270032 - IO - Operations Research

Coordinating unit: 270 - FIB - Barcelona School of Informatics
Teaching unit: 715 - EIO - Department of Statistics and Operations Research
Academic year: 2019
Degree: BACHELOR'S DEGREE IN INFORMATICS ENGINEERING (Syllabus 2010). (Teaching unit Optional)
ECTS credits: 6
Teaching languages: Catalan, Spanish

Teaching staff
Coordinator: - Esteve Codina Sancho (esteve.codina@upc.edu)
Others: - Elena Fernández Areizaga (e.fernandez@upc.edu)

Prior skills
Students must have sufficient knowledge of algebra to assimilate the methods exposed. Algorithms should also be able to read English at a technical level.

Requirements
- Prerequisite PE

Degree competences to which the subject contributes

Specific:
CCO1.3. To define, evaluate and select platforms to develop and produce hardware and software for developing computer applications and services of different complexities.
CCO2.4. To demonstrate knowledge and develop techniques about computational learning; to design and implement applications and system that use them, including these ones dedicated to the automatic extraction of information and knowledge from large data volumes.
CSI1. To demonstrate comprehension and apply the principles and practices of the organization, in a way that they could link the technical and management communities of an organization, and participate actively in the user training.
CSI2.1. To demonstrate comprehension and apply the management principles and techniques about quality and technological innovation in the organizations.
CSI2.2. To conceive, deploy, organize and manage computer systems and services, in business or institutional contexts, to improve the business processes; to take responsibility and lead the start-up and the continuous improvement; to evaluate its economic and social impact.
CSI2.6. To demonstrate knowledge and capacity to apply decision support and business intelligence systems.
CSI3.5. To propose and coordinate changes to improve the operation of the systems and the applications.

General:
G6. SOLVENT USE OF THE INFORMATION RESOURCES: To manage the acquisition, structuring, analysis and visualization of data and information of the field of the informatics engineering, and value in a critical way the results of this management.
G8. APPROPRIATE ATTITUDE TOWARDS WORK: to have motivation to be professional and to face new challenges, have a width vision of the possibilities of the career in the field of informatics engineering. To feel motivated for the quality and the continuous improvement, and behave rigorously in the professional development. Capacity to adapt oneself to organizational or technological changes. Capacity to work in situations with information shortage and/or time and/or resources restrictions.
Learning objectives of the subject

1. Knowing the basic methodology and scope of Operations Research
2. Learn simple models of O.R., and special solutions
3. Understand and identify the components of an optimization problem
4. Identification of objectives in a decision process. Learn how to express constraints, both linear and nonlinear, to meet the conditions for decision variables in the model. To formulate multiobjective programming models and goal programming models.
5. Understanding the structure and properties of linear and non-linear programming problems
6. Understand and apply the simplex method to solve linear programming problems
7. Know how to solve linear programming problems in which variables are associated to a graph. networks flow problems.
8. Understand and apply basic techniques for solving linear problems with integer variables
9. Understand and identify the inputs and outputs of Operations Research models underlying various information systems and decision support systems described in the practical sessions.
10. Being able to apply heuristic methods for integer linear programming problems
11. Know and be able to apply different kinds of metaheuristics seen in the course
12. Being able to effectively use information resources in O.R.
13. Having proper attitude and motivation towards work

Study load

<table>
<thead>
<tr>
<th>Total learning time: 150h</th>
<th>Hours large group: 30h</th>
<th>20.00%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours medium group:</td>
<td>15h</td>
</tr>
<tr>
<td></td>
<td>Hours small group:</td>
<td>15h</td>
</tr>
<tr>
<td></td>
<td>Guided activities:</td>
<td>6h</td>
</tr>
<tr>
<td></td>
<td>Self study:</td>
<td>84h</td>
</tr>
</tbody>
</table>

Teaching methodology

Learning is done following the methodology of cases, from problems in the area of Operations Research. From these problems will develop the knowledge necessary formal theory classes, classroom and exhibition, and its application in laboratory classes, so that will strengthen the assimilation of various concepts. Used software available on the UPC (AMPL,OPL/Studio Excel).
## Content

### Introduction to modeling decisions:

**Degree competences to which the content contributes:**

**Description:**
The modeling in the process of decision making. Models of Operations Research. The cycle of operations research methodology

### Continuous programming. Properties and methods

**Degree competences to which the content contributes:**

**Description:**

### Continuous programming models and systems to support decision making

**Degree competences to which the content contributes:**

**Description:**

### Integer Linear Programming

**Degree competences to which the content contributes:**

**Description:**
Integer Linear programming problem properties. Some problems ple: the problem of scheduling workers, problems with routing problems fixed cost and location algorithms PLE: secant planes; Branch &amp; Bound algorithm

### Heuristic methods for solving ILP problems

**Degree competences to which the content contributes:**

**Description:**

### Search and evaluation of information for conducting a task in O.R.
Motivation and attitude to work in O.R.

**Degree competences to which the content contributes:**

**Description:**
Motivation for liability, the quality of their work and professional realization. Ability to adapt to organizational changes, technological. Teamwork. Adapting the lack of information and material limitations and time.
# Planning of activities

| Block 1. Presentation of the objectives of the basic models of IO and IO | Hours: 2h  
Theory classes: 1h  
Practical classes: 0h  
Laboratory classes: 0h  
Guided activities: 0h  
Self study: 1h |
|---|---|
| **Description:**  
Monitoring of exposures and review the material proporcionat for the corresponding session. Assimilation of the role of optimization problems as a source of modeling.  
**Specific objectives:**  
1, 2, 3 |
| Analysis of information sources | Hours: 6h 30m  
Theory classes: 0h 30m  
Practical classes: 0h  
Laboratory classes: 0h  
Guided activities: 0h  
Self study: 6h |
| **Description:**  
Analysis and evaluation of information provided by certain references (software packages / references that can provide solutions to coursework.  
**Specific objectives:**  
12 |
| Block 2. Continuous optimization models and systems to aid decision making | Hours: 12h  
Theory classes: 4h  
Practical classes: 2h  
Laboratory classes: 0h  
Guided activities: 0h  
Self study: 6h |
| **Description:**  
Follow the models exhibited in the theory sessions. Resolution of monitored and modeling exercises. In the lab sessions, training in the use of algebraic representation languages.  
**Specific objectives:**  
1, 3, 4 |
| Using search engines referrals, BD and Electronic | Hours: 4h 30m  
Theory classes: 0h 30m  
Practical classes: 0h  
Laboratory classes: 0h  
Guided activities: 0h  
Self study: 4h |
## Description:
Search for publications of certain writers in relation to coursework. Viewing videos
http://bibliotecnica.upc.edu/habilitats/eines-de-cerca-dinformacio
http://bibliotecnica.upc.edu/habilitats/l039estrategia-de-cerca # 4

### Specific objectives:
- 12

### Evaluation of the search for references in relation to course work

<table>
<thead>
<tr>
<th>Description:</th>
<th>Hours: 0h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery report with the 5 most significant references and details of the search tools used to find them</td>
<td>Guided activities: 0h</td>
</tr>
<tr>
<td></td>
<td>Self study: 0h</td>
</tr>
</tbody>
</table>

### Specific objectives:
- 12

## Block 3. Continuous programming problems

| Hours: 16h |
| Theory classes: 5h |
| Practical classes: 3h |
| Laboratory classes: 0h |
| Guided activities: 0h |
| Self study: 8h |

### Description:
Tracking theory classes with the support of teaching materials produced specifically. Assimilation of basic concepts feasible optimal basis, optimal local and global. Ability to perform the steps of the simplex algorithm. Individual and monitored resolution of problems. Ability to define linear and non linear models using algebraic languages in the lab sessions

### Specific objectives:
- 5, 6

## Attitude and motivation toward work. A1

| Hours: 4h |
| Theory classes: 0h |
| Practical classes: 0h |
| Laboratory classes: 1h |
| Guided activities: 0h |
| Self study: 3h |

### Description:
Students discuss laboratory exercises delivered according to guidelines contained in a section.

### Specific objectives:
- 14
| Evaluation of information sources | Hours: 0h  
Guided activities: 0h  
Self study: 0h |
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Delivery of a report of the evaluation</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>12</td>
</tr>
</tbody>
</table>

| Assessing motivation and attitude towards work. A1 | Hours: 0h  
Guided activities: 0h  
Self study: 0h |
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Using rubrics</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>14</td>
</tr>
</tbody>
</table>

| Block 4. Network Flow Problems | Hours: 14h  
Theory classes: 4h  
Practical classes: 3h  
Laboratory classes: 0h  
Guided activities: 0h  
Self study: 7h |
<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Make simplex iterations for the problem of min-cost. application of minimal paths algorithms. implementation of the max-flow algorithm min.cut</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>1, 7</td>
</tr>
</tbody>
</table>

| Evaluation of a lab 1 | Hours: 0h  
Guided activities: 0h  
Self study: 0h |
<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Handed a questionnaire completed by the end of the session. This questionnaire will go.</td>
</tr>
<tr>
<td><strong>Specific objectives:</strong></td>
<td>2, 3, 4, 5, 6, 7</td>
</tr>
<tr>
<td>Part 1</td>
<td>Hours: 6h</td>
</tr>
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<td>---</td>
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</tr>
<tr>
<td><strong>Description:</strong></td>
<td>Guided activities: 2h</td>
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<tr>
<td></td>
<td>Self study: 4h</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Block 5. Integer linear programming modeling</th>
<th>Hours: 12h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td></td>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td></td>
<td>Laboratory classes: 0h</td>
</tr>
<tr>
<td></td>
<td>Guided activities: 0h</td>
</tr>
<tr>
<td></td>
<td>Self study: 6h</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Attitude and motivation toward work. A2</th>
<th>Hours: 7h</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Theory classes: 0h</td>
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<tr>
<td></td>
<td>Practical classes: 0h</td>
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<tr>
<td></td>
<td>Laboratory classes: 2h</td>
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<tr>
<td></td>
<td>Guided activities: 0h</td>
</tr>
<tr>
<td></td>
<td>Self study: 5h</td>
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<table>
<thead>
<tr>
<th>Assesing motivation and attitude towards work. A2</th>
<th>Hours: 0h</th>
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<tbody>
<tr>
<td><strong>Description:</strong></td>
<td>Guided activities: 0h</td>
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<tr>
<td></td>
<td>Self study: 0h</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Specific objectives:</th>
<th>1, 2, 3, 4, 5, 6, 7</th>
</tr>
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<tbody>
<tr>
<td>1, 9</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td></td>
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<tr>
<td>14</td>
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</tbody>
</table>
### Block 6. Integer Linear Programming Problems

**Description:**
Assimilation of the concepts of branching and quoting. Make iterations of the Branch and Bound algorithm with small problems.

**Specific objectives:**
- 8

<table>
<thead>
<tr>
<th>Hours</th>
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<tbody>
<tr>
<td>8h</td>
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</table>

<table>
<thead>
<tr>
<th>Theory classes:</th>
<th>2h</th>
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</thead>
<tbody>
<tr>
<td>Practical classes:</td>
<td>2h</td>
</tr>
<tr>
<td>Laboratory classes:</td>
<td>0h</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>0h</td>
</tr>
<tr>
<td>Self study:</td>
<td>4h</td>
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</tbody>
</table>

### Attitude and motivation toward work. A3

**Description:**
Oral presentation of course work in a limited time (10min to the working group)

**Specific objectives:**
- 14

<table>
<thead>
<tr>
<th>Hours</th>
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<tbody>
<tr>
<td>7h</td>
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<table>
<thead>
<tr>
<th>Theory classes:</th>
<th>0h</th>
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</thead>
<tbody>
<tr>
<td>Practical classes:</td>
<td>0h</td>
</tr>
<tr>
<td>Laboratory classes:</td>
<td>2h</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>0h</td>
</tr>
<tr>
<td>Self study:</td>
<td>5h</td>
</tr>
</tbody>
</table>

### Assessing motivation and attitude towards work. A3

**Description:**
Oral presentation

**Specific objectives:**
- 14

<table>
<thead>
<tr>
<th>Hours</th>
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</thead>
<tbody>
<tr>
<td>0h</td>
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</table>

| Guided activities: | 0h |
| Self study: | 0h |

### Block 7. Heuristic methods for integer linear programming problems. Metaheuristics

**Description:**
Understand the main principles of construction heuristic solutions. Learn to build algorithms based on metaheuristics described. Simulated annealing method, tabu search, greedy search.

<table>
<thead>
<tr>
<th>Hours</th>
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<tbody>
<tr>
<td>12h</td>
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</table>

<table>
<thead>
<tr>
<th>Theory classes:</th>
<th>4h</th>
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</thead>
<tbody>
<tr>
<td>Practical classes:</td>
<td>2h</td>
</tr>
<tr>
<td>Laboratory classes:</td>
<td>0h</td>
</tr>
<tr>
<td>Guided activities:</td>
<td>0h</td>
</tr>
<tr>
<td>Self study:</td>
<td>6h</td>
</tr>
</tbody>
</table>
### Evaluation of lab 2

**Description:**
Handed a questionnaire completed by the end of the session. This questionnaire will go.

**Specific objectives:**
2, 4, 8, 9, 10, 11

**Hours:**
- Guided activities: 0h
- Self study: 0h

### Laboratory 1 and 2

**Description:**
Reading the previous questionnaire and preparation of practice. Execution of the exercise and delivery of completed questionnaire

**Specific objectives:**
3, 5, 6, 7, 8

**Hours:**
- Theory classes: 0h
- Practical classes: 0h
- Laboratory classes: 4h
- Guided activities: 2h
- Self study: 4h

### Block 8. Course work.

**Description:**
Assimilating the different stages of formulation, analysis and testing of an optimization model as part of a system to support decision making. Analysis of performance and computational tools used in the performance of the developed model. Development of skills associated to this subject.

**Specific objectives:**
1, 3, 4, 7, 9, 10, 11

**Hours:**
- Theory classes: 2h
- Practical classes: 0h
- Laboratory classes: 6h
- Guided activities: 0h
- Self study: 8h

### Assessment Course work

**Hours:**
- Guided activities: 0h
- Self study: 0h
### Description:
A model will be proposed to the students for its development along the course. Specific lab sessions will be used for monitoring this activity.

**Specific objectives:**
- Development of a model based on optimization problems as part of a system to aid decision making.
- Analyze the performance of the computational model developed for use in the environment of proper systems to aid decision making.

**Specific objectives:**
1, 3, 4

### Part 2

<table>
<thead>
<tr>
<th>Description</th>
<th>Hours: 6h</th>
</tr>
</thead>
<tbody>
<tr>
<td>It consists of test problems for blocks 5, 6 and 7 of the subject and the corresponding block 8 related blocks 5.6 and 7.</td>
<td>Guided activities: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 4h</td>
</tr>
</tbody>
</table>

**Specific objectives:**
8, 9, 10, 11

### Final Exam

<table>
<thead>
<tr>
<th>Description</th>
<th>Hours: 8h</th>
</tr>
</thead>
<tbody>
<tr>
<td>It covers all blocks of the subject</td>
<td>Guided activities: 2h</td>
</tr>
<tr>
<td></td>
<td>Self study: 6h</td>
</tr>
</tbody>
</table>

**Specific objectives:**
1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11
Qualification system

NT = Note of Theory
NL = Note for Laboratory sessions. This note will consist of the marks obtained in the two lab exercises, each one of them weighting 50% of NL
NTC = Note for Laboratory Labour Course
NC = Note for skills

N = 0.45*NT + 0.2*NL + 0.25 * NTC + 0.1*NC

If 0.5* NExP1 + 0.5* NExP2 >= 5 then no need to submit the final exam

NT = Max (NExF, 0.5 * NExP1 + 0.5*N*ExP2)

NExF Note of the final exam,
NExP1, NExP2 Notes of partial exams 1 and 2.

Mark NC will depend on the degree reached at the skills assigned to the subject and the mark will be an average of the marks obtained at each of the skills. (There are two skills, C1, C2. Then mark NC will obtained as NC = 0.5*NC1 + 0.5*NC2

For a given skill i there is the following matching between the level obtained at that skill and the mark NC1, NC2 involved in the final mark

A level A is equivalent to a mark NC1 (or NC2) that will be between 8.5 and 10
A level B is equivalent to a mark NC1 (or NC2) that will be between 6.5 and <8.5
A level C is equivalent to a mark NC1 (or NC2) that will be between 5 and < 6.5
A level D is equivalent to a mark NC1 (or NC2) that will be between 0 and <5

Marks for skills are obtained through activities carried out in bloc 8 (Laboratory Labour Course) and Lab sessions.

Marks NC1, NC2 for skills assigned to this subject will obey to the following expression:

NCi = 0.25 * NTC + 0.10*NL + Specific Activities for the skill; i=1,2
# Bibliography

**Basic:**


**Complementary:**


**Others resources:**

- Hyperlink
  - [http://people.brunel.ac.uk/~mastjjb/jeb/or/contents.html](http://people.brunel.ac.uk/~mastjjb/jeb/or/contents.html)
- [http://ifors.org/web/](http://ifors.org/web/)
- [http://www.hsor.org/](http://www.hsor.org/)
- [http://www.ampl.com/](http://www.ampl.com/)