270613 - CC - Computational Complexity

Coordinating unit: 270 - FIB - Barcelona School of Informatics  
Teaching unit: 723 - CS - Department of Computer Science  
Academic year: 2019  
Degree: MASTER'S DEGREE IN INNOVATION AND RESEARCH IN INFORMATICS (Syllabus 2012). (Teaching unit Optional)  
ECTS credits: 6  
Teaching languages: English

Degree competences to which the subject contributes

Basic:
CB8. Capability to communicate their conclusions, and the knowledge and rationale underpinning these, to both skilled and unskilled public in a clear and unambiguous way.  
CB9. Possession of the learning skills that enable the students to continue studying in a way that will be mainly self-directed or autonomous.

Specific:
CEE3.1. Capability to identify computational barriers and to analyze the complexity of computational problems in different areas of science and technology as well as to represent high complexity problems in mathematical structures which can be treated effectively with algorithmic schemes.  
CEE3.3. Capability to understand the computational requirements of problems from non-informatics disciplines and to make significant contributions in multidisciplinary teams that use computing.

General:
CG1. Capability to apply the scientific method to study and analyse of phenomena and systems in any area of Computer Science, and in the conception, design and implementation of innovative and original solutions.  
CG3. Capacity for mathematical modeling, calculation and experimental designing in technology and companies engineering centers, particularly in research and innovation in all areas of Computer Science.

Transversal:
CTR6. REASONING: Capacity for critical, logical and mathematical reasoning. Capability to solve problems in their area of study. Capacity for abstraction: the capability to create and use models that reflect real situations. Capability to design and implement simple experiments, and analyze and interpret their results. Capacity for analysis, synthesis and evaluation.

Teaching methodology

Blackboard lectures for theory classes and discussion sessions for the problem classes. The theory classes will follow the main textbook for the class [Arora and Barak] rather closely. Since we plan to cover more topics than is possible in the given time, students will be required to read the details in the textbook as homework (a draft of the book is available online for free). The aim of the discussion sessions is to solve some problems from that book and to discuss the reading material.

Learning objectives of the subject
### Study load

<table>
<thead>
<tr>
<th>Study load</th>
<th>Hours</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total learning time</td>
<td>150h</td>
<td></td>
</tr>
<tr>
<td>Hours large group</td>
<td>36h</td>
<td>24.00%</td>
</tr>
<tr>
<td>Hours medium group</td>
<td>18h</td>
<td>12.00%</td>
</tr>
<tr>
<td>Hours small group</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td>Guided activities</td>
<td>0h</td>
<td>0.00%</td>
</tr>
<tr>
<td>Self study</td>
<td>96h</td>
<td>64.00%</td>
</tr>
</tbody>
</table>
## Computational Models and Complexity Measures

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

**Description:**

## P, NP and NP-completeness

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

**Description:**

## Polynomial-time Hierarchy and Alternations

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

**Description:**
Oracle reducibility. NP and co-NP. Levels of the hierarchy. Quantifier alternations. Complete problems.

## Space Complexity

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

**Description:**

## Randomized Computation

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

**Description:**
Bounded-error and zero-error probabilistic polynomial time. Error-reduction. Randomized reductions. Valiant-Vazirani reduction to Unique SAT.

## Counting and Enumeration

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


## Probabilistic Proofs

### Degree competences to which the content contributes:

### Description:
- Interaction and randomness in proofs. Probabilistic proofs for graph non-isomorphism. Probabilistic proofs for \#P and Shamir's Theorem: \( \text{IP} = \text{PSPACE} \).

## Circuit Lower Bounds

### Degree competences to which the content contributes:

### Description:
- Monotone circuits. Lower bounds for clique and perfect matching.
- Bounded-depth circuits. Hastad's switching lemma.
- Approximation by polynomials.
### Planning of activities

<table>
<thead>
<tr>
<th>Activity</th>
<th>Hours</th>
<th>Guided activities</th>
<th>Self study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Submission first problems sheet</td>
<td>8h</td>
<td>0h</td>
<td>8h</td>
</tr>
<tr>
<td>Submission second problems sheet</td>
<td>8h</td>
<td>0h</td>
<td>8h</td>
</tr>
<tr>
<td>Submission third problems sheet</td>
<td>8h</td>
<td>0h</td>
<td>8h</td>
</tr>
<tr>
<td>Submission forth problems sheet</td>
<td>8h</td>
<td>0h</td>
<td>8h</td>
</tr>
<tr>
<td>Submission fifth problems sheet</td>
<td>8h</td>
<td>0h</td>
<td>8h</td>
</tr>
<tr>
<td>Final exam</td>
<td>15h</td>
<td>3h</td>
<td>12h</td>
</tr>
</tbody>
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### Qualification system

Students will be required to submit 5 problem/discussion sheets. Each will be given a grade in $[0,1]$ ($P_1,\ldots,P_5$). There will be a final exam graded in $[0,10]$ ($E$). The final grade of the course will be $\text{MAX}(P_1+P_2+P_3+P_4+P_5+E/2, E)$.

The problem/discussion sheets will consist of problems from the main textbook [Arora-Barak] and/or multiple choice questions that test if the student understood the material from the theory class (also covered in the main textbook).
Bibliography

Basic:


Complementary:
