Fall Term 2004

COMP 522
Modelling and Simulation

"model everything"

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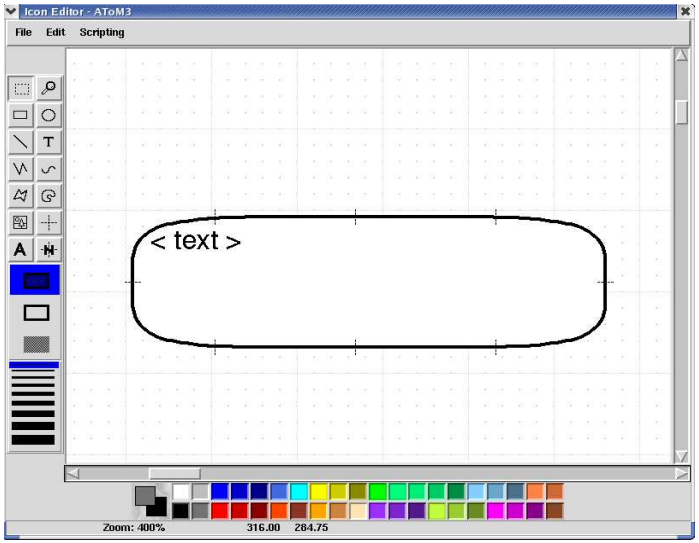
COMP 522A: Modelling and Simulation

- . . . to study *structure* and *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 Aspects of Complex Systems

A Variety of Complex Systems . . .



Need to be modelled

- at appropriate *levels of abstraction*
- in appropriate *formalisms*

Overview

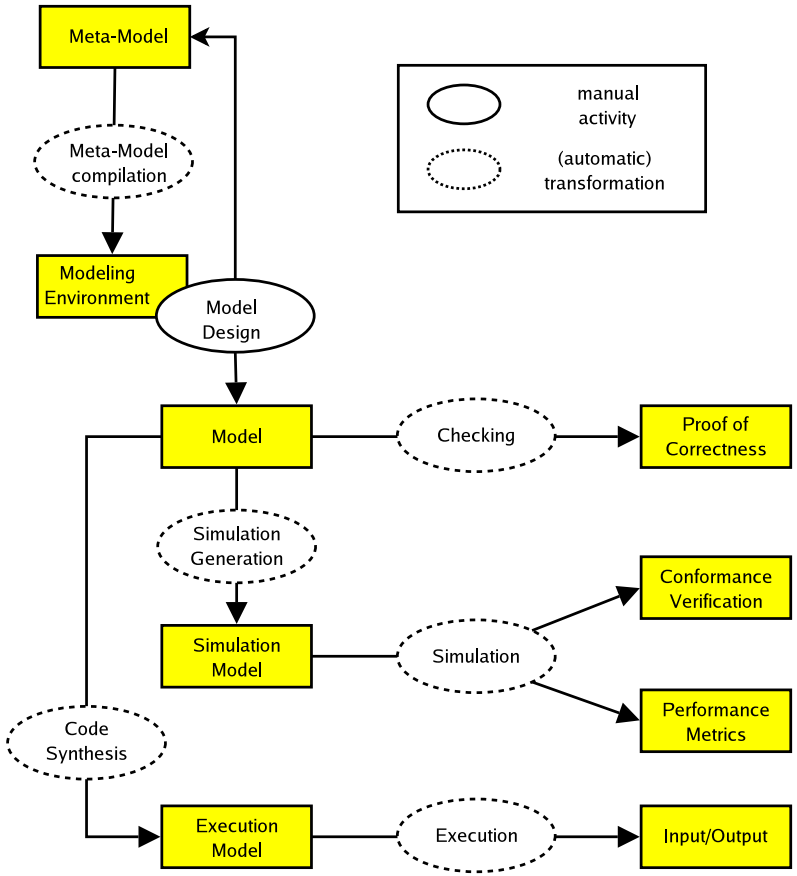
1. What is Modelling and Simulation ?
2. Which topics does COMP 522 cover ?
3. What are the pre-requisites ?
4. How is evaluation done ?
5. What are the assignments about ?
6. Where do I get the material covered in CS522 ?
7. What is the schedule ?

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



Modelling and Simulation in action: Training

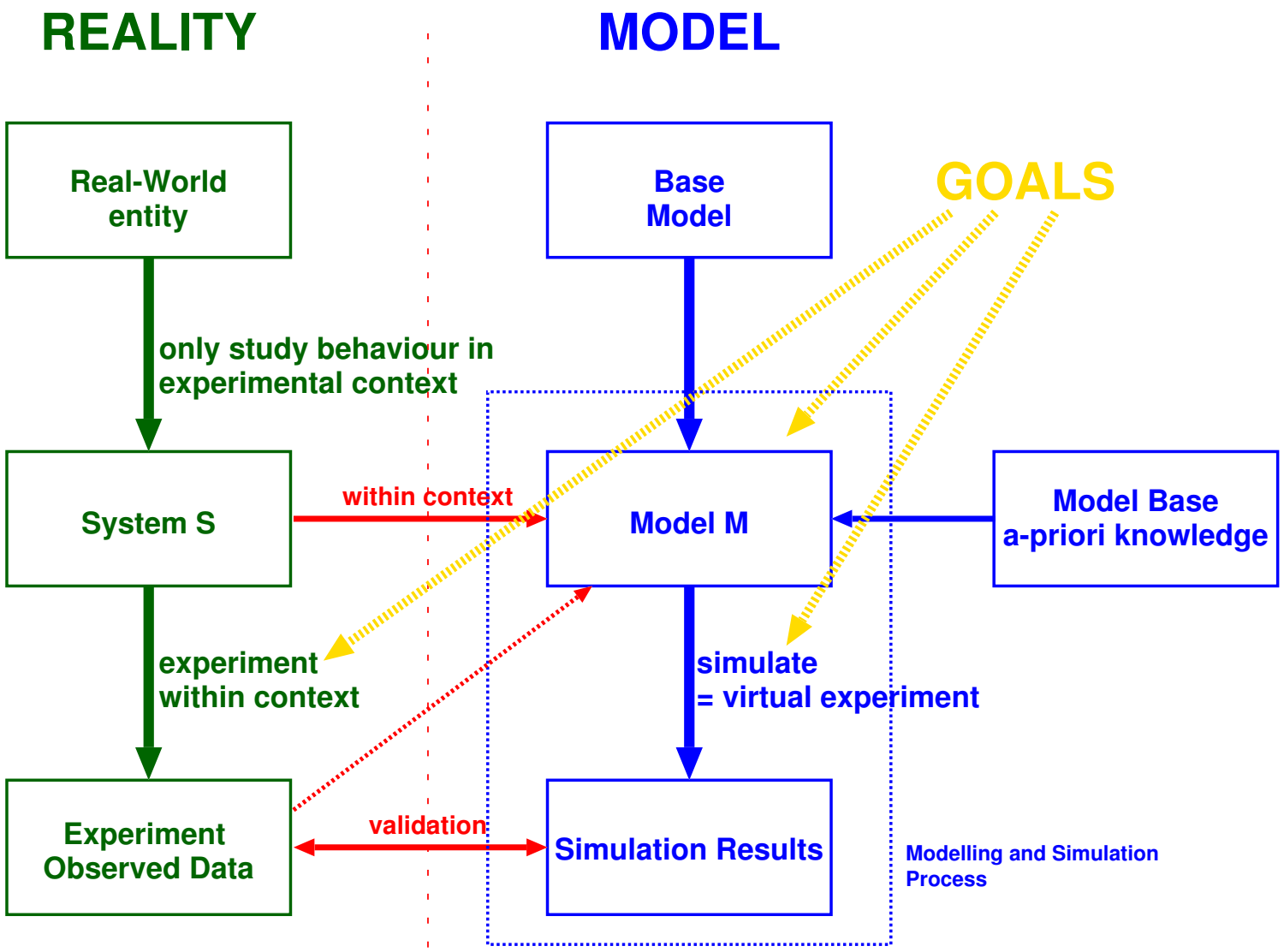
USC Institute for Creative Technologies

`www.ict.usc.edu`

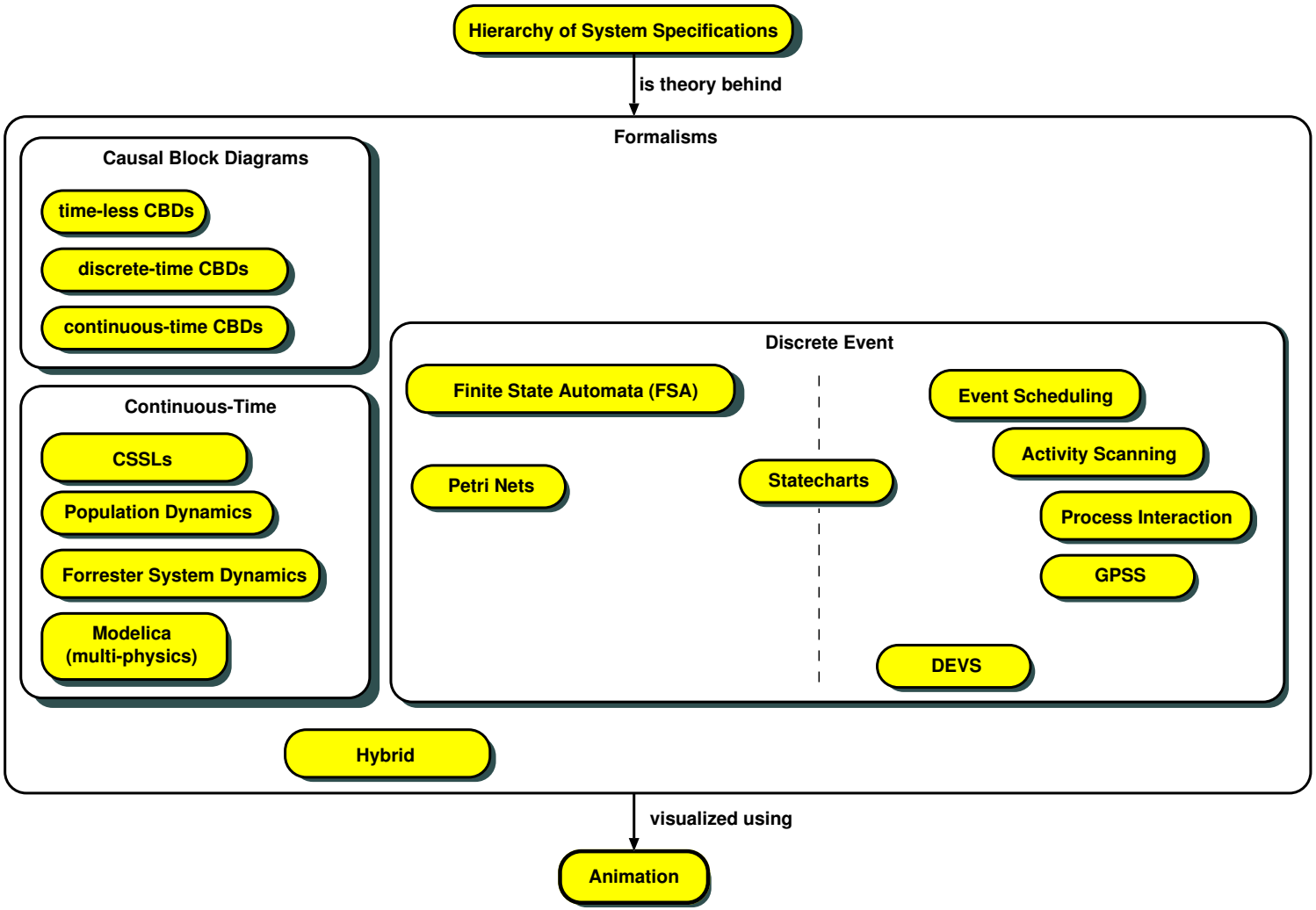
Modelling and Simulation . . .

- . . . 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. Formalism *syntax* and *semantics*. Causal Block Diagrams.
2. Hierarchy of System Specifications, Systems Theory.
3. 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).
4. Timed Discrete Event Formalisms:
   (a) Timed Automata.
   (b) Event Scheduling.

(c) Activity Scanning (AI).

(d) Three Phase Approach.

(e) Process Interaction for queueing systems (GPSS).

(f) 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.

8. Hybrid (continuous-discrete) modelling and simulation.

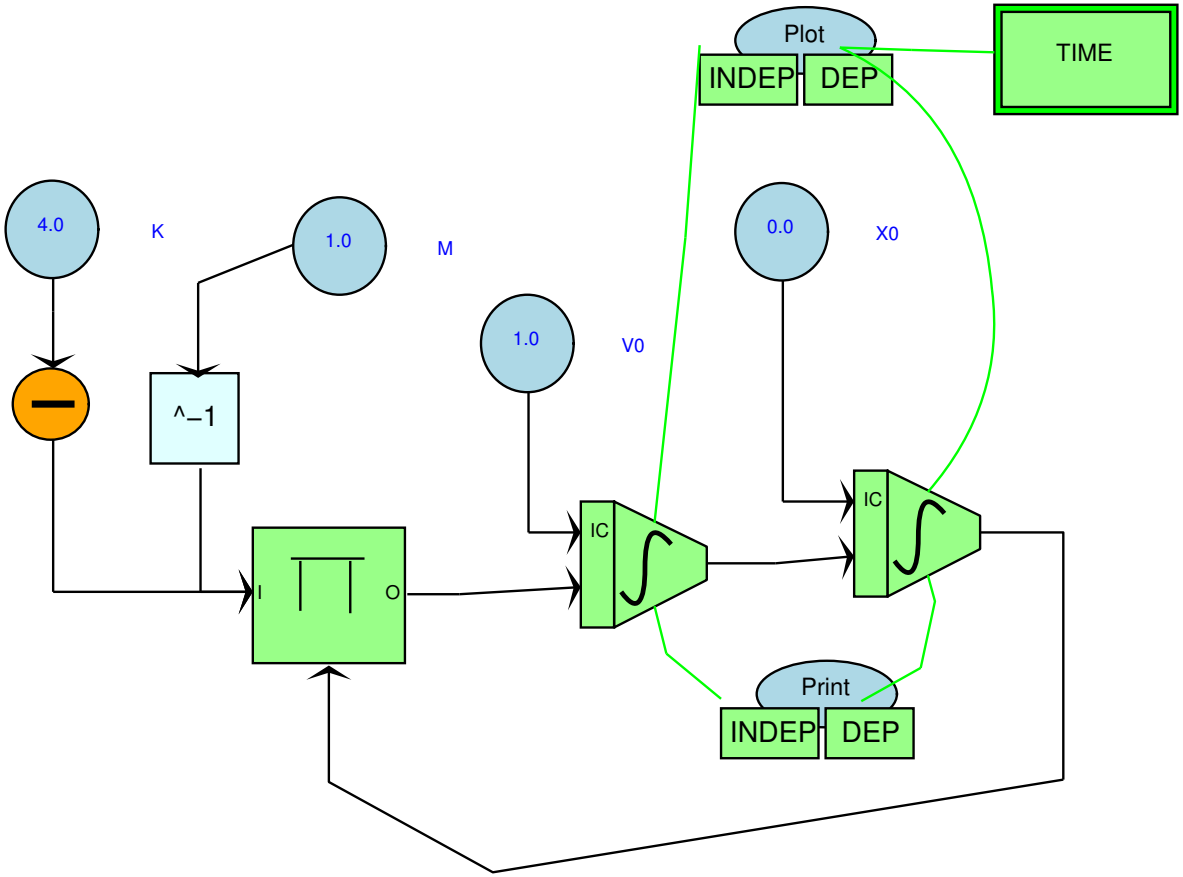
Assignments (5): cover these topics

Project:

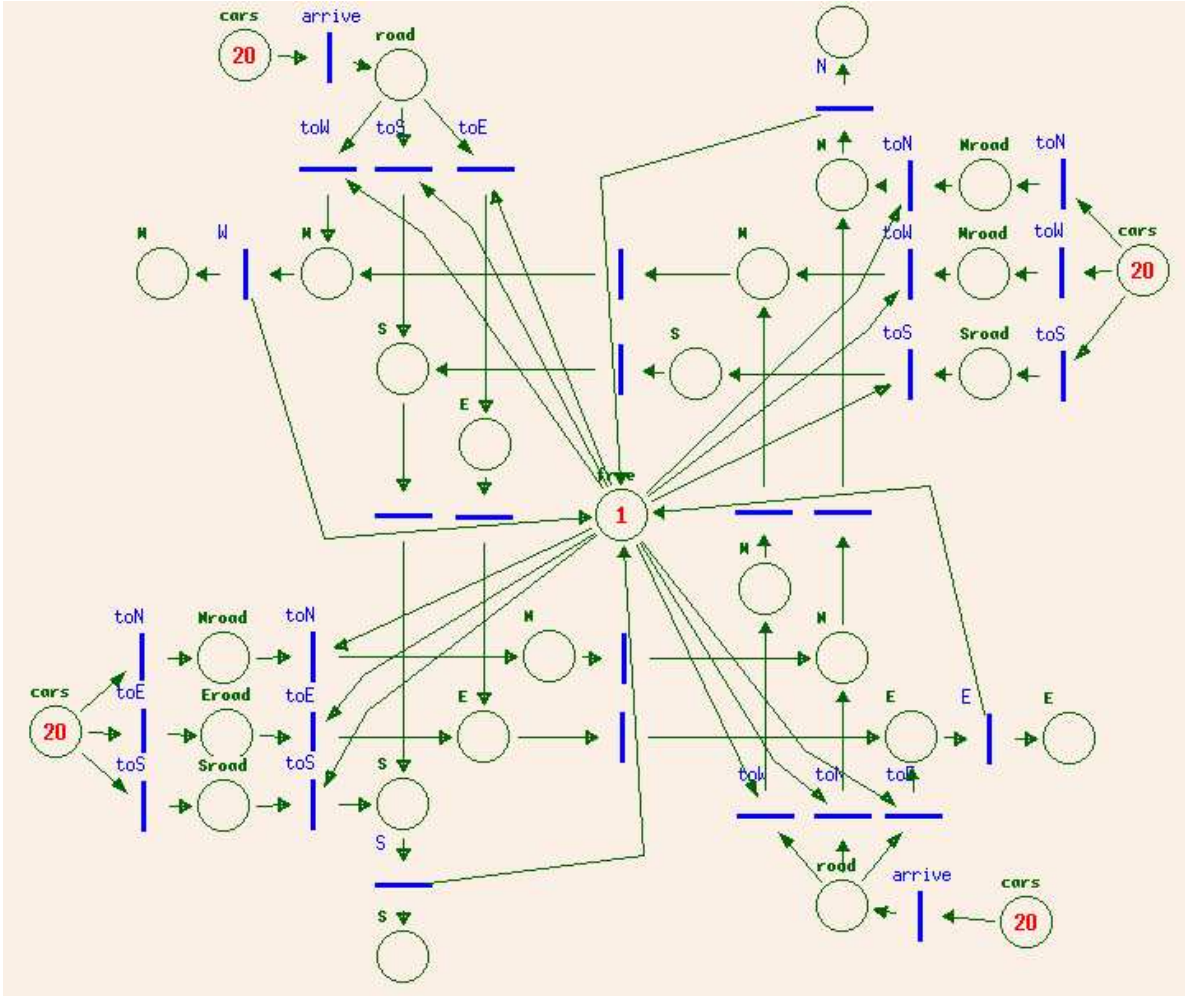
- For a formalism of choice (possibly construct your own): build a modelling and/or simulation environment.
- Using an existing modelling/simulation system: study a specific problem.

Exam: mini-quiz during last lecture

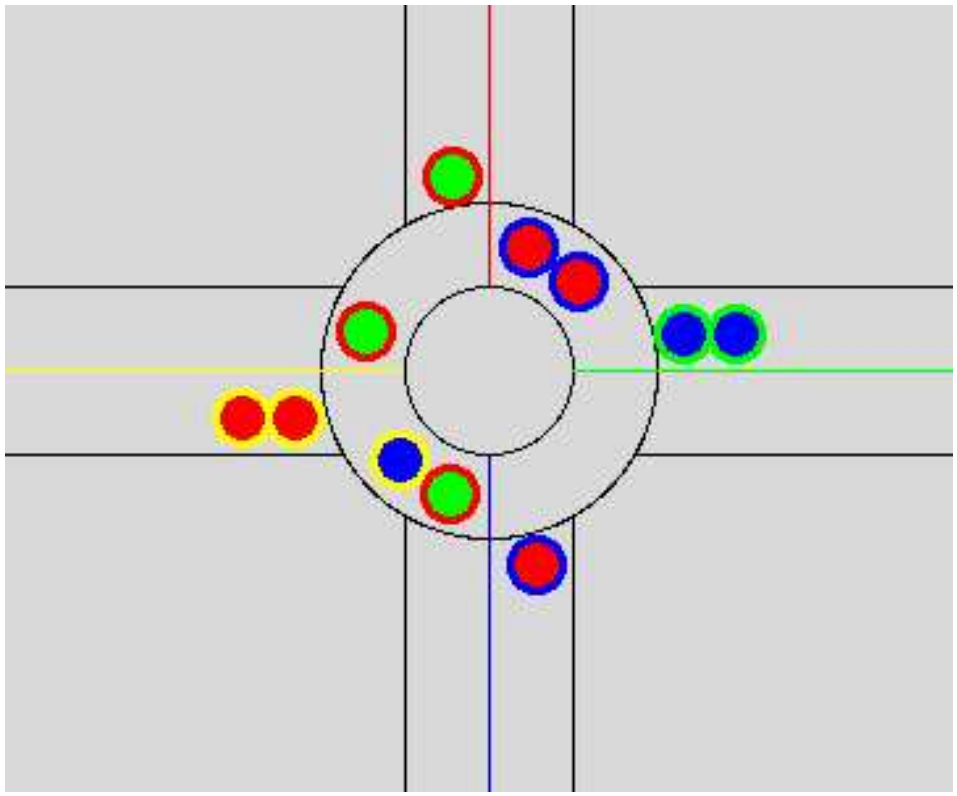
Causal Block Diagrams (cfr. Matlab/Simulink)



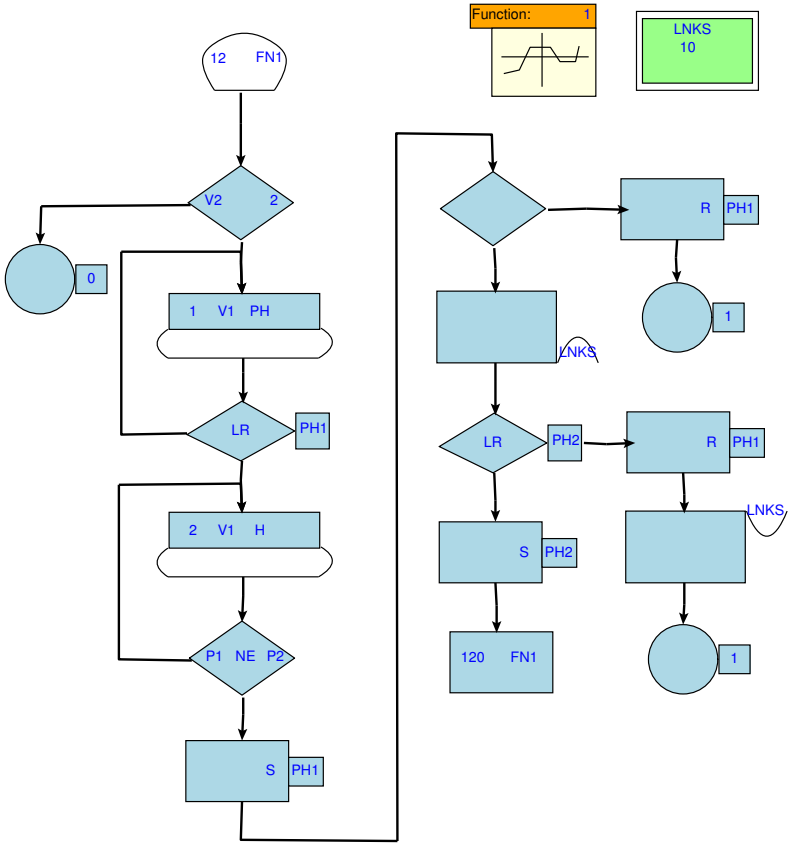
Petri Net model of intersection



trafficDEVS intersection animation



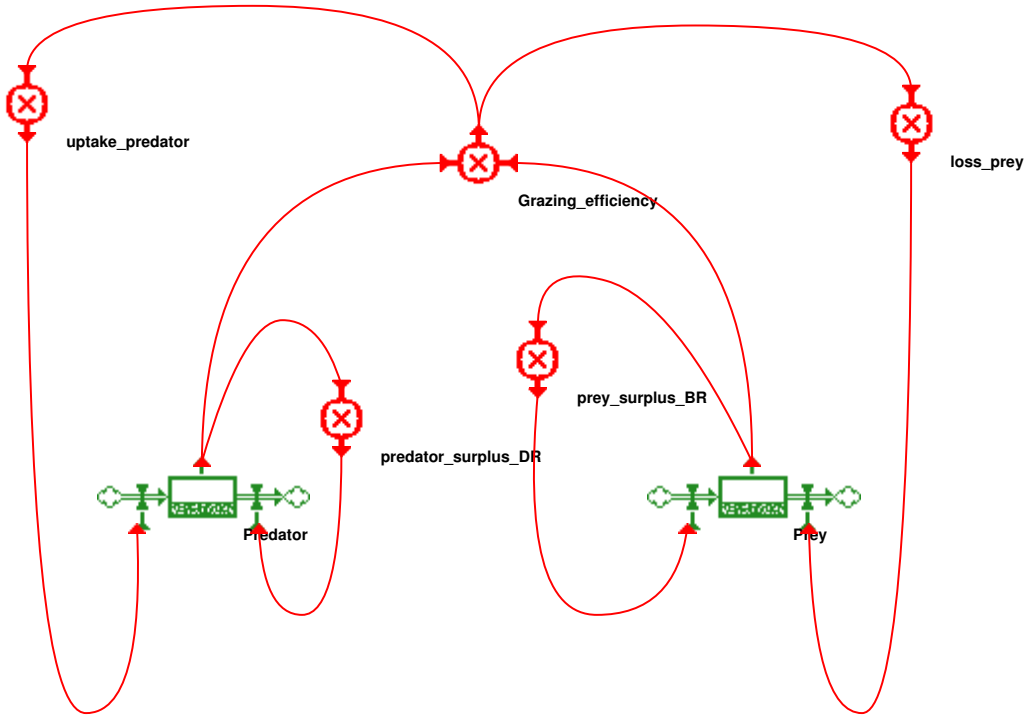
GPSS model of a Telephone Exchange



Process Interaction DEV: GPSS

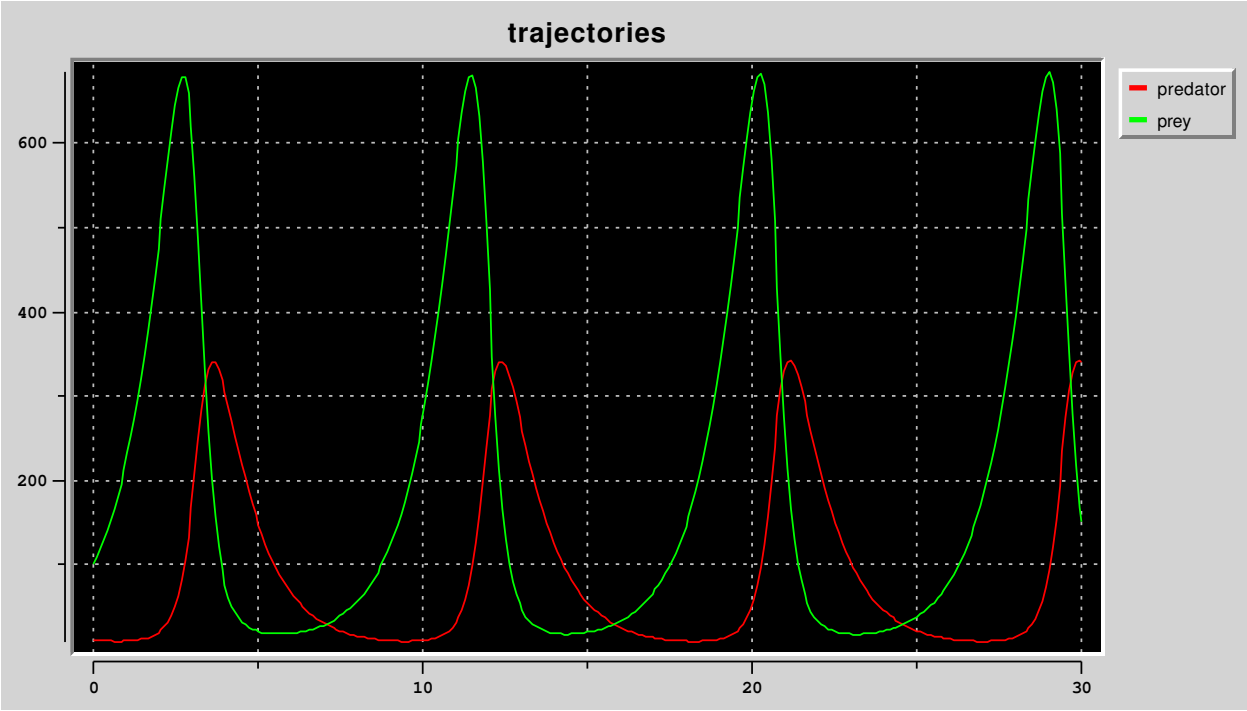
```
       SIMULATE

*
*      GPSS/H Block Section (the model)
*

*
*      MANUFACTURING SHOP - MODEL 1
*      Time unit = 1 minute
*
       GENERATE    5          Create parts
       ADVANCE     4,3        Inspect
       TRANSFER    .1,ACC,REJ Select rejects
ACC    TERMINATE   1          Accepted parts
REJ    TERMINATE   1          Rejected parts

*
*      GPSS/H Control Statements (the experiment(s))
*
       START       1000       Run 1000 parts

       END
```

Population Dynamics, System Dynamics



2–species predator–prey system

Trajectory



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
- no prior knowledge required, read Tutorial at `www.python.org`

How is evaluation done ?

- 65% on 5 assignments (more than 10% per assignment !!).
- 30% on the project (work, correctness, presentation).
- 5% on a mini-quiz during the last lecture.

Together, assignments, mini-quiz 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 in groups of 2, project in groups of maximum 3.
- 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 10:00 - 18:00 in MC328
- See the TA (Marc Provost) Wednesday 11:30 - 13:00 in MC202
- 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 assignments about ?

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

What are the project subjects ?

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

Suggestions are welcome !

Where do I get the material covered in CS522 ?

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

The schedule (tentative)

All lectures and tutorials are held 8:00 – 9:30 in Trottier 1080.

Wednesday	1	September	Course Introduction
Friday	3	September	Causal Block Diagrams – time-less
Monday	6	September	– Labour Day, no class –
Wednesday	8	September	Causal Block Diagrams – discrete-time
Friday	10	September	*tutorial:* AToM^3 internals
Monday	13	September	Causal Block Diagrams – continuous-time
Wednesday	15	September	The Modelling and Simulation Process

The schedule (tentative)

Friday	17	September	A Hierarchy of System Specification
Monday	20	September	A Hierarchy of System Specification
Wednesday	22	September	State Automata
Friday	24	September	*demo:* model-based complex systems design
Monday	26	September	Petri Nets (basics)
Wednesday	28	September	Petri Nets (analysis)
Friday	1	October	*presentation:* projects
Monday	4	October	Statecharts (intro)
Wednesday	6	October	Statecharts (semantics)
Friday	8	October	*tutorial:* DCharts in AToM^3
Monday	11	October	– Thanksgiving Day, no class –
Wednesday	13	October	Statecharts (applications)

The schedule (tentative)

Friday	15	October	The Event Scheduling World View
Monday	18	October	The Process Interaction World View
Wednesday	20	October	GPSS
Friday	22	October	*tutorial:* GPSS World
Monday	25	October	– no class –
Wednesday	27	October	– no class –
Friday	29	October	– no class –
Monday	1	November	GPSS
Wednesday	3	November	GPSS
Friday	5	November	DEVS (atomic)
Monday	8	November	DEVS (coupled)
Wednesday	9	November	DEVS (simulator)
Friday	11	November	*tutorial:* PythonDEVS

The schedule (tentative)

Monday	14	November	Animation
Wednesday	16	November	Continuous-time models (causal)
Friday	18	November	Population Dynamics
Monday	21	November	Forrester System Dynamics
Wednesday	23	November	Modelica: OO Modelling of Physical Systems
Friday	25	November	– work on project –
Monday	29	November	– work on project –
Wednesday	1	December	Project Presentations
Friday	3	December	Project Presentations