
MYTHBUSTERS

Algorithms for decision support

Lecture 1

Introduction to course

Intro…….

Marjan van den Akker

- Master and PhD Mathematics TU/e
- Engineer Netherlands Aerospace Center (NLR)
- Lecturer/researcher Algorithms and Complexity group:
  - Coordination (second year) master COSC
  - Course Algorithms for decision support (COSC),
  - Algorithms for planning and scheduling
  - Sustainability, smart energy systems
  - Public transportation
  - Robustness

Other people involved in this course

- Alison Liu:
  - teacher,
  - starting October 1 at UU
- Roel van den Broek (R.W.vandenBroek@uu.nl):
  - supervisor simulation assignment,
  - contact person for questions simulation assignment,
  - final grading simulation assignment
- Ruben Meuwese:
  - student assistant,
  - milestones meetings simulation assignment

In this lecture

- You learn about the topics and objectives of this course
- You learn the idea of discrete-event simulation

- **All information on the course:**
  www.cs.uu.nl/docs/vakken/mads

An example problem to set the scene

People with reduced mobility (PRM) require assistance when travelling through the airport

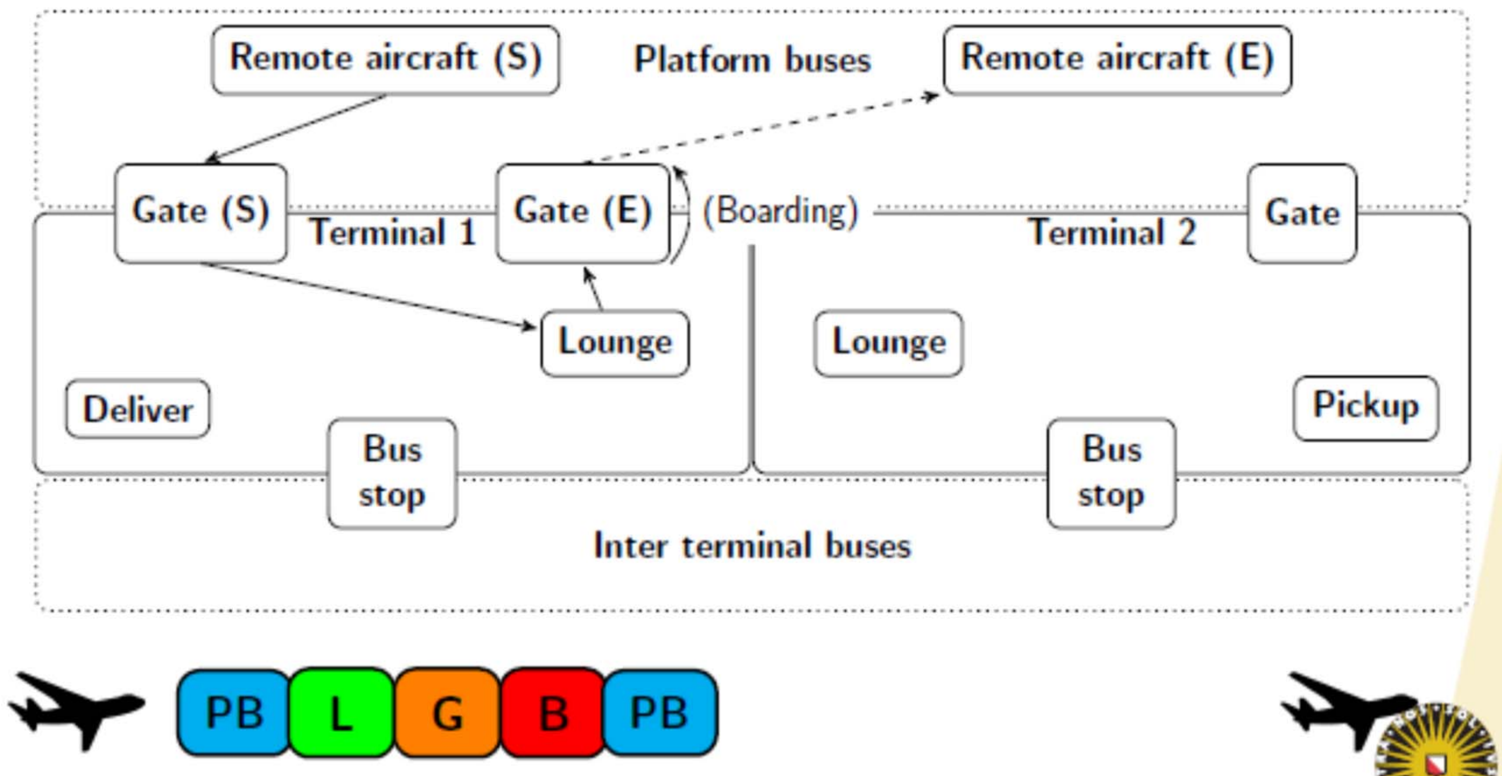
http://www.schiphol.nl/Travellers/AtSchiphol/InformationForPassengersWithReducedMobility.htm

PRM’s at airports

- Airport with different terminals
- Within terminal:
  - Employees transporting up to two PRMs, depending on their disability.
  - Supervised lounges
- Special interterminal busses
- Special platform busses to access aircraft at a remote stand
- Most PRM book assistance at least one day ahead

Journeys of PRMs

- Arrival journey
- Departure journey
- **Transfer journey**
- **Journey has different segments (arcs),** can be supervised by different employees (or busses).



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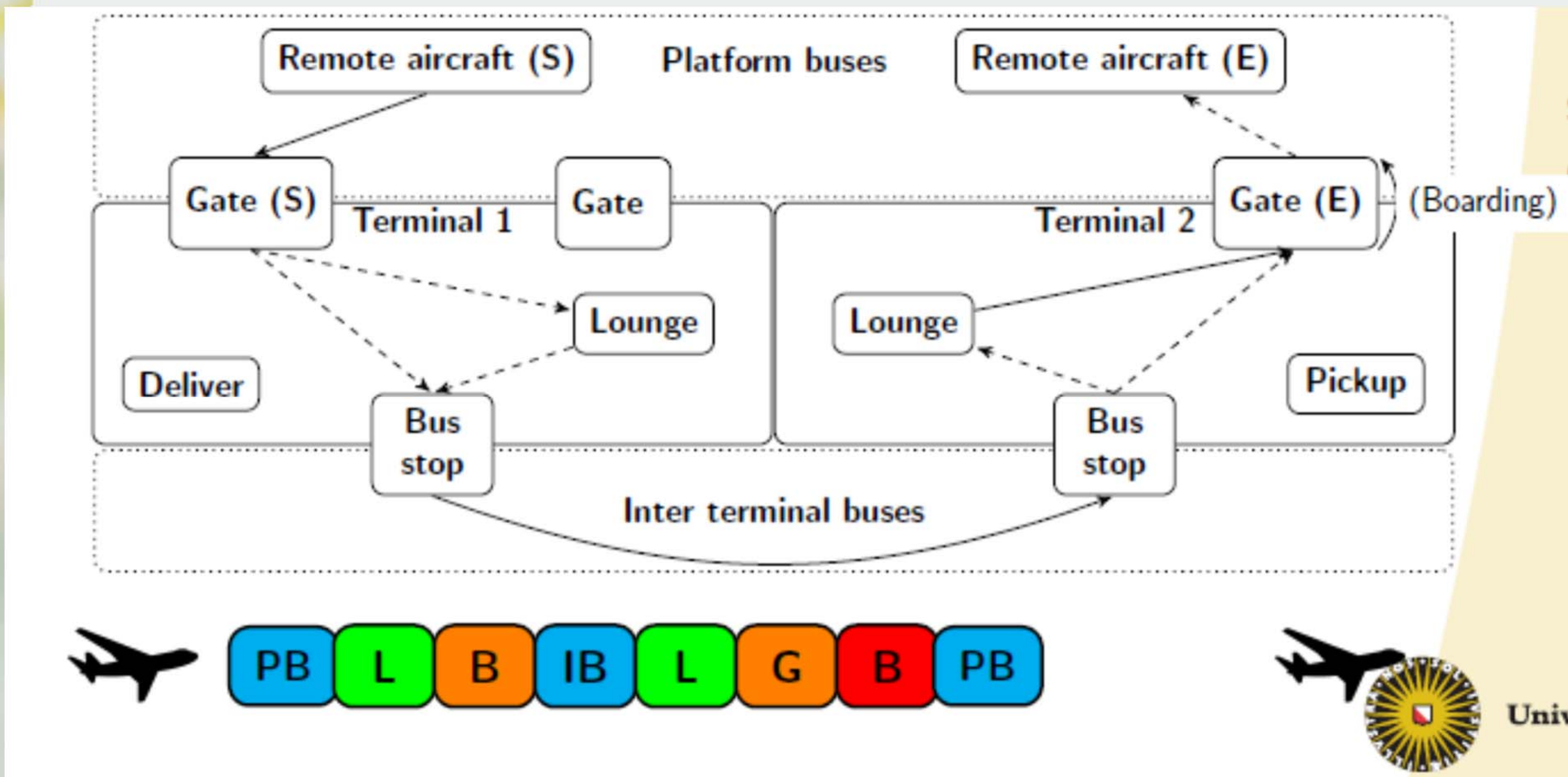


How can the airport management make sure that the supervision of PRMs performs as well as possible?

- Suppose they are not happy with the current performance and want to improve.
- Can mathematical/computer models help?

Questions

1. How do you characterize, quantify performance?
2. What are actions of decisions that influence the performance?
3. Which information/data do you need to make a model?

How do you characterize, quantify performance?

- Number of PRM's served
- Waiting time of PRM's
- Number of PRM's that do not make their flight
- Flexibility to deal with flight delays and other unexpected events.

- Cost attained by:
  - Number of special busses
  - Number of employees

What are actions of decisions that influence the performance?

- Investment in busses
- Hire additional employees
- Expand the number of lounges
- Change the locations of the lounges
- New transportation equipment

- Good schedules for employees: which PRM is supervised by which employee and at what time
- Good schedules for busses: at what time do the busses leave from which place and which PRMs are transported

Which information/data do you need to make a model?

- Arrival and departure times of flights
- Working shifts of employees who provide assistance and of bus drivers
- Details on layout of the terminal
- Transportation times of PRMs through the terminal

Possible techniques for decision support

- Management considers to change the locations of the lounges and to extend the number of lounges
- Management want to find good rules for assigning PRMs to employees

1. Define a few different options
2. Imitate the process of supervising PRMs in the computer
3. Run each option and compute the performance
4. Compare and select the best option

Discrete-event simulation

Possible techniques for decision support (2)

1. Management wants to find the best locations of the lounges
2. Management wants to determine the assignment of PRM's to employees such the waiting time for the PRM's outside the lounges is minimal.
   - You need an algorithm to compute the optimal schedule

- **Combinatorial optimization (integer linear programming, local search)**

- You may have encountered this also in Algoritmiek, Optimalisering.
- Actually solving the assignment problem requires an advanced algorithm that will be explained in Scheduling and Timetabling

Simulation and/or optimization

Depending on:

- The details that you want to include in your model
- The question that you want to answer

Solving the PRM problem may require:

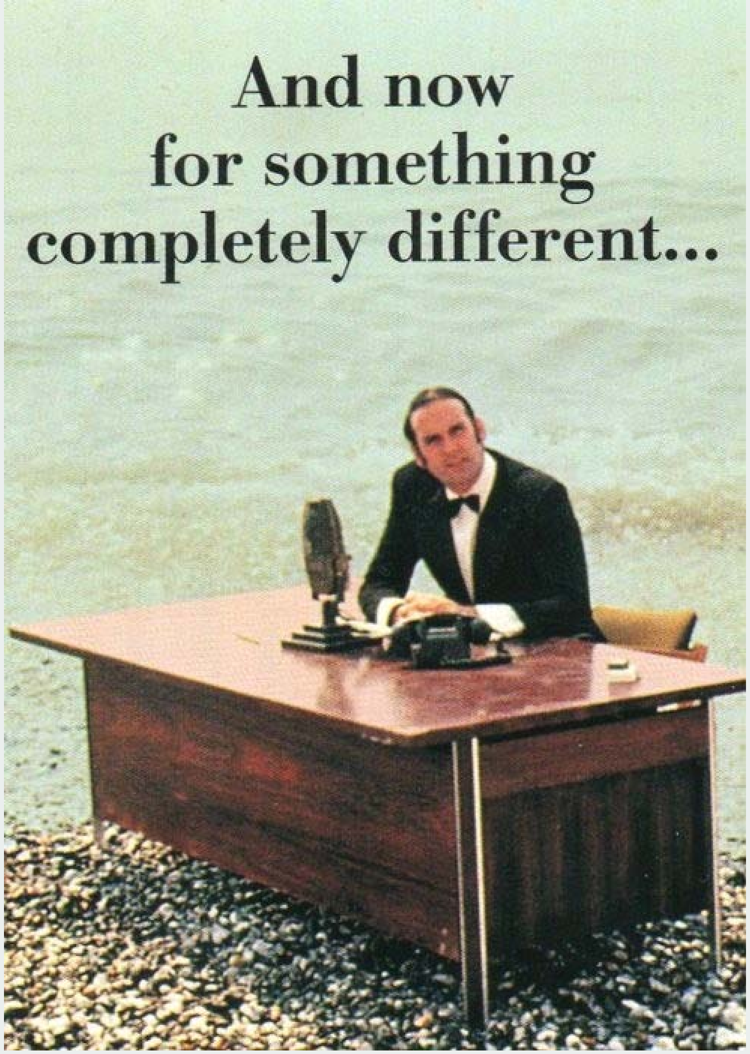
- Discrete-event simulation
- Optimization models and algorithms

Idea of the course

In the working area that COSC is aiming at you might encounter combinatorial optimization and simulation problems. We want to give a useful basis to all COSC students.

The course includes topics that

- are important for the working area of algorithms (in practice and theory)
- are prerequisites for other courses in the COSC program
- that are not encountered by all students in the bachelor
- Feel free to skip a lecture if you already know the topic



Different kind of topics

Topics of the course

- Discrete-event simulation
- Integer linear programming
- Complexity theory
- The landscape of algorithms

Discrete-event simulation

- General and frequently used method for evaluating systems subject to uncertainty.

- Example: new luggage system at Schiphol

- Models
- Validation
- Input and output analysis
- Random number generation

Simulation assignment: the Uithoflijn

- In 2017 it was said: “ *A new tramline between Utrecht CS and the Uithof will start operating in Summer 2018*”
- Now: Test runs are in process
- The goal of the simulation assignment is to perform a simulation study of the operational performance of the Uithoflijn
- More information and *realistic data* will available on the course website and explained in lecture 3.

Integer linear programming

- Mainstream optimization method in scientific research
- Extremely important optimization algorithm in practice
- Used by Tennet to analyse the system adequacy (leveringszekerheid) of the Dutch electricity network
- Used by U-OV to determine the sequence of trips for each of their buses
- Record for solving Travelling Salesman Problem

Complexity theory

- Which optimization problems are hard and which are easier?
- P vs NP

"I can't find an efficient algorithm, but neither can all these famous people."

Solution quality Computation time	Optimum	Bound on quality	Good solution, no quality guarantee
Polynomial	Polynomial solution algorithms	Approximation algorithms	Construction heuristics
Super polynomial and/or no guarantee	Exact algorithms: • Tree search • Dynamic programming • Integer linear programming • ……	Hybrid algorithms • Column generation without complete branch-and-price	Meta heuristics: • Local search • Genetic algorithms

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Zooming out a bit

- It all starts out with data
- Where is this course in the field of data analysis?

Types of Data Analysis

Descriptive	Predictive	Prescriptive
• Aims to help uncover valuable insight from the data being analyzed • Answers the question **"What happened?"**	• Helps forecast behavior of people and markets • Answers the question **"What could happen?"**	• Suggests conclusions or actions that may be taken based on the analysis • Answers the question **"What should be done?"**

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What exactly happened when 100 PRMs missed their flight at July 14, 2018?	How many PRMs will ask for assistance next month?	What is the best schedule for the employees assisting the PRMs?

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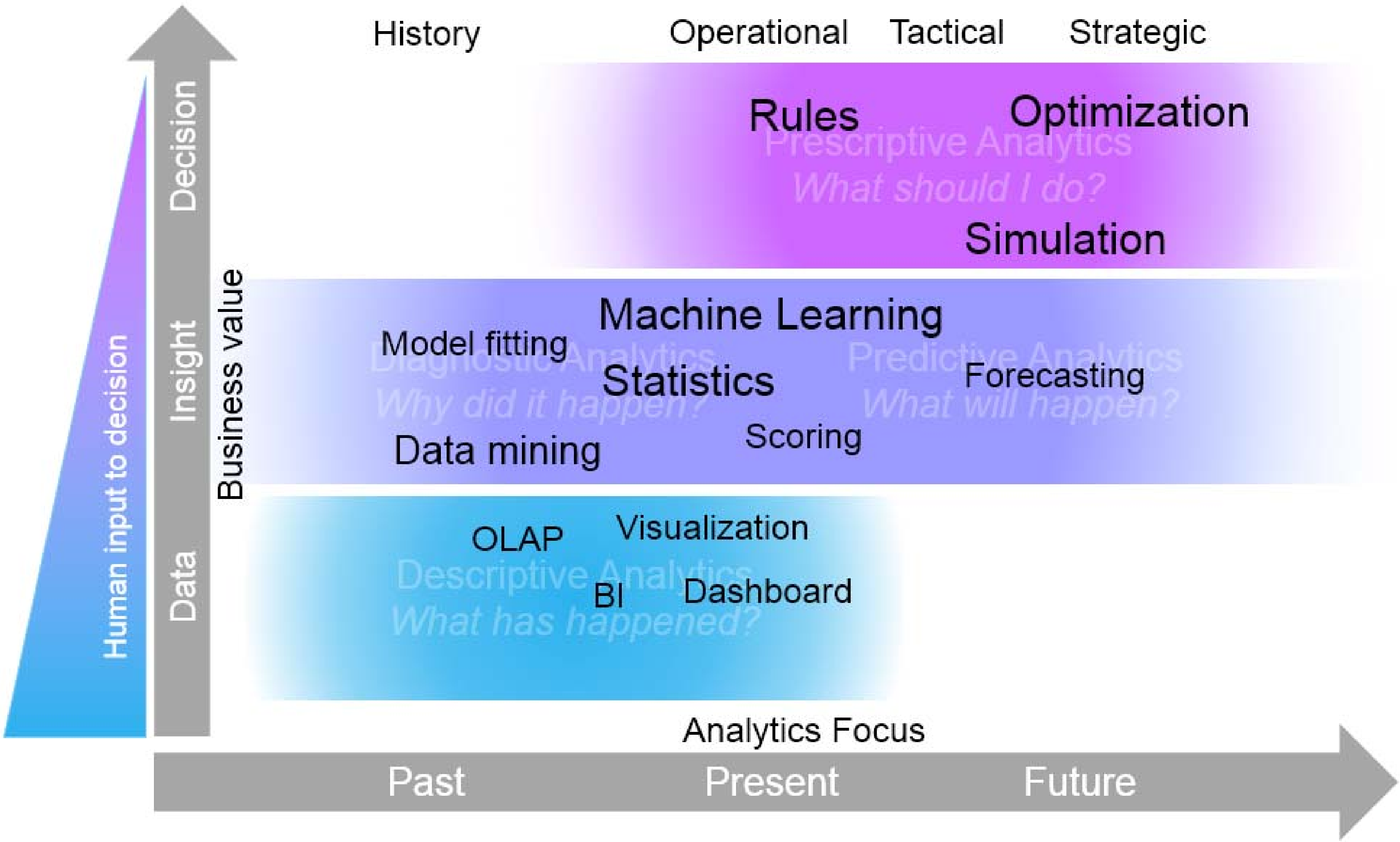
Scorecards Data visualization …………..	Data mining Machine learning Forecasting	Optimization Simulation



Source: http://ibm.co/1gJyfl3

Method of working: why is master different from bachelor?

- Interesting, specialized topics
- Relation to research
- No tutorials (werkcolleges)
- No single textbook, but different sources of information, including scientific papers
- Larger assignments, you have to do your own planning
- Research-oriented assignments, no unique solution but you have motivate your choices and maybe find reading material by yourself
- Larger reports and presentations
- More time-consuming than UU-CS bachelor

More interesting!!!, but more effort, more independence

Lectures

- YOU should learn the material (I already know it)
- If I am the only person talking, you will probably only remember 5%
- Therefore, include interactive elements and exercises

Material

- www.cs.uu.nl/docs/vakken/mads
- *Simulation* :
  - Slides,
  - References to sections of the book by Law (copies of the most important section are available),
  - Exercises, and some solutions.
  - Background material on statistics.
- *Integer linear programming* :

  slides, lecture notes, exercises, and solutions.
- *Complexity*: slides, exercises, and solutions.

How to get 7.5 ECTS

Graded deliverables:

- Simulation assignment, 50 %:
  - completeness of the report, this means that it has to contain all the parts given in the workplan
  - You attended the final feedback discussion **in person**. It is not sufficient if other members of your group attended.
- Written exam, 50 %, **unrounded grade should be at least 5!**
- Written exam will have more ILP, Complexity, Algorithms than simulation (probably 70-30).

Additional examination

- Minimum required effort
  - Your final grade is at least 4
  - You received a pass for the milestones of the simulation assignment
  - You attended every milestone meeting **in person**. It is not sufficient if other members of your group attended.
- Retake for at most one part (out of simulation assignment and exam)
- If exam < 5, then retake exam
- If exam < 6 and retake exam >= 6 would be sufficient, then retake exam
- Otherwise, either retake exam or repair assignment
- For repair assignment, permission of teacher required
- Maximum grade for repair assignment is 7
- If there are unforeseen extreme circumstances because of which you cannot make a milestone, you have to notify the teacher **beforehand** by e-mail.

First: basics on simulation

Simulation

=

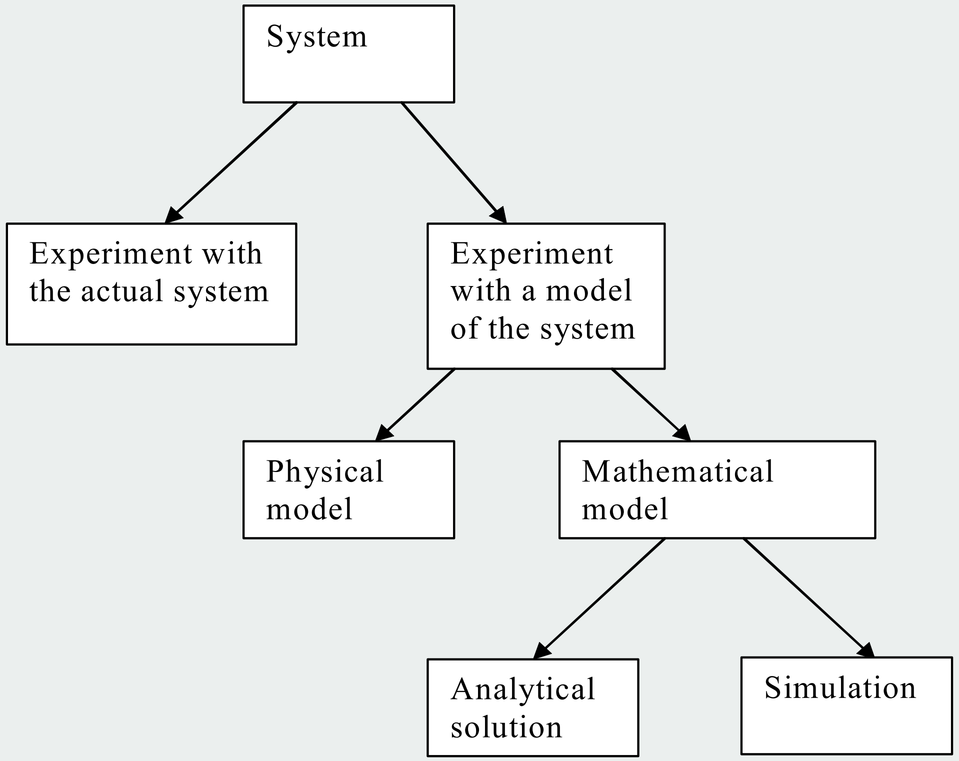
Imitating a system on the computer

Examples

- Luggage handling system at Schiphol (InControl)
- Design of new airport near Athens
- Delay management for connected bus lines
- Robust planning of platform busses at Schiphol
- Buffer sizes in manufacturing
- Design of chemical production plant
- Weather forecast
- Technique of Electronic Road Pricing (Rekeningrijden)
- Telecommunication networks
- Serious games

System analysis

"A system is defined to be a collection of entities, e.g. people or machines, that act and interact together towards the accomplishment of some logical end "(Schmidt, Taylor, 1970)



A news item

NOS Teletekst 108

NS start proef spoorboekloos rijden

Tussen Eindhoven,Utrecht en Amsterdam begint de NS vandaag een proef met spoorboekloos rijden.14 woensdagen lang rijden er dan zes intercity's per uur in plaats van vier treinen.Als de proef slaagt,wordt het in december ingevoerd.

Uiteindelijk wil de NS op alle drukke trajecten elk uur zes intercity's en twee tot zes sprinters laten rijden.Het is de bedoeling dat die treinen volgens hetzelfde idee gaan rijden als metro's, dus zonder spoorboek.Dat moet in 2028 al ingevoerd worden.

Reizigersorganisatie Rover is kritisch. De organisatie zegt dat door de proef veel mensen hun overstap niet halen.

volgende nieuws weer&verkeer sport

System analysis (background)

- Actual system:
  - wind tunnel, e.g. test aerodynamics of a car,
  - supermarket fast queue.
- If you want to try out something and you can easily switch back, e.q. supermarket fast queue for people with at most 10 items, then you would experiment with the actual system.

- Physical model:
  - water management lab=Deltares,
  - wind tunnel with model (aircraft which are put upside down with a rope to the ceiling, otherwise they go flying)
  - Mythbusters (moon hoax)
- Mathematical model: $x = vt$

Experimenting with a physical model

https://www.youtube.com/watch?v=zPj60sy9Cfw

Advantages of simulation

- Why prefer a simulation compared to experiments with the real system?
  - Lower cost
  - Safety
  - Different circumstances
  - Different variants
  - Possibility to repeat experiments

Simulation model

- Static vs. dynamic
- Discrete vs. continuous
  - Continuous include:
    - Navier-Stokes equations: model flows of liquid, gasses
    - No proof for existence or uniqueness of solutions http://www.claymath.org/millennium-problems/navier-stokes-equation
    - Even made it to television show DWDD
  - Hybrid

Examples

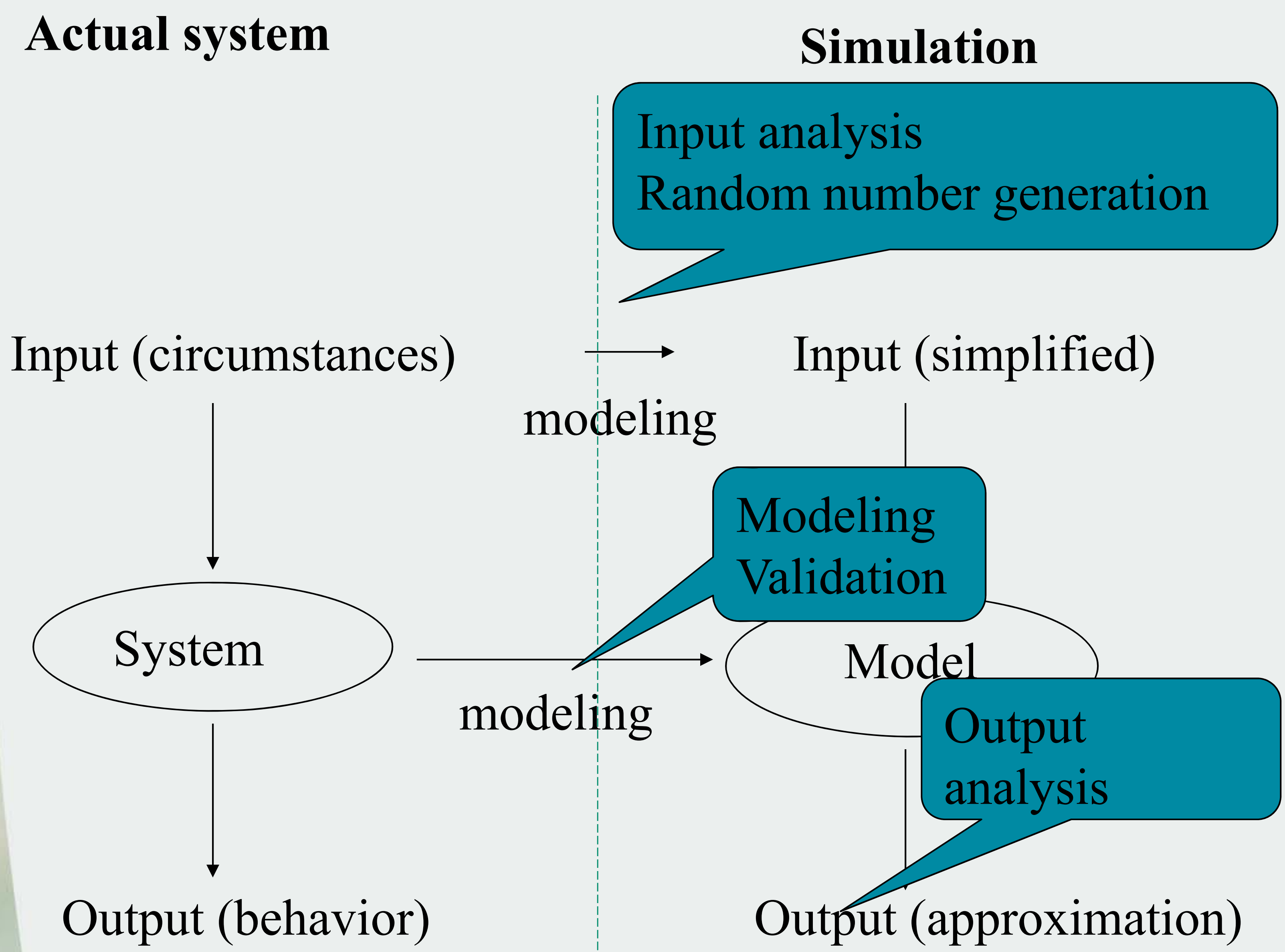
- Static: solving difficult computations by Monte Carlo simulation
- Dynamic: process changes over time, crowd simulation

- Discrete: check-in desk, discrete parts manufacturing
- Continuous: flying aircraft, flows around aircraft, weather.
- Hybrid: bouncing ball, billiard

- Deterministic: fluid flow,
- Stochastic: check-in desk, traffic lights.

Simulation model (2)

- Deterministic vs. stochastic
- Influence of uncertainty; example
- Discrete-event simulation: discrete, dynamic, stochastic


Actual system
Simulation
Input analysis
Random number generation
Input (circumstances)
modeling
Input (simplified)
Modeling
Validation
System
Model
modeling
Output
analysis
Output (behavior)
Output (approximation)

Discrete-event simulation

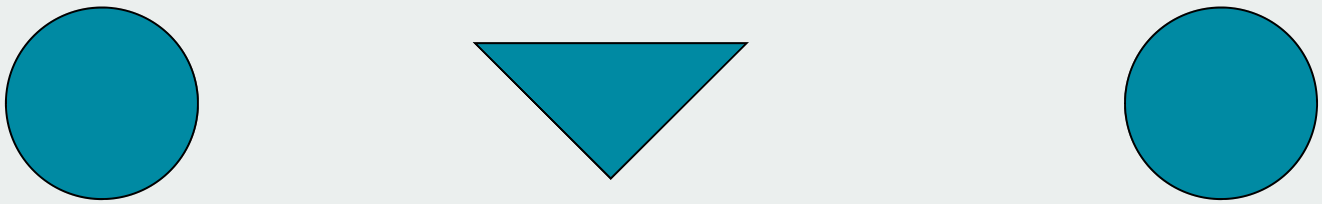
- *State*: collection of variables that describe the system at a particular moment in time
- *Event* : may change the state of the system
- *Discrete-event simulation*: state variables change instantaneously at separate points in time

Example: two-machine production line (fruit drink)

M_1:
add fruit and mash

buffer

M_2:
mix and filter



rate r_1 liter per minute
Stochastic lifetime *X*, mean *E(X)*
Stochastic repair time *Y*, mean *E(Y)*

size *K*

rate r_2 liter per minute
perfect

Question: What is the throughput (number of liters per minute)

Two-machine production line Special cases:

- $r_1 < r_2$: not interesting: $r_1 \frac{E(X)}{E(X)+E(Y)}$
- $r_1 > r_2$:
  - $K = 0$: $r_2 \frac{E(X)}{E(X)+E(Y)}$
  - $K = \infty$: $\min(r_1 \frac{E(X)}{E(X)+E(Y)}, r_2)$

For exponential distribution known formule. Advantage: expression for different values. Disadvantage: you need a specific assumption.

Example: two-machine production line (fruit drink)

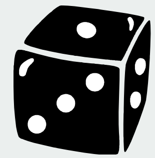
- DO NOT SIMULATE if analysis is possible

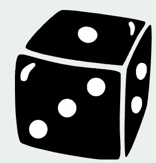
- State?
- Events?

- State:
  - up/down line 1
  - Buffer content
- Events:
  - Line 1 goes down
  - Line 1 is repaired

Measure throughput by empty time of buffer during down time of line 1

```
time = 0;
buffercontent = 0;
empty = 0;

while (time < runlength)
{
        x = new lifetime; (random)
        time = time + x;

        if (buffercontent + x * (r1 - r2) < K)
                buffercontent = buffercontent + x * (r1 - r2);
        else    buffercontent = K;

        y = new repairtime; (random)
        time = time + y;

        if (buffercontent - y * r2 >0)
                buffercontent = buffercontent - y * r2;
        else{   empty = empty + y - buffercontent/r2;
                buffercontent = 0;
                }
}
```

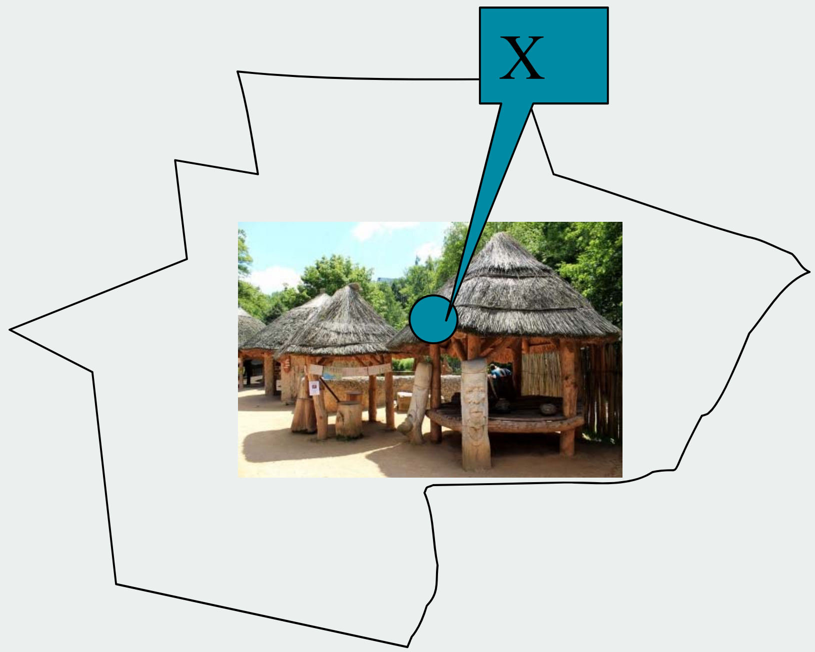




throughput = r2 * (1 - empty/time);

Monte Carlo simulation

- Static, stochastic
- Red cross wants to drop relief supplies in an isolated area after a flood.
- What is the success rate?



$N(X,\sigma^2)$

- Success rate = #successes/#trails