

CONSTRAINT PROGRAMMING

Syllabus: ISyE 4134/6134 Constraint Programming The Star Wars Edition

ISYE 4134/6134, Online Class

Interactive Sessions: MW 5:00–6:15 p.m EST.

Instructor:

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The Teaching Assistants

- TBD

Catalog Description

This course is an introduction to constraint programming (the “force”), from its modeling language to its computational methodology and its applications to scheduling, routing, and resource allocation.

Course Description

The course is intended primarily for senior undergraduates, Master students, and incoming PhD students. The course is an introduction to the “force” with an emphasis on modeling and solving optimization problems. It is not primarily a course about the implementation of constraint programming systems, although the class will cover the working of constraint programming solvers since this is critical to model problems correctly.

Undergraduate Prerequisites: ISyE 3133, CS 2316 (both with an A ideally)

The course involves numerous assignments in the OPL programming language. If you find learning a new programming language difficult and/or if you dislike programming, this is the wrong class for you. *We also recommend that you test the concepts that you learn in the video using the OPL system, so that you get familiar with the syntax and semantics of the language. Practicing the language is really important for later projects.*

Videos, Texts, and other resources

Professional videos of the lectures as well as PDFs of the lecture slides will be made available on the course website. They will cover all the material needed for learning the course outcomes. The OPL Studio system will be available for your assignments. It contains a sophisticated online documentation that should help design the projects. But the videos should be sufficient to learn OPL, including three especially devoted to the topic.

Minimum Technology Requirements

A modern laptop (or equivalent) is necessary to attend this course. Students will download the IBM Optimization studio which will be used for most of the assignments.

Attendance

This is an online class. The material is presented in high-quality videos and complemented with optional interactive online sessions. The online material is organized in modules. The material is released on Tuesday at 12:00am EST for the Wednesday class and at Thursday at 12:00am EST for the next Monday class. *The interactive sessions are optional, since this is a pure online class. They are provided as a way for you to ask questions, review the material with the instructor, and discuss your assignments.*

Students are expected to have reviewed the videos before the interactive sessions. The interactive sessions review the material, include Q/A sessions, and go over the assignments and projects. They also include one-on-one sessions with the instructor and the teaching assistants. They are a great learning experience, and we recommend that you attend them if you can. Experience has shown that significant learning happens in these sessions. The interactive sessions are not recorded.

Course Outcomes

By the end of this course the students should understand the modeling methodology and computational paradigms underlying constraint programming. Understand how to use constraint programming to model and solve problems in a variety of engineering and scientific fields.

- Describe the fundamental properties of good constraint programming models and how they differ from other methodologies.
- Be able to determine when/how to use constraint programming for practical applications in areas such as scheduling, routing, and resource allocation.
- Achieve fluency in the modeling language OPL for constraint programming.
- Recognize when additional features (e.g., new constraints and dedicated search procedures) are necessary to solve a problem and understand what this involves.

Grading

The grades will be based on 14 project assignments, a midterm exam, and a final exam. The percentage for each assignment is listed in the table below. Some of the assignments are routine, others are significantly more challenging. It is strongly recommended to start the assignments early. They have been adapted to online learning and to make sure that the learning process is gradual based on the instructor's experience in teaching online, in academia and industry. All assignments are due at 11:59pm EST on the due date. In case of disagreements in dates and points between the missive and the Canvas modules, the canvas module is the truth, the only truth, and the whole truth. The midterm will last around 3 hours and is similar to an easy project (it will not require any significant creativity). The final will take place over 4 hours.

Project	Due	Points
The Galaxy	Aug 31	5
Han Solo	Sep 2	5
Luke Skywalker	Sep 9	5
Stormtroopers	Sep 9	5
Jedi School	Sep 16	10
The Republic	Sep 21	10
COVID-26	Sep 28	15
Podraces	Oct 7	15
The Empire Strikes Back	Oct 14	10
The Return of the Jedi	Oct 21	15
Midterm	Oct 28	50
Takodana	Nov 2	10
R2D2	Nov 11	15
The Force Awakens	Nov 23	20
Millenium Falcon	Nov 30	10
Final	Dec 11	100
Total		300

Assignments

Assignments are graded on a scale that aligns with the below. Some of the assignments are extremely challenging even for experts in the field. This is the nature of optimization problems. One of the goals of the course is to help you understand this reality.

It is important for you to make sure that you have working solutions for the projects. Start early. **Every assignment must have detailed comments on the meaning of each decision variables and each constraint / group of constraints.** Assignments with no comments will not be graded. Assignments should prove optimality within 5 minutes unless explicitly mentioned otherwise.

The class starts slow, with easy projects initially. The pace then picks up quickly and the last projects are challenging. Plan ahead and do not be fool by the simplicity of the early projects. They are an opportunity for you to master the OPL language.

Regrading

If the grader has made a mistake in grading an assignment, we will be happy to correct it. All requests for regarding must be submitted with 7 days from the test date.

Extensions, Late Assignments

Late projects will be accepted with a 20% penalty per day late. Projects handed in more than three days late will not be graded. A Dean's excuse or a note from health services is required for any kind of exception to be made to the rules above. Once you have one of these, you should talk with the instructor, who is the only person who can give extensions.

Letter grade

The overall grades are the summation of grades from assignments. The final letter grades will be assigned based on

$$A \geq 270, B \geq 240, C \geq 210, D \geq 180.$$

AI Policy

Use of AI tools/LLMs/chatbots etc. is allowed for projects. These tools may not be used for exams. However, you are ultimately responsible for your submissions. It is important to understand the concepts covered in the course and how to break down the problems, and you should be able to explain and understand all parts of your code.

Permissions

You must ensure that your course documents have permissions which do not permit other students to view them. Ask an IT consultant for help with permissions if necessary.

Projects

You should not be looking at anyone else's write-up, nor should you permit anyone to look at your write-up. An obvious consequence of this policy is that you cannot debug the code of anyone else, and no one, with the exception of the instructor and the teaching assistants, can debug your code. Finally, you cannot search the web or any other physical or online medium to help you design your solution (with the exception of OPL and CPLEX documentation).

Excused Absences from Assignments

We only accept notifications from Dean's office https://gatech-advocate.symlicity.com/care_report/index.php/pid167160 or Institute Approved Absences <https://registrar.gatech.edu/info/institute-approved-absence-form-for-students>.

Please inform the instructor of your approved absences timely. If the notification from Dean's office is for instructor's discretion and your absence prevents you from completing assignments or tests, please discuss the accommodations with the instructor as soon as possible. Since it is difficult to create a different but fair test, and solutions to assignments may have already been published, the accommodation might not be a makeup test or assignment.

Course Outline

1. Basic Concepts
 - 1.1. Getting started
 - 1.2. Basic concepts I
 - 1.3. Basic concepts II

- 1.4. OPL Primer
- 2. Elements of Constraint Programming
 - 2.1. Reified constraints
 - 2.2. Optimization
 - 2.3. Expressions
- 3. Theoretical Foundation
 - 3.1. Computational Model
- 4. Global Constraints
 - 4.1. The element constraint
 - 4.2. The table constraint
 - 4.3. Combinatorial Constraints
 - 4.4. The pack constraint
 - 4.5. The circuit constraint
 - 4.6. The lex constraints
- 5. Modeling in Constraint Programming
 - 5.1. Symmetry breaking
 - 5.2. Subexpression elimination
 - 5.3. Redundant constraints I
 - 5.4. Redundant constraints II
- 6. Search in Constraint Programming
 - 6.1. Search tree and Impact
 - 6.2. Restart and nogoods
- 7. Implementation of Constraint Programming
 - 7.1. Packing
 - 7.2. AllDifferent
 - 7.3. NoOverlap
- 8. Scheduling in Constraint Programming
 - 8.1. Interval variables and noOverlap
 - 8.2. The Sequence Constraints
 - 8.3. Cumulative Constraints
 - 8.4. The House Problem II
 - 8.5. The House Problem III
 - 8.6. The Perfect Square Problem
 - 8.7. State Constraints
 - 8.8. The Trolley Application
 - 8.9. Optional Activities
 - 8.10. Standard Scheduling Problems
 - 8.11. Calendars
- 9. Advanced Topics
 - 9.1. Large neighborhood search

- 9.2. Scripting models
- 9.3. Routing
- 9.4. CP in Python
- 10. Implementation in MiniCP
 - 10.1. Semantics of CP
 - 10.2. Operational Model of CP
 - 10.3. Inference
 - 10.4. Search
 - 10.5. Advanced Inference
 - 10.6. Advanced Search

Exams

During the midterm and final exams, you cannot communicate or collaborate with any other students.

Course Expectations & Guidelines

Following [Georgia Tech policies and procedures](#) and [Course Policies](#), the policies are described below for this class.

1. Academic Integrity

Georgia Tech aims to cultivate a community based on trust, academic integrity, and honor. Students are expected to act according to the highest ethical standards. For information on Georgia Tech's Academic Honor Code, please visit <http://www.catalog.gatech.edu/policies/honor-code/> or <http://www.catalog.gatech.edu/rules/18/>. Any student suspected of cheating or plagiarizing on a project or an assignment will be reported to the Office of Student Integrity, who will investigate the incident and identify the appropriate penalty for violations. We use software tools to detect similarities between assignments.

2. Accommodations for Students with Disabilities

If you are a student with learning needs that require special accommodation, contact the Office of Disability Services at (404)894-2563 or <http://disabilityservices.gatech.edu/>, as soon as possible, to make an appointment to discuss your special needs and to obtain an accommodations letter. Please also e-mail an instructor as soon as possible in order to set up a time to discuss your learning needs.

3. Student-Faculty Expectations Agreement

At Georgia Tech we believe that it is important to strive for an atmosphere of mutual respect, acknowledgement, and responsibility between faculty members and the student body. See <http://www.catalog.gatech.edu/rules/22/> for an articulation of some basic expectation that you can have of us and that we have of you. In the end, simple respect for knowledge, hard work, and cordial interactions will help build the environment we seek. Therefore, we encourage you to remain committed to the ideals of Georgia Tech while in this class.

Interactive sessions

These are optional sessions, but, if in attendance, the camera is required to be on. Please mute yourself in the online interactive sessions if you are not speaking. Please provide questions for the Q&A in advance on the forum and/or in the chat of the interactive sessions. Your instructor will

moderate them for the benefits of the class. We strongly encourage to ask questions and participate as it greatly improves the learning experience. There is an extra credit to the final grade that will be awarded by the instructor to those who are interacting frequently during the interactive sessions and have their videos on. The one-on-one sessions in the breakout rooms are limited to 10 minutes when there are other students waiting.

Online Forum

The class uses an online forum called Ed Discussion. There are a few rules to observe on the forum

- The first replies will be to conceptual questions. Debugging questions will be answered last
- Instructor and teaching assistants do not respond to questions by email. Use Ed instead, and private posts if necessary.
- Instructor and teaching assistants do not answer debugging questions on Ed. Use the online sessions and breakout rooms for debugging.
- Questions should be conceptual in nature.
- No code should be posted in Ed public posts.
- There is an extra credit to the final grade that will be awarded by the instructor to those students who answer many questions of their peers over the course of the semester.

Additional Class Policies

Personal Communication

Obi-Wan Kenobi will reply only to brief email and urgent messages that are not appropriate for Ed discussion. The interactive sessions will provide the vehicles to ask as many questions as you want. Personal questions can also be addressed to course staff through private Ed posts.

Campus Resources for Students

Check the [academic resources](#) at Georgia Tech, which include the library, databases, the Communication Center, Counseling Center, The Division of Student Life, or Women's Resource Center).