Mesleki İngilizce - Technical English

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- Notes:
  - In the slides,
    - texts enclosed by curly parenthesis, {…}, are examples.
    - texts enclosed by square parenthesis, […], are explanations related to examples.

Computer Simulation

- Learning Objectives
  - to acquire basic knowledge about simulation kinds and history
  - to understand difference between simulation and modelling
  - to understand the power of simulation and its influence on modern science
- Sub-areas covered
  - Computer simulation
  - Computer graphics
  - Mathematics

Computer Simulation

- Keywords
  - mathematical model
    - an abstract model that uses mathematical language to describe a system
  - stochastic process
    - a process with an indeterminate or random element as opposed to a deterministic process that has no random element
  - Discrete
    - not supporting or requiring the notion of continuity
      - discrete objects are countable sets such as integers

Computer Simulation

- Keywords
  - Computer Generated Imagery (CGI)
    - an application of the field of computer graphics (or, more specifically, 3D computer graphics) to special effects in films, television programs, commercials and simulation
  - differential equation
    - a mathematical equation for an unknown function of one or several variables that relates the values of the function itself and of its derivatives
  - Gamut
    - a complete range or extent
  - Monte Carlo method
    - a computational algorithm which relies on repeated random sampling to compute its results

Computer Simulation

- Reading text
- Pre-reading questions
  - How can we solve problems in cases where physical models are too complex or expensive to build?
  - Name some problems which can be solved using computer simulation?

Computer Simulation

- A computer simulation
  - also referred to as a computer model or a computational model
  - is a computer program, or network of computers, that attempts to simulate an abstract model of a particular system.
- Computer simulations have become a useful part of the mathematical modelling of many natural systems in physics (computational physics), chemistry and biology; human systems in economics, psychology, and social science, and in the process of engineering new technology, so as to gain insight into the operation of those systems or to observe their behaviour.

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Computer Simulation

- Computer simulations vary from computer programs that run a few minutes, to network-based groups of computers running for hours or ongoing simulations that run for days.
- The scale of events being simulated by computer simulations has far exceeded anything possible (or perhaps even imaginable) using the traditional paper-and-pencil mathematical modelling: over 10 years ago.
- A desert-battle simulation, of one force invading another, involved the modelling of 66,239 tanks, trucks and other vehicles on simulated terrain around Kuwait, using multiple supercomputers in the DoD High Performance Computer Modernization Program.

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Computer Simulation

- A desert-battle simulation, of one force invading another, involved the modelling of 66,239 tanks, trucks and other vehicles on simulated terrain around Kuwait, using multiple supercomputers in the DoD High Performance Computer Modernization Program.
- Another simulation ran a 1-billion-atom model, where previously, a 2.64-million-atom model of a ribosome, in 2005, had been considered a massive computer simulation.
- The Blue Brain project at EPFL (École Polytechnique Fédérale de Lausanne, Switzerland) began in May 2005 to create the first computer simulation of the entire human brain, right down to the molecular level.

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Simulation versus modelling

- Traditionally, the formal modelling of systems has been via a mathematical model,
  - which attempts to find analytical solutions to problems,
    - which enables the prediction of the behaviour of the system from a set of parameters and initial conditions.
- While computer simulations might use some algorithms from purely mathematical models, computers can combine simulations with the reality of actual events, such as generating input responses to simulate test subjects that are no longer present.

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Simulation versus modelling

- Although the missing test subjects (i.e. the users of equipment or systems) are being modelled/simulated,
  - the whole process can be conducted with the actual equipment or system they use,
    - revealing performance limits or defects in long-term use by the simulated users.
- Note that the term computer simulation is broader than computer modelling,
  - which implies that all aspects are being modelled in the computer representation.

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Simulation versus modelling

- However, computer simulation also includes generating inputs from simulated users to run actual computer software or equipment,
  - with only part of the system being modelled:
    - an example would be flight simulators which can run machines as well as actual flight software.
- Computer simulations are used in many fields, including
  - science, technology, entertainment, and business planning and scheduling.

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History

- Computer simulation was developed hand-in-hand with the rapid growth of the computer,
  - following its first large-scale deployment during the Manhattan Project in World War II to model the process of nuclear detonation.
    - It was a simulation of 12 hard spheres using a Monte Carlo algorithm.
- Computer simulation is often used as an adjunct to, or substitution for, modelling systems for which simple closed form analytic solutions are not possible.
  - [adjunct:something joined or added to another thing but not essentially a part of it]

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History

- There are many different types of computer simulation;
  - the common feature they all share is the attempt to generate a sample of representative scenarios for a model in which a complete enumeration of all possible states of the model would be prohibitive or impossible.
- Computer models were initially used as a supplement for other arguments, but their use later became rather widespread.
- The data input/output for the simulation can be either through formatted text files or a pre- and post processor.

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Types of computer simulation

- Computer models can be classified according to several criteria including:
  - stochastic or deterministic
    - and as a special case of deterministic, chaotic
  - steady-state or dynamic
  - continuous or discrete
    - and as an important special case of discrete, discrete event or DE models
  - local or distributed.

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Types of computer simulation

  - For example, steady-state models use equations defining the relationships between elements of the modelled system and attempt to find a state in which the system is in equilibrium.
- Such models are often used in simulating physical systems as a simpler modelling case before dynamic simulation is attempted.
- Dynamic simulations model changes in a system in response to (usually changing) input signals.

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Types of computer simulation

- Stochastic models use random number generators to model chance or random events;
  - they are also called Monte Carlo simulations.
- A discrete event simulation (DES) manages events in time.
  - Most computer, logic-test and fault-tree simulations are of this type.
    - In this type of simulation, the simulator maintains a queue of events sorted by the simulated time in which they should occur.
    - The simulator reads the queue and triggers new events as each event is processed.
  - It is not important to execute the simulation in real time.
  - It's often more important to be able to access the data produced by the simulation,
    - to discover logic defects in the design or the sequence of events.

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Types of computer simulation

- A continuous dynamic simulation performs numerical solutions of differential-algebraic equations or differential equations (either partial or ordinary).
  - Periodically, the simulation program solves all the equations, and uses the numbers to change the state and output of the simulation.
- Applications include
  - flight simulators,
  - simulation games,
  - chemical process modelling,
  - simulations of electrical circuits.

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Types of computer simulation

- Originally, these kinds of simulations were actually implemented on analogue computers,
  - where the differential equations could be represented directly by various electrical components such as op-amps.
- By the late 1980s, however, most "analogue" simulations were run on conventional digital computers that emulate the behaviour of an analogue computer.

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Analog computer

- Polish analog computer AKAT-1, 1959.

- Any of a class of devices in which continuously variable physical quantities such as electrical potential, fluid pressure, or mechanical motion are represented in a way analogous to the corresponding quantities in the problem to be solved.
- The analog system is set up according to initial conditions and then allowed to change freely.
- Answers to the problem are obtained by measuring the variables in the analog model.

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Types of computer simulation

- A special type of discrete simulation which does not rely on a model with an underlying equation, but can nonetheless be represented formally, is agent-based simulation.
- In agent-based simulation, the individual entities (such as molecules, cells, trees or consumers) in the model are represented directly (rather than by their density or concentration) and possess an internal state and set of behaviours or rules which determine how the agent's state is updated from one time-step to the next.

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Types of computer simulation

- Distributed models run on a network of interconnected computers, possibly through the Internet.
  - Simulations dispersed across multiple host computers like this are often referred to as "distributed simulations".
- There are several standards for distributed simulation, including
  - Aggregate Level Simulation Protocol (ALSP),
  - Distributed Interactive Simulation (DIS),
  - the High Level Architecture (HLA),
  - the Test and Training Enabling Architecture (TENA).

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CGI computer simulation

- Formerly, the output data from a computer simulation was sometimes presented in a table, or a matrix,
  - showing how data was affected by numerous changes in the simulation parameters.
- The use of the matrix format was related to the traditional use of the matrix concept in mathematical models;
  - however, psychologists and others noted that humans could quickly perceive trends by looking at graphs or even moving-images or motion-pictures generated from the data, as displayed by computer -generated-imagery (CGI) animation.

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CGI computer simulation

- Although observers couldn't necessarily read out numbers, or spout maths formulas, from observing a moving weather chart, they might be able to predict events (and "see that rain was headed their way"), much faster than scanning tables of rain-cloud coordinates.
- Such intense graphical displays, which transcended the world of numbers and formulae, sometimes also led to output that lacked a coordinate grid or omitted timestamps, as if straying too far from numeric data displays.

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CGI computer simulation

- Today, weather forecasting models tend to balance the view of moving rain/snow clouds against a map that uses numeric coordinates and numeric timestamps of events.
- Similarly, CGI computer simulations of CAT scans can simulate how a tumour might shrink or change, during an extended period of medical treatment, presenting the passage of time as a spinning view of the visible human head, as the tumour changes.
  - [CAT scan: an X-ray image made using computerized axial tomography]
- Other applications of CGI computer simulations are being developed to graphically display large amounts of data in motion, as changes occur during a simulation run.

Computer simulation in science

- The following are generic examples of types of computer simulations in science,
  - which are derived from an underlying mathematical description:
- A *numerical simulation* of differential equations which cannot be solved analytically.
  - Falling into this category are:
    - theories which involve continuous systems such as phenomena in physical cosmology
    - fluid dynamics (e.g. climate models, roadway noise models, roadway air dispersion models)
    - continuum mechanics and chemical kinetics

Computer simulation in science

- A *stochastic simulation*, typically used for discrete systems where events occur probabilistically, and which cannot be described directly with differential equations (this is a discrete simulation in the above sense).
  - Phenomena in this category include:
    - genetic drift
    - biochemical or gene regulatory networks with small numbers of molecules (See also: Monte Carlo method).

Computer simulation in science

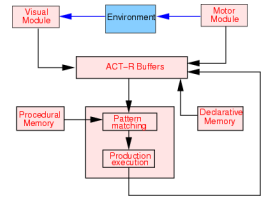
- Specific examples of computer simulations follow:
- *statistical simulations* based upon an agglomeration of a large number of input profiles, such as the forecasting of equilibrium temperature of receiving waters, allowing the gamut of meteorological data to be input for a specific locale.
  - [gamut: the complete range or scope of something]
  - [agglomeration : a mass or collection of things; an assemblage]
  - This technique was developed for thermal pollution forecasting.

Computer simulation in science

- *agent based simulation* has been used effectively in ecology,
  - where it is often called individual based modelling and has been used in situations for which individual variability in the agents cannot be neglected,
    - such as population dynamics of salmon and trout (most purely mathematical models assume all trout behave identically)
- *time stepped dynamic model*; in hydrology there are several such hydrology transport models such as the SWMM and DSSAM developed by the U.S. Environmental Protection Agency for river water quality forecasting
  - [SWMM: Storm Water Management Model]
  - [DSSAM: Dynamic Stream Simulation and Assessment Model]

Computer simulation in science

- computer simulations have also been used to formally model theories of human cognition and performance, e.g. ACT-R
- ACT-R is a cognitive architecture:



  - a theory about how human cognition works.
    - On the exterior, ACT-R looks like a programming language;
    - however, its constructs reflect assumptions about human cognition.
    - These assumptions are based on numerous facts derived from psychology experiments.

Computer simulation in science

- computer simulation using molecular modelling for drug discovery
- computational fluid dynamics simulations are used to simulate the behaviour of flowing air, water and other fluids.
  - There are one-, two- and three- dimensional models used.
    - A one dimensional model might simulate the effects of water hammer in a pipe.
    - A two-dimensional model might be used to simulate the drag forces on the cross-section of an aeroplane wing.
    - A three-dimensional simulation might estimate the heating and cooling requirements of a large building.

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Computer simulation in science

- Understanding of statistical thermodynamic molecular theory is fundamental to the appreciation of molecular solutions.
- Development of the Potential Distribution Theorem (PDT) allows one to simplify this complex subject to down-to-earth presentations of molecular theory.
- Notable, and sometimes controversial, computer simulations used in science include:
  - Donella Meadows' World3 used in the Limits to Growth
  - James Lovelock's Daisyworld
  - Thomas Ray's Tierra.

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Simulation environments for physics and engineering

- Graphical environments to design simulations have been developed.
- Special care was taken to handle "events"
  - situations in which the simulation equations are not valid and have to be changed.
- The open project Open Source Physics was started in order to develop reusable libraries for simulations in Java, together with Easy Java Simulations,
  - a complete graphical environment that generates code based on these libraries.

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Pitfalls in computer simulation

- It is very important to perform sensitivity analysis to ensure that the accuracy of the results is properly understood.
  - For example, the probabilistic risk analysis of factors determining the success of an oilfield exploration program involves combining samples from a variety of statistical distributions using the Monte Carlo method.
    - If, for instance, one of the key parameters (i.e. the net ratio of oil-bearing strata) is known to only one significant figure, then the result of the simulation might not be more precise than one significant figure,
      - although it might (misleadingly) be presented as having four significant figures.

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Computer simulation in practical contexts

- Computer simulations are used in a wide variety of practical contexts, such as:
  - analysis of air pollutant dispersion using atmospheric dispersion modelling
  - design of complex systems such as aircraft and logistics systems
  - design of noise barriers to effect roadway noise mitigation
  - flight simulators to train pilots
  - weather forecasting

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Computer simulation in practical contexts

  - behaviour of structures (such as buildings and industrial parts) under stress and other conditions
  - design of industrial processes, such as chemical processing plants
  - strategic management and organizational studies
  - reservoir simulation for the petroleum engineering to model the subsurface reservoir
  - Process Engineering Simulation tools
  - robot simulators for the design of robots and robot control algorithms

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Computer simulation in practical contexts

- The reliability and the trust people put in computer simulations depends on the validity of the simulation model,
  - therefore verification and validation are of crucial importance in the development of computer simulations.
- Another important aspect of computer simulations is that of reproducibility of the results,
  - meaning that a simulation model should not provide a different answer for each execution.

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Computer simulation in practical contexts

- Although this might seem obvious, this is a special point of attention in stochastic simulations,
  - where random numbers should actually be semi-random numbers.
- An exception to reproducibility are "human-in-the-loop" simulations,
  - such as flight simulations and computer games.
    - Here a human is part of the simulation and thus influences the outcome in a way that is hard if not impossible to reproduce exactly.

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Computer simulation in practical contexts

- Computer graphics can be used to display the results of a computer simulation.
- Animations can be used to experience a simulation in real-time e.g. in training simulations.
- In some cases animations may also be useful in faster than real-time or even slower than real-time modes.
  - For example, faster than real-time animations can be useful in visualizing the build-up of queues in the simulation of humans evacuating a building.
- Furthermore, simulation results are often aggregated into static images using various ways of scientific visualization.

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Computer simulation in practical contexts

- In debugging, simulating a program execution under test (rather than executing natively) can detect far more errors than the hardware itself can detect and,
  - at the same time, log useful debugging information such as instruction trace, memory alterations and instruction counts.
- This technique can also detect buffer overflow and similar "hard to detect" errors as well as produce performance information and tuning data.

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Grammar revision

- **Verbs+object+infinitive; Verbs+object+to-infinitive**
  - New developments in computing are often designed to make something easier.
  - The following verbs are often used to describe such developments:
    - allow
    - let
    - enable
    - permit
    - help

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Grammar revision

- For example:
  - {A GUI *lets you point* to icons and click a mouse button to execute a task.}
  - {A GUI *allows you to use* a computer without knowing any operating system commands.}
  - {The X Window System *enables Unix-based computers to have* a graphical look and feel.}
  - {Voice recognition software *helps disabled users (to) access* computers.}

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Grammar revision

- Allow, enable and permit are used with the following structure:
  - verb + object + to-infinitive
- Let is used with the following structure:
  - verb + object + infinitive
- Help can be used with either structure.