Modeling & Simulation (CS-503)

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Outline

- Objective of the Course
- Scope of the Course
- Course Outline
- Course Requirements
- Assessment Method
Course Objective

• In this course, modeling and simulation (M&S) methodologies considering both practical and theoretical aspects
  – Primarily in the context of defense industry and game programming will be studied in details.
• By taking the lecture, you will be supported with sufficient knowledge about
  – A wide range of M&S concepts that will lead you to develop your own M&S applications.

What is M&S ?

• Discipline of understanding and evaluating the interaction of parts of a real or theoretical system by;
  – Designing its representation (model) and
  – Executing (running) the model including the time and space dimension (simulation).
What is a System?

- An entity (unit, process, event...), which exists and operates in time and space through the interaction of its parts.

What is a Model?

- A simplified representation of a real or theoretical system at some particular point in time or space intended to provide understanding of the system.
What is a Simulation?

• The manipulation of a model in such a way that it operates in time or space to summarize it.

A Popular R&D Area

• In recent decades,
  – M&S has become a very popular research and development area, which can be applied in many domains.
Some Application Areas

- Medical research, training & support
- Industrial engineering designs & presentations (Factory process design, ...)
- Civil engineering designs & presentations (Building design, city & infrastructure planning, ...)
- Mechanical engineering designs & presentations (Engine designs, Aerodynamic design, ...)
- Nature sciences (Physics, Chemistry, Biology, Meteorology, Astronomy, ...)
- Geographic Information Systems (Earth modeling, ...)
- Military Decision Support (War modeling, ...)
- Training (Simulators, games, ...)
- Entertainment (Games, ...)

Practical Scope of Course

- **Modeling & Simulation in:**
  - Defense Industry, and
  - Game Programming.
- **Includes:**
  - Earth modeling,
  - Entity modeling,
  - Behavior modeling,
  - Sensor & weapon systems modeling,
  - Distributed simulations,
  - Simulation based optimization and analysis.
**Course Outline**

- Introduction To Modeling & Simulation
  - What is Modeling and Simulation?
  - Complexity Types
  - Model Types
  - Simulation Types
  - M&S Terms and Definitions

- Input Data Analysis
  - Simulation Input Modeling
  - Input Data Collection
    - Data Collection Problems
    - Practical Suggestions
    - Effect of Period of Time
  - Input Modeling Strategy
    - Histograms
    - Probability Distributions
    - Selecting a Probability Distribution
    - Evaluating Goodness of Fit
Course Outline

• Random Variate Generation
  – Random Numbers
  – Random Number Generators
  – Random Variate Generation
    • Factors to be considered
    • General principles
      – Inverse Transform Method
      – Acceptance-Rejection Method
      – Composition Method
      – Relocate and Rescale Method
    • Specific distributions

Course Outline

• Output Data Analysis
  – Introduction
    • Types of Simulation With Respect to Output Analysis
    • Stochastic Process and Sample Path
    • Sampling and Systematic Errors
    • Mean, Standard Deviation and Confidence Interval
  – Analysis of Finite-Horizon Simulations
    • Single Run
    • Independent Replications
    • Sequential Estimation
  – Analysis of Steady-State Simulations
    • Removal of Initialization Bias (Warm-up Interval)
    • Replication-Deletion Approach
    • Batch-Means Method
Course Outline

• Comparing Systems via Simulation
  – Introduction
  – Comparison Problems
    • Comparing Two Systems
    • Screening Problems
    • Selecting the Best
    • Comparison with a Standard
    • Comparison with a Fixed Performance

Course Outline

• Discrete Event Simulations
  – Introduction
    • Next-Event Time Advance
    • Arithmetic and Logical Relationships
    • Discrete-Event Modeling Approaches
  – Event-Scheduling Approach
  – Process-Interaction Approach
Course Outline

• Specific Practices
  – Overview of Some M&S Tools and Systems
    • Well-Known Simulation Modeling Tools
      – GPPS
      – Arena
    • Well-Known International M&S Systems
      – JTLS
      – Janus
      – JCats
      – Items
      – SAF
      – JSAF
      – OneSAF
    • National M&S Systems
      – Sensim
      – Ramos
      – Baskın
      – Kama
      – Mühatem

• Surrounding Environment Modeling
  – Common Data Representation Types
    • Raster Maps
    • Vector Maps
  – Earth Modeling
    • Terrain Surface Modeling
      – Source Data Formats
      – Data representations
      – Remote Sensing
    • Water Surface Modeling
      – Source Data Formats
      – Data representations
    • Underwater Modeling
      – Source Data Formats
      – Data representations
    • Meteorological Modeling
      – Source Data Formats
      – Data representations
      – Meteorological computations
    • Astronomical Modeling
      – Data representations
      – Astronomical computations
  – Earth Visualization
    • What is DirectX & OpenGL?
    • Terrain Surface rendering
    • Water Surface rendering
    • Underwater rendering
    • Atmosphere rendering
    • Astronomical rendering
Course Outline

- Entity Modeling
  - Entity Body Modeling
  - Entity Body Visualization
  - Entity Body Animation
  - Entity Interaction Modeling
  - Building Modeling

Course Outline

- Distributed Simulation
  - High Level Architecture (HLA)
  - Federation Development and Execution Process (FEDEP)
  - SISO RPR FOM
Course Outline

• Behavior Modeling
  – General AI Algorithms
    • Decision Trees
    • Neural Networks
    • Finite State Machines
    • Logic Programming
    • Production Systems
  – Path Planning
    • Off-Line Path Planning
    • Incremental Path Planning
    • Real-Time Path Planning
  – Script Programming
    • Script Parsing
    • Script Execution

Course Outline

• Optimization Algorithms
  – Genetic Algorithms
  – Simulated Annealing
Course Outline

- Sensor Systems Modeling
  - Human Eye Modeling
  - Optical Sensor Modeling
  - Radar Modeling

Course Outline

- Weapon Systems Modeling
  - Target Acquisition & Engagement
  - Target Movement Estimation
  - Direct Fire Modeling
  - Indirect Fire Modeling
  - Damage Assessment
Course Requirements

• Develop a small-scale M&S project with a team of preferably at most three people.
• The project will include:
  – Documentation,
  – Implementation and
  – A class presentation.

Course Requirements

• The project topic can be either;
  – Proposed by the team or
  – Selected from a list of projects provided by the lecturer,
  • Which will be towards the development of an experimental game development environment on Windows platform.
Course Requirements

• Preferred:
  – Microsoft Word, and
  – C++ programming language:
    (1) Borland C++ Builder or
    (2) Microsoft Visual Studio.

Project Topics Proposed

• Topics proposed will be towards the development of an experimental game environment.
• Basic implementation will be provided with the source code by the lecturer in Borland C++ Builder 6.0 or Microsoft Visual Studio 2005.
Project Topics Proposed

1) Environment modeling
   1.1) Waterfall modeling
   1.2) Water surface modeling
   1.3) Grassland modeling
   1.4) Scrubland modeling
   1.5) Tree modeling
      1.5.1) Needle leaf tree modeling
      1.5.2) Broad leaf tree modeling
      1.5.3) Leafless tree modeling
   1.6) Sky modeling
   1.7) 3D game world modeling
3D game world modeling
Tree modeling
Wind effects modeling
Tree modeling
Water surface modeling
Ground surface modeling

Waterfall modeling
Sky modeling
Scrubland modeling
Grassland modeling

Project Topics Proposed

2) Behavior modeling
   2.1) Fish behavior modeling
   2.2) Bird behavior modeling
   2.3) Land animal behavior modeling
   2.4) Attack behavior modeling
   2.5) Defense behavior modeling
   2.6) Head/looking direction modeling
Project Topics Proposed

3) Body movement (bone structure) modeling
   3.1) Human body movement modeling
   3.2) Land animal body movement modeling
Project Topics Proposed
(Body Movement Modeling)

Human body movement modeling
Bone structures
Land animal body movement modeling
3D animation tools
Motion Capture

4) Effects modeling (wind effect integrated)
   4.1) Particle effect modeling (smoke, flame, explosion, missile trail)
   4.2) Rain and snow modeling
   4.3) Volumetric cloud modeling
Project Topics Proposed
(Effects Modeling)

Explosion modeling
Partial effects modeling

Effect of wind
Smoke modeling

Aircraft/missile trail modeling
Flame/fire modeling

Rain and snow modeling
Helicopter rotor modeling

Light lobs

CS-503 37
Project Topics Proposed

5) Physics modeling
   5.1) Rigid body collision detection and avoidance
   5.2) Parachute modeling

Project Topics Proposed (Effects Modeling)

- Rigid body collision detection
- Parachute modeling
- Explosion effects and damage modeling
- Breaking into pieces
- Collision avoidance
Project Topics Proposed

6) Distributed simulation
   6.1) Multi player land vehicle modeling with HLA
   6.2) Massive multi player role playing game environment modeling

7) Sensor Modeling
   7.1) Night vision goggles modeling
   7.2) Analysis of sensor detection, recognition and identification performance

8) Sound programming
   8.1) 3D sound effects modeling
Assessment Method

- A project will be developed including:
  - Project Progress Report 10%
  - Project Final Report 25%
  - Project Demo & Source Code 30%
  - Project Presentation 30%
- Attendance to M&S Seminar (6-10 October) 5%
  Prof. Dr. Tuncer Ören
  Ottawa University, Canada
  See www.modsim.org.tr > Modsim Platform > Aktiviteler

References