200615 - OEC - Integer and Combinatorial Optimization

Coordinating unit: 200 - FME - School of Mathematics and Statistics
Teaching unit: 715 - EIO - Department of Statistics and Operations Research
Academic year: 2016
Degree: 3. CE-2. Ability to master the proper terminology in a field that is necessary to apply statistical or operations research models and methods to solve real problems.
ECTS credits: 5
Teaching languages: Spanish

Teaching staff

Coordinator: ELENA FERNÁNDEZ AREIZAGA
Others: Primer quadrant:
ELENA FERNÁNDEZ AREIZAGA - A
JESSICA RODRÍGUEZ PEREIRA - A

Prior skills

The level of the course, as well as its content follow, to a large extent, the text:

Requirements

In order to follow properly this course and obtain its maximum output it is necessary to have previous basic knowledge on the following disciplines:
> Linear Algebra: Basic concepts on matrices and bases in vector spaces.
> Computing: Basic programming techniques.

Degree competences to which the subject contributes

Specific:
3. CE-2. Ability to master the proper terminology in a field that is necessary to apply statistical or operations research models and methods to solve real problems.
4. CE-3. Ability to formulate, analyze and validate models applicable to practical problems. Ability to select the method and / or statistical or operations research technique more appropriate to apply this model to the situation or problem.
5. CE-5. Ability to formulate and solve real problems of decision-making in different application areas being able to choose the statistical method and the optimization algorithm more suitable in every occasion.
6. CE-6. Ability to use appropriate software to perform the necessary calculations in solving a problem.

Transversal:
1. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.
2. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.
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Teaching methodology

Theoretical sessions:
Lectures in which the topics of the syllabus are introduced and discussed. Slides will be used for some topics, while others will be dealt on the board. The faculty intranet will be used for making available teaching material related with the course: notes for some subjects, resolved problems and previous exams.

Problem-solving sessions:
Classes in which numerical problems concerning the subjects studied in the theory sessions are posed and solved. Students are given a certain amount of time to solve problems themselves, and then the problems will be resolved and discussed collectively.

Practicals:
There is a practical assignment that must be completed individually. A couple of sessions will be held in the computer hall to introduce students to practical procedures. The practical assignment consists of the implementation of some of the studied methods, when applied to the traveling salesman problem, and the computational study of its performance. The student will have to program some parts of the practical, although in other parts a standard software package will be used.

Learning objectives of the subject

This course studies models and techniques of Integer Programming. Special attention is is given to the potential applications of the models and their relation to combinatorial optimization. The main techniques that are studied are enumerative methods (branch-and-bound), methods related to cutting planes and Lagrangean relaxation. Basic concepts related to the description of polyhedra are also introduced. The application to classical combinatorial optimization models, like the traveling salesman problem or the knapsack problem, is also presented.

The main learning objectives of this course are:

- To provide a basic grounding in operations research, particularly in the field of Integer Programming. To familiarize students with methods for solving some practical applications of integer programming and combinatorial optimization problems.
- To know the possible modeling alternatives for the different types of problems of discrete optimization as well as their potential applications.
- To know the basic methodology of integer programming and, in particular, enumerative and cutting plane methods, as well as possible combinations of the above.
- To know results of duality theory and their implications in discrete programming. To exploit the properties of duality and the characteristics of the structure of a problem for solving discrete problems.
- To know the properties of the Lagrangean Dual for the case of discrete optimization.
- To know some basic heuristic methods for some combinatorial optimization problems.

Skills to achieve:
* The ability to find a suitable formulation and to design and implement a prototype method for the solution of a specific problem of combinatorial optimization.
* The ability to solve an integer programming problem using an enumerative algorithm.
* The ability to identify inequalities valid for typical problems in integer programming, such as the knapsack problem or the travelling salesman problem.
* The ability to formulate a Lagrangian relaxation for an optimization problem with constraints. The ability to determine the existence or not of a dual gap (or saddle points) for a particular optimization problem. Know how to apply the appropriate subgradient optimization technique for solving the Lagrangian dual.
### Study load

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<tr>
<th></th>
<th>Hours large group:</th>
<th>Hours medium group:</th>
<th>Hours small group:</th>
<th>Guided activities:</th>
<th>Self study:</th>
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<td><strong>Total learning time:</strong></td>
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<td><strong>Combinatorial optimization problems</strong></td>
<td><strong>Learning time:</strong> 2h</td>
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<td><strong>Description:</strong></td>
<td>Theory classes: 2h</td>
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<td><strong>Characteristics of Integer Programming models</strong></td>
<td><strong>Learning time:</strong> 9h</td>
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<td>Self study : 5h</td>
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<td><strong>Learning time:</strong> 7h</td>
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<td>Short recall of the Simplex method in matrix form</td>
<td>Laboratory classes: 1h</td>
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<td>Self study : 5h</td>
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<td><strong>Cutting plane methods</strong></td>
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<td>Self study : 8h</td>
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## Enumerative methods.

**Learning time:** 15h  
Theory classes: 5h  
Laboratory classes: 2h  
Self study: 8h

**Description:**  

## Lagrangean relaxation in integer programming.

**Learning time:** 15h  
Theory classes: 5h  
Practical classes: 2h  
Self study: 8h

**Description:**  

## The knapsack problem.

**Learning time:** 15h  
Theory classes: 5h  
Practical classes: 2h  
Self study: 8h

**Description:**  

## Practical presentation

**Learning time:** 2h  
Laboratory classes: 2h

**Description:**  
Practical presentation

**Specific objectives:**  
Practical presentation
The traveling salesman problem.

Description:

Learning time: 15h
Theory classes: 5h
Laboratory classes: 2h
Self study: 8h

Practical fulfillment

Description:
Development of practical assignment

Learning time: 30h
Self study: 30h

Qualification system

Continuous evaluation:
Exams: There will be a partial exam (in which a minimum grade of 5 releases from repetition of this part in the final exam), and a final exam.
Practical: Completion of an assigned individual piece of work.
Optional: To issue a collection of solved exercises.
Active participation in class will be assessed

In order to pass the course by means of the continuous evaluation it is necessary to score a minimum of 4 in both the exam and the practical. The final course result is calculated as follows:

0.4 (exam grade) + 0.4 (practical grade) + 0.1 (optional exercises) + 0.1 (participation in class)

Single act evaluation:
There will be an exam covering the entire syllabus as well as a practical assignment. The final course result for the single act evaluation call is computed as follows:

0.7 (exam grade) + 0.3 (practical grade)

For the single act evaluation, an score of at least 7 in the practical assignment of the continuous evaluation will release from repeating the practical project. Otherwise the student will be assigned a new practical.
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Bibliography

Basic:


Complementary:


Others resources:

Computer material

CPLEX

Software for the solution of integer programming problems