Catalog Description
Formal methods for specifying, modeling, and analyzing concurrent systems, and mathematical basis for such methods. Automated and semi-automated tools to apply these methods to analyze emergent behavior of computing related applications.

Instructor Information
Prof. Susan Older (sueo@ecs.syr.edu)
Office: CST 4-131, x4679 (email is much better than phone)
Office hours: Tuesdays (4-5:30pm), Wednesdays (4-5:30pm), or by appointment (I’m also easy to catch after lectures)

Course Web Address
http://www.cis.syr.edu/~sueo/mcs

Textbook
Relevant papers and notes will be distributed in class or via the course web page.

Course Objectives
Concurrent systems comprise multiple agents that execute simultaneously and interact with one another. This definition is deliberately broad: it includes networks, computing clusters, distributed databases, and even e-commerce and security protocols. Our increasing reliance on these systems raises a sobering question: Why should we believe they work correctly?

Designing concurrent systems is inherently difficult: increasing system size linearly introduces exponentially more possible interactions to consider. As a result, ad hoc analyses are insufficient for assuring that a system works correctly: we need sound mathematical bases for specifying what constitutes correct behavior and for verifying that the resulting designs satisfy these specifications.

The primary goal of this course is to provide you with an in-depth understanding of one particular approach—using process algebras and modal logic—for specifying, modeling, and analyzing system behavior for nontrivial applications. An important component of this course will be hands-on experience in using automated tools to analyze systems. However, using the tools successfully requires you to have a firm grasp of the underlying principles.

Prerequisites
To do well in this course, you must be familiar and reasonably comfortable with predicate logic, as well as sets and relations (à la CIS 375 or CIS 607).

Course Outcomes
After completing this course, you should be able to use the process algebra CCS and the modal \( \mu \)-calculus to specify and model a variety of concurrent systems. You should also be able to analyze and evaluate a system’s conformance to its desired properties.

More specifically, you should be able to do the following:
• When given a CCS process, draw its transition diagram.
• When given a valid transition between two CCS processes, construct a formal derivation for that transition.
• When given a high-level process description in English, write a CCS process that captures the desired behavior.
• When given a precise but informal description of a modal property in English, translate that description into a modal μ-calculus formula.
• When given a modal μ-calculus formula, translate it into English.
★ When given a CCS process description and a modal property, determine whether or not the process satisfies the given property.
• When given two [nonequivalent] modal properties, construct a process that satisfies exactly one of those two properties.
• When given a modal functional, use the method of approximants to calculate its greatest and least fixed points.
• When given a binary relation on CCS processes, prove that it is a strong (or weak) bisimulation or explain convincingly why it is not a bisimulation.
• When given a pair of CCS processes that are strongly (or weakly) bisimilar, construct a strong (or weak) bisimulation that relates them.
★ When given a pair of CCS processes that are not equivalent (under strong or weak bisimulation, or under observational congruence), construct a modal μ-calculus formula that distinguishes them.
★ When given a pair of CCS processes, determine whether or not they are equivalent (under strong or weak bisimulation, or under observational congruence).
• When given a property about bisimulations, modal properties, or both, determine its validity and provide either a rigorous proof or a counter-example.
• Apply these techniques and use a model checker to specify, analyze, and evaluate nontrivial applications.

Note: For those outcomes labeled with a star (★), you should be able to make the determination both by hand (for relatively simple processes) and by using a model checker (CAAL, Concurrency Workbench Aalborg Edition) for more complicated processes. “By hand” means that you can support your answer with either a proof or a counterexample.

Outcome Measurement
An important goal of this course is to provide you with experience (1) using a model checker to analyze nontrivial applications and (2) analyzing and critiquing the results. However, using the model checker successfully also requires you to understand the basic underlying principles. As a result, grades will be based on a combination of homework assignments, quizzes, and a final exam (optional for CIS 400, required for CIS 632).

Homeworks are intended to keep you up-to-date with the material and to familiarize you with the tools; homeworks later in the semester will provide you the opportunity to apply the material to nontrivial applications and to reflect on the results. Unless otherwise noted, you are free to discuss the homeworks with others and to submit joint work, in accordance with the class honor policy. Quizzes and the final exam will allow you to demonstrate your understanding of the fundamental concepts.

Assignments are due by the date and time stated on them: No late assignments will be accepted. I
also expect students to attend class regularly: I reserve the right to change the course-grading policy if attendance becomes an issue.

Homeworks, quizzes and the final exam will generally have additional or more challenging tasks for CIS 632 students. In addition, the calculation of grades will differ:

- **For students taking CIS 400**, grades will be based on the following factors: 35% homeworks, and 65% quizzes. The *optional* final exam can be used to replace the quiz-portion of the final grade; I’ll use the greater of (1) your cumulative average of the in-class quizzes and (2) your score on the final exam.

- **For students taking CIS 632**, grades will be based on the following factors: 35% homeworks, and 45% quizzes, and 20% final exam (which is *required*).

**Course Topics**
CCS operators and syntax, including: actions, labels, prefixing, summation, recursion, parallel composition, restriction, and relabeling. CCS transition rules and derivations. Hennessy-Milner logic and the modal $\mu$-calculus. Notions of equivalence, such as strong and weak bisimulation. Safety and liveness properties.

**Other Information**

**Academic Integrity**
Syracuse University’s Academic Integrity Policy reflects the high value that we, as a university community, place on honesty in academic work. The policy defines our expectations for academic honesty and holds students accountable for the integrity of all work they submit. Students should understand that it is their responsibility to learn about course-specific expectations, as well as about university-wide academic integrity expectations. The policy governs appropriate citation and use of sources, the integrity of work submitted in exams and assignments, and the veracity of signatures on attendance sheets and other verification of participation in class activities. The policy also prohibits students from submitting the same work in more than one class without receiving written authorization in advance from both instructors. Under the policy, students found in violation are subject to grade sanctions determined by the course instructor and non-grade sanctions determined by the School or College where the course is offered as described in the Violation and Sanction Classification Rubric. SU students are required to read an online summary of the University’s academic integrity expectations and provide an electronic signature agreeing to abide by them twice a year during pre-term check-in on MySlice. For more information about the policy, see [http://academicintegrity.syr.edu](http://academicintegrity.syr.edu).

My expectations for this course are the same as those enumerated in the University’s policy: you should (1) credit your sources, (2) do your own work, (3) communicate honestly, and (4) support academic integrity. Every student must read and sign a copy of the course Honor Policy, which elaborates on how academic integrity applies to this course. Students will receive zeroes on all coursework until this sheet is turned in.

The Violation and Sanction Classification Rubric establishes recommended guidelines for the determination of grade penalties by faculty and instructors, while also giving them discretion to select the grade penalty they believe most suitable, including course failure, regardless of violation level. Any established violation in this course may result in course failure, regardless of the violation level.
Accommodations
Our community values diversity and seeks to promote meaningful access to educational opportunities for all students. Syracuse University and I are committed to your success and to supporting Section 504 of the Rehabilitation Act of 1973 as amended and the Americans with Disabilities Act (1990). This means that in general no individual who is otherwise qualified shall be excluded from participation in, be denied benefits of, or be subjected to discrimination under any program or activity, solely by reason of having a disability.

If you believe that you need accommodations for a disability, please contact the Office of Disability Services (ODS), http://disabilityservices.syr.edu, located at 804 University Avenue, Room 309, or call 315-443-4498 for an appointment to discuss your needs and the process for requesting accommodations. ODS is responsible for coordinating disability-related accommodations and will issue students with documented disabilities “Accommodation Authorization Letters,” as appropriate. Because accommodations may require early planning and generally are not provided retroactively, please contact ODS as soon as possible.

Attendance
I expect all students to attend lectures. If you are unable to attend a lecture for some reason, then please send me email before that lecture begins: I will generally excuse a missed quiz or participation grade if I receive prior notice of your absence.

Computers and Other Electronic Devices
I recognize that a small number of students like to use a computer to take notes in class. However, computers and other electronic devices also frequently become distractions, either to their owner or to others in the classroom. I ask that you put away your computer/phone/tablet/etc during lecture, unless you are using the device to take notes. If I find that these devices are becoming a distraction to you or others, I may require you to put them away.

Religious Observances  SU’s religious observances policy, found at
http://supolicies.syr.edu/emp_ben/religious_observance.htm,
recognizes the diversity of faiths represented among the campus community and protects the rights of students, faculty, and staff to observe religious holy days according to their tradition. Under the policy, students are provided an opportunity to make up any examination, study, or work requirements that may be missed due to a religious observance provided they notify their instructors before the end of the second week of classes. For fall and spring semesters, an online notification process is available through MySlice/Student Services/Enrollment/My Religious Observances from the first day of class until the end of the second week of class.