# ISyE 4134 CONSTRAINT PROGRAMMING

## Concentration Selective Elective for OR and Analytics and Data Sci.

**Format**, 3 – 0 – 3

**Coordinator**: Professor Pascal Van Hentenryck

**Prerequisites**: ISyE 3133 with concurrency, CS 2316

### Texts and other resources

PDFs of the lecture slides will be made availabe on the course website for you to print out and take to class if you wish. It is recommended that you take notes on and save these copies, as they will be a valuable resource for the project.

The OPL Studio system will be available for your assignments. It contains a sophisticated online documentation that should help design the projects.

**Catalog Description**

This course is an introduction to constraint programming, from its modeling language to its computational methodology and its applications to scheduling, routing, and resource allocation.

**Course Description**

Please add

**Topics outlines**

| Topics | Wks |
|---|---|
| Basic Concepts (Week 1): Getting started, basic concepts I, basic concepts II, OPL primer | 1 |
| Elements of Constraint Programming (Week 2): Reified constraints, Optimization, Expressions | 1 |
| Theoretical Foundation (Week 3): Computational Model | 1 |
| Global Constraints (Week 4): The element constraint, the table constraint, combinatorial Constraints, the pack constraint, the circuit constraint, the lex constraints | 1 |
| Modeling in Constraint Programming (Week 5): Symmetry breaking, subexpression elimination, redundant constraints I, redundant constraints II, | 1 |
| Search in Constraint Programming (Week 6): Search tree and impact, restart and nogoods | 1 |
| Implementation of Constraint Programming (Week 7): Packing, AllDifferrent, NoOverlap | 1 |

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| Scheduling in Constraint Programming (Week 8-12): Interval variables and noOverlap, The sequence constraints, cumulative constraints, the house problem II, the house problem III, the perfect square problem, state constraints, the trolley application, optional activities, standard scheduling problems, calendars | 5 |
| Advanced Topics (Week 13): Large neighborhood search, scripting models, routing, CP in Python | 1 |
| Implementation in MiniCP (Week 14): Semantics of CP, operational model of CP, inference, search, advanced inference, advanced search | 1 |
| Total | 14 |

**Course Learning Outcomes and Relationship to BSIE Program Outcomes**

By the end of this course the students should

1. Understand the modeling methodology and computational paradigms underlying constraint programming.
2. Understand how to use constraint programming to model and solve problems in a variety of engineering and scientific fields.
3. Understand the fundamental properties of good constraint programming models and how they differ from other methodologies.
4. Be able to determine when and how to use constraint programming to solve practical applications.
5. Be able to model and solve practical applications with constraint programming in areas such as scheduling, routing, and resource allocation.
6. Achieve fluency in the modeling language OPL for constraint programming and its derivatives in Python.
7. Recognize when additional features (e.g., new constraints and dedicatd search procedures) are necessary to solve a problem and understand what this involves.

| Course outcome \ Program Outcomes | 1. identify, formulate solve engg prob by engg, sci & Math | 2. produce solutions consider public health, safety, welfare, global, cultural, social, environ & | 3 communicate with a range of audience | 4 recognize ethical & professional responsibilities, make informed judgement consider resolutions in global, economic, environ and | 5. effective on a team provide leadership, collaborative and inclusive envirn, plan tasks & meet | 6. develop and conduct experiment, analyze and interpret data & use engineering judgement to draw | 7. acquire and apply new knowledge using appropriate learning strategies |
|---|---|---|---|---|---|---|---|
| 1. Understand the modeling methodology and computational paradigms underlying constraint programming. | | | | | | | |
| 2. Understand how to use constraint programming to model and solve problems in a variety of engineering and scientific fields. | | M | | | | | |
| 3. Evaluate monetary and environmental costs and benefits of technology choices (by exam) | | | | | | M | |
| 4. Be able to determine when and how to use constraint programming to solve practical applications. | | | | | | | |
| 5. Be able to model and solve practical applications with constraint | | M | | | | | |

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| programming in areas such as scheduling, routing, and resource allocation. | | | | | | | |
| 6. Achieve fluency in the modeling language OPL for constraint programming and its derivatives in Python. | | | | | | | |
| 7. Recognize when additional features (e.g., new constraints and dedicatd search procedures) are necessary to solve a problem and understand what this involves. | | | | | | | |

**Evaluation of the important course outcomes**

This elective course will not be used for assessing Student Outcomes.

**The approximate relationship from prior ABET a – k to new ABET 1 – 7.**

| OLD Criterion 3. Student Outcomes<br>The program must have documented student outcomes that prepare graduates to attain the program educational objectives.<br>Student outcomes are outcomes (a) through (k) plus any additional outcomes that may be articulated by the program. | NEW Criterion 3: Student Outcomes The program must have documented student outcomes that support the program educational objectives.<br>Attainment of these outcomes prepares graduates to enter the professional practice of engineering.<br>Student outcomes are outcomes (1) through (7), plus any additional outcomes that may be articulated by the program. |
|---|---|
| (a) an ability to apply knowledge of mathematics, science, & engineering<br>(e) an ability to identify, formulate, and solve engineering problems | (1) An ability to identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics. |
| (b) an ability to design and conduct experiments, as well as to analyze and interpret data | (6) An ability to develop and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions. |
| (c) an ability to design a system, component, or process to meet desired needs within realistic constraints such as economic, environmental, social, political, ethical, health & safety, manufacturable, & sustainable | (2) An ability to apply engineering design to produce solutions that meet specified needs with consideration for public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors. |
| (d) an ability to function on multidisciplinary teams | (5) An ability to function effectively on a team whose members together provide leadership, create a collaborative & inclusive environment, establish goals, plan tasks, and meet objectives. |
| (f) an understanding of professional and ethical responsibility<br>(h) the broad education necessary to understand the impact of engg solutions in a global, economic, environmental, & societal context<br>(j) a knowledge of contemporary issues | (4) An ability to recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts. |
| (g) An ability to communicate effectively. | (3) An ability to communicate effectively with a range of audiences. |
| (i) a recognition of the need for, and an ability to engage in life-long learning | (7) An ability to acquire and apply new knowledge as needed, using appropriate learning strategies. |
| (k) an ability to use the techniques, skills, and modern engineering tools necessary for engineering practice. | Implied in 1, 2 and 6 |