CARLETON UNIVERSITY
Department of Systems and Computer Engineering
4th Year Engineering project proposed subjects
2005-2006
Prof. Gabriel A. Wainer

These descriptions show basic ideas about different topics available. A number of other topics related to the ones here presented are also available. The students are encouraged to discuss these ideas with Prof. Wainer, who will explain the different available projects to develop in each of these areas. These descriptions show the different types of projects available, and it is not an exhaustive list. Beware that many of the topics here presented have a high degree of complexity; student's qualifications will be reviewed before assigning some of the most challenging ones (check prerequisites with Prof. Wainer). Further details about related projects can be found in:

http://www.sce.carleton.ca/faculty/wainer/roadmap.doc
http://www.sce.carleton.ca/faculty/wainer/research
http://www.sce.carleton.ca/faculty/wainer/4thYear

I. Development of real-time embedded systems using a model-based approach (1-4 students)

Real-time systems are built as sets of components interacting with their environment. In most cases (including robotics, traffic control, manufacturing and industrial applications, etc.), these applications must satisfy "hard" timing constraints. If these constraints are not met, systems decisions (even correctly computed) can lead to catastrophic consequences for goods or lives. The development of real-time controllers in distributed environments has been proven a very complex task, in terms of both development difficulties and related costs. We have provided a new systematic method and associated automated tools to develop hard real-time control applications reducing both development costs and delivery time. We use a simulation-based methodology for development, incrementally replacing simulated components by their real counterparts interacting with the surrounding environment.

The candidate will follow the methodology for developing real-time embedded application. A target application will be identified (to be discussed with the candidate according to his/her background and interests), and a complete application will be developed from scratch using our techniques and tools (which include advanced visualization tools, a development environment, and specialized hardware). The activities will be carried out in the *CFI Advanced Laboratory for Real-Time Simulation*. This infrastructure consists of a high-performance computing platform (64 high speed processors linked with a very high speed interconnect) to support an advanced real-time simulation engine (including AD/ DA interfaces and graphics workstations for human interaction). Some of the projects include development of embedded applications in the Intel IXA platform.

Expected learning opportunities include:

- an introduction to modeling and simulation tools
- fine tuning C++ skills
- fine tuning Java skills
- real-time and embedded systems development techniques

experience in an advanced high performance computing environment

II. Parallel/Distributed simulation of complex systems (1-3 students)

Simulation of very complex systems usually requires significant amounts of compute time. Therefore, the use of sequential models makes difficult obtaining significant results through simulations. To improve the performance, several approaches for parallel and distributed simulation have been proposed. The CD++ tool permits that users execute parallel simulation of very large complex models using DEVS and Cell-DEVS (two very advanced modeling and simulation techniques). This tool lets the user to run previously defined model in a distributed fashion. The tools are built over the Warped environment, which uses the MPI standard to build the simulators.

The goal is to analyze performance results of executing CD++ under different parallel simulation algorithms, trying to identify which are the most suitable to solve given classes of problems. The candidate will build automated regression tests, an automated performance testing benchmark, and will analyze performance results. The candidate will interact with a group of graduate students and visiting research scholars. The activities will be carried out in the *CFI Advanced Laboratory for Real-Time Simulation* (ARS). This infrastructure consists of a high-performance computing platform (64 high speed processors linked with a very high speed interconnect) to support an advanced real-time simulation engine (including AD/ DA interfaces and graphics workstations for human interaction).

Expected learning opportunities include:

- an introduction to modeling and simulation tools
- responsibility in considering alternatives and justifying decisions
- fine tuning C++ skills
- parallel simulation and parallel programming techniques
- experience in an advanced high performance computing environment

III. Visualization of complex simulation models (1-4 students)

Cell-DEVS is a technique that enables defining grid-shaped discrete event models. Very complex systems can be modeled easily thanks to the availability of high level techniques and associated tools. We have recently defined very complex models using Cell-DEVS (ranging from fire spreading, watershed forming, or ant foraging up to analysis of the behavior of the heart tissue).

Different visualization techniques have been applied to the current simulation engines (based on Java and VRML). The goal of this project is to improve 3D visualization techniques based on VRML, XML and Java3D. The goal of this project is to improve the currently existing graphical environment enabling the users to easily visualize the simulation models in 3D worlds. This includes distributed execution via the Internet using a web-based interface. The activities will be carried out in the *CFI Advanced Laboratory for Real-Time Simulation* (ARS). This infrastructure consists of a high-performance computing platform (64 high speed processors linked with a very high speed interconnect) to support an advanced real-time simulation engine (including AD/ DA interfaces and graphics workstations for human interaction).

Expected learning opportunities include:

- an introduction to modeling and simulation tools
- fine tuning Java skills
- VRML/XML/Java 3D
- experience in an advanced high performance computing environment

IV. A microkernel for model execution in handheld devices (1-3 students)

The main goal of this project is to include communication between the CD++ tool and handheld environments. In this way, a user with a handheld can feed a simulation running on a server, which will provide on-line results. This requires using wireless services in the handheld systems, which must be integrated to the modelling tool.

V. Interfacing RT-OO systems and embedded systems (1-2 students)

The idea is to provide means for interfacing Real-Time CD++ models with hardware in the new Embedded Systems lab. The goal is to enable real-time embedded applications to interact with higher level models running in an independent modelling environment. We have different projects in this area (details can be discussed with the instructor). These projects will be developed in the new Advanced laboratory for Real-Time Simulation and the new Embedded Systems lab. This will include definition of submodels in the new Intel IXA processors to be integrated in the *CFI Advanced Laboratory for Real-Time Simulation.*

VI. Developing models of hardware in n-VHDL (1-2 students)

At present we have developed a library of models based on an extension of VHDL. The goal of this project is to continue the definition of such a library, and use the models to run in an embedded environment. These projects will be developed in the new Advanced laboratory for Real-Time Simulation and the new Embedded Systems lab.

VII. The IEEE Computer Society International Design Competition

The goal of the IEEE Computer Society International Design Competition (CSIDC) is to advance excellence in education by having student teams design and implement computer-based solutions to real-world problems. Every year the focus of the Competition changes. At this stage, we only need to set up a competitive team (3 or 4 students) willing to participate in the competition. Finalist teams must show the final projects in a contest held in Washington D.C. Winning teams are awarded different prizes. The applications are developed using hardware/software provided by the IEEE every year (previous competitions included health care improvement tools, Bluetooth Wireless Technology, etc.). The goal is to develop a complete project following standard engineering procedures throughout the development. The winner is chosen using similar criteria than the ones used to grade the course (the resulting application and the quality of the report describing it). The competition schedule takes several months, overlapping with the 4^{th} Year Project timetable.

VIII. ATLAS: a language for modelling and simulation urban traffic (1-2 students)

ATLAS (Advanced Traffic LAnguage Specifications) is a modelling language focused to analyze detailed behavior of traffic. A city section can be easily described, including definitions for traffic signs, traffic lights, etc. A modeler can concentrate in the problem to solve, instead of being in charge of defining a complex simulation. Different projects include:

- The development of a graphical environment enabling the users to easily define the traffic models using an easy-to-use tool. It will also use the outputs provided by the tool, and will translate them into VRML, enabling the user to see the traffic flow using Virtual Reality tools. This includes distributed execution via the Internet using a web-based interface.
- the analysis and execution of existing models of traffic (including a model of traffic on campus) in a parallel execution engine in order to improve the generation of results based on parallel execution of the models.

IX. Alfa-1: a simulated processor (1-2 students)

The Alfa-1 is a simulated computer based on the architecture of the SPARC processor. It was built using a simulation tool (CD++, a modelling tool enabling the definition of discrete event models) under different environments (Solaris, AIX, Linux, and Windows). The simulated computer is available for public domain, and it is being used in various universities around the world. Students participating in any of these projects would be presenting the results in the annual Usenix conference, according to the quality of the results obtained. We have different projects in this area (details can be discussed with the instructor). The following descriptions show some of the possible topics.

X. Modelling of very complex physical systems (1-3 students)

Cell-DEVS is a technique that enables defining grid-shaped discrete event models. Very complex systems can be modeled easily thanks to the availability of high level techniques and associated tools. The goal of this project is to define very complex models using the Cell-DEVS formalism. Some examples include the definition of plant growth, fire spreading, watershed forming, ant foraging models, and heart tissue behavior. The performance of these models will be improved using a parallel environment. We have different projects in this area (details can be discussed with the instructor). These projects will be developed in the new Advanced laboratory for Real-Time Simulation.

XI. Carleton University Carpool system (1-2 students)

Traffic problems increases according to the complexity of the city developments, and with the growth of urban sections with inadequate planning. Car Pools has been useful ways of avoiding traffic jams in big urban centers, allowing reducing pollution, improving the traffic flow, and reducing the travelling expenses of the users. The goal of this project is to build a Web-based Car Pool system that can be applied at Carleton University, so that members of the University community can share daily driving time and expenses. The project involves the definition of the whole system, making a detailed requirements definition , risk analysis, system analysis and design, and implementation, considering diverse aspects (security, privacy, legal aspects, etc.)

XII. Development of Real-Time applications with Atlantis technology

Atlantis is an advanced computing model that allows the construction of real time controllers for a variety of applications in such areas as: Communications, Networking, Transportation, Energy, Information Technology and Manufacturing (developed by Satellite Forces (http://satelliteforces.ca in partnership with Cincom Systems http://cincom.com). The goal is to develop sample applications in Atlantis, and to interface the controllers developed in Atlantis with the CD++ Modelling toolkit.

Students will have opportunities to use Atlantis to create applications in such areas as:

- <u>Fault Tolerant Computing</u>
    - Fault Tolerant computing is used in mission critical applications such as telecommunications, networks, manufacturing, air traffic control systems.
- <u>Transportation</u>
    - Build a Road Safety Control System that utilizes sensors and heuristics to predict and manage weather conditions on transportation routes.
- <u>RFID</u>
    - Utilize an RFID sensor set to build a real time control system for manufacturing.
    - RFID technology is used in manufacturing and transportion industries to control the flow of parts and materials.
- <u>Communications</u>
    - Utilize a digital audio stream in conjunction with a real time controller to generate a Voice Over IP Control System.
- <u>Energy</u>
    - Using the Atlantis technology, design an optimization solution for sustainable Energy and Environmental Control System.