Northeastern University
OR 7260 – Constraint Programming

Instructor	**E-mail**	**Office**	**Phone**	**Office hours**
Ayten Turkcan				

Class Schedule	**Location**
TBA	TBA

Text: Lecture notes

References used to prepare lecture notes:

[1] Hooker, J.N., Logic-based Methods for Optimization. Springer, 2000.
[2] Hooker, J.N., Integrated Methods for Optimization. Springer, 2012.
[3] Apt, K.R., Principles of Constraint Programming. Cambridge University Press, 2003.
[4] Rossi, F., van Beek, P., and Walsh, T., Handbook of Constraint Programming, Elsevier, 2006.

Course webpage: Blackboard

Course description (from catalog):
Constraint programming uses techniques from artificial intelligence, computer science, and operations research to solve combinatorial problems such as planning, scheduling, vehicle routing, TSP, staff rostering, and course timetabling. The course covers the basic foundations of logic-based modeling and constraint programming, which includes logic of propositions, discrete variables and 0-1 inequalities, global constraints (alldifferent, cardinality, cumulative, stretch, disjunctive, element, sum), consistency, constraint propagation, domain reduction and search strategies (branching, backtracking). Integrated constraint programming and mathematical programming methods such as Benders decomposition, column generation, relaxation and local search methods will also be covered.

Prerequisites: IE 6205 (Deterministic Operations Research)

Course Objectives:
Upon successful completion of this course, students are expected to

- understand logic based modeling
- know the basics of constraint programming such as constraint generation, domain reduction, and consistency
- model combinatorial optimization problems such as production planning, scheduling, vehicle routing, traveling salesman, matching, map coloring, assignment problems
- solve constraint programming models using a software (i.e., Ilog CP Optimizer, Eclipse)
- understand the methods integrating constraint programming and mathematical programming

Grading:

Short lecture	5%
Homework	30%
Midterm	30%
Course Project	35%

Short lecture:

- The instructor will provide a list of presentation topics.
- Each student will choose one of the presentation topics and present it in the class.
- The presentation will not be more than 15 minutes.

Homework Policies:

- There will be four homework assignments.
- Homeworks will be submitted by 5pm on the specified due date. Instructions on how to submit homework will be posted.
- Late homework will not be accepted.
- Homework re-grades require a written request and should be submitted within three days of the homework being returned.

Project requirements:

- Select a combinatorial optimization or satisfaction problem (production planning, lot sizing, scheduling, vehicle routing, traveling salesman, map coloring, frequency assignment, crew assignment, etc.).
- Formulate the problem by a mathematical programming model
- Formulate the problem by a constraint programming model
- Solve both mathematical programming (MP) and constraint programming (CP) models
- Try to improve the performance of constraint programming model by the techniques you have learnt throughout the semester (constraint generation, domain reduction, etc.)
- Compare different search methods
- Perform computational study to solve a number of problems with different sizes
- Submit a professionally written paper that includes:
    - Abstract
    - Problem definition
    - Literature review
    - MP model
    - CP model
    - Techniques used to improve the performance of the CP model
    - Numerical example, if necessary
    - Computational study
    - Conclusion
    - References
    - Appendix: Codes and problem data
- At the end of the semester, you will be required to make a 10-15 minute class presentation on your project. The last two classes will be used for presentations.

Software installation:

- You will need to use IBM's ILOG Cplex and ILOG CP optimizer to solve the mathematical programming and constraint programming models.
- IBM Academic Initiative provides ILOG optimization software for free to academics and graduate research assistants.
- Most of you should be able to register and install the software on your computers.
- If you are not eligible for academic initiative, the instructor can provide the software. You can use the software just for this class.

IBM Academic Initiative:

Information about Academic Initiative program for IBM ILOG Optimization products can be found at:
http://www-01.ibm.com/support/docview.wss?uid=swg21419058

You can register, read and accept the terms of IBM Academic Initiative at:
https://www.ibm.com/developerworks/university/academicinitiative

To get the required software installer, search for the product after clicking the 'Download from the Software Catalog' link at:
https://www.ibm.com/developerworks/university/software/get_software.html

Enter: IBM ID and Password
Install software: IBM ILOG CPLEX Optimization Studio V12.5.1 (for Windows)

Course Schedule

Week	Topic
1	Introduction to constraint programming Modeling: Logical constraints, alldifferent constraint, element constraint (variable indexing)
2	Modeling: Logical, alldifferent, element constraints IBM ILOG CP Optimizer Tutorial
3	Modeling: Circuit, cumulative, disjunctive constraints Examples: TSP, Scheduling
4	Modeling: Nvalue, stretch, cardinality constraints Examples: Staff rostering, course timetabling, crew scheduling IBM ILOG CP Optimizer – Scheduling
5	IBM ILOG CP Optimizer – Scheduling Logic of propositions (Boolean logic), resolution, implied constraints
6	Pseudo-Boolean optimization, non-serial dynamic programming, Logic of 0-1 inequalities (absorption, reduction, diagonal summation, implied cardinality clauses), logic of discrete variables
7	Consistency: Node, arc, hyper-arc, bounds consistency Global constraints (element, alldifferent, cardinality)
8	Global constraints (stretch, disjunctive, cumulative, sequence)
9	Constraint generation: k-consistency, backtracking Search, inference, relaxation
10	Search, inference, relaxation: Examples
11	Constraint-directed search
12	Integrated methods: Benders' decomposition Integrated methods: Relaxation
13	Integrated methods: Column generation, local search
14	Project presentations

Presentation Topics

Week	Date	Topic	Reference
7	2/20	Alldifferent: domain consistency	Hooker (2012) 6.8.2
	2/20	Element: domain consistency	Hooker (2012) 6.7.1
	2/20	Cardinality: domain consistency	Hooker (2012) 6.9.3
8	2/24	Stretch: domain consistency	Hooker (2012) 6.11.2
	2/24	Disjunctive: Edge finding	Hooker (2012) 6.14.1
	2/27	Cumulative: Edge finding	Hooker (2012) 6.15.1
	2/27	Sequence: domain consistency Flow-based filtering	Hooker (2012) 6.10.4
10	3/13	Constraint propagation: Forward checking, partial lookahead, full lookahead	Apt (2003) 8.4.1
13	4/3	Integrated methods: Relaxation of alldifferent constraint	Hooker (2012) 7.9.1
	4/3	Integrated methods: Relaxation of element constraint	Hooker (2012) 7.8.1
	4/3	Integrated methods: Relaxation of cardinality constraint	Hooker (2012) 7.10.1
	4/3	Integrated methods: Relaxation of disjunctive constraint	Hooker (2012) 7.12.1

Possible Project Topics

1. Vehicle routing with time windows
2. Machine scheduling with earliness/tardiness objectives
3. Resource constrained scheduling
4. Job shop scheduling
5. Course timetabling
6. Final exam scheduling
7. Staff (nurse, physician,…) scheduling
8. Crew scheduling
9. Assembly line sequencing
10. Transportation problems
11. Network flow problems