Simulation

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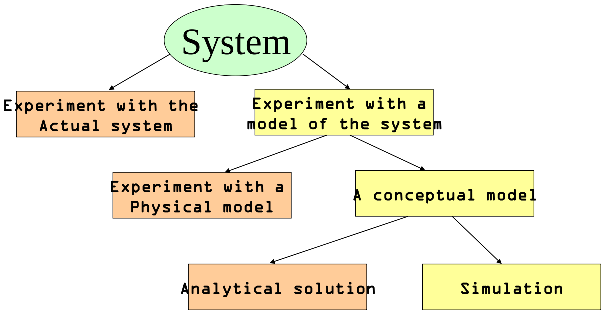
What is simulation?

Simple synonym: imitation

We are interested in studying a system

Instead of experimenting with the system itself we experiment with a model of the system

Ways to study a system


System
Experiment with the Actual system
Experiment with a model of the system
Experiment with a Physical model
A conceptual model
Analytical solution
Simulation

Why not experiment with the system itself?

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

Different kinds of systems

- Continuous systems
  - Examples: temperature in an engine, air pressure around an aeroplane etc
  - Are usually modelled by differential equations
- Discrete systems
  - Examples: systems described by queues
- Hybrid systems

Application areas

- Communication systems
- Computer systems performance
- Transportation
- Manufacturing and material handling
- Health systems
- Public services
- Military systems

Advantages of simulation

- Makes it possible to predict impact of changes
- Makes it possible to look at detailed behaviour
- Can give a good understanding of a system
- Can visualize a system
- Find bottlenecks in a system
- Gives a possibility to train a team

Disadvantages of simulation

- Model building requires special training
- Time consuming and expensive
- Limitations of accuracy (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

Two approaches to simulation

- Event-scheduling method
- Process-interaction method

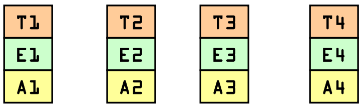
Event-scheduling method

The following is needed:

- A description of the state
- The events that can occur
- Rules describing what will happen if an event occurs

The event list

Keeps track of when events shall happen



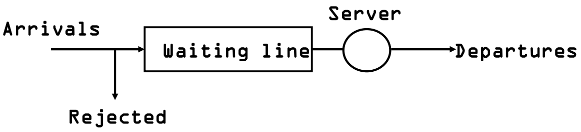
T1	T2	T3	T4
E1	E2	E3	E4
A1	A2	A3	A4

Ti = time when event Ei will take plac
Ai = attributes to event I
The list is sorted: T1 < T2 < T3 < T4

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 queuing system



It might be of interest to find
- Probability of rejection
- Mean of time spent in system
- The mean number of customers in the sy

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 desire

Events that may take place

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

What we also need to know

Assume the following:

- The service time is always 2
- The mean time between arrivals is random between 2 and 4
- 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 arrival event 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

Time and state:

Time = 0

N = 0

Event list:

3 Arrival

5 measurement

Step 1

Time and state:

Time = 3

N = 1

Event list:

4 Arrival

5 measurement

9 Departure

Step 2

Time and state:

Time = 4

N = 2

Event list:

5 measurement

9 Departure

10 Arrival

Step 3

Time and state:

Time = 5

N = 2

Event list:

9 Departure

10 Arrival

14 Measurement

Step 4

Time and state:

Time = 9

N = 1

Event list:

10 Arrival

12 Departure

14 Measurement

```
begin
   simulationlength := 1000;
   No_in_queue := 0;
   time := 0;
   insert_event(measurement,Random(2,4));
   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.
```

Detta är pseudokod

```
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;
```