**CARLETON UNIVERSITY**
**Department of Systems and Computer Engineering**

# SYSC 5104/HCIN 5405. METHODOLOGIES FOR DISCRETE EVENT MODELLING AND SIMULATION

## Course Outline

Gabriel A. Wainer. Room 3216 VS
http://www.sce.carleton.ca/faculty/wainer.html
E-mail: **gwainer@sce.carleton.ca**

**Course Objectives:**

Simulation is a powerful tool used to study complex systems and to propose alternative solutions to existing problems. In recent years, several modelling formalisms have been developed to specify dynamic systems formally, ranging from queuing systems up to functional models, and object-oriented techniques. The main goal of this course is to introduce different modeling and simulation techniques, focusing in the practical use of the techniques for modeling and simulation of complex systems. Complex physical systems and discrete event systems will be analyzed using the DEVS and Cell-DEVS formalisms. Parallel simulation synchronization mechanisms will be introduced. The focus will be put into DEVS techniques, but comparison with other existing mechanisms will be attacked.

DEVS (Discrete EVents Systems specification) is one of these techniques, which is based on generic dynamic systems concepts. A DEVS model can be described as composed of several submodels, each being behavioural (atomic) or structural (coupled). Tested models can be reused, enhancing reliability, reducing testing time and improving productivity. Recently, the field of cellular computing has received important advances. Cellular models are usually defined as infinite regular n-dimensional lattices whose cells can take one finite value. The states in the lattice are up-dated according with a local rule function using the present cell state and a finite set of nearby cells. The Cell-DEVS formalism uses the DEVS formalism to define a cell space where each cell is defined as a DEVS atomic model. The goal is to build discrete event cell spaces, improving their definition by making the timing specification more expressive. This new method allows proper definition of timing properties for the model. The simulation literature shows that the use of parallel simulation mechanisms is a promising approach to obtain results, because it allows speedups in the simulation process. The provision of a meaningful sample of behavior by using sequential execution is a time consuming process. These assertions are valid for the simulation of Cell-DEVS, because they involve a high degree of computation time.

**Textbook:**
"Discrete-Event Modeling and Simulation: a Practitioner's approach". G. Wainer. CRC Press. Taylor and Francis. 2009.

**References:**
Different materials will be posted in the course website: http://www.sce.carleton.ca/courses/sysc-5104/ , including:
- "CD++: a toolkit to define discrete-event models". G. Wainer. In *Software, Practice and Experience*. Wiley. Vol. 32, No.3. November 2002. pp. 1261-1306
- "N-Dimensional Cell-DEVS". G. Wainer, N. Giambiasi. In *Discrete Events Systems: Theory and Applications*, Kluwer. Vol. 12, No. 1. January 2002. pp. 135-157.
- "Timed Cell-DEVS: modeling and simulation of cell spaces". G. Wainer, N. Giambiasi. In *Discrete Event Modeling & Simulation: Enabling Future Technologies*. Springer-Verlag. 2001.

*Support materials (some on hold in the University's Library):*
ZEIGLER, B.; KIM, T.; PRAEHOFER, H. "Theory of Modeling and Simulation ". *Academic Press*. 2000.
ZEIGLER, B. "Object-oriented simulation with hierarchical modular models". *Academic Press*, 1990.
SARJOUGHIAN, H; CELLIER F. (Eds.) "Advances in discrete-events simulation", Springer-Verlag 2001.
ZEIGLER, B.; KIM, T.; PRAEHOFER, H. "Theory of Modeling and Simulation". *Academic Press*. 1976.
FISHWICK, P. "Simulation model design and execution". Prentice-Hall. 1995.

**PREREQUISITES:** The course is self-contained. It is expected the students are able to program in C++ (basic knowledge). If you have any doubts about your background, ask the instructor.

**Course components**

- Assignments (2): Assignment 1: modeling discrete-event systems using DEVS. Assignment 2: Modeling physical systems using Cell-DEVS. Every assignment will be based on model development in the area of expertise of each student, and chosen by the students according to their personal interests. An initial requirement report will be requested (1-page report indicating the main aspects of the model to develop). The students will have 2 weeks to solve each assignment, after which a final report will be submitted.

- Term Project/Seminar: a project on the design and implementation of a simulation model based on the techniques taught in the course OR extensive literature reading/summarizing (including a Seminar presentation) Different projects/topics will be available (see some examples of previous projects in the course webpage).. Group projects will be permitted. The final report will be due the last day of classes. The students will have one month to develop the final project. The students will do a 15 minutes presentation about their term project during the last weeks of classes (the students are expected to present their project general aspects and status). During the WIP presentation, the students select the Best Project award. *Most of the projects in the course are very original and they are usually submitted to conferences and/or student paper contests* (see examples in the course webpage).

**Grading Scheme:**

| | |
|---|---|
| Assignments: | 40% (20% each) |
| Term Project: | 50% |
| Project WIP presentation: | 10% |

**Tentative Week-By-Week Outline**

1. Course objectives, organization and administration. Introduction to general Modeling and Simulation concepts. Model categories: conceptual, declarative, functional, and spatial. System dynamic formalisms. Classification. Examples of different systems dynamics: DESS, DTSS, DEVS. Multimodel formalisms.
2. Systems theoretical formalisms. Declarative Model definition with state machines. Introduction to Petri Nets. Introduction to the DEVS formalism. DEVS atomic model definition.
3. DEVS models dynamic behavior. DEVS coupled model definition. Tie-breaking for simultaneous events. Closure under coupling. The CADMIUM tool.
4. Modeling and simulation of DEVS using the CADMIUM tool. Modeling and simulation of DEVS using the CADMIUM tool (Tutorial).
5. Space-based approaches. Cellular Automata.
6. Introduction to the Cell-DEVS formalism. Specification of models using Cell-DEVS.
7. Specification of models using Cell-DEVS and related tools. Advanced Cell-DEVS models using CADMIUM DEVS related tools in different areas. Specification of models using Cell-DEVS and related tools (Tutorial).
8. Continued: advanced Cell-DEVS models using CADMIUM DEVS related tools in different areas: : biology (watersheds, fire spread, ant colonies), physics (crystal growth, lattice gases, heat diffusion), and artificial systems (urban traffic, etc). Triangular and hexagonal meshes. Definition of continuous and hybrid systems in DEVS.
9. Definition of continuous and hybrid systems in DEVS. DEVS simulation mechanisms. DEVS simulation mechanisms for spatial models.
10. Parallel DEVS and Parallel Cell-DEVS simulators. Cell-DEVS simulators. Hierarchical and flat simulators. Definition of parallel DEVS and parallel Cell-DEVS models using the CADMIUM toolkit. High performance techniques using parallel simulation. Synchronization mechanisms in parallel simulations.
11. Model definition based on Logical Process partition. Optimist and pessimist algorithms.
12. Presentation of Term Projects.
13. Current advances in DEVS and Cell-DEVS research. Review and best project award presentation.

**Academic Accommodation:** You may need special arrangements to meet your academic obligations during the term. You can visit the Equity Services website to view the policies and to obtain more detailed information on academic accommodation at http://www.carleton.ca/equity/ For an accommodation request, the processes are as follows:

- **Pregnancy or Religious obligation**: Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details see https://carleton.ca/equity/wp-content/uploads/Student-Guide-to-Academic-Accommodation.pdf
- **Academic Accommodations for Students with Disabilities**: The Paul Menton Centre for Students with Disabilities (PMC) provides services to students with Learning Disabilities (LD), psychiatric/mental health disabilities, Attention Deficit Hyperactivity Disorder (ADHD), Autism Spectrum Disorders (ASD), chronic medical conditions, and impairments in mobility, hearing, and vision. If you have a disability requiring academic accommodations in this course, please contact PMC at 613-520-6608 or pmc@carleton.ca for a formal evaluation. If you are already registered with the PMC, contact your PMC coordinator to send me your ***Letter of Accommodation*** at the beginning of the term, and no later than two weeks before the first in-class scheduled test or exam requiring accommodation (*if applicable*). **Requests made within two weeks will be reviewed on a case-by-case basis.** After requesting accommodation from PMC, meet with me to ensure accommodation arrangements are made. Please consult the PMC website (www.carleton.ca/pmc) for the deadline to request accommodations for the formally-scheduled exam (*if applicable*).
- **Survivors of Sexual Violence:** As a community, Carleton University is committed to maintaining a positive learning, working and living environment where sexual violence will not be tolerated, and where survivors are supported through academic accommodations as per Carleton's Sexual Violence Policy. For more information about the services available at the university and to obtain information about sexual violence and/or support, visit: https://carleton.ca/sexual-violence-support/.
- **Accommodation for Student Activities:** Carleton University recognizes the substantial benefits, both to the individual student and for the university, that result from a student participating in activities beyond the classroom experience. Reasonable accommodation must be provided to students who compete or perform at the national or international level. Please contact your instructor with any requests for academic accommodation during the first two weeks of class, or as soon as possible after the need for accommodation is known to exist. For more details, see https://carleton.ca/senate/wp-content/uploads/Accommodation-for-Student-Activities-1.pdf

**Copyright on Course Materials**: The materials created for this course (including the course outline and any slides, posted notes, labs, project, assignments, quizzes, exams and solutions) are intended for personal use and may not be reproduced or redistributed or posted on any web site without prior written permission from the author(s).

**Academic Integrity:** Students should be aware of their obligations with regards to academic integrity. Please review the information about academic integrity at: https://carleton.ca/registrar/academic-integrity/. This site also contains a link to the complete Academic Integrity Policy that was approved by the University's Senate.

**Plagiarism:** Plagiarism (copying and handing in for credit someone else's work) is a serious instructional offense that will not be tolerated.

**Health and Safety information:** Here is the link to the health and safety manual www.sce.carleton.ca/courses/health-and-safety.pdf