Simulation

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Course Contents and Evaluation Criteria

- Lectures
- Labs (three, last two assessable)
- Home assignments (two, assessable)
- Home exam (if you need grade 4 or 5)

Important dates

- For home assignment 1: 26^{th} of April
- For home assignment 2: 24^{th} of May
- For the home exam: 14^{th} of June

Literature

1. A free compendium available from the university library, see the home page
2. Material on the home page
   - Home assignments
   - Skeleton code
   - Slides from the lectures
   - Course program
   - etc.

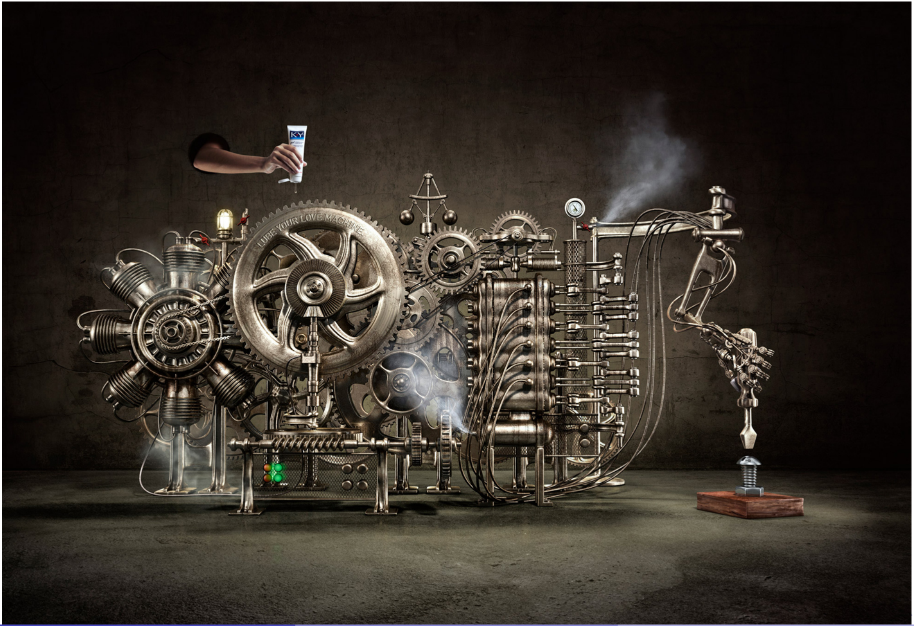
Course content

- Discrete event simulation (investigate system)
- Short intro to optimization
- Meta heuristics for simulated optimization

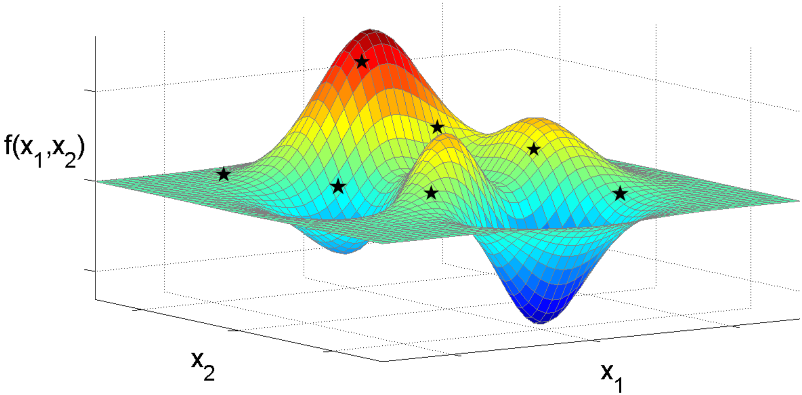
How does it fit together?

- Simulation is done to find out different things:
- In this course, two main things

1) Find out properties and behaviour



2) When we know how it works, can we improve (optimise) it?



Assumed knowledge

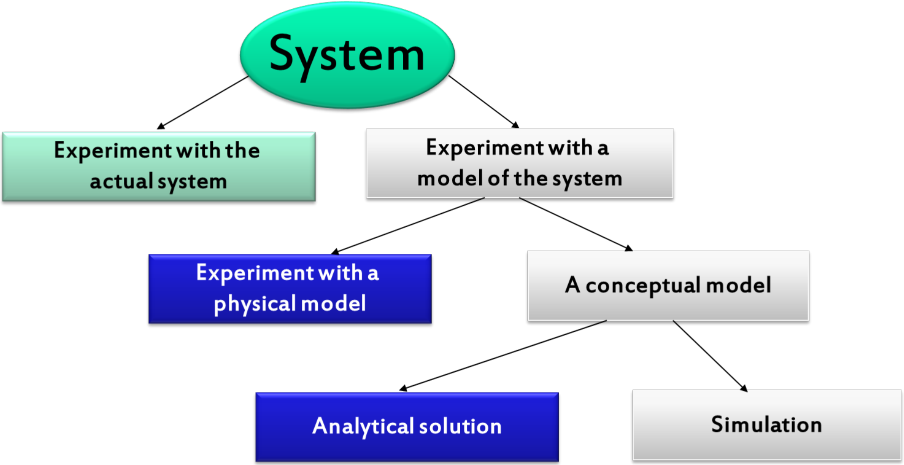
- Programming in JAVA (this is not a programming course)
- Basic statistics
- One lab will use Matlab and dare I say it, Excel.

What is simulation?

- Simple synonym: imitation
- We are interested in studying a system

But, instead of experimenting with the system itself we experiment with a model of the system

How to study a system



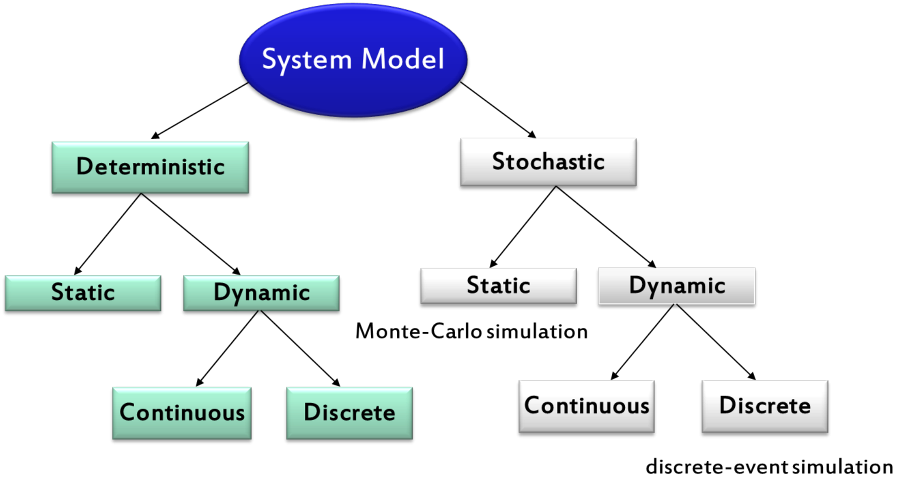
Why not experiment with the system itself?

1. It might be dangerous (control system in a nuclear power plant)
2. The system does not exist yet
3. It is expensive to experiment with the system
4. It is impossible to experiment with a system

What kind of systems do exist?

1. Continuous systems
   - Example: air pressure around an aeroplane
   - Are usually modelled by differential equations
2. Discrete systems
   - Example: systems described by queues
3. Hybrid systems
   - Example: a bouncing ball (continuous dynamics before a bounce and discrete dynamics after each bounce

Characterizing a model

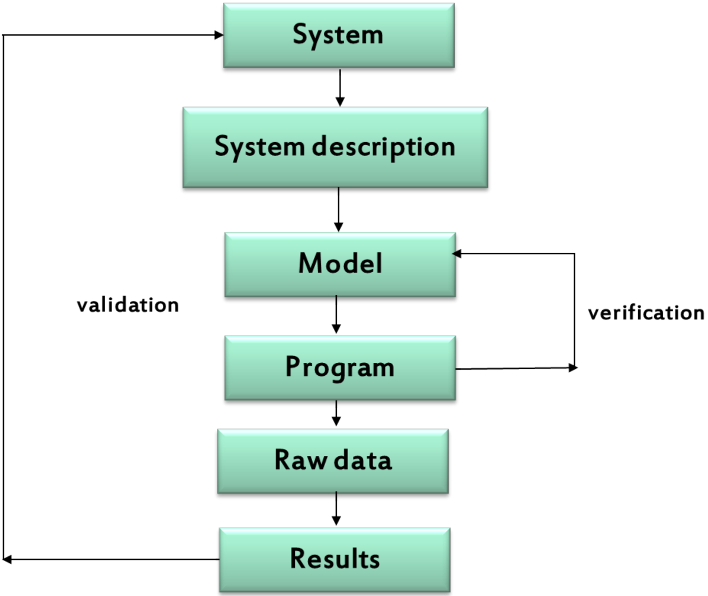


Different kinds of models

1. Continuous – discrete
2. Static – dynamic
3. Deterministic – stochastic

In this course our models will be discrete, dynamic and (usually) stochastic.

Steps in a simulation study



Art and Science combined

First Art then Science

1. First Art
   - ⋆ Analyse problem
   - ⋆ Build model / Structure scientific work
2. Then Science/Engineering
   - ⋆ Implement model / code
   - ⋆ Verify
   - ⋆ Validate
   - ⋆ Interpret results

Example application areas

- Communication systems
- Computer systems performance
- Transportation
- Manufacturing and material handling
- Health systems
- Economy
- Logistics

Advantages of simulation

1. Makes it possible to predict impact of changes
2. Makes it possible to look at detailed behaviour
3. Can give a good understanding of a system
4. Can visualize a system
5. Find bottlenecks in a system
6. Gives a possibility to train a team

Disadvantages of simulation

1. Model building requires special training
2. Time consuming and expensive
3. Limitations of accuracy (approximations or rare events)

Modelling concepts

- A model is an abstract representation of a system
- A discrete model has
  - ⋆ State variables
  - ⋆ Events that change the state
  - ⋆ Rules that describes what shall happen at an event

Modelling concepts

- Entity – represents an object that requires definition
  - ⋆ Can move around (customers, airplanes etc.)
  - ⋆ Can be static (bank clerk, highway crossing etc)
- Attributes – entities have attributes, i.e. data connected to the attribute
- Resource – an entity that serves other entities

Modelling structures

- Event-scheduling method
- Process-interaction method
- Other methods (later in the course)

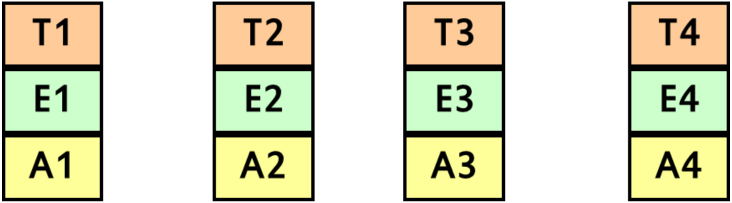
Event-scheduling method

The following is needed:

1. A description of the state
2. The events that can occur
3. Rules describing what will happen if an event occurs

The Event List

Keeps track of when events shall happen

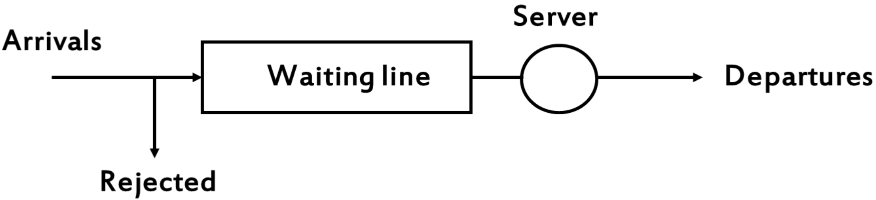


T_i = time when event E_i will take place
A_i = attributes to event i
The list is sorted: $T_1 < T_2 < T3 < T_4$ etc.

How a simulation run is done?

1. Extract the first element in the event list
2. Set Time = the time of the extracted event
3. Update the state of the system and insert new events if needed
4. If not finished, Go to 1

An example: a web server



It might be of interest to find

- Probability of rejection
- Mean (or variance) of time spent in system
- The mean number of customers in the system

The state description

Assume that we want to find the mean number of customers in the queue.

N = number of customers in the system

The appropriate state description depends on the results we look for.

Events that may take place

- Arrival
- Departure (when service is finished)
- Measurement (does not change the state)

What do we also need to know?

Assume the following:

- The service time distribution is exponential with mean 2
- The mean time between arrivals is exponential with mean 3
- The number of places in the waiting line is infinite

Rule at arrival

$N := N + 1$;
If N=1 then
    add departure to event list ;
Add a new arrival to event list;

When we add the departure and arrival we have to draw a random number (exponentially distributed)

Rule at departure

```
N := N - 1;
If N > 0 then
    add departure to event list ;
```

Rule at measurement

Write (N);
Add a new measurement to event list ;

When the simulation begins

System State		Event List	
Sim_Time	N	Event_Time	Event_Type
0	0	3	Arrival
		5	Measurement

Step 1

System State		Event List	
Sim_Time	N	Event_Time	Event_Type
3	1	4	Arrival
		5	Measurement
		9	Departure

Step 2

System State		Event List	
Sim_Time	N	Event_Time	Event_Type
4	2	5	Measurement
		9	Departure
		10	Arrival

Step 3

System State		Event List	
Sim_Time	N	Event_Time	Event_Type
5	2	9	Departure
		10	Arrival
		14	Measurement

Step 4

System State		Event List	
Sim_Time	N	Event_Time	Event_Type
9	1	10	Arrival
		12	Departure
		14	Measurement

Main Process

```
a := 3; ( mean time between arrivals = 3 )
s := 2; ( mean service time = 2)
m := 10; ( mean time between measurements = 10)
simulationLength := 1000;
No_in_queue := 0;
time := 0;
insert_event(measurement,Exp(m));
insert_event(arrival, Exp(a));
while time < simulationlength do
begin
   dummy := FirstInQueue(eventlist);
   time := dummy.eventtime;
   case dummy.eventkind of
      arrival: arrive;
      departure: depart;
      measurement: measure;
   end;
end;
end.
```

Other Processes

```
procedure arrive;
begin
  if No_in_queue = 0 then
    insert_event(departure,Exp(s));
  No_in_queue := No_in_queue + 1;
  insert_event(arrival, Exp(a));
end;
procedure depart;
begin
  No_in_queue := No_in_queue - 1;
  if No_in_queue > 0 then
    insert_event(departure, Exp(s));
end;
procedure measure;
begin
  write(utfil, No_in_queue);
  insert_event(measurement, Exp(m));
end;
```

First home assignment

You will get a Java program that simulates a simple queue.
You shall modify that program and do some investigations.

THE END