teaching 14 (TTh 8:30-9:45), 14 (TTh 2:30-3:45)
- Schedule 2 POST: teaching 17 (MWF 8-8:50), 14 (MWF 1:25-2:15), 14 (TTh 8:30-9:45)

A Closer Look at Some Instructors

Professor 8

- No forced change, happy with original schedule
- ➤ **Schedule 1:** teaching 37 (TTh 8:30-9:45) and 18 (TTh 10-11:15)
- ► Schedule 1 PRE: teaching 27 (MWF 8-8:50)
- Schedule 1 POST: teaching 14 (MWF 10:10-11), 27 (TTh 8:30-9:45)
- ➤ **Schedule 2:** teaching 37 (TTh 8:30-9:45) and 38 (TTh 10-11:15)
- Schedule 2 PRE: teaching 44 (MWF 8-8:50), 31 (MWF 10:10-11)
- Schedule 2 POST: teaching 27 (TTh 8:30-9:45), 26 (TTh 1:00-2:15)
- None of new classes were highly ranked

Conclusions

- Schedule builder seems to create a reasonable schedule
- Even "minimizing" changes still creates a lot of changes
- ► Easier to keep courses at the same time than keep professors teaching the same courses
- Might want to make some schedule builder constraints soft(er) in change minimizer if the number of changes is more important
- Generating a schedule can be automated in a way that seems to be effective, but hard to know if the lack of "human touch" makes a difference without seeing the hand-made schedule
- ► At this stage, the change minimizer might be better used as a tool to see a possible way of accommodating changes
 - Our code might create a domino effect of changes to satisfy constraints when you could just switch two people and technically break a constraint, but save a lot of changes from being made

Future Ideas

- Implement constraints for same vs. different classes, back to back classes, forcing 2 days/week if needed
- Compare our output with actual schedule for next semester
- ► Make preference data less arbitrary by changing how the department gathers preferences: ask them to explicitly weight time slots and courses 0-1
- Experiment with other ways of formulating change minimizer objective function to get better results
 - More softness of schedule builder constraints
 - Potentially include preference data
- Look at individual-level results of more instructors to identify any potential biases or issues

Bibliography

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