Course Code	Course name		L	T	P	C
CSEG8003	Modelling and Simulation		2	0	1	3
Total Units to be Covered:		Total Contact Hours: 60				
Prerequisite(s):		Syllabus version: 1.0				

Course Objectives

Introduction to computer simulation technologies and techniques, provide the foundations for the student to understand computer simulation needs, and to implement and test a variety of simulation and data analysis libraries and programs. This course focusses what is needed to build simulation software environments, and not just building simulations using pre existing packages. Introduce concepts of modelling layers of society's critical infrastructure networks and build tools to view and control simulations and their results.

Course Outcomes

At the end of this course student should be able to

CO1: Discuss computer simulation needs and implement and test a variety of simulation and data analysis libraries and programs.

CO2: Design simulation software environments.

CO3: Recognize modelling layers of society's critical infrastructure networks.

CO4: Design tools to view and control simulations and their results.

CO-PO Mapping

Course Outcome	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO12	PSO1	PSO2	PSO3

CO1	**2**	**-**	**-**	**-**	**2**	**2**	**2**	**2**		**2**	**-**	**-**	**-**	**-**	**-**
CO2	**-**	**3**	**3**	**3**	**2**	**-**	**-**	**-**	**-**	**2**	**-**	**-**	**3**	**3**	**-**
CO3	**-**	**3**	**-**	**-**	**2**	**-**	**2**	**2**	**3**	**-**	**-**	**-**	**3**	**-**	**-**
CO4	**-**	**3**	**-**	**3**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**3**	**-**
Average	**2**	**3**	**3**	**3**	**2**	**2**	**2**	**2**	**3**	**2**	**-**	**-**	**3**	**3**	**-**

Syllabus

UNIT 1: Simulation Basics 7 Lecture Hours

Handling Stepped and Event-based Time in Simulations, Discrete versus Continuous Modelling, Numerical Techniques, Sources and Propagation of Error, Stochastic Modelling and Simulation, Optimization in Simulation Models, Hybrid and Multi-Scale Modelling, Modelling and Simulation Standards, Simulation Software and Tools, Ethical and Practical Considerations.

UNIT 2: Dynamical, Finite State, and Complex Model Simulations 7 Lecture Hours

Graph or Network Transitions Based Simulations, Actor Based Simulations, Mesh Based Simulations, Hybrid Simulations, Agent-based and Multi-Agent Simulations, Cellular Automata Based Simulations, Monte Carlo and Probabilistic Simulations, Event-Driven Simulation Architectures, Simulations of Complex Adaptive Systems, Domain-Specific Simulation Applications.

UNIT 3: Converting To Parallel and Distributed Simulations 7 Lecture Hours

Partitioning the Data, Partitioning the Algorithms, Handling Inter-partition Dependencies, Dynamic Partitioning, Communication Patterns in Partitioned Systems, Scalability Challenges in Partitioned Systems, Partitioning in Graph-based Systems, Hybrid Partitioning Approaches, Fault Tolerance in Partitioned Systems, Partitioning for Emerging Architectures.

UNIT 4: Probability and Statistics for Simulations and Analysis 5 Lecture Hours

Introduction to Queues and Random Noise, Random Variates Generation, Sensitivity Analysis

UNIT 5: Simulations Results Analysis and Viewing Tools 4 Lecture Hours

Display Forms: Tables, Graphs, and Multidimensional Visualization, Terminals, X and MS Windows, and Web Interfaces, Validation of Model Results

Total lecture Hours 30

References*

Textbooks	1. Acha, E., Fuerte-Esquivel, C. R., Ambriz-Pérez, H., and Angeles-Camacho, C. (2004), FACTS: Modelling and Simulation in Power Networks. John Wiley and Sons.
Reference books	1. Al-Begain, K., and Bargiela, A., Eds. (2016), Seminal Contributions to Modelling and Simulation: 30 Years of the European Council of Modelling and Simulation. Springer. 2. Arifin, S. N., Madey, G. R., and Collins, F. H. (2016), Spatial Agent-Based Simulation Modeling in Public

	Health: Design, Implementation, and Applications for Malaria Epidemiology. John Wiley and Sons. 3. Asmussen, S., and Glynn, P. W. (2007), Stochastic Simulation: Algorithms and Analysis (Vol. 57), Springer Science and Business Media. 4. Axelrod, R. M. (1997), The Complexity of Cooperation: Agent-Based Models of Competition and Collaboration. Princeton University Press. 5. Banks, J., Ed. (1998), Handbook of Simulation: Principles, Methodology, Advances, 6. Applications, and Practice, John Wiley & Sons, New York, NY.
Web Resources	
Journals	
MOOCs, online courses	

Modes of Evaluation: Quiz/Assignment/ presentation/ extempore/ Written Examination

Examination Scheme

Components	IA	MID SEM	End Sem	Total
Weightage (%)	50	20	30	100

Modelling & Simulation Lab

List of Experiments

Experiment 1: Handling Stepped and Event-Based Time in Simulations

This experiment focuses on implementing and comparing two simulation techniques: stepped-time and event-based simulations. Using a simple system such as traffic signal management, students will simulate a stepped-time model where state transitions occur at fixed intervals. They will also create an event-based model that triggers transitions only when specific events occur. The performance, efficiency, and practicality of both approaches will be analysed to understand their respective strengths and use cases in dynamic systems.

Experiment 2: Discrete versus Continuous Modelling

In this experiment, students will explore the differences between discrete and continuous modelling by simulating a population growth scenario. They will first create a discrete model where population changes occur in steps and then develop a continuous model using differential equations to represent smooth growth. By analysing the outputs, students will compare the two approaches, focusing on their advantages, limitations, and real-world applicability.

Experiment 3: Stochastic Modelling and Simulation

This experiment aims to simulate stochastic processes, such as stock market price fluctuations or random walks, to understand uncertainty modelling. Students will generate random variables representing unpredictable elements and apply Monte Carlo simulations to analyse the processes. The results will be visualized and interpreted, highlighting the role of stochastic simulations in handling real-world variability.

Experiment 4: Graph or Network Transitions-Based Simulations

Students will implement graph-based simulations to study phenomena such as disease spread within a network of individuals. A graph-based network will be designed, with nodes representing individuals and edges denoting interactions. The simulation will model infection and recovery transitions based on probabilities, allowing students to analyse the impact of network structures on the spread of diseases.

Experiment 5: Cellular Automata-Based Simulations

This experiment introduces cellular automata to simulate a physical phenomenon like forest fire propagation. Students will define rules for the spread of fire, simulate it across a grid of cells, and observe the dynamics. By varying parameters such as wind direction and intensity, they will evaluate the influence of environmental factors and visualize the results to gain insights into spatial dynamics.

Experiment 6: Monte Carlo and Probabilistic Simulations

In this experiment, students will apply Monte Carlo techniques to estimate mathematical constants like π or solve probabilistic problems. By simulating random points within a geometric boundary and analysing their distribution, they will estimate π and evaluate the accuracy of the results as the number of iterations increases. This will deepen their understanding of Monte Carlo methods.

Experiment 7: Parallel and Distributed Simulations

This experiment challenges students to design and execute a parallel simulation for a computationally intensive task, such as matrix multiplication. They will partition data and algorithms for parallel processing, handle inter-partition dependencies using synchronization methods, and measure performance metrics like speedup and scalability. The experiment underscores the importance of parallelism in large-scale simulations.

Experiment 8: Random Variates Generation and Sensitivity Analysis

Students will explore random variate generation techniques, such as uniform and normal distributions, to simulate stochastic systems like queueing models. They will perform sensitivity analysis to determine how variations in input parameters affect system performance. By presenting results through graphs and charts, students will gain insights into the impact of randomness and parameter sensitivity in simulations.

Experiment 9: Simulation Results Analysis and Validation

This experiment emphasizes the importance of validating simulation results and analysing outputs effectively. Students will simulate a system (e.g., traffic flow), collect data, and validate results against theoretical predictions or known benchmarks. Visualization tools such as matplotlib or Tableau will be used to display data in graphs and tables, ensuring clarity and interpretability.

Experiment 10: Building Web Interfaces for Simulations

In the final experiment, students will design a web-based interface to interact with and visualize simulation results. Using web development tools like HTML, CSS, and JavaScript, they will create a user-friendly interface that integrates with a backend simulation engine. The interface will allow users to input parameters and view results interactively, showcasing the practical application of simulation tools in real-world scenarios.

Total Lab hours 30

References*

Textbooks	1 .Acha, E., Fuerte-Esquivel, C. R., Ambriz-Pérez, H., and Angeles-Camacho, C. (2004), FACTS: Modelling and Simulation in Power Networks. John Wiley and Sons.
Reference books	1. Al-Begain, K., and Bargiela, A., Eds. (2016), Seminal Contributions to Modelling and Simulation: 30 Years of the European Council of Modelling and Simulation. Springer. 2. Arifin, S. N., Madey, G. R., and Collins, F. H. (2016), Spatial Agent-Based Simulation Modeling in Public Health: Design, Implementation, and

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Web Resources	
Journals	
MOOCs, online courses	

Modes of Evaluation: Quiz/Assignment/ presentation/ extempore/ Written Examination

Examination Scheme: Continuous Assessment

Components	Quiz & Viva	Performance & Lab Report
Weightage (%)	50	50