Tshwane University of Technology
We empower people

You Have a DREAM

That’s Why You Are Here

We Are Here

To Make That DREAM Come TRUE

MODELING AND SIMULATION

MSI118G

By

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Academic Qualifications

Ph.D in Computer Science (UFH/ UT)

Masters in Computer Science (UFH)

BSc Honors in Computer Science (BUSE)

Work Experience

Walter Sisulu University

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University of Fort Hare

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Why Doing This Module

Modeling and simulation are crucial in computer science, they allow researchers and professionals to analyze, predict, and optimize complex systems:

- **1. Understanding Complex Systems**
- **2. Optimization and Decision-Making**
- **3. Cost-Effective Testing**
- **4. Predictive Analysis**
- **5. Software and Hardware Development**
- **6. Artificial Intelligence & Machine Learning**
- **7. Cybersecurity and Network Analysis**
- **8. Scientific and Engineering Applications**
- **9. Education and Training**
- **10. Digital Twin Technology**

Self Driven Cars

Module Outline

A.1. Understand fundamentals of Modelling and Simulation
B.1. Understand model building process in problem-solving.

C.1. Understand the simulation process in problem solving.

D.1. Using Simulation techniques and tools in problem-solving.

E.1. Investigating approaches to validating models.

F.1. Investigating results presentation and interpretation.
G.1. Displaying data visually.

Outcome

By the end of the unit, you should be able to:

A.1.1 Define Model and simulation in a broad context.

A.1.2 Explain Modelling and simulation as problem- solving methods.

A.1.3 Explain Systems concept from real and theoretical perspectives using schematic diagram

A.1.4 Differentiate Static and Dynamic system concepts within the context of Modelling and Simulation

A.1.5 Explain the relationship between modelling and simulation as problem-solving methods on a continuum.

A.1.6 Explain Models as abstractions of simulations with a practical illustrative example.

A.1.7 Explain Simulations as dynamic modelling with a practical illustrative example.

A.1.8 Explain Modelling and Simulation as a problem-solving method with a practical illustrative example.

A.1.9 Highlight the benefits of simulation and modelling in a range of important application areas with illustrative examples.

A.1.10 Identify examples with rationale of application problem domains appropriate for modelling and simulation problem-solving

A.1.11 Identify examples of existing software tools for modelling and simulation a their salient functional features.

Recommended Reading Material

- Uri Wilensky and William Rand (2016), An Introduction To Agent-Based Modeling: Modeling Natural, Social, and Engineering Complex Systems with NETLOGO.
- Juan Carlos Garcia Vazquez and Fernando Sancho Caparrini, 2014. NetLogo, A modelling tool.
- Wainer, G. A., and Mosterman, P. J., Eds. (2016), Discrete-Event Modeling and Simulation: Theory and Applications. CRC Press.
- Bungartz, H.J., Zimmer, S., Buchholz, M., Pflüger, D, 2014. Modeling and Simulation: An Application-Oriented Introduction. Springer Undergraduate texts in Mathematics and Technology. Springer-Verlag Berlin, Heidelberg ISBN 978-3-642-39524-6

Recommended Reading Material

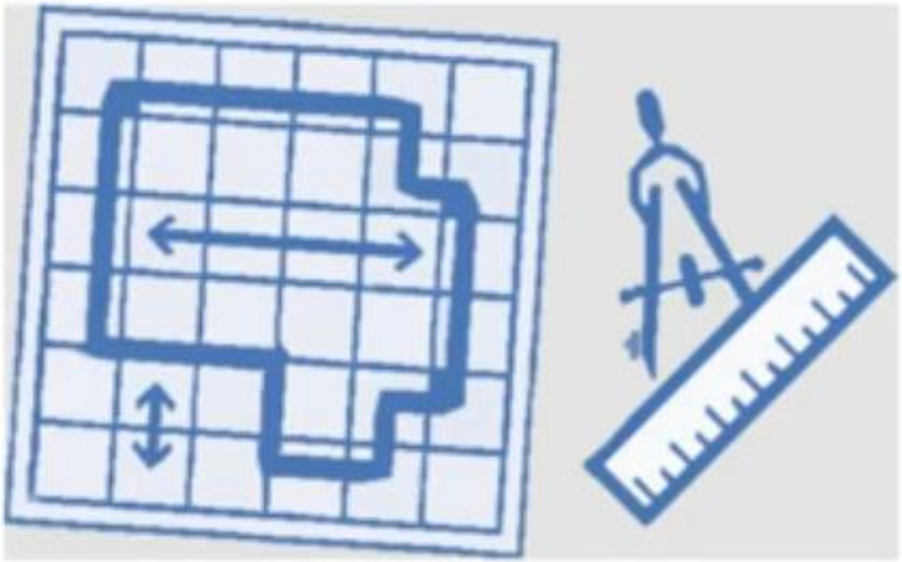
- Summative Test 30%
- Assignments 30%
- Oral Exam 10%
- Project 30%

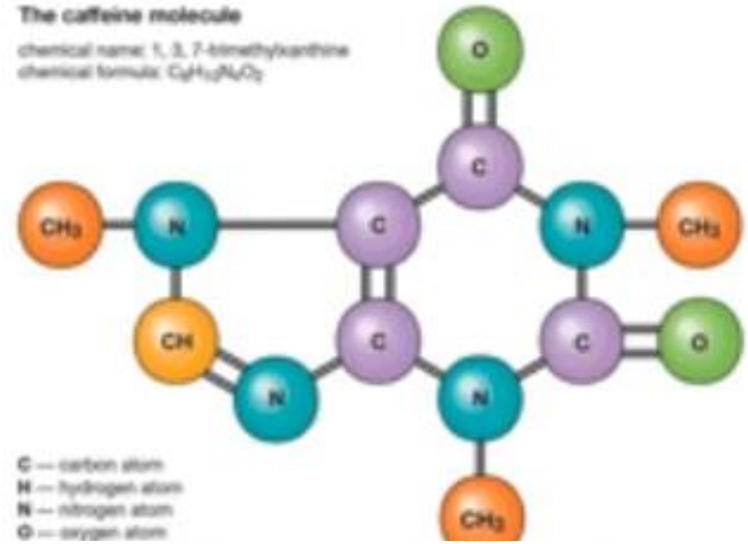
- CLASS REP??

Model

What is a model? Perhaps the best (or, at least, the most parsimonious) definition of a model is that it is a representation of a real-world entity but not the "real thing" itself. This definition, necessarily vague, encompasses just about any type of model.

Model





A 3D model of a planned community

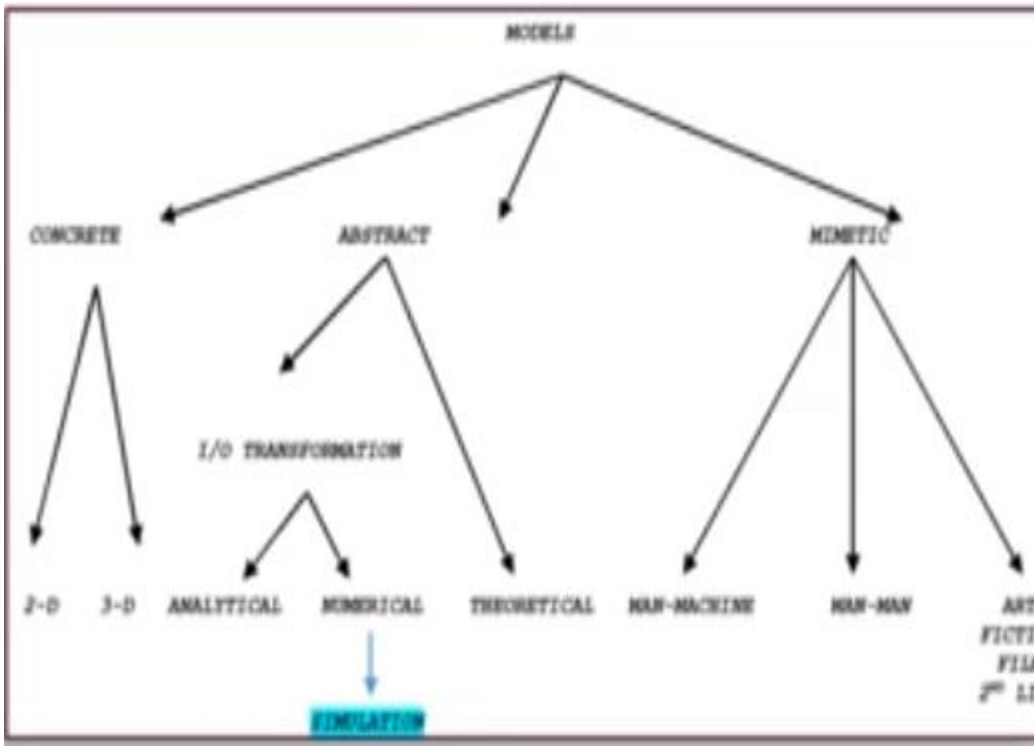
Mathematical Model

$$Y_i = \beta_0 + \beta_1 X_i + \epsilon_i$$

Classifying Models

- *Physical models* resemble the system being studied, e.g., full-scale mockup for training pilots.
- *Scaled models* also resemble the system under study, but at a different size. e.g., scaled up model of an atom.
- *Analog models*. A property of the real (studied) object is represented by a substituted property that often behaves in a similar manner. e.g., voltage through an electronic analog computer network may represent flow of goods through a system. A graph is an analog model: distance represents time, temperature, sales, etc. Another example is an organizational chart.
- *Schematic model* is a pictorial representation of a system, e.g., blueprint, graph.
- Games, or *man-machine models*, include management games, war games, planning, competition
- *Simulation models*, such as discrete-event system simulation models, have no human interaction. an abstract model, e.g., an algorithm or a step-by-step computation or computer program.
- *Mathematical models*. Symbols represent entities. These are the most generalized models, with the risk of oversimplification.
- *Heuristic model* is a collection of descriptors or decision rules, usually computer-based, which is not limited by physical, diagrammatic or mathematical bounds.

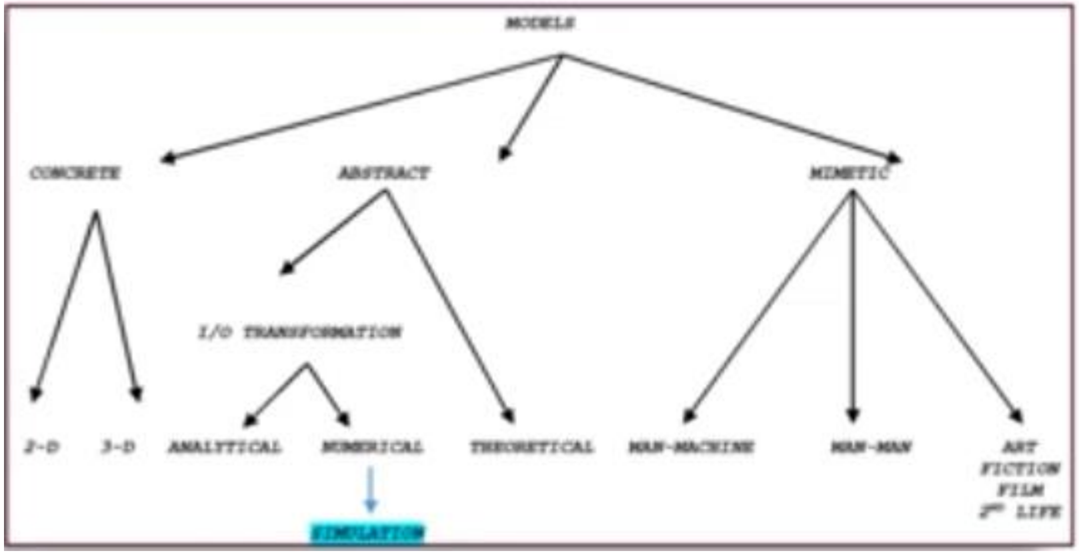
Classifying Models



Concrete, or physical, models can be two-dimensional, e.g., the blueprints used by architects, or three-dimensional, such as the architect's miniaturized rendering of a large building complex, a model of an atom or a molecule, or a clothing model in a department store window.

Abstract models can be analytical formulas of, e.g., those of statistics, queuing or econometrics; the numerical models used in simulation; or theoretical models such as those of quantum physics, chaos theory, the technology acceptance model (TAM) of information systems, or Kuhn's paradigms of scientific research.

Classifying Models



Mimetic models are those that involve imitation of life or the creation of alternative universes. They include man-machine models such as venture capital games – indeed, most gaming models – and virtual reality environments. Man-man models can include those used in psychology and education, for example: role playing, role models, and the what-if scenarios used in the military, law enforcement, and intelligence communities. Also included in the mimetic models branch are the models of culture or society used in art, fiction, film, and theater. These models may represent a version of the world as it really is or, often, an alternative version of the world as the author or artist imagines it to be, such as a utopian or dystopian view of the world.

Each model:

- is a view of reality
- has a purpose
- employs abstraction, structure, and information hiding

In addition, each model alters reality to some degree. Even physical models, which we may expect to be fairly good representations, may be faster, slower, flatter, larger, or smaller than the reality they purport to represent.

Modelling

- Modeling is the process of creating an abstract representation of a real-world system, phenomenon, or process.

Abstraction models reality or, at the very least, a chosen view of reality in which irrelevant objects or properties are ignored … making the model simpler conceptually and easier to study, manipulate, and implement.

- A model is a simplified version that captures essential characteristics while omitting less relevant details.
- Models can be mathematical, conceptual, physical, or computational, depending on the domain and purpose. Modelling is a way we can solve real-world problems.
- The model-building phases - mapping the real world to the world of models, choosing the abstraction level, and choosing the modelling language.
- Modelling is about finding the way from the problem to solution through a risk-free world where we're allowed to ma mistakes, undo things, go back in time, and start over again.

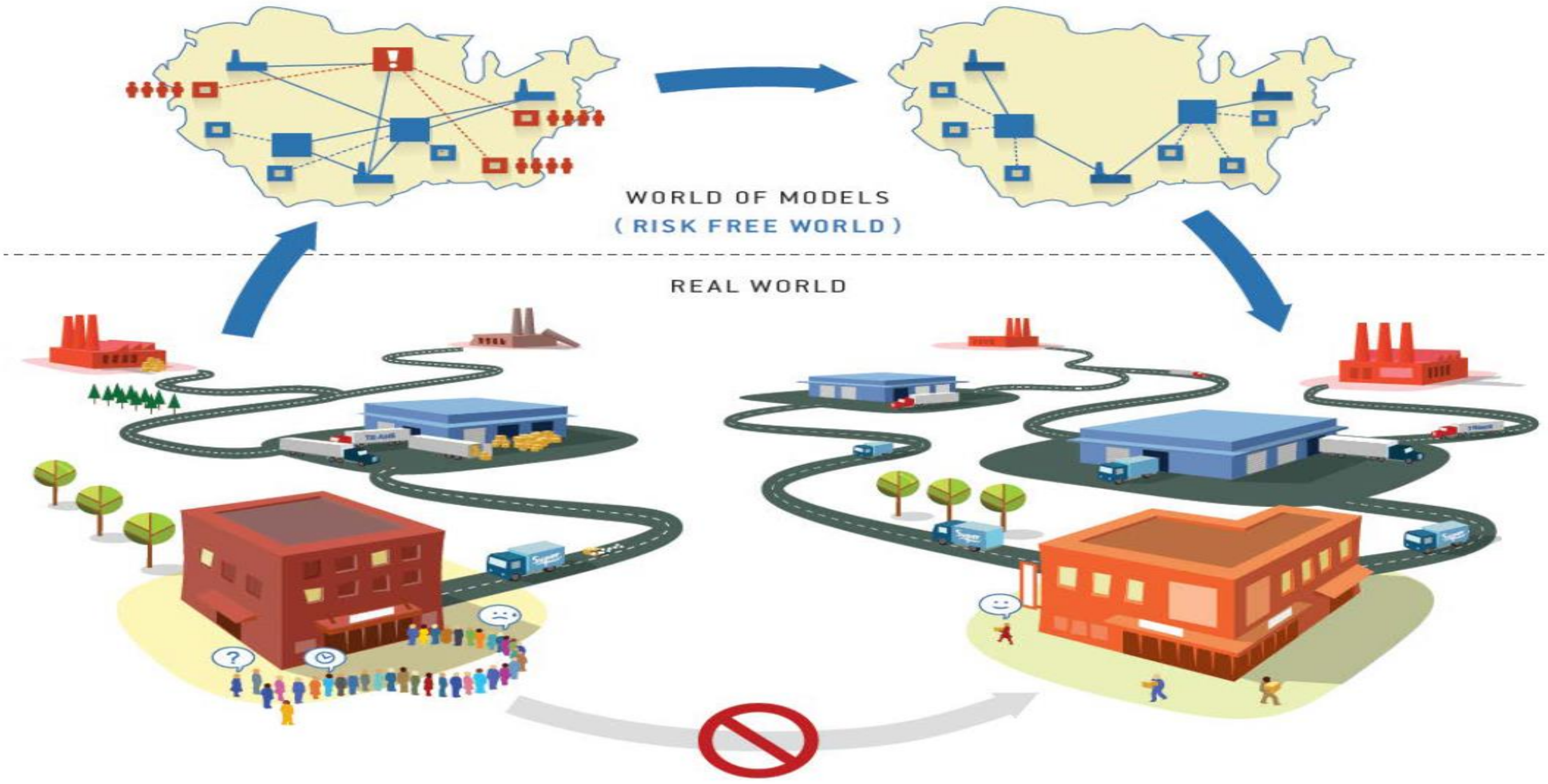
Key Features:

- Represents a system, process, or phenomenon.
- Can be physical (e.g., scale models), mathematical (e.g., equations), or computational (e.g., AI models).
- Aims to understand, analyze, or predict behaviors in real-world scenarios.

Examples

- A mathematical equation modeling population growth.
- A neural network model predicting student dropout rates.
- A 3D CAD model of a bridge before construction.

Modelling



ABSTRACTION AND INFORMATION HIDING

The general model governing **abstraction** is the so-called *black box model*, adopted from the engineering disciplines to many diverse areas. In this model, a set of inputs is mapped to a set of outputs or results by means of a transform. To use the transform, once it has been built, one need not know how it works; only that it does work. For example, we do not need to understand much about electricity to know that when we flip the light switch (input), the bulb will light up (output).

The Black Box Model

All abstraction uses the concept of **information hiding**. When models are well designed, they are relatively independent. They communicate with each other only through well defined interfaces. Unneeded information may be hidden from the user, protecting the integrity of individual systems and reducing the confusion that comes along with too much information. Abstraction also allows one to ignore the tedious and possibly irrelevant details (at least temporarily) and concentrate on the larger picture.

Simulation

- **Simulation is the process of using a model to replicate and study the behavior of a system under different conditions.**
- **It involves running experiments on a model to observe how the system reacts to changes in input parameters.**

(1) designing a model of a real system, and	(2) conducting experiments with this model.

Why Simulate?

- estimation of some quantity or measure of effectiveness
- to gain an understanding of the behavior of the system
- evaluation of various alternative strategies

Key Features:

- Uses a model to imitate real-world processes.
- Allows testing different scenarios without affecting the actual system.
- Can be dynamic (changing over time) or static (fixed conditions).

Examples

- Running a weather prediction model to simulate climate changes.
- Using a flight simulator to train pilots.
- Simulating network traffic in a cybersecurity experiment.

Types of Simulation

- Analog simulation. Physical simulation models, e.g., analog cockpit simulator for pilot training.
- Digital simulation – Continuous or Discrete
  - Continuous simulation. Physical events are expressed as mathematical models using difference and differential equations to express relationships. Deals with continuously changing variables, e.g., fluid dynamics (dams, waste disposal), monetary flow models.
  - Discrete-event Simulation (DES or DEVS). Models discrete entities.
  - Hybrid. Some discrete, some continuous elements.
- System simulation models are (usually) large, complex computer programs that represent a Dynamic and Probabilistic system composed of people, machinery, computers, processes, etc.

Key Difference

Aspect	Modeling	Simulation
Definition	Creating an abstract representation of a system.	Using a model to imitate system behavior under different conditions.
Purpose	Understand, analyze, or predict real-world systems.	Experiment with and observe system behaviors under various scenarios.
Nature	Static representation (e.g., equations, structures).	Dynamic execution of a model to observe system changes.
Output	A conceptual, mathematical, or computational framework.	Data, visualizations, or insights from running the model.
Example	A machine learning model predicting student performance.	Running the model to simulate student performance under different teaching strategies.

- **Modeling and simulation are closely related but distinct.**
- **Modeling focuses on building an abstract representation of a system, while simulation involves using that model to study behaviors, test scenarios, or make predictions.**
- **Together, they are essential tools in fields like engineering, healthcare, and climate science.**

Conclusion

- All models are a simplified representation of reality, an abstraction
- Simulation is just one type of model, a numerical model which presumes experimentation
- A DiscreteEventSimulation is discrete, stochastic and dynamic.
- Since it moves over time it must therefore include facilities for the collection of output measures that change over time.

I REST MY CASE

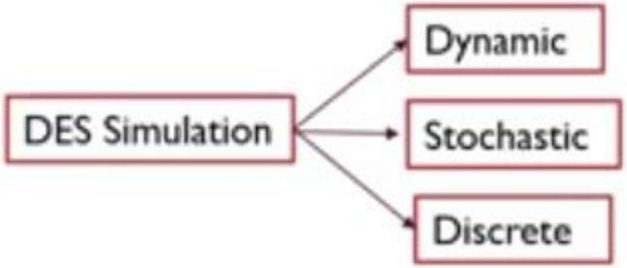
THANK YOU
Q & A

VAMBE
WILLIAM T

A.1.4 Differentiate Static and Dynamic system concepts within the context of Modelling and Simulation.

FURTHER CHARACTERISTICS OF MODELS

- Static vs. Dynamic. Does the model have a time element, does it "move" over time? An example of Static-Numerical model is Monte Carlo Sampling; An example of Dynamic-Analytical model is Time Series regression (a linear model).
- Deterministic vs. stochastic. Does the model mimic probabilistic phenomena?
- Discrete vs. Continuous.
  - Discrete. Variables change at distinct points in time
  - Continuous. Variables change continuously.
- System Simulation: Experimenting with an abstract model over time, this experimentation involving sampling from probability distributions.



APPLICATION AREAS EXAMPLES