Fall Term 2006

COMP 522
Modelling and Simulation

"model everything"

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Jean Bézivin

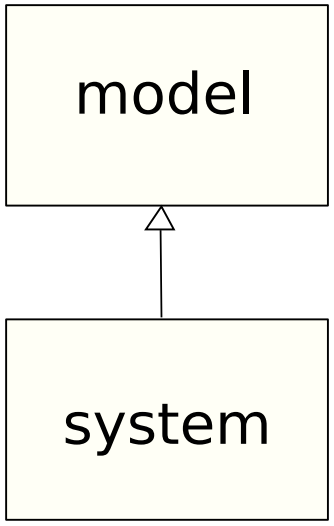
Everything is a model !

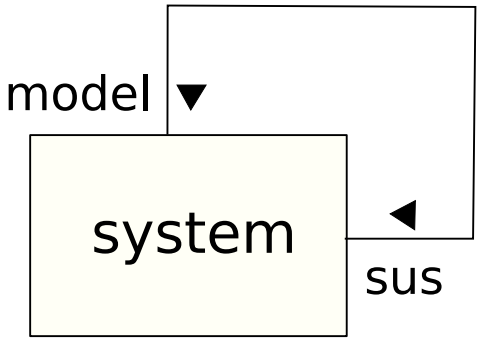
Jean-Marie Favre

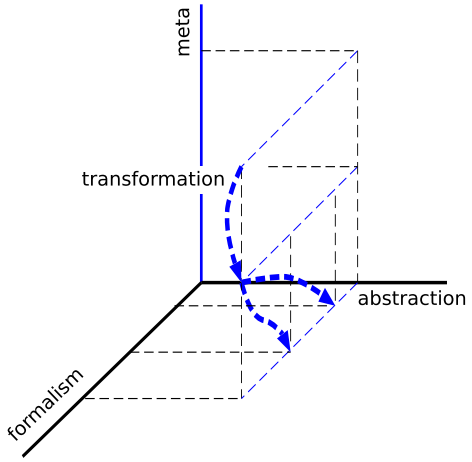
Nothing is a model !

Hans Vangheluwe

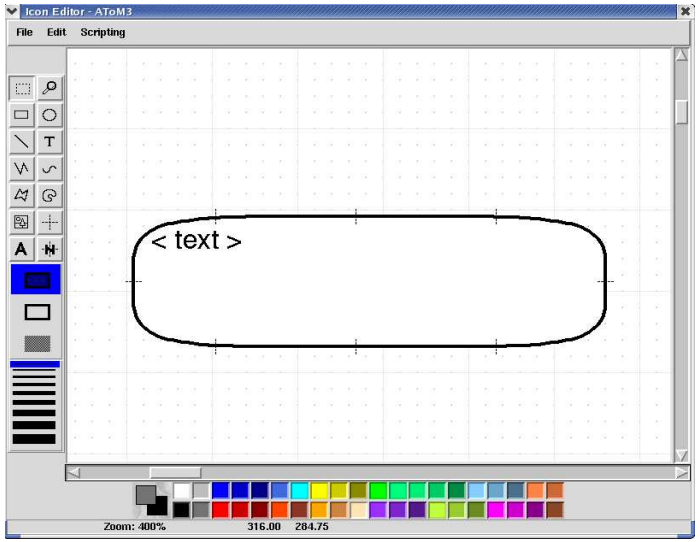
Model everything !







A Variety of Complex Systems . . .

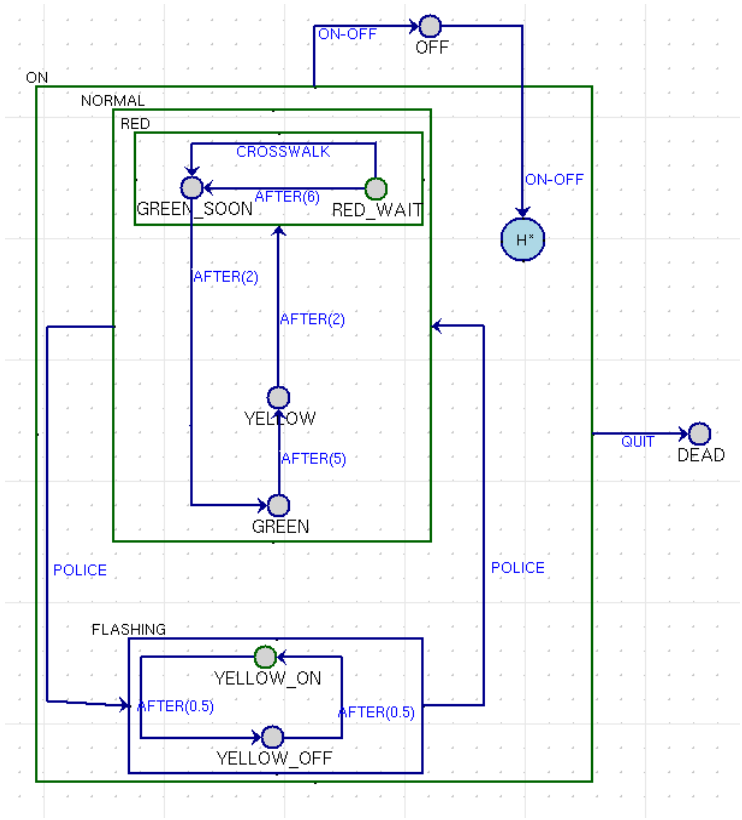


Need to be **modelled**

- at most appropriate **level of abstraction**
- in most appropriate **formalism(s)**

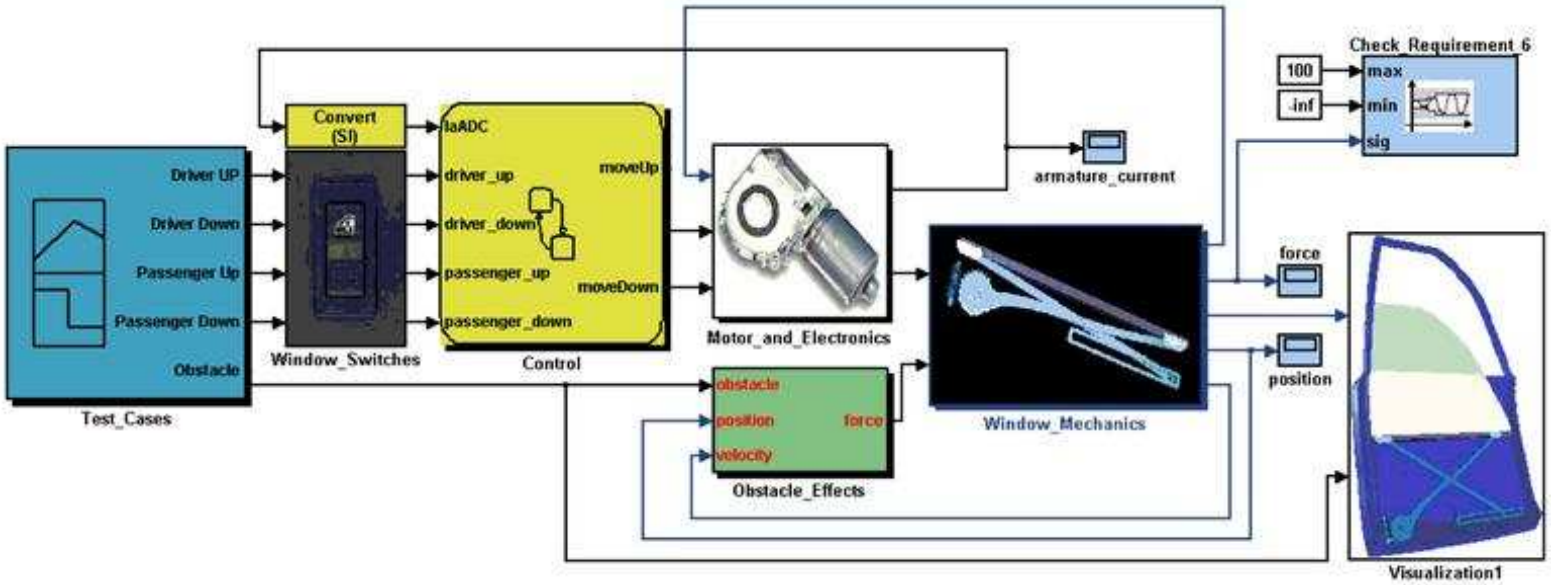
Available Information, Questions to be Answered, . . .

$\Rightarrow$ choice of Abstraction Level/Formalism



Power Window

Power Window: need for multiple formalisms



`http://www.mathworks.com/products/demos/simulink/PowerWindow/html/PowerWindow1.html`

COMP 522A: Modelling and Simulation

- . . . to study (static/dynamic) **structure** and (dynamic) **behaviour**
- . . . for **analysis** and **design** of **complex** systems
- . . . for different **application domains**:
  computer networks, software design, traffic control, software engineering, biology, physics, chemistry, management, . . .
- . . . implemented using Computer Science
- . . . focus on Software Engineering

Overview

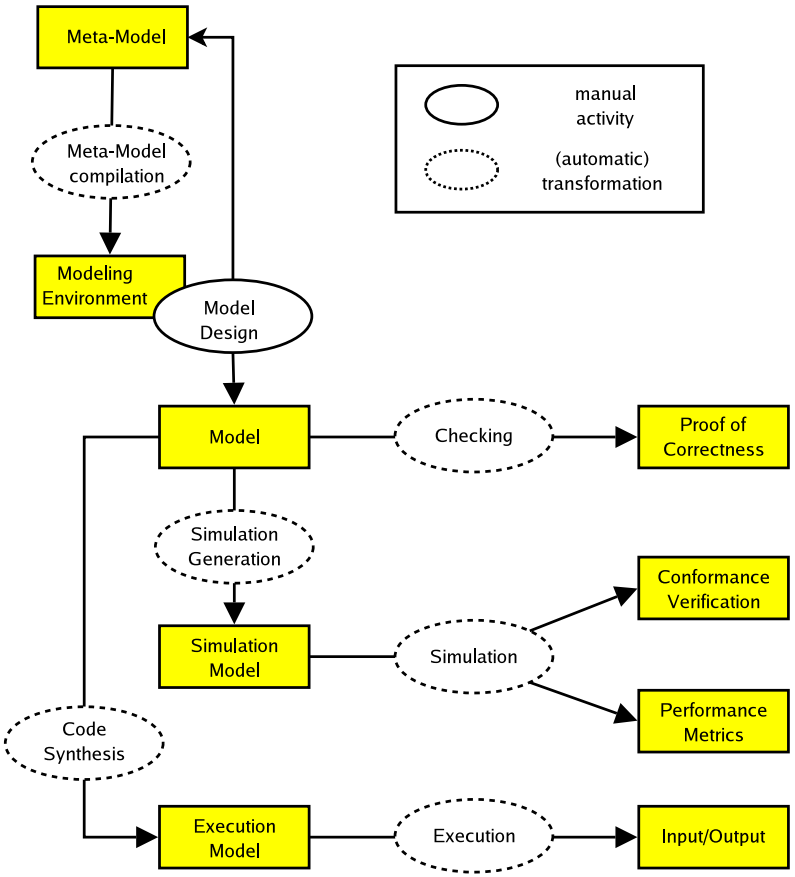
1. What is Modelling and Simulation ?
2. Which topics does COMP 522 cover ?
3. What are the pre-requisites ?
4. How is evaluation done ?
5. What are the assignments about ?
6. Where do I get the material covered in CS522 ?

What is Modelling and Simulation ?

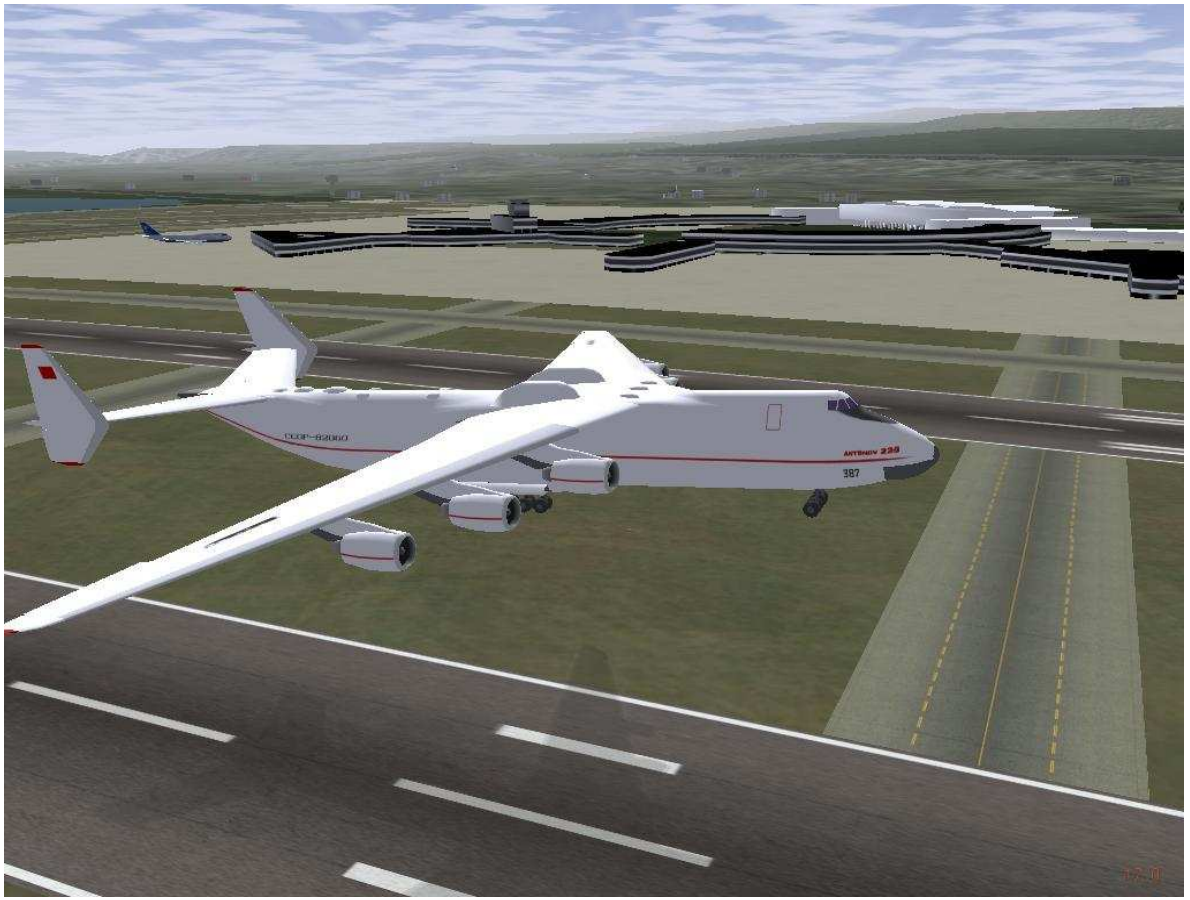
- **Modelling**: represent/re-use/exchange *knowledge* about system *structure* and *behaviour*
- **Simulation**: to *accurately* and *efficiently emulate* real behaviour
- Why ?
  - cost, danger, ...
  - what-if analysis ?
  - optimization (do it right the first time) !

  $\Rightarrow$ **modelling and simulation based design**

Modelling and Simulation Based Design



M&S in action: Flight Simulation



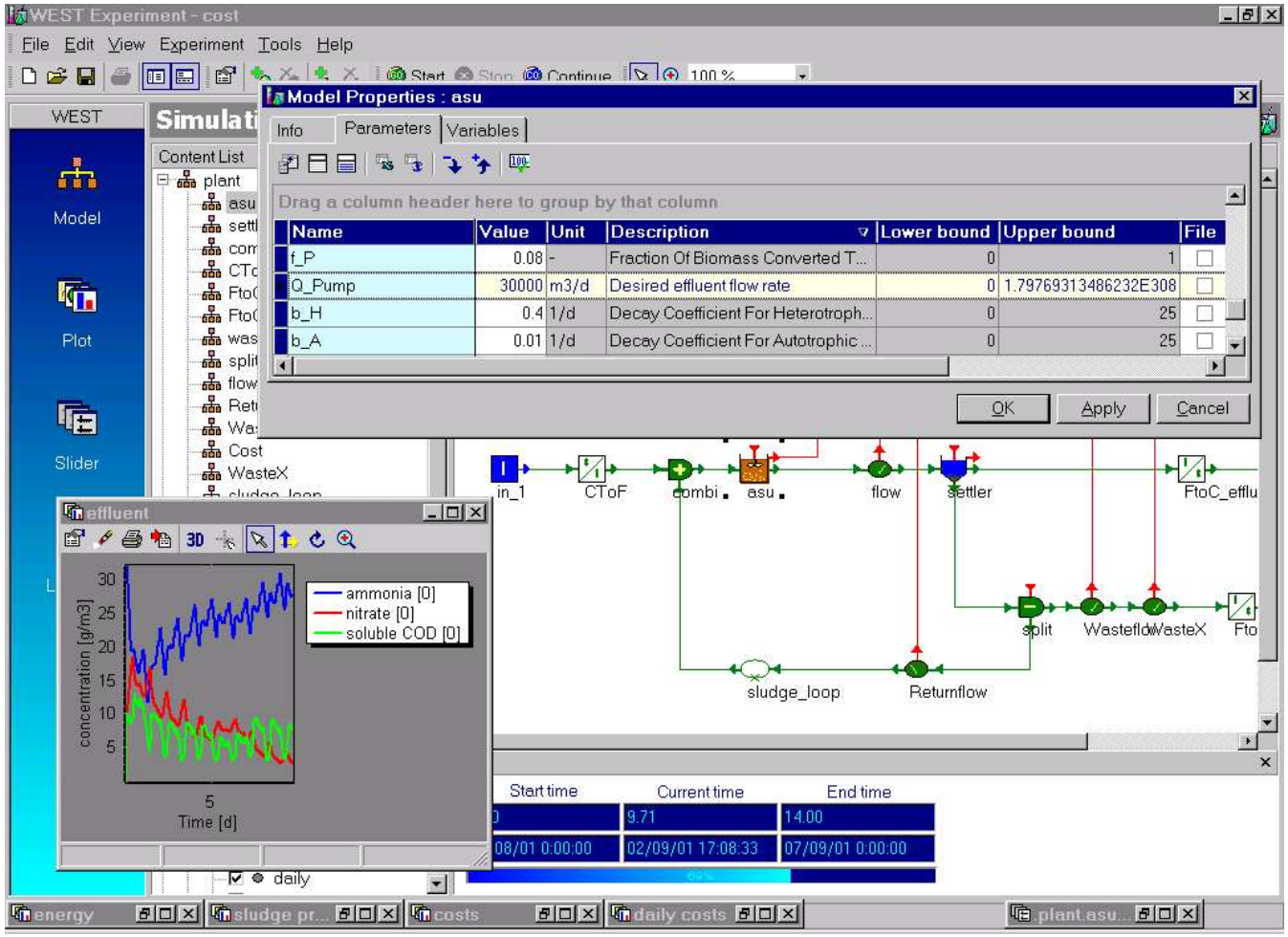
www.flightgear.org

M&S in action: Environment

NATO's Sarajevo WWTP

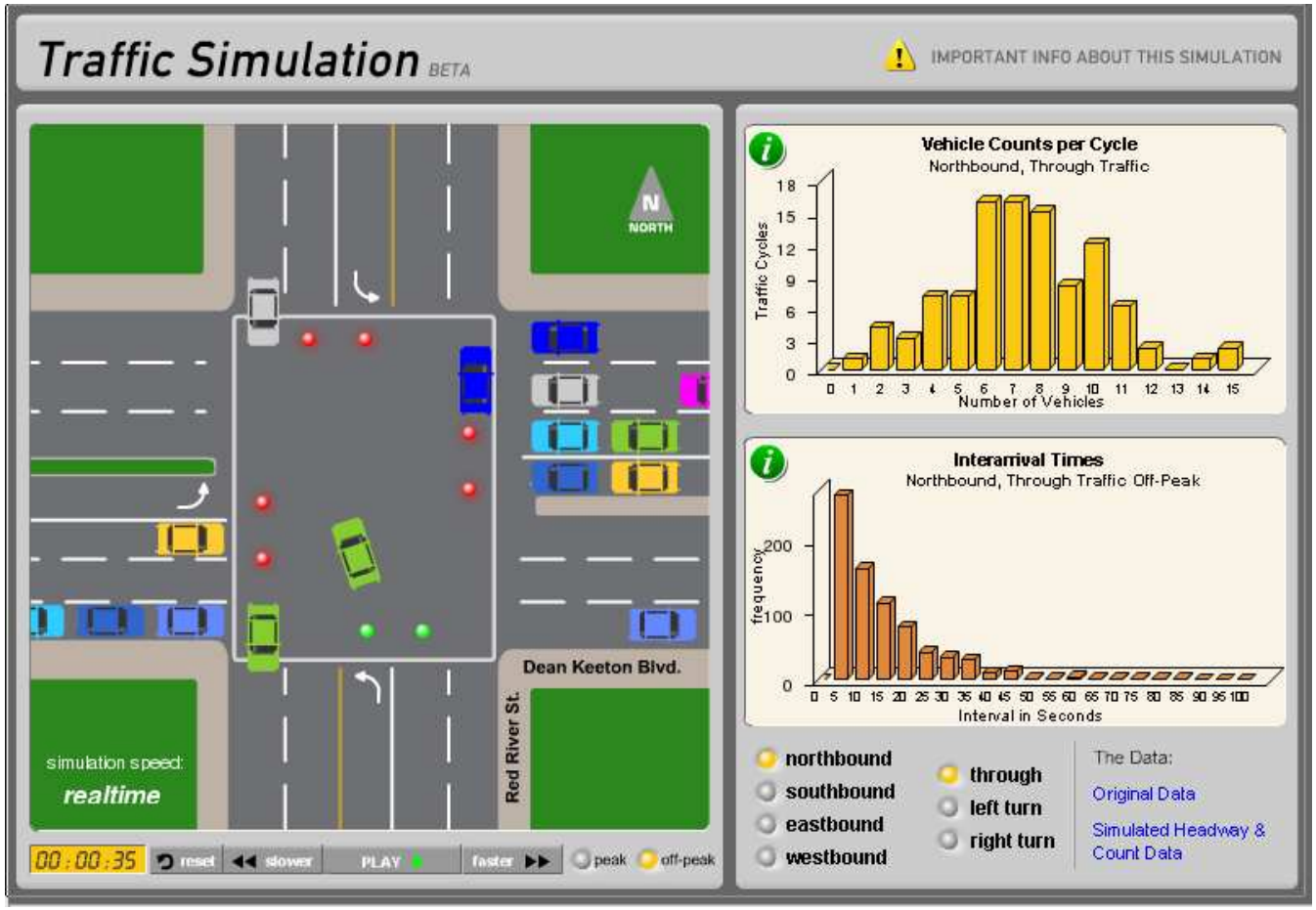
`www.nato.int/sfor/cimic/env-pro/waterpla.htm`

M&S in action: Environment



www.hemmis.com/products/west/

M&S in action: Traffic



www.engr.utexas.edu/trafficSims/

M&S in action: Training

USC Institute for Creative Technologies

`www.ict.usc.edu`

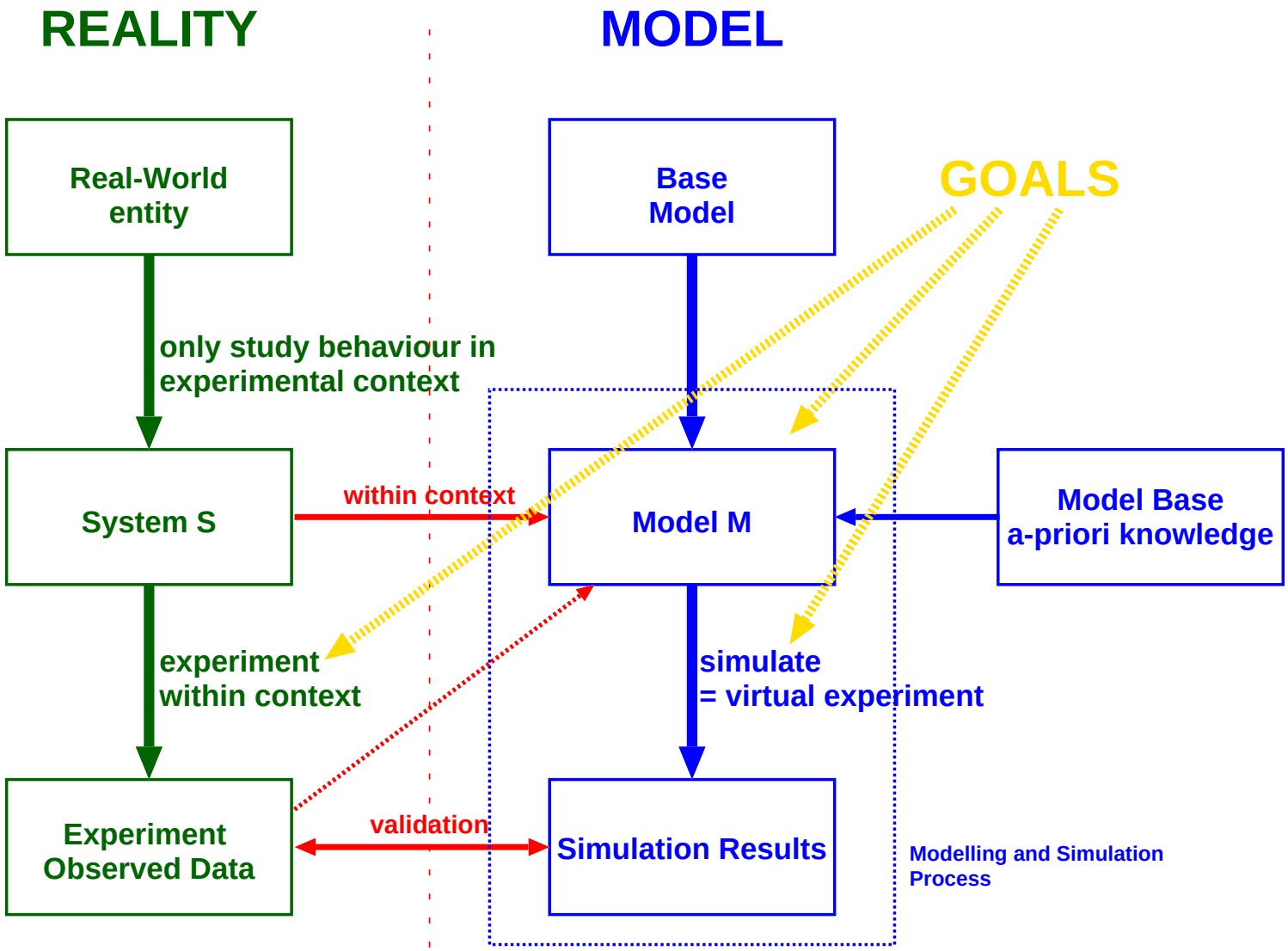
M&S in action: Game AI, Physics, Narratives, ...

`www.info.ea.com/company/company_tw.php`

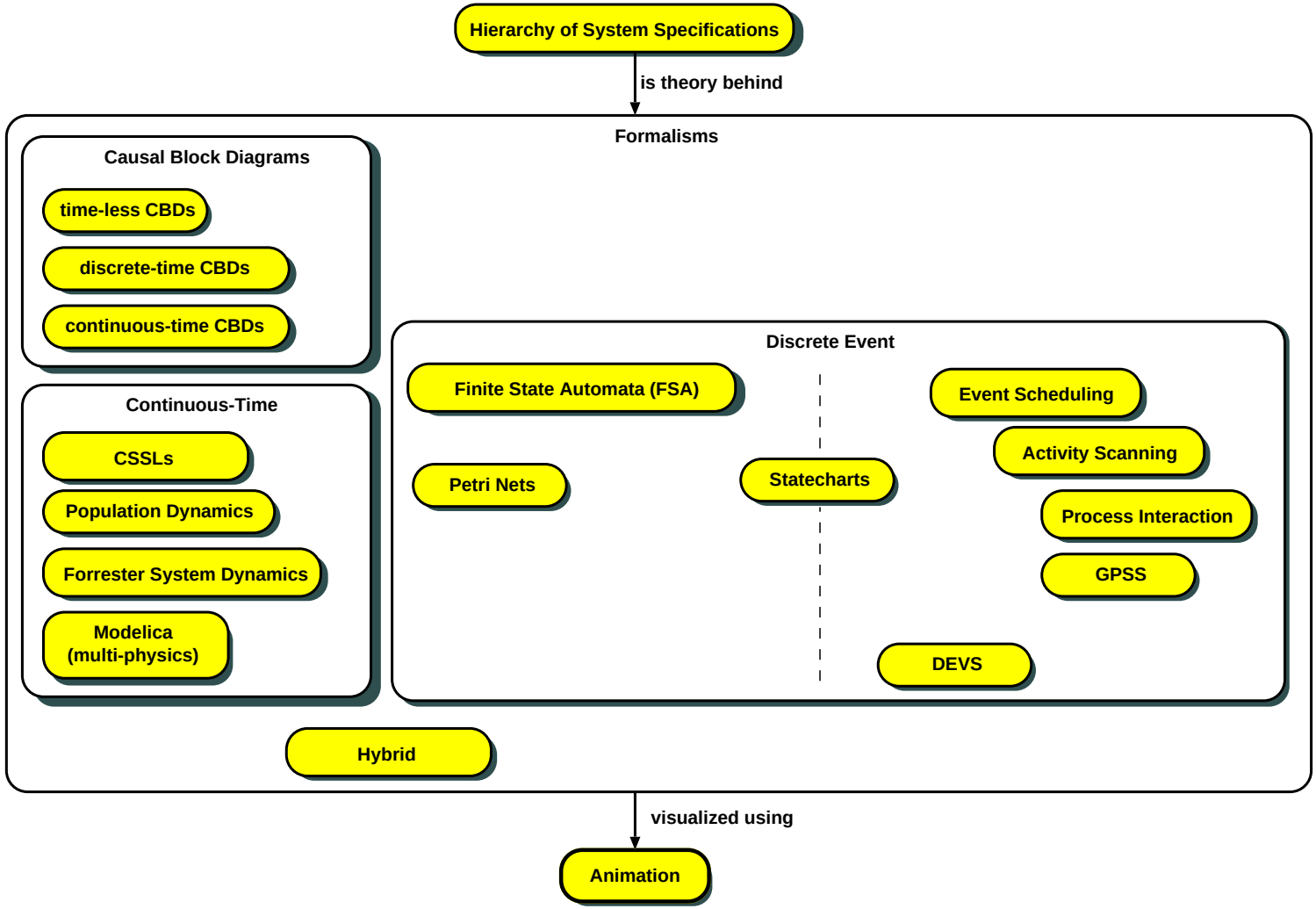
Modelling and Simulation . . .

- . . . is Computer Science, Artificial Intelligence
- . . . is Numerical Analysis, Computer Algebra
- . . . is Systems Theory, Control Theory
- . . . is Operations Research
- . . . is Application Domain: Mechanical Engineering, . . .

. . . or something more GENERIC ?

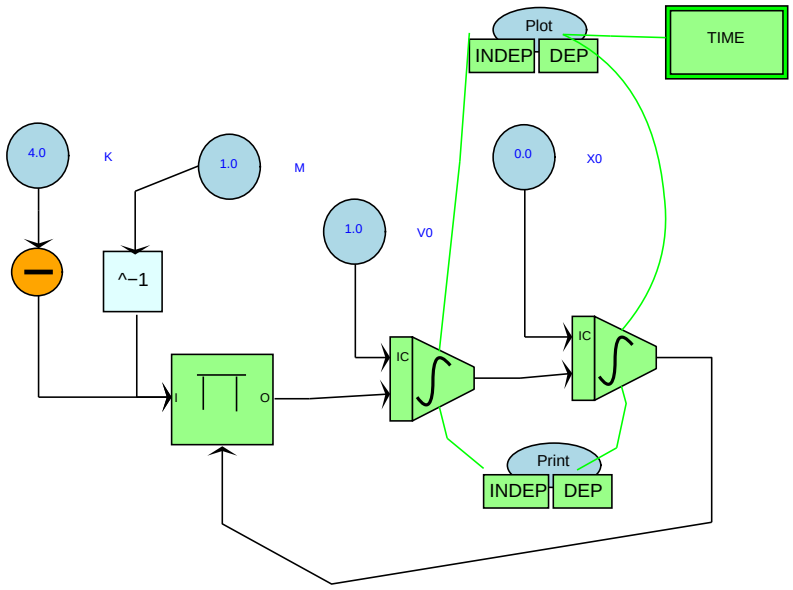

REALITY
MODEL
Real-World entity
Base Model
GOALS
only study behaviour in experimental context
System S
within context
Model M
Model Base a-priori knowledge
experiment within context
simulate = virtual experiment
Experiment Observed Data
validation
Simulation Results
Modelling and Simulation Process

COMP 522 Concept Map



Which topics does the course cover ?

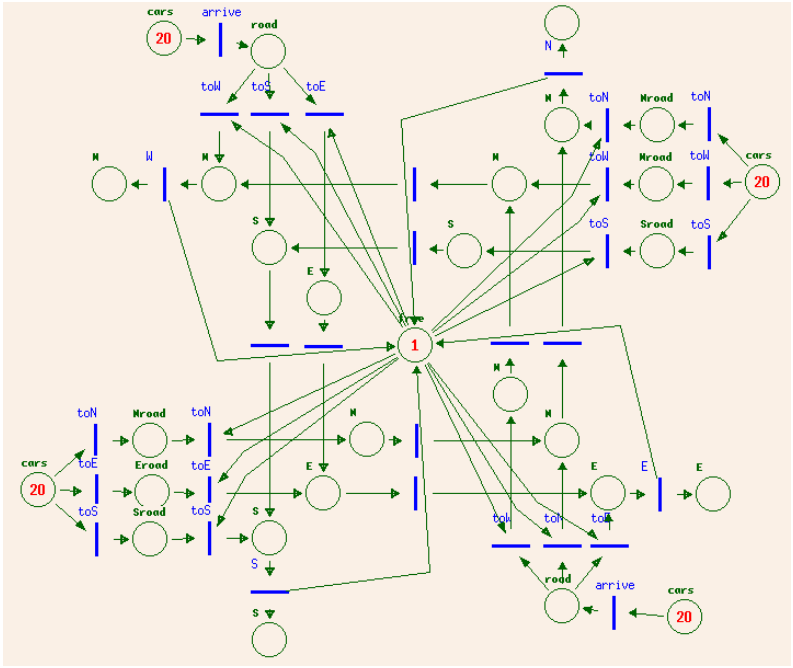
1. Modelling formalism *syntax* and *semantics*.
   The **Causal Block Diagram** formalisms.



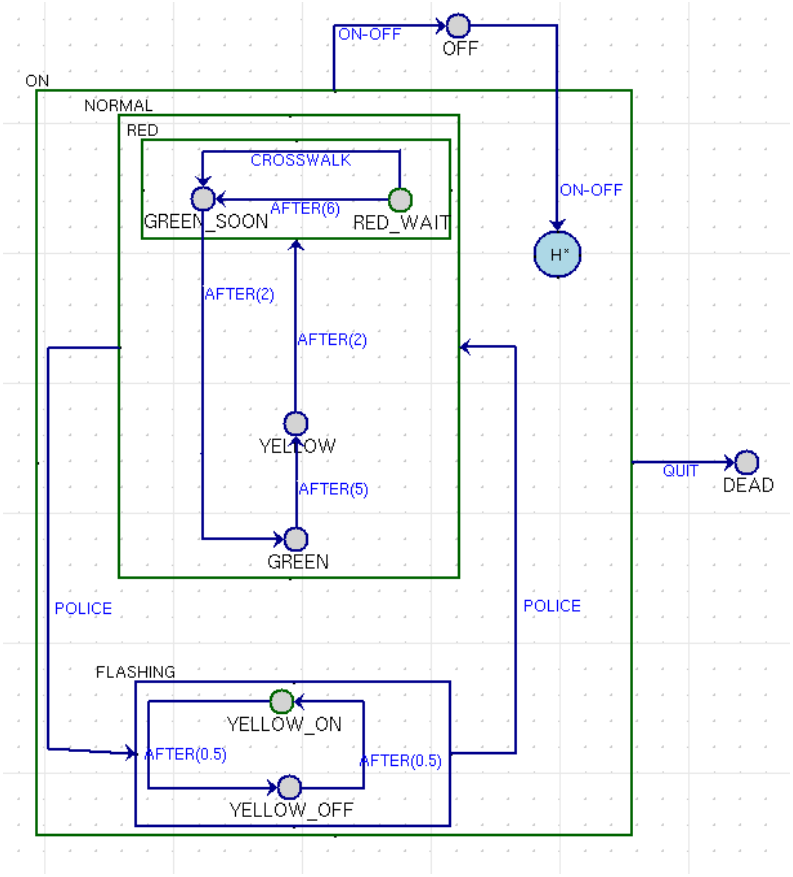
2. Untimed Discrete Event Formalisms:

   (a) (non)Deterministic **State Automata**.

   (b) Adding Concurrency and Synchronisation: **Petri Nets** (*e.g.*, specifying network protocols).



(c) Adding Hierarchy and Orthogonality: **Statecharts**
(*e.g.*, UML, specifying reactive software).



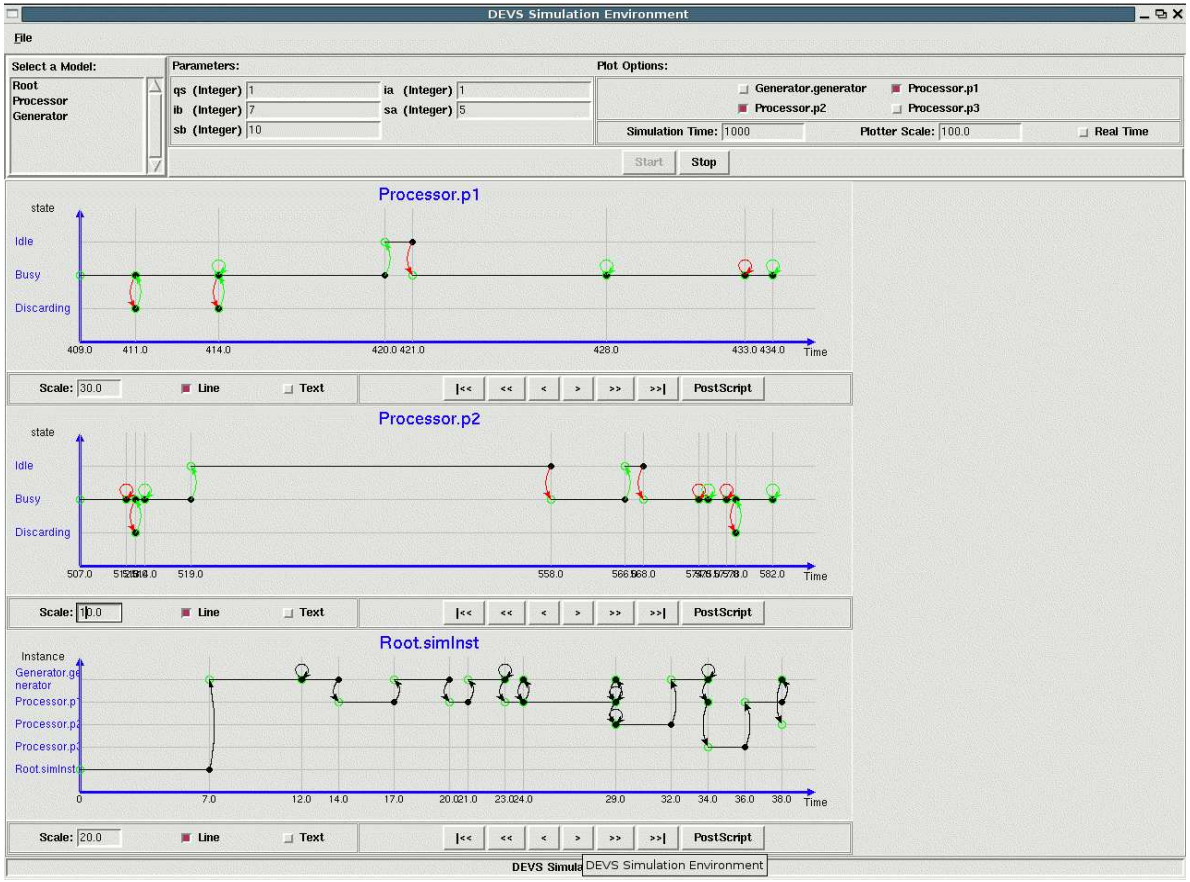
3. Communicating Sequential Processes (CSP/kiltera).

```
process sender[output]:
  seq
    print ("sender","sending","message")
    wait 0 ->
      send "message" to output ->
        print ("sender","sent message")

process receiver[input]:
  seq
    print ("receiver","waiting for input")
    wait 2 ->
      receive msg from input ->
        print ("receiver","received",msg)

main
  channel a in
    par
      sender[a]
      receiver[a]
```

4. Timed Discrete Event Formalisms:

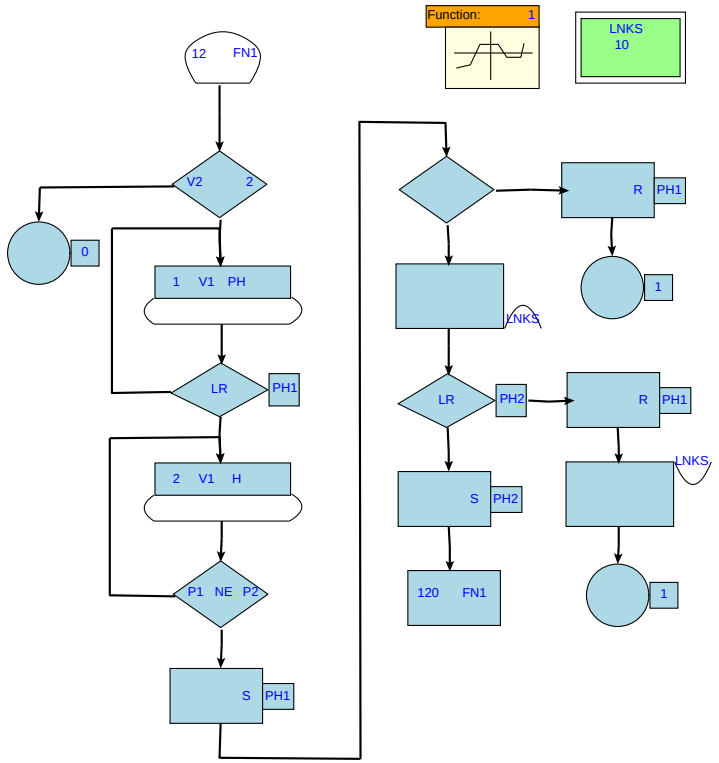


(a) **Event Scheduling**.

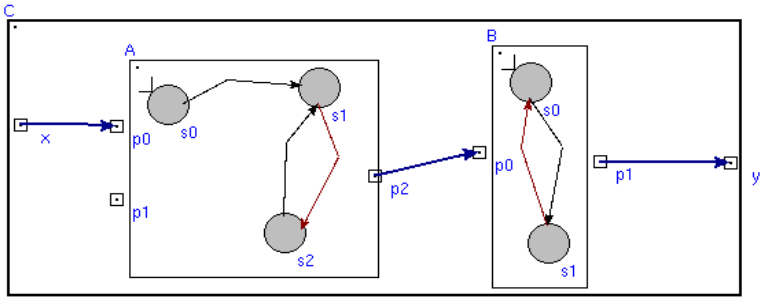
(b) **Activity Scanning**.

(c) **Three Phase Approach**.

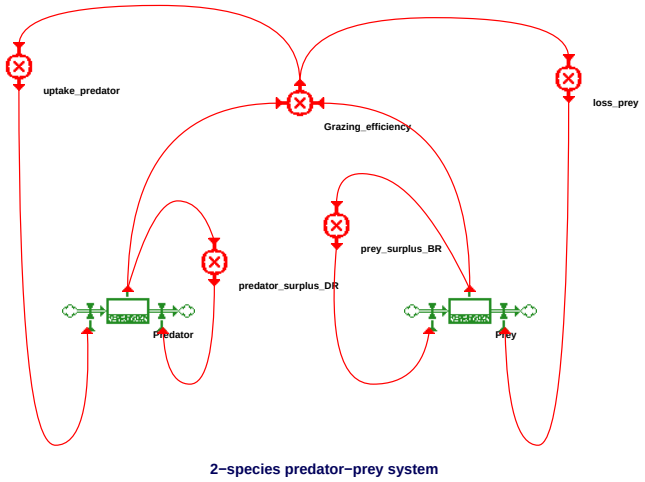
(d) **Process Interaction** for queueing systems (**GPSS**).

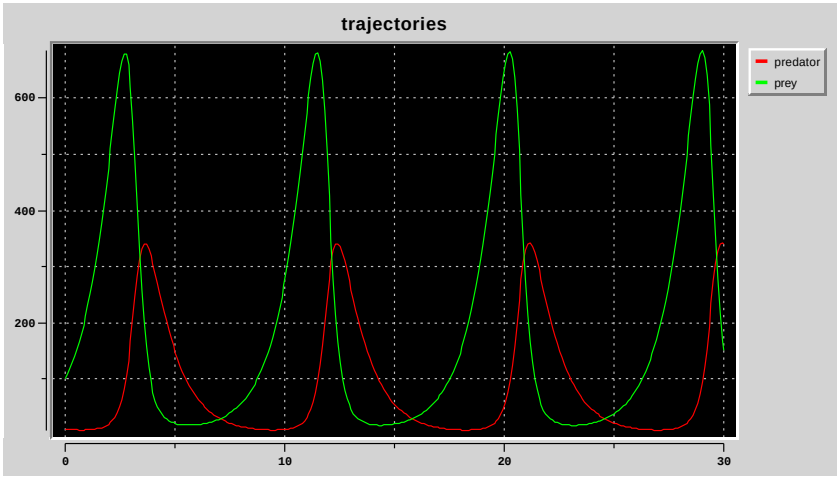


(e) **DEVS** as a rigourous basis for hierarchical modelling.



5. Deterministic Simulation of Stochastic Processes:
   (a) Pseudo Random Number Generation.
   (b) Gathering Statistics (performance metrics).
6. Animation
7. Continuous-time Formalisms:
   (a) **Ordinary Differential Equations**, Algebraic Equations, Differential Algebraic Equations.
   (b) CSSLs: sorting and algebraic loop detection.
   (c) **Forrester System Dynamics**, **Population Dynamics**.





(d) Object-oriented Physical Systems Modelling:
non-causal modelling, **Modelica** (`www.modelica.org`).

8. Hierarchy of System Specifications, Systems Theory.

Assignments cover these topics

1. A Causal Block Diagram simulation tool.
2. Petri Net model and analysis.
3. Statechart model and software synthesis.
4. kiltera model
5. GPSS (process interaction) model of a queueing system.
6. A DEVS model of a traffic system.

Project

- For a formalism of choice (possibly construct your own):
  build a modelling and/or simulation environment.
- Using an existing modelling/simulation system:
  study a specific problem.

Exam: mini-quiz(es)

What are the pre-requisites ?

- COMP 251 (data structures and algorithms),
- COMP 302 (programming languages and paradigms),
- COMP 350 (numerical computing).

. . . or equivalent (see me).

Note:

- *all* assignment/project programming in Python (where appropriate)
- no prior knowledge required, read Tutorial at `www.python.org`

How is evaluation done ?

- 60% on assignments.
- 30% on the project (work, correctness, presentation).
- 10% on a mini-quiz(es).

Together, assignments, mini-quiz(es) and project cover the entire course.
Hence, there is **no final exam**.

Assignment/project rules of the game ?

- Completely in HTML form: requirements, design, code, discussion.
- Submit via WebCT.
- All coding in Python `www.python.org` (where appropriate).
- Assignments and projects in teams of 2. Clearly describe work distribution !
- Original work, some presented in class.
- Respect deadlines (or do more work to compensate).
- Alternate subjects may be proposed.

Need help ?

- Use the discussion forum in WebCT
- Come and see me Monday 16:00 - 18:00 in MC328
- See the TA (Ximeng Sun) in MC202
- Send TA or me e-mail
- Talk to me after class or make an appointment
- Assignments/projects are never fully specified ! Give feedback !

Undergraduate or Graduate course ?

- Challenging course (work load)
- "graduate" flavour (independent thinking)
- some of the highest grades ever were obtained by ugrads

What are the project subjects ?

- Model/simulate a particular application (*e.g.*, traffic, biology)
- Build a modelling/simulation/animation tool for a particular formalism

Give suggestions !

Where do I get the material covered in CS522 ?

`moncs.cs.mcgill.ca/people/hv/teaching/MS/`

- Class presentations/notes online in PDF format.
- Some handouts during the term.
- Links and references for background info.