Course outline for IT461: Stochastic simulation

1. **Title:** Stochastic simulation and applications

2. **Credit Structure (L-T-P-Cr):** 3 0 0 3

3. **Course Code:**

4. **Semester:**

5. **Category:** Technical elective

6. **Prerequisites:** Basic probability theory and programming skills.

7. **Foundation for:**

8. **Abstract Content:**

   **Course outline**

   This course aims to equip the student with the mathematical techniques behind stochastic modeling and simulation. Solving problems based on random simulation has a long history. In the 19th century Buffon performed an experiment in which he threw a needle repeatedly on a board ruled with parallel lines to experimentally infer the value of Pi from the observations of the number of intersections between needles and lines. The methods of stochastic simulation were called ‘Monte Carlo’ a term coined by John Von Neumann because of the roulette which is a simple random number generator. Currently there is a proliferation of stochastic simulation algorithms in fields as wide ranging as biology and finance. The importance of these methods can be realized from the fact that the Monte Carlo algorithm was named as one of the ten most important algorithms of the twentieth century.

   A stochastic or probabilistic model is a model which has got inherent randomness built in it. A simple example is a single server queue where both the waiting time and the arrival time is a random number. Such queuing models occur in inventory management as well as traffic and internet protocol modeling. One of the reasons for simulating probabilistic models on a computer is that many models are mathematically hard to analyze since computation of the relevant quantities of interest often require integration over a large dimensional space. It is also more cost effective to test and iterate a model on a computer before actually implementing a large scale system. The basic method of stochastic simulation is the Monte Carlo method which solves problems with very large degrees of freedom by imitating a random process. The idea is to repeatedly sample from a distribution to compute important quantities like expectation of a function of a random variable. Markov chain Monte Carlo method is a modification of the above method that constructs a Markov chain that has the desired distribution as its equilibrium distribution. This course will focus on the mathematical tools and techniques needed for simulation. The course will cover basics of probability and Markov chains before going into specific algorithms and applications. Applications covered will be from but not restricted to statistical physics, image analysis, queuing theory.
Optional:

9. Suggested Text/s:
- Introduction to Probability by Laurie Snell (online text)

10. Detailed Contents:

<table>
<thead>
<tr>
<th>Topic Name</th>
<th>Content (2-3 lines per 4-6 lectures)</th>
<th>No of lectures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability Basics</td>
<td>Introduction to Probability Space, Conditional probability, Random variables and their distributions, Conditional distributions, Law of large numbers and Central limit theorem.</td>
<td>6</td>
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<tr>
<td>Basics of Monte Carlo and sampling techniques.</td>
<td>Random number generation, Sampling techniques: Inverse Transform method, acceptance-rejection method etc., statistical validation of simulation data.</td>
<td>10</td>
</tr>
<tr>
<td>Applications</td>
<td>Discussion of applications to various fields like Networking, Pattern recognition, Bioinformatics etc.</td>
<td>12</td>
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11. Outcomes and Objectives

- At the end of the course student will be familiarized with the important aspects of probabilistic modeling and simulation.
- The student will be exposed to simulation in the context of different applications in ICT area.
- The student will be able to understand the mathematical concepts behind the stochastic modeling.

12. Grading Policy

1. Assignments including computer programming.
2. Final project/Paper presentation.