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PURDUE UNIVERSITY
Space Management & Academic Scheduling

Comprehensive Approach to Student Sectioning

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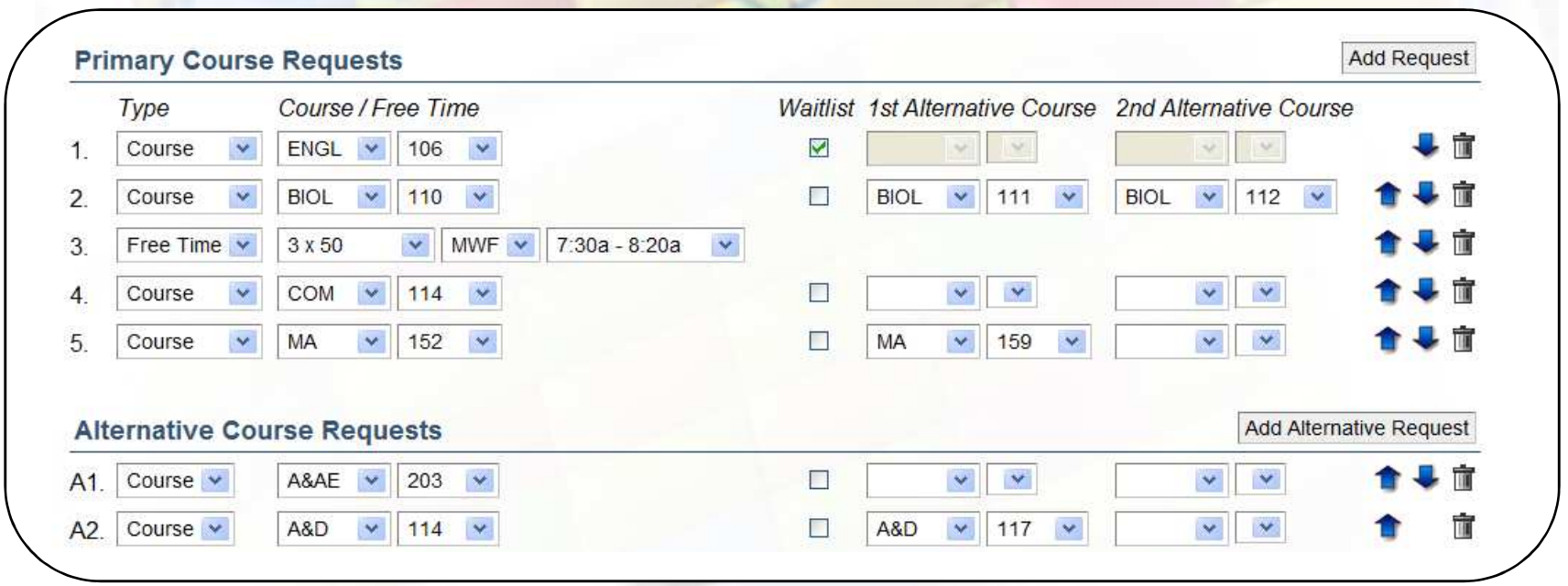
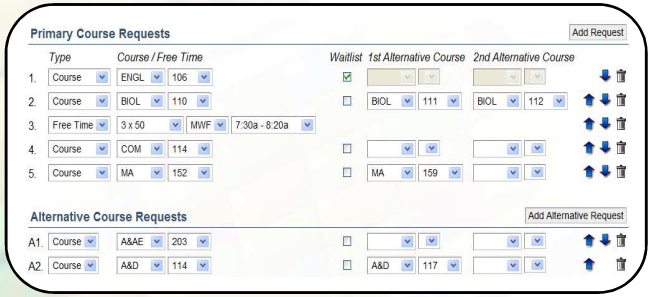
Student Sectioning Problem

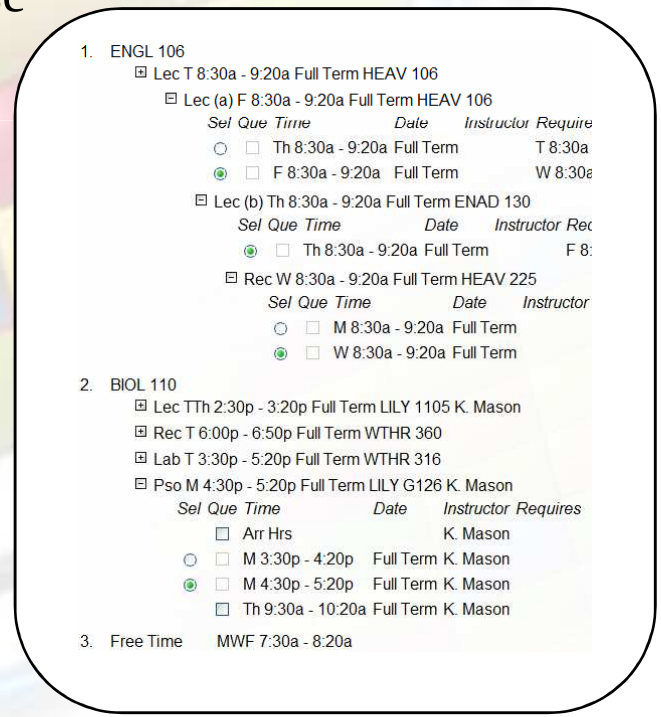
- What is Student Sectioning?
  - Student requests courses, system determines classes (sections)
    - Respects course structure, reservations, student preferences, etc.
- Why is Student Sectioning needed?
  - Multi section courses, optimization of student – class enrollments, dynamic reservations of space in sections with excess demand



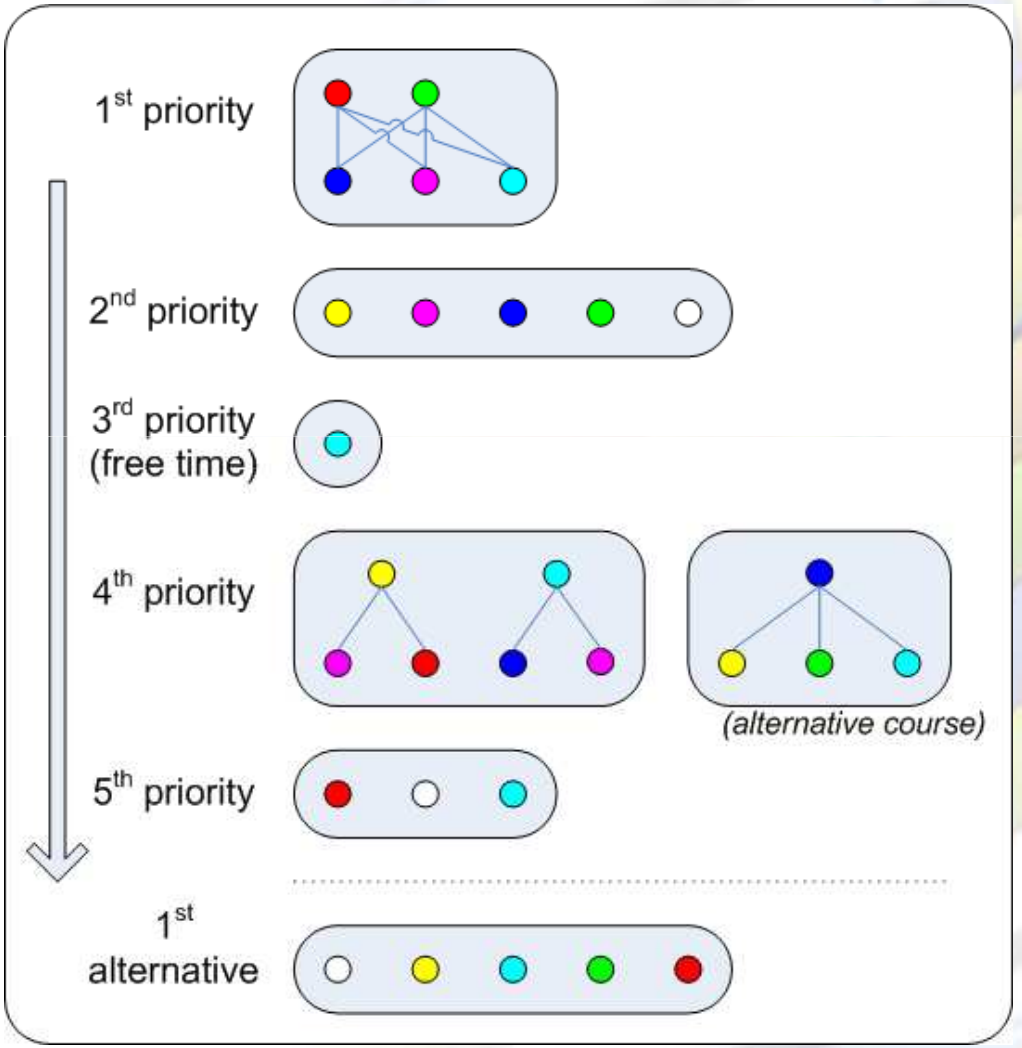
Student Sectioning Problem Model

- Variables
  - Individual student course requests
    - including priorities, free times, alternates
- Values
  - A valid set of classes of the requested course (or its alternative), requested free time
- Constraints
  - Course structure, class timetable
  - Course & class limits
  - Course & class reservations
- Solution
  - A set of (most complete) student schedules
  - Maximizing overall request priorities, minimizing use of alternatives, etc.

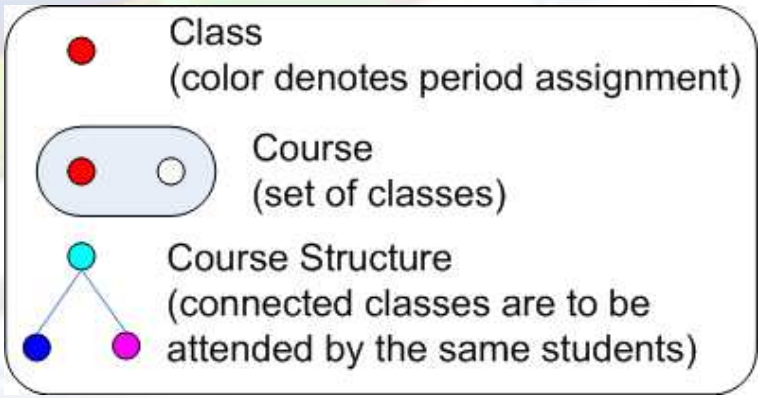




Student Sectioning Example



- Input
  - Student requests ordered by priority
- Output
  - Enrollment of a student to valid, not overlapping combinations of classes



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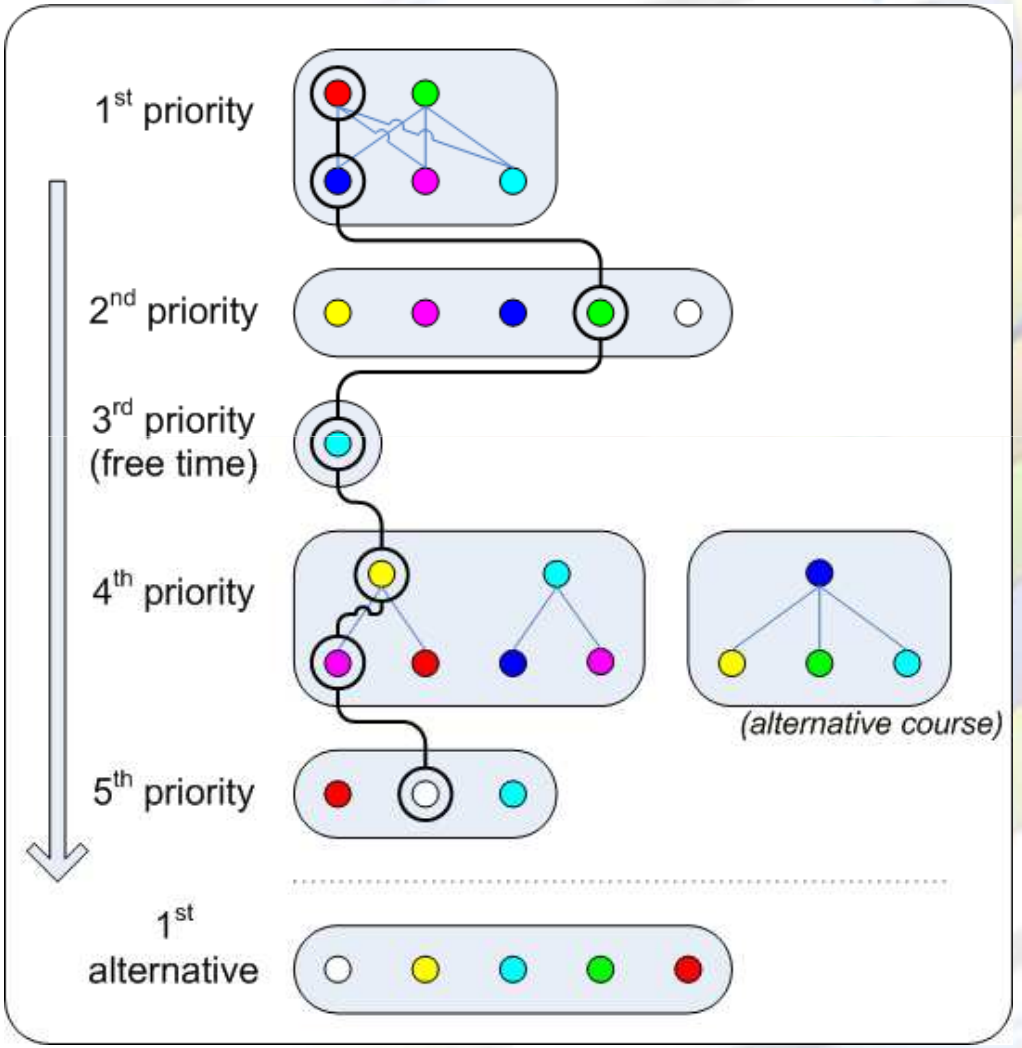
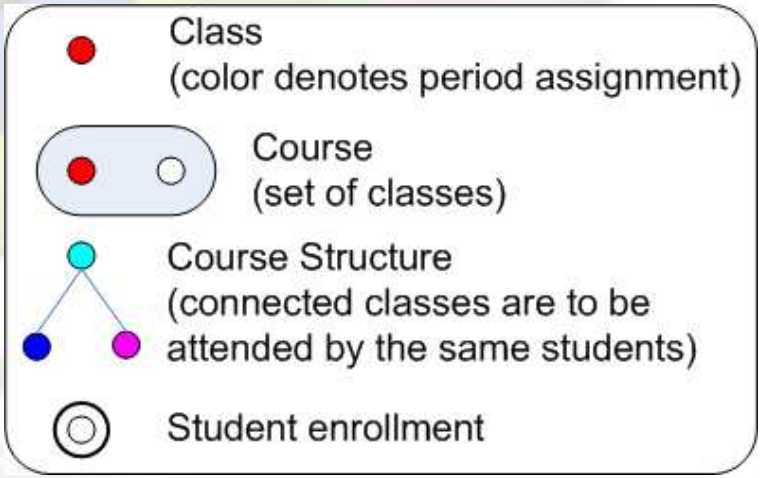


- Search Criteria
  - Complete schedule
  - Priorities, alternatives
- Maximize over all student schedules



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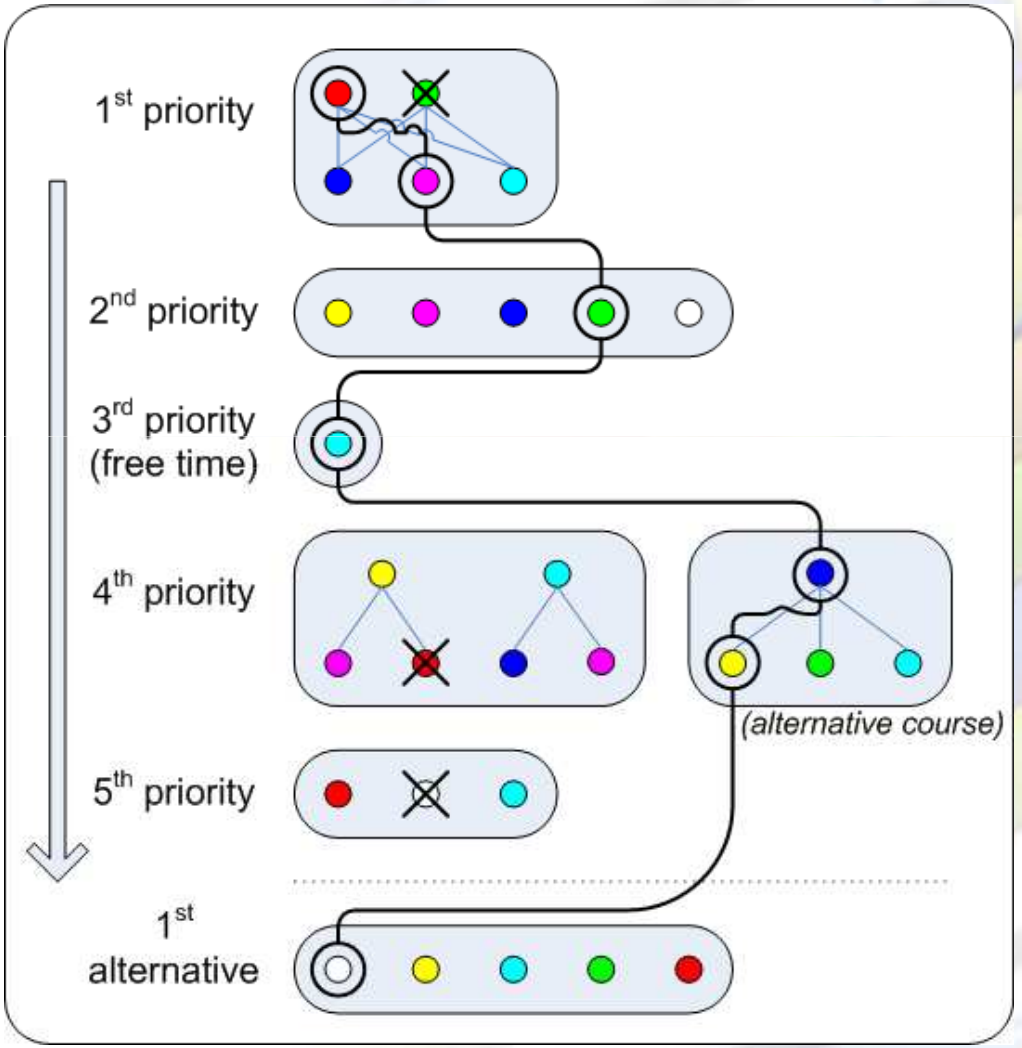
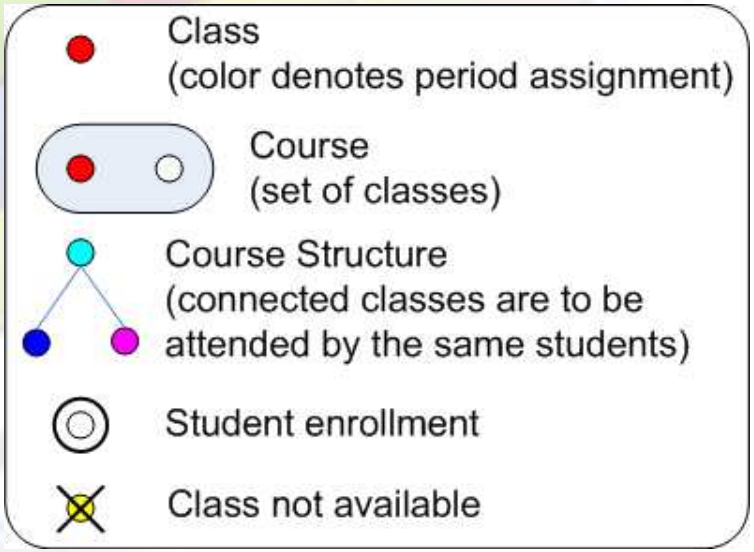
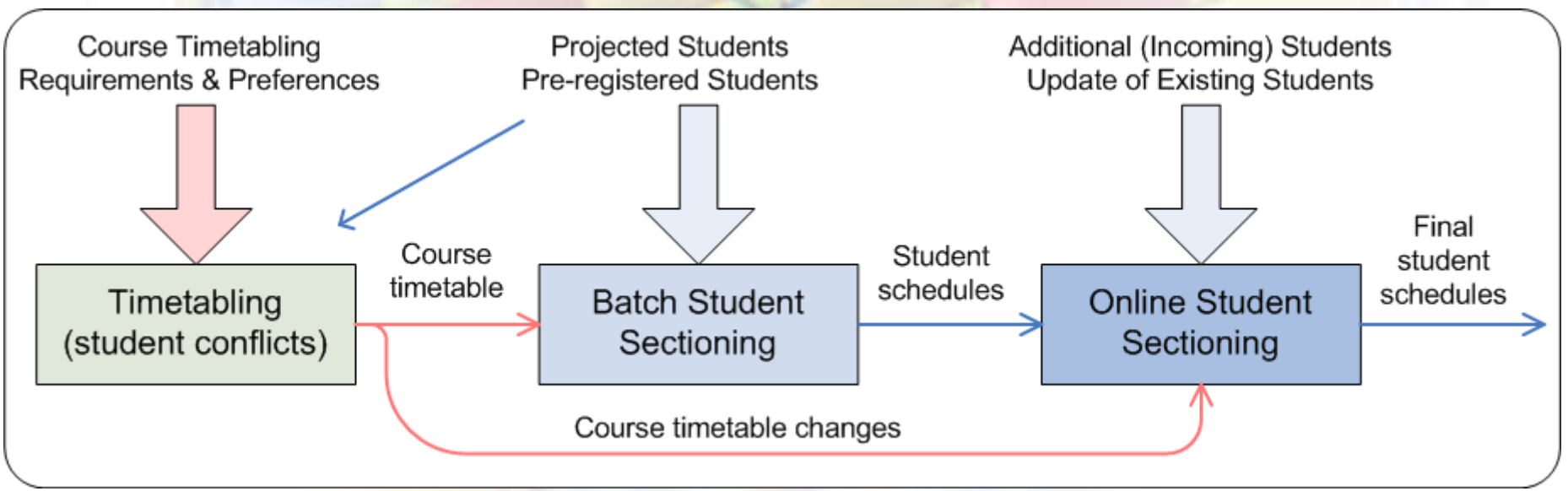


- Some sections may become unavailable
  - Reservations,
  - Other students (limits),
  - …

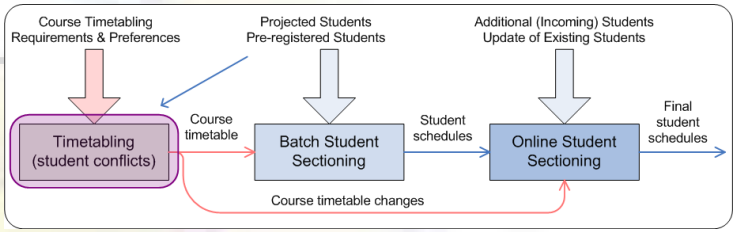


Student Sectioning Phases

- Initial Sectioning (during timetabling)
  - Timetabling solver minimizes potential student conflicts
- Batch Sectioning
  - Registration of classes for students, reservations, wait lists
- Online Sectioning
  - Registration of first year students, changes in existing enrollments



Initial Sectioning

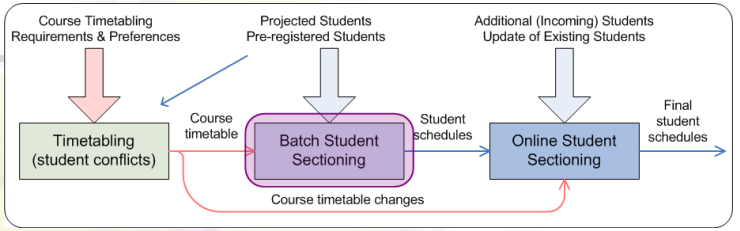


- Student Course Requests
  - Last-like semester student course demands
  - Current course requests from pre-registered students
    - with priorities, alternatives, free times, …
  - Course enrollment projections
  - Reservations

Reservations limit what classes/courses are available to which students.

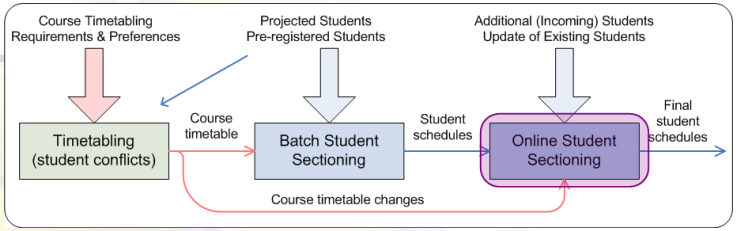
- → minimization of student conflicts
  - Two classes overlapping in time (or being back-to-back in distant locations) with common students
  - Weighted by request priorities
- Solver
  - Additional criterion in the timetabling solver
  - Initial sectioning (before timetabling starts), re-sectioning of students between alternative classes during or after the search

Batch Sectioning



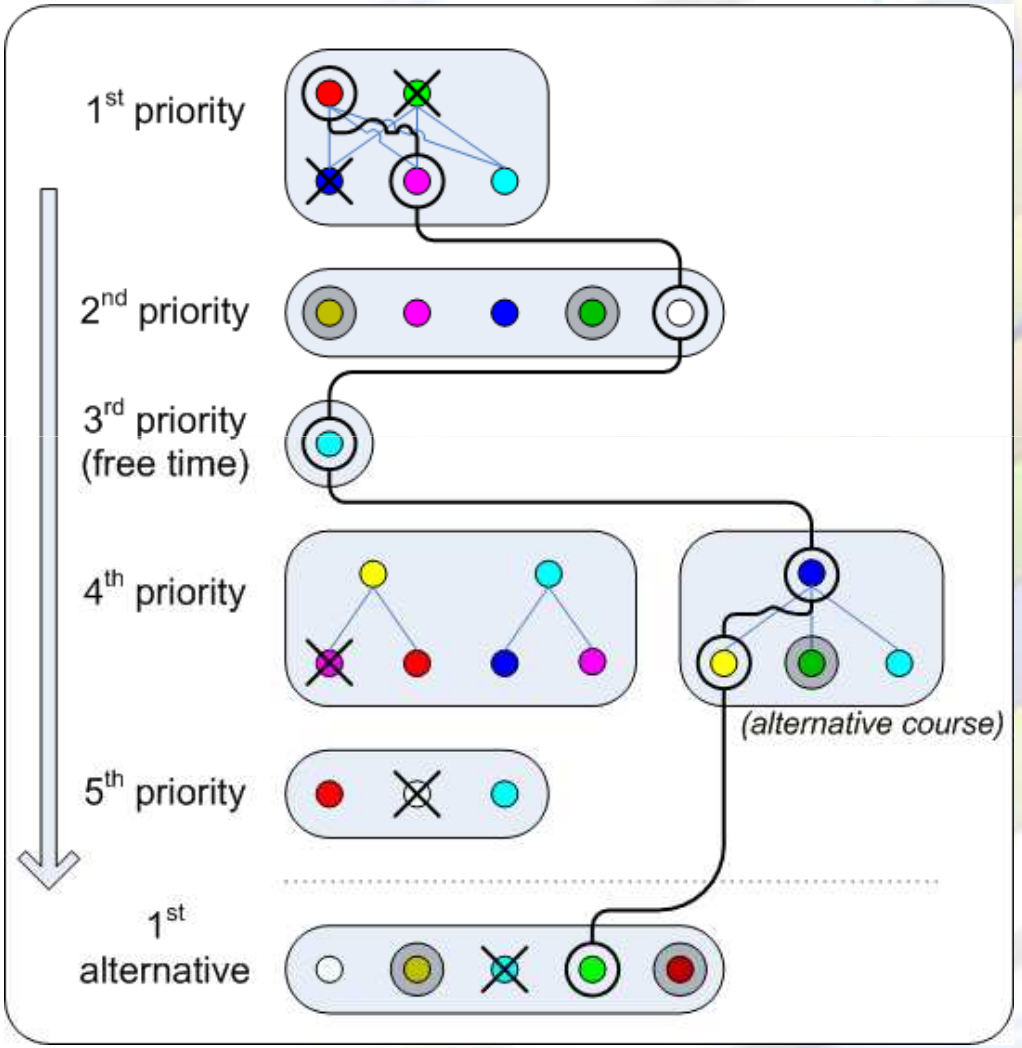
- All students are sectioned altogether
  - Projected student information is used
  - However, first priority is to give pre-registered students full schedule
- $\rightarrow$ maximization of assigned student requests
  - Pre-registered students are enrolled to classes and/or to wait-lists
  - Reservations for expected (not yet registered) students are created
- Solver
  - CPSolver library is used
    - Open source, local-search based, also used in course timetabling
    - Works with incomplete feasible solutions (no constraint is violated)
  - Various neighborhoods including
    - Branch&bound over all requests of a student
    - Limited-depth backtracking search (over a request and its conflicts)
    - Student swap (swapping of student enrollments between sections)

Online Sectioning

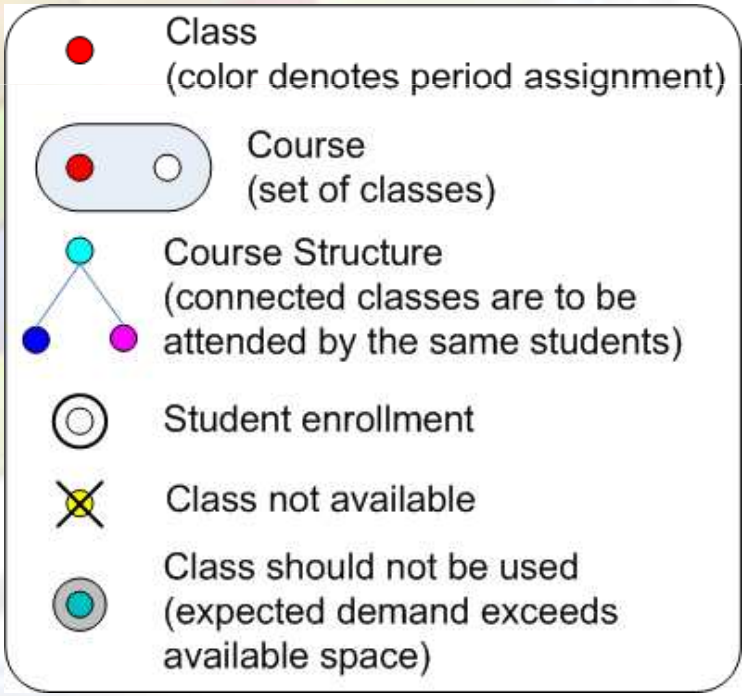


- One student is processed at a time
  - Returning a most-complete schedule
    - Considering priorities, alternatives, free-time requests
- → same model (as for batch sectioning), different algorithm
  - Branch&bound returning most complete schedule,
  - optimizing the given preferences (free times, alternatives),
  - avoiding sections reserved for expected students
- Can be an iterative process
  - Student can change requests / choices based on the provided results, assignments are committed at the end
- Reservation of space for expected students
  - Based on projected student enrollments from batch sectioning
  - In each class, a given number of spaces is reserved for new students
    - These reservations are updated as the students are enrolled into classes

Online Student Sectioning Example



- Classes with excessive demand should be avoided



Online Sectioning: Expected / Held Space

- Computation (after batch sectioning)
  - Counter for each class using enrollments of projected (last-like) students
  - Express availability of the class to projected students

$$f_{exp}(\text{class } c \text{ of a course } C) = \sum_{\substack{\text{projected students } s \\ \text{requesting course } C}} \frac{|\text{available enrollments to C containing c}|}{|\text{available enrollments to C}|}$$

- New Student
  - Difference between expected and currently available space
    - Directing students from classes most likely to be needed to other future students
  - Counters are updated after each new student is sectioned
- Existing Student *(students already enrolled in the course)*
  - Held space in a class (unavailable to existing students)
  - Computed as the number of projected students after batch sectioning

Practical Results

- Fall 2007 course timetable from Purdue University
  - 9 000 classes, 570 rooms, 39 000 students with 190 000 course requests
- Student data
  - Last-like (Fall 2006) student course requests
    - 185 494 course requests from 38 740 students
  - Real (Fall 2007, data as of July 11, 2007) student course requests
    - 187 847 course requests from 36 117 students
  - No alternatives, free time requests, or reservations ☹
  - Invalid course requests were eliminated (~2000 requests)
- Test cases
  - Batch sectioning of last-like student course requests
    - → results used for expected / held spaces for online sectioning
  - Batch sectioning of real student course requests
  - Online sectioning of last-like and real student course requests
    - Students are sectioned one by one in a random (or given) order
  - Sectioning by student preferences (uniform, mid-day, early/late)
  - Number of choices provided to the students

Practical Results: Batch versus Online

- Fall 2007 course timetable, Fall 2006/2007 student course requests
- Average and RMS values from 20 independent runs
- Percentage (and actual number) of unassigned course requests
- For online sectioning runs, expected space computed from the best last-like sectioning batch run (316 unassigned course requests)

	Projected Students	**Real Students**
Batch Sectioning *(Average ± RMS of 20 runs)*	0.171% ± 0.001% (317.4 ± 1.6)	0.140% ± 0.001% (264.6 ± 1.9)
Online Sectioning *(Random order)*	0.294% ± 0.007% (545.2 ± 13.5)	0.411% ± 0.011% (772.5 ± 20.3)
Online Sectioning *(Students with more choices first)*	0.401% ± 0.007% (744.0 ± 12.5)	0.556% ± 0.008% (1043.7 ± 15.0)
Online Sectioning *(Students with less choices first)*	0.249% ± 0.002% (461.6 ± 3.6)	0.318% ± 0.002% (597.0 ± 4.3)
Online Section Balancing *(Random order, no expected space)*	0.828% ± 0.013% (1696.4 ± 16.3)	0.789% ± 0.015% (1481.9 ± 27.4)

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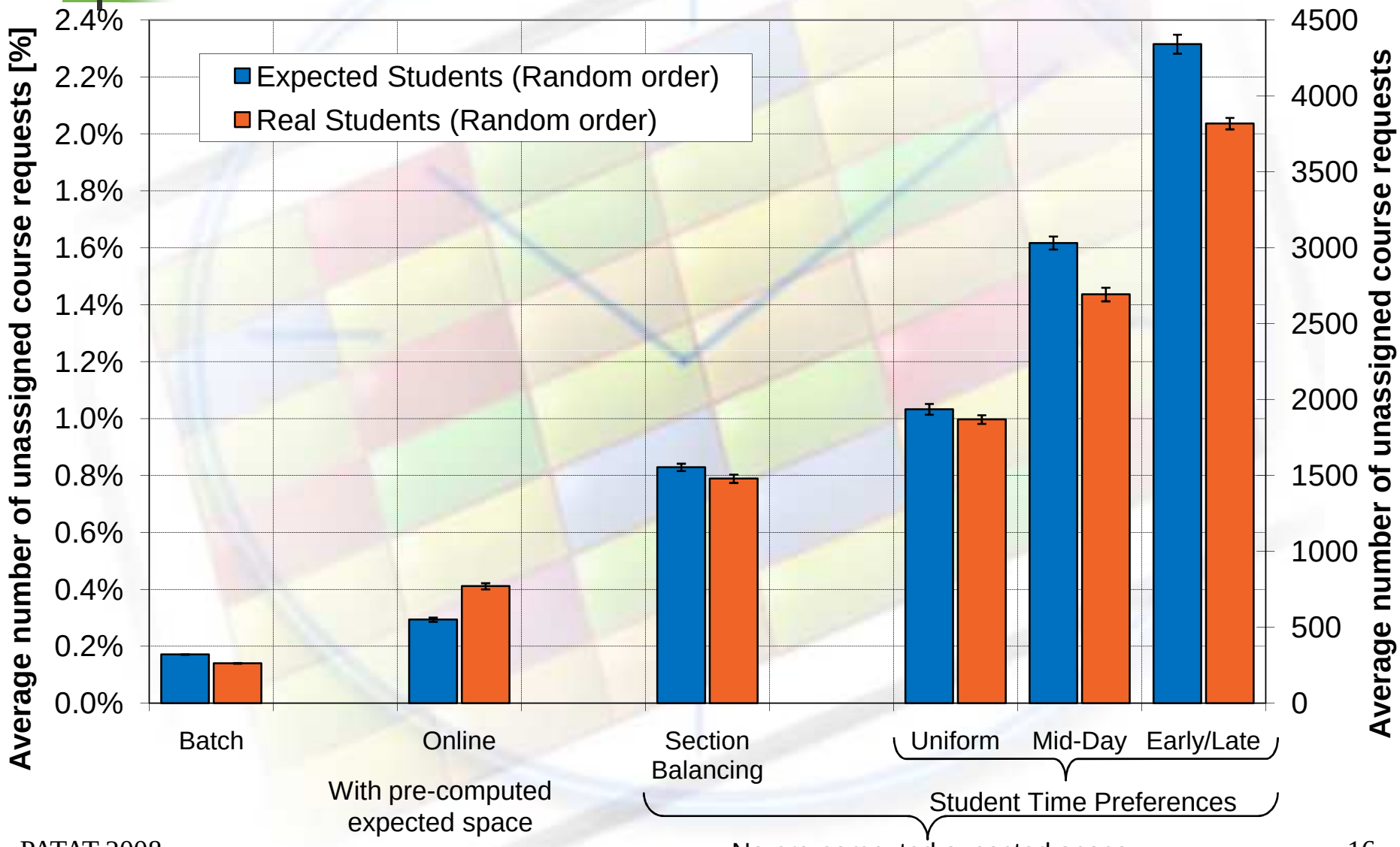
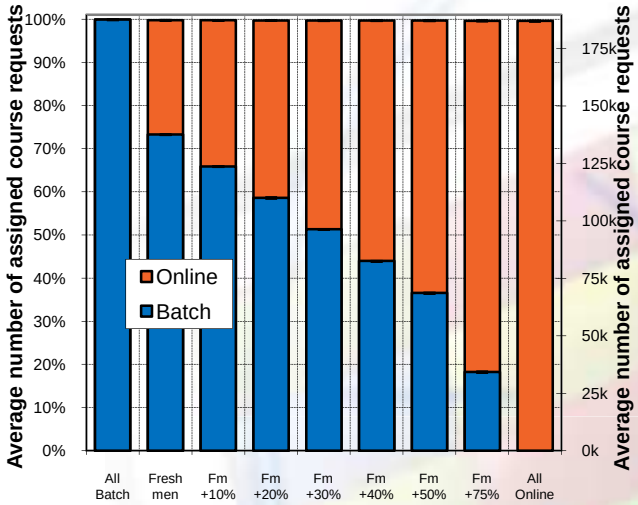
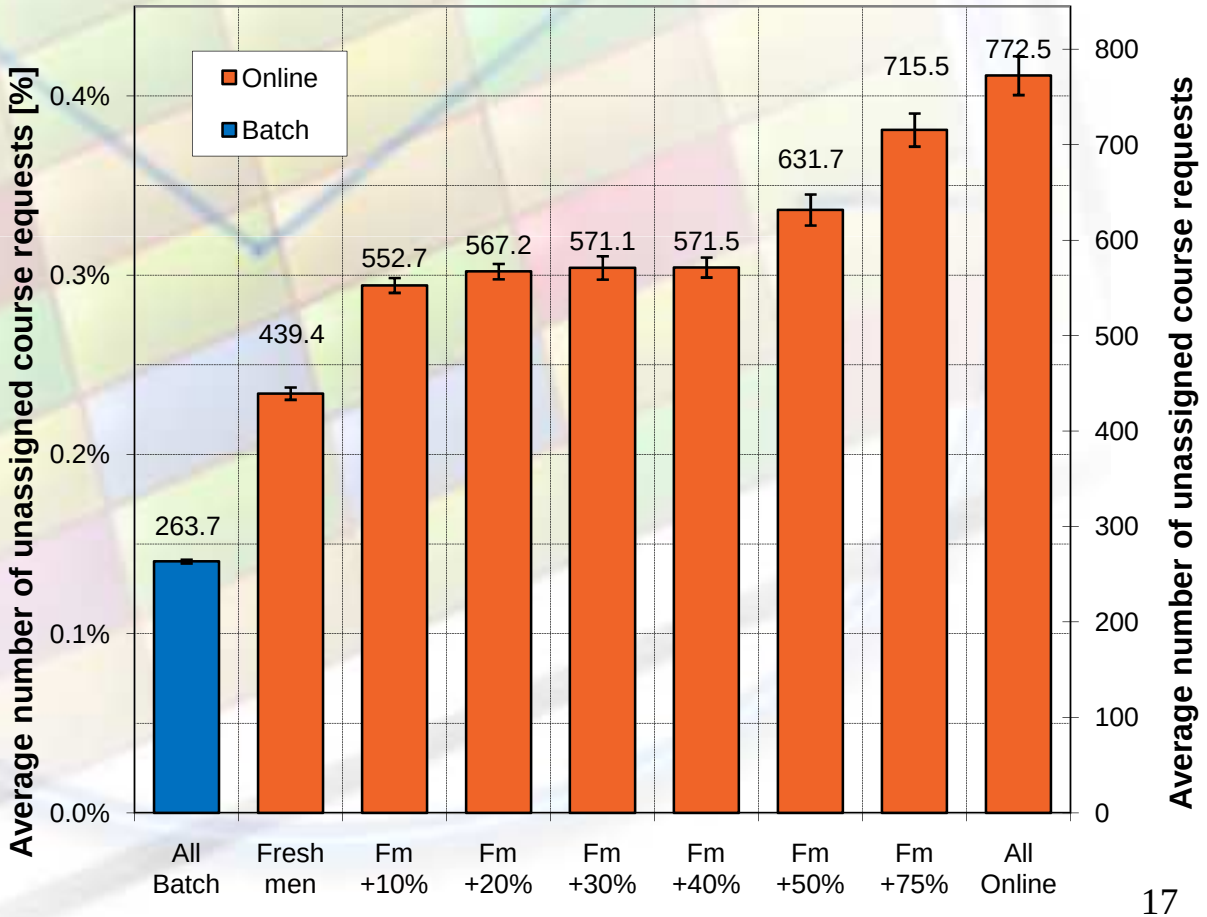
Practical Results: Batch, Online, Time Preferences

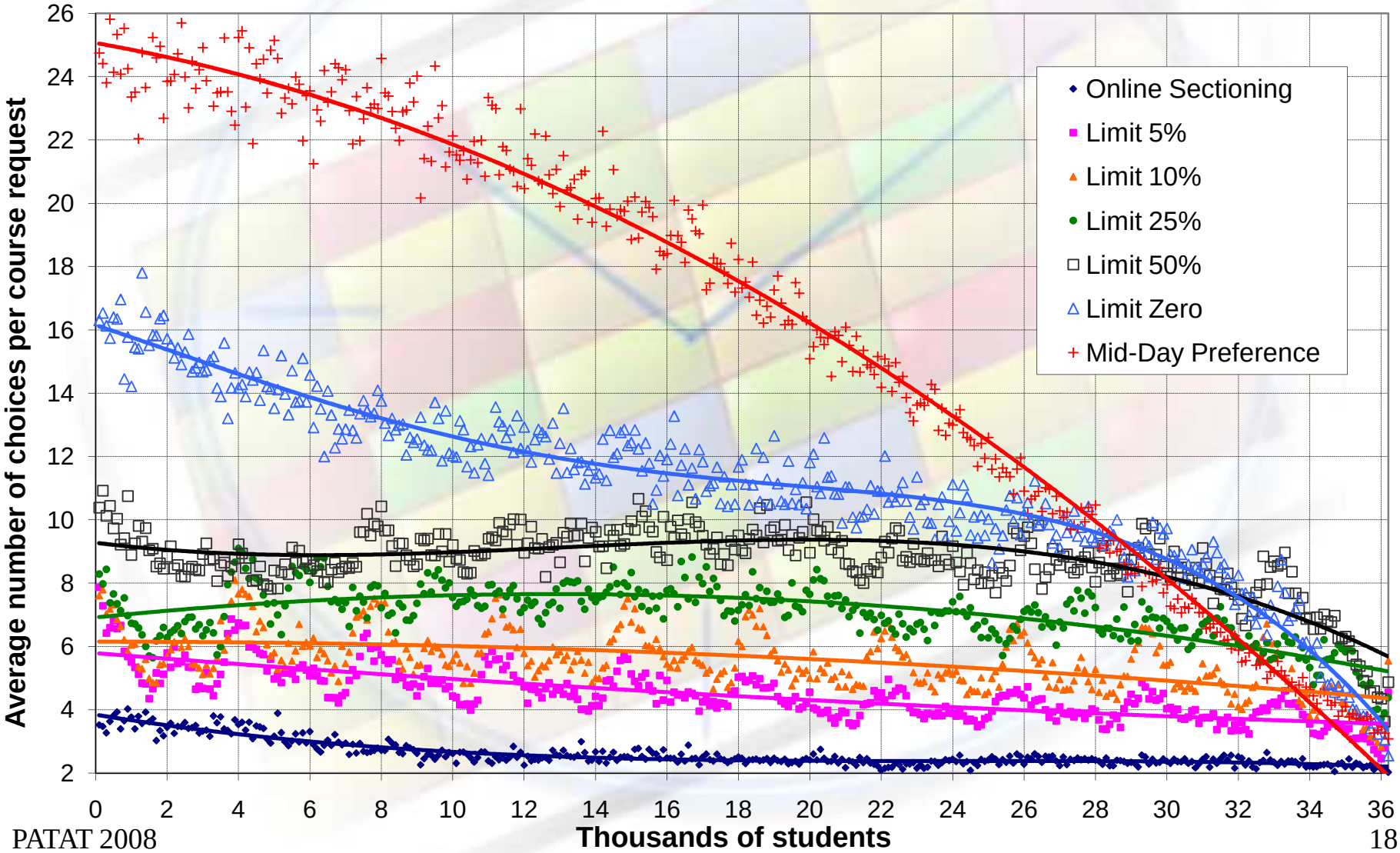


Practical Results: Combining Batch & Online

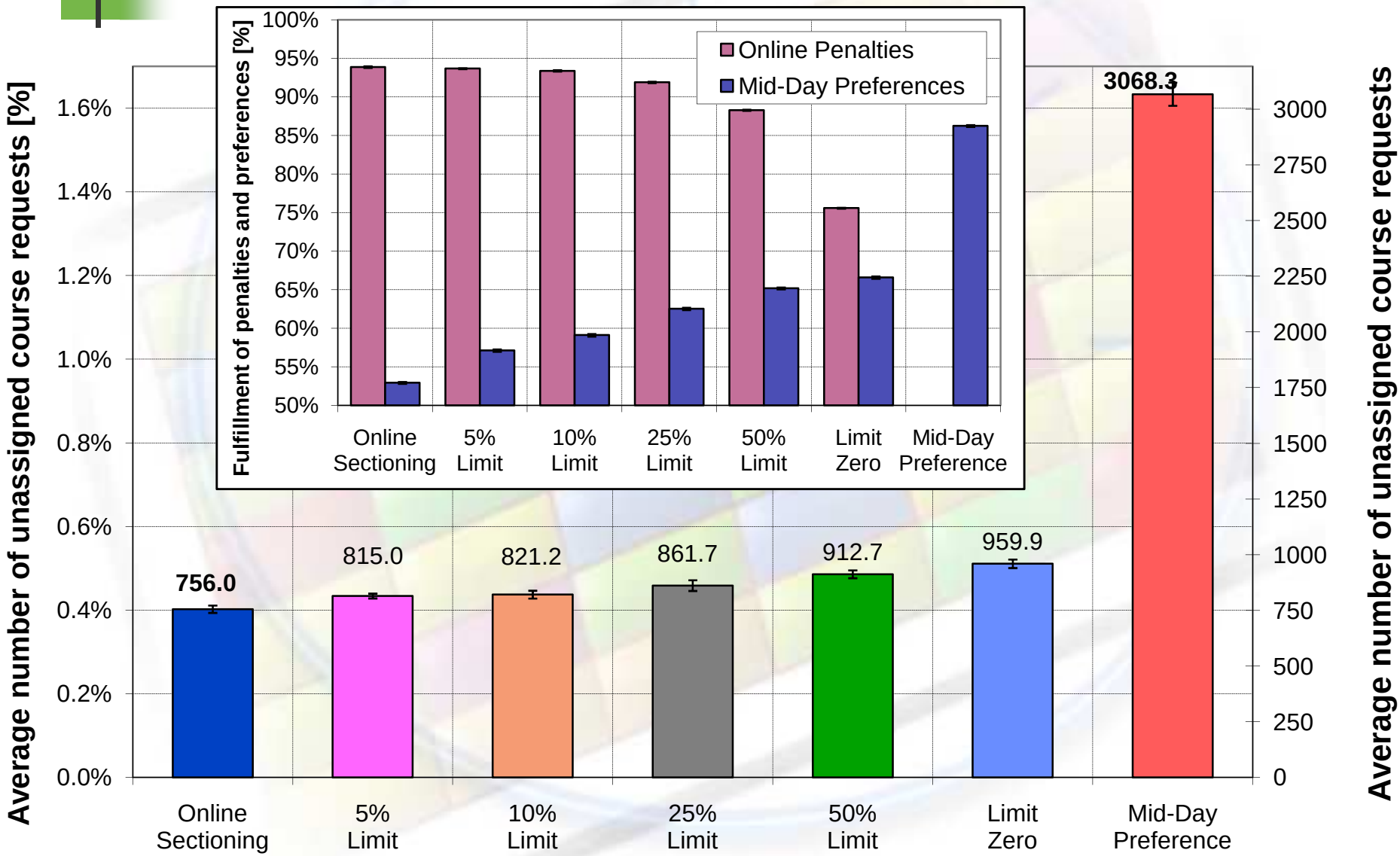




Practical Results: Student Choice

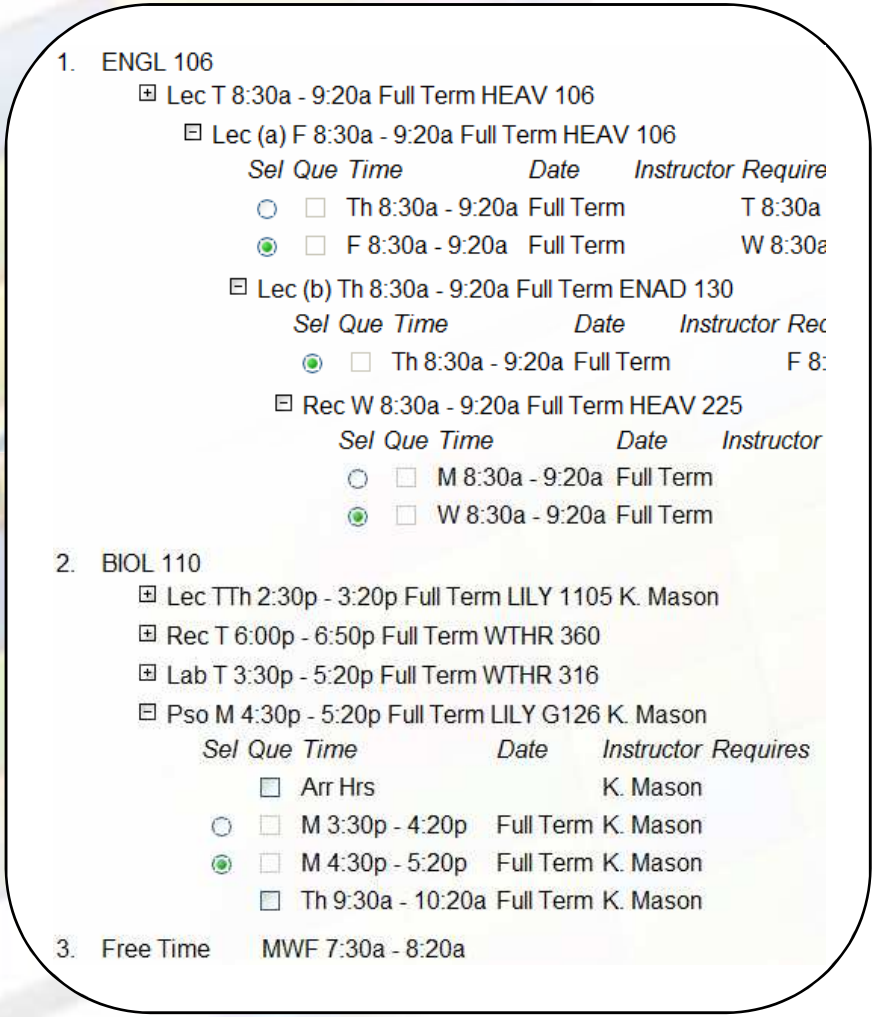


Practical Results: Student Choice



Future Work

- Reservations
  - On courses or classes
  - Academic area, major / minor, learning-communities, individual
- Wait-listing on Courses
- Re-Sectioning
  - Wait-list processing, course timetable changes, mass cancellations, etc.
- Student Choices
  - (Limited) ability to choose time and instructor
  - Choice between available classes
  - Wait-listing for classes that are not available



Conclusions & Further References

- Conclusions
  - Demand based timetabling and sectioning provides the best results
  - However, master timetabling with online sectioning can be significantly improved using past information on student course demands

  → The presented hybrid approach is highly applicable in practice
    - Allows for earlier planning, but improves on the efficiency of current sectioning approaches

- Further References
  - http://www.unitime.org
    - Software available for download
    - Documentation
    - Ongoing research
    - Real-life benchmark data sets