

Computer Science Undergraduate Handbook

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The School of Computing offers a Bachelor of Science degree in Computer Science. The undergraduate program begins with a set of three courses that give students a solid background in programming and discrete math while exposing them to the breadth of issues that arise in computer science. Students then take five core courses in software engineering, computer architecture, algorithms and data structures, software systems, and theory. Students build on this background by choosing seven electives from the breadth of the School's course offerings (which includes advanced courses in theoretical computer science, scientific computing, artificial intelligence, software systems, programming languages, graphics, computer architecture, and digital design). Each student's undergraduate program is capped with a senior project. Along with an in-depth study of computing, the undergraduate curriculum encompasses a general education in mathematics, science, and the humanities.

The School also offers an honors version of the Bachelor of Science degree for students who are contemplating a career in research, and a minor in Computer Science for students who want to use computers in another field. In addition, selected service courses are offered to provide an introduction to the use of computers as tools for students of many backgrounds and interests.

A Bachelor of Science in Computer Engineering is jointly offered by the School of Computing and the Department of Electrical and Computer Engineering. Information about that program is available in a separate handbook or from the web page referenced below.

The University of Utah is committed to policies of equal opportunity, affirmative action, and nondiscrimination. The University seeks to provide equal access to its programs, services, and activities for people with disabilities. Reasonable prior notice is needed to arrange accommodations.

(This handbook is available online at <http://www.cs.utah.edu/dept/handbooks>.)

Faculty

Professors	Martin Berzins, Ph.D. Alan L. Davis, Ph.D. Thomas C. Henderson, Ph.D. John M. Hollerbach, Ph.D. Robert Kessler, Ph.D. Richard F. Riesenfeld, Ph.D. Frank Stenger, Ph.D.	Elaine Cohen, Ph.D. Ganesh Gopalakrishnan, Ph.D. Lee A. Hollaar, Ph.D. Christopher R. Johnson, Ph.D. Gary E. Lindstrom, Ph.D. Kris Sikorski, Ph.D. William B. Thompson, Ph.D.
Clinical Professors	David Hanscom, Ph.D.	Joseph L. Zachary, Ph.D.
Research Professor	Stephen Jacobsen, Ph.D.	
Emeritus Professors	Robert R. Johnson, Ph.D.	Kent Smith, Ph.D.
Associate Professors	Erik Brunvand, Ph.D. Charles Hansen, Ph.D. Ellen M. Riloff, Ph.D. Claudio Silva, Ph.D.	John Carter, Ph.D. Wilson Hsieh, Ph.D. Peter Shirley, Ph.D. Ross Whitaker, Ph.D.
Clinical Associate Professor	Art Lee, Ph.D.	
Research Associate Professors	Sam Drake, Sc.D.	Jay Lepreau
Assistant Professors	Rajeev Balusubramonium, Ph.D. Wilson Hsieh, Ph.D. Emil Praun, Ph.D. Konrad Slind, Ph.D.	Matthew Flatt, Ph.D. Sneha Kasera, Ph.D. John Regehr, Ph.D. Cynthia Thompson, Ph.D.
Research Assistant Professors	Steven Parker, Ph.D.	
Adjunct Associate Professors	Robert McDermott, Ph.D.	Chris Myers, Ph.D.
Adjunct Assistant Professor	Sally Creem-Regehr, Ph.D.	Oleg Portniaguine, Ph.D.

Administration

Christopher Johnson	Director	581-6456
Martin Berzins	Associate Director	585-1545
Al Davis	Associate Director	581-3991
Dave Hanscom	Director, Undergraduate Studies	581-7023
Erik Brunvand	Director, Computer Engineering	581-4345
Joe Zachary	Director, Educational Programs	581-7079
Ross Whitaker	Director, Graduate Studies	587-9549
Kris Sikorski	Director, Computational Engineering and Science	581-8579

Administrative Staff

Ann Torrence	Manager	581-7631
Phil Willden	Administrative Manager	581-3950
Erin Phillips	Administrative Assistant	581-8226
Sara Mathis	Administrative Secretary	581-8226

Academic Advising

Sandy Hiskey	Undergraduate Academic Counselor	581-8224
Karen Feinauer	Graduate Counselor	581-8224
Emily Preece	Graduate Admissions Coordinator	581-8224

Technical Staff and Services

Corey Hatch	Digital Systems Laboratory Manager	581-7845
Monica Heaton	Administrative Officer	581-9371
Chad Lake	Computing Facility Director	585-7614
Mark Gully	Undergraduate Lab Manager	585-9047

A complete staff listing can be found at <http://www.cs.utah.edu/people.html>.

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The Computer Science Major and Minor

The School of Computing offers a Bachelor of Science in Computer Science. This is a software-oriented degree whose requirements include 17 computer science courses. A student must be admitted as a computer science major by the School in order to take upper-division courses and pursue the computer science degree. The School also offers an honors version of the Bachelor of Science, as well as a minor in computer science consisting of six computer science courses.

1.1 Becoming a Computer Science Major

Any student can become a computer science pre-major by informing the University Registrar or the School of Computing Academic Counselor. It is advisable to do this early to ensure receiving information about the major and staying advised of any changes that may be made in degree requirements. Declaration of a major will also enable participation in activities associated with the degree program such as the Undergraduate Student Advisory Committee.

Only computer science majors, computer engineering majors, and computer science minors can take upper-division (3000 or higher) computer science classes. Advancement to full major status is a competitive process. To be considered for full major status in computer science, a student must have:

1. A minimum grade of C– in all of the following classes or their equivalents. *None of these classes may be taken on a credit/no-credit basis.*
 - Computer Science 2010, 2020, and 2100.
 - Mathematics 1210 and 1220.
 - Physics 2210.
 - University English writing requirement
2. A grade of CR in CS 1010 (a credit/no-credit class).
3. A cumulative University of Utah grade point average of 2.25 or higher. (Note that *much* higher grades in the required classes listed above are typically needed.)

A student may apply for full major status no earlier than the semester during which he or she expects to complete these requirements. Applications may be submitted any time during the first session of the spring and fall semesters. Students

whose applications are accepted will be advanced to full major status effective the following semester. (For example, students who apply between August 20 and October 13, 2003, and who are subsequently accepted, will become full majors at the beginning of Spring Semester of 2004.) Students whose applications are not accepted are free to apply one more time.

The School determines how many new majors will be admitted based on laboratory facilities, computer resources, and available faculty. The following factors are considered in determining which students to admit:

1. Grades in the required pre-major classes listed above. (Grades in classes taken at accredited engineering schools will be weighted more heavily than those from other schools.)
2. ACT, SAT, and/or TOEFL scores. (You must arrange for your scores to be officially reported to the School of Computing unless they have already been officially reported to the University.)
3. A personal goals statement.
4. An optional programming portfolio. (This should be submitted only by students who have written significant, interesting programs outside of a classroom setting.)

No pre-major class may be taken more than twice. If a class is repeated, the grade received the second time is used. If a student receives *any* grade in a class—including W (withdrawal), I (incomplete), or V (audit)—the student is considered to have taken the class. Only three classes may be repeated.

If credit is granted for any of the above classes based on advanced placement test scores or courses taken at other schools, grades are assigned for use in the calculation. Check with the Undergraduate Academic Counselor for details.

1.2 Undergraduate Advising

Each student who majors in computer science is assigned a faculty advisor. The School also has an Undergraduate Academic Counselor (Sandy Hiskey, 3190 MEB, 581-8224, shiskey@cs.utah.edu) who is available to answer questions regarding registration for CS classes, transfer of credits, degree requirements, recent School actions, etc. The Academic Counselor can also arrange appointments with the faculty advisor.

A student is welcome to meet with the faculty advisor whenever necessary to discuss schedule plans or current problems. The responsibility for arranging an appointment is left to the student. Students should always feel free to seek advice from the advisor regarding their programs and plans.

1.3 Requirements for the Bachelor of Science Degree

The computer science degree can be completed in four full-time years of study if the student is capable of completing an intensive set of computer science, calculus, and physics courses during the freshman year. Only strong training in high school will allow a student to begin at this level. If a student must instead take preparatory classes as a freshman, more than four years may be required to earn a degree. In any event, it is important to take the required pre-major classes early to allow advancement to full major status as soon as possible.

1. **General Education:** The General Education requirements are described in the University of Utah General Catalog. The requirements for computer science majors are more specific.
 - (a) The University writing requirement is required for computer science pre-majors.
 - (b) The quantitative reasoning requirement is satisfied by Math 1210 and 1220, which are required for computer science pre-majors.

- (c) Students must take two intellectual explorations courses in each of fine arts, humanities, and social sciences. (The two-course requirement in physical and life sciences is automatically satisfied by the pre-major classes.) *These six courses must include two upper division courses.*

A General Education Approval form can be obtained from the Academic Counselor. Students must complete this form and receive approval for their programs.

- (d) The American Institutions requirement can be satisfied by taking one of Economics 1740, History 1700, Honors 2212, or Political Science 1100.

Incoming engineering students may want to consider the Engineering LEAP (E-LEAP) program organized by the Office of Undergraduate Studies. It is a year-long cohort program set up to allow students to take several classes together during their first year on campus. Two of these classes are seminar courses that satisfy University General Education and Diversity requirements. The program also includes sections of Writing, Calculus, and Physics. For more information on E-LEAP, contact the College of Engineering Advisor at 585-7769.

2. **University graduation requirements:** The University graduation requirements for the Bachelor of Science degree are described in the University of Utah General Catalog.

- (a) The communication/writing requirement is satisfied by either Writing 3200 or 3400, one of which is required for computer science majors.
- (b) The quantitatively intensive course requirement is satisfied by CS 3510 and 3810, which are required for computer science majors.
- (c) The diversity requirement can be satisfied by taking a course from the approved list as part of the intellectual explorations requirement.
- (d) Students must complete a minimum of 122 semester hours of course work. At least 40 of the 122 hours must be upper division classes. (Upper division classes are numbered 3000 or above. Credits from two-year colleges will not count toward University upper division hours.) At least 30 of the total credit hours and 20 of the last 30 hours must be taken at the University.

3. **Writing:** Two classes in writing are required:

- (a) Either Writing 2010 or ESL 1060 (for students who speak English as a second language) is required.
- (b) Either Writing 3200 or 3400 is required. Writing 3400 is recommended for most students; Writing 3200 is an option for transfer students.

4. **Math, Science, and Engineering:** Seven classes in math, science, and/or engineering are required.

- (a) Mathematics 1210 and 1220 (Calculus I and II) are required.
- (b) Physics 2210 (Physics I) is required.
- (c) Students must take four additional courses, *each of which must be at least three semester hours*, chosen from among Physics 2220 (Physics II), Biology 1000 (General Biology), Chemistry 1210 (General Chemistry), or any class (other than a computer science class) from the Colleges of Engineering, Mines, or Science that requires a full year of calculus as a prerequisite or corequisite. Students should take the prerequisites of computer science electives into consideration when planning how to satisfy this requirement.

5. **Computer Science:** A minimum of 17 computer science classes must be taken. Figure 1.1 gives an example four-year degree program leading to a Bachelor's Degree in computer science. Figure 1.2 summarizes the prerequisites for computer science courses.

- (a) Required. The following classes must be taken:
 - CS 1010 Introduction to Unix
 - CS 2010 Introduction to Computer Science I
 - CS 2020 Introduction to Computer Science II
 - CS 2100 Discrete Structures
 - CS 3500 Software Practice
 - CS 3510 Algorithms and Data Structures
 - CS 3810 Computer Architecture
 - CS 4400 Computer Systems
 - CS 4500 Software Engineering Lab

Year	Full major status after two semesters				Full major status after three semesters			
	Fall		Spring		Fall		Spring	
1	Math 1210 [†]	(4)	Math 1220 [†]	(4)	Math 1210 [†]	(4)	Math 1220 [†]	(4)
	CS 1010 [†]	(0.5)	Physics 2210 [†]	(4)	CS 1010 [†]	(0.5)	Physics 2210 [†]	(4)
	CS 2010 [†]	(4)	CS 2020 [†]	(4)	Writing [†]	(3)	CS 2010 [†]	(4)
	Writing [†]	(3)	CS 2100 [†]	(3)	Gen Ed	(4)	Gen Ed	(3)
	Gen Ed	(3)			Gen Ed	(3)		
		<u>(14.5)</u>		<u>(15)</u>		<u>(14.5)</u>		<u>(15)</u>
2	CS 3500	(4)	CS 3510	(4)	CS 2020 [†]	(4)	CS 3500	(4)
	CS 3810	(4)	CS elective	(3)	CS 2100 [†]	(3)	CS 3810	(4)
	Writing 3400	(3)	Math/sci elective	(3)	Math/sci elective	(3)	Math/sci elective	(4)
	Gen Ed	(4)	Gen Ed	(4)	Gen Ed	(3)	Writing 3400	(3)
					Gen Ed	(3)		
		<u>(15)</u>		<u>(14)</u>		<u>(16)</u>		<u>(15)</u>
3	CS 4400	(3)	CS elective	(3)	CS 3510	(4)	CS 4400	(3)
	CS theory elective	(3)	CS elective	(3)	CS theory elective	(3)	CS elective	(3)
	Math/sci elective	(4)	Math/sci elective	(4)	Math/sci elective	(4)	CS elective	(3)
	Gen Ed	(3)	Gen Ed	(3)	Gen Ed	(4)	Math/sci elective	(4)
	Free elective	(3)	Free elective	(3)			Free elective	(3)
		<u>(16)</u>		<u>(16)</u>		<u>(15)</u>		<u>(16)</u>
4	CS elective	(3)	CS 4500	(3)	CS elective	(3)	CS 4500	(3)
	CS elective	(3)	CS elective	(3)	CS elective	(3)	CS elective	(3)
	CS elective	(3)	Math/sci elective	(4)	CS elective	(3)	CS elective	(3)
	Gen Ed	(4)	Gen Ed	(3)	Gen Ed	(4)	Free elective	(3)
	Free elective	(3)	Free elective	(3)	Free elective	(3)	Free elective	(3)
		<u>(16)</u>		<u>(16)</u>		<u>(16)</u>		<u>(15)</u>

These tables give two example eight-semester programs leading to a Bachelor of Science degree in computer science. The program on the left is for students who advance to full major status after two semesters, and the program on the right is for students who advance to full major status after three semesters (not counting summers). It is meant only as a guide, since the scheduling of electives and General Education classes depends on which ones are selected. Advancement to full major status in two semesters requires taking Computer Science 2010, Math 1210, and Writing during the first semester, unless the student has advanced placement credit. ([†]Class required of pre-majors.)

Figure 1.1: Example Computer Science Degree Program

(b) Theory restricted elective. Students must take one of the following.

CS 3100 Models of Computation

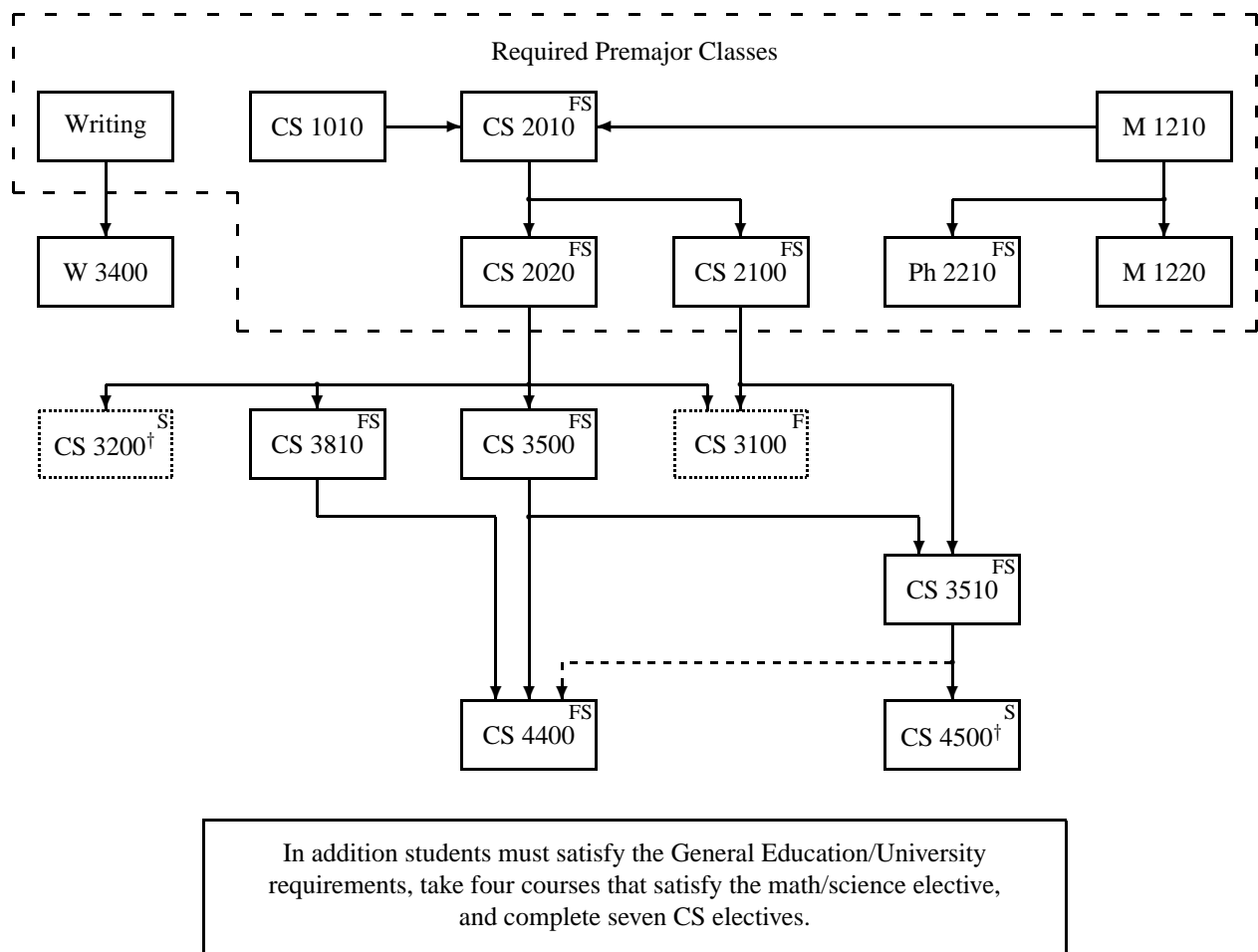
CS 3200 Scientific Computing

(c) Electives. Seven additional Computer Science classes numbered at the 3000, 4000, or 5000 level, totaling at least 21 semester hours, must be taken. CS 3050/51, 5010/20, 5050/51, and seminars may not be counted. Only one of CS 5600/5605 and only one independent study class (with special permission) may be counted.

(d) Duplication of credit. No single class may be counted toward more than one of the requirements listed above.

6. **Continuing Performance:** All computer science, mathematics, science, engineering, and writing courses taken to satisfy the requirements listed above must be passed with a grade of C– or better (except for CS 1010, in which a grade of CR is required). A student may repeat such courses only one time. With the exception of the American Institutions requirement and CS 1010, all courses listed above must be taken for a letter grade (i.e., they may not be taken CR/NC).

To remain in good standing and graduate, a student must maintain a cumulative grade point average at the University of 2.25 or higher, and also to maintain a grade point average (GPA) of 2.25 in computer science classes. Students whose GPA in either of these categories falls below 2.25 are notified that they are on probation and will be given



This graph illustrates the order in which classes must be taken to satisfy prerequisite and corequisite requirements in Computer Science. Prerequisites are connected bottom-to-top; corequisites are connected side-to-side; recommended prerequisites are dashed. One of the two courses contained in dashed boxes must be taken. Where not otherwise indicated, courses are offered during both semesters as well as the summer. (†CS 3200 has Math 2250 as a prerequisite; CS 4500 can be taken only by students who are on track to graduate before the next offering of CS 4500.)

Figure 1.2: Computer Science Prerequisites

conditions for a return to good standing. Normally, these conditions must be satisfied during the next two semesters, excluding summers. Students failing to meet their probationary conditions are dropped from the rolls of the major.

All students admitted as full majors are placed on probationary status. If a student's GPA in either of the above categories is below 2.25 at the end of the first academic year during which they take upper level CS classes, the student is dropped from the rolls of the major.

Students are expected to complete all requirements for their degree within four years of acceptance to full major status. Students not making satisfactory progress toward their degrees may be dropped from the rolls and declared inactive. The determination that a student is not making satisfactory progress is made in one of two ways. Either (1) the student has not completed a CS course for a period of one year, or (2) there is no reasonable way in which the student can complete all degree requirements by the end of the required period of time.

In order to be reinstated from inactive status or from being dropped due to low GPA, students must petition the Computer Science Undergraduate Committee. Reinstated students proceed under the latest graduation requirements.

If personal circumstances prevent completion of all degree requirements within four years of acceptance as a full major, a student may request an extension of a specific duration and submit a revised schedule of completion.

1.4 Computer Science Honors Degree

The School offers an Honors Bachelor's Degree in Computer Science. This program is intended primarily for students thinking of a career in research, but any student can apply. Students who wish to be admitted into the honors track must indicate this on their application for advancement to major status. Each student who applies will either be admitted to the honors track on probationary status, admitted to the regular track, or denied admission. Admission decisions will be based on the same criteria that are used to evaluate applications for major status.

After completion of CS 3505 and 3510, students with probationary status in the honors track will either be moved to the regular track or to full status in the honors track.

The degree requirements for the honors degree are detailed below.

1. **General Education:** The General Education requirements are described in the University of Utah General Catalog. Except for the following changes, they are the same as for the standard degree program.
 - (a) The University writing requirement can be optionally satisfied by taking Honors 2211.
 - (b) At least one of the six courses taken to satisfy the intellectual explorations requirement must carry an honors designation.
2. **University graduation requirements:** The University graduation requirements are the same as for the standard degree program.
3. **Writing:** The writing requirement is the same as for the standard degree program.
4. **Math, Science, and Engineering:** Seven classes in math, science, and/or engineering are required.
 - (a) Mathematics 1210 and 1220 (Calculus I and II) are required. Honors versions of these classes, if available, can be substituted at the student's option.
 - (b) Physics 2210 (Physics I) is required. An honors version of this class, if available, can be substituted at the student's option.
 - (c) Students must take four additional courses. Each must be a class (other than a computer science class) from the Colleges of Engineering, Mines, or Science that requires a full year of calculus as a prerequisite or corequisite and that carries three or more credit hours. Chemistry 1210 (General Chemistry) can also be taken. *At least two of these classes must be math classes.*
5. **Computer Science:** As in the standard degree program, a minimum of 17 computer science classes must be taken. The specific requirements are slightly different, however.
 - (a) Required. The following classes must be taken:
 - CS 1010 Introduction to Unix
 - CS 2010 Introduction to Computer Science I
 - CS 2020 Introduction to Computer Science II
 - CS 2100 Discrete Structures
 - CS 3505 Honors Software Practice
 - CS 3510 Algorithms and Data Structures
 - CS 3810 Computer Architecture
 - CS 4400 Computer Systems
 - CS 4999 Honors Bachelor's Thesis
 - (b) Theory requirement.
 - CS 3100 Models of Computation
 - (c) Advanced graduate electives. Two additional Computer Science classes numbered at the 6000 level or higher, totaling at least 6 semester hours, must be taken. Seminars and independent study may not be counted.
 - (d) Graduate electives. Two additional Computer Science classes numbered at the 5000 level or higher, totaling at least 6 semester hours, must be taken. CS 5010, 5020, 5050, seminars, and independent study may not be counted.

- (e) Electives. Three additional Computer Science classes numbered at the 3000 level or higher, totaling at least 9 semester hours, must be taken. At most one independent study class may be counted. CS 3050, 5010, 5020, 5050, and seminars may not be counted.
- (f) Duplication of credit. No single class may be counted toward more than one of the requirements listed above.

6. University Departmental Honors Track Requirements

The University's departmental honors track requirements must be satisfied. The current requirements, including advice on how they can be satisfied by Honors Computer Science majors, appear below.

- (a) At least 24 hours in designated honors courses must be taken. The following three honors courses, totaling 10 hours, are listed above as required courses:
 - CS 3505 (Honors Software Practice) (4 hours)
 - CS 4999 (Honors Thesis) (3 hours)
 - An honors course that counts toward the intellectual explorations requirement (3 hours)

The remaining 14 hours in designated honors courses can be selected by the student. The student can take any combination of designated honors courses. The choice can include, but is not limited to, the following courses, which simultaneously satisfy other requirements detailed above.

- CS 5605 (Honors Introduction to Graphics)
- Honors 2211 (Writing for Honors)
- Honors 2212 (American Institutions)
- Honors versions of Math 1210 and 1220.
- Honors versions of Physics 2210 and 2220.
- Honors versions of intellectual explorations courses.
- Honors versions of technical electives.

- (b) The honors bachelor's thesis is satisfied by CS 4999, which is required by all Honors Computer Science majors.

- 7. **Continuing Performance:** The School's Undergraduate Committee will establish minimum performance standards for students in the honors B.S. program. Students who fall below these standards will be removed from the honors track and placed in the regular track.

At graduation, the University requires that honors students have a GPA of at least 3.5 in the major and at least 3.4 overall.

1.5 Computer Science as a Minor

The School of Computing offers a minor for students who desire to gain sufficient background to use and program computers in another field.

In order to be admitted as a CS minor, a student must have a declared major in another department and be making progress in that major. The admission process is similar to that for majors and is carried out at the same times. Students are evaluated for admission based on

- grades in Math 1210, English writing, and Computer Science 2010/2020/2100,
- ACT, SAT, and/or TOEFL scores,
- a personal goals statement.

The minor consists of a minimum of 18.5 semester hours of computer science classes.

- Required. The following classes must be taken.

CS 1010	Introduction to Unix
CS 2010/2020	Introduction to Computer Science
CS 2100	Discrete Structures
CS 3500	Software Practice
- Elective. Students must take at least one additional Computer Science class at the 3000 level.

Computer science minors are guaranteed admission into only the upper division classes that comprise their minor. Students in the minor will not be able to do phone registration for upper division classes; they must add them through the undergraduate office each semester.

1.6 Students Pursuing a Second Degree or a Double Major

Some students may wish to earn a degree in computer science as their second B.S. This is possible as long as the requirements for both degrees are met. In some cases, fewer additional class hours are needed because of overlaps in the two degrees. This is especially true of students whose other degree is in computer engineering or mathematics, where upper level classes may serve as computer science electives. Students pursuing a double major must notify the Academic Counselor.

1.7 Course Enrollment Priorities for Non-Majors

All of the upper division computer science courses are listed with the Registrar as available only to full majors in computer science or computer engineering. This means that other students, including computer science minors, will not be able to pre-register for said classes, and must place their names on a waiting list maintained in the Undergraduate Office prior to the first day of class. If there are vacancies in the classes, the School's director will decide who will receive permission to add the classes based on considerations such as GPA and grades in prerequisites. Computer science and computer engineering majors, and computer science minors, will receive priority in classes needed to complete their program.

1.8 Undergraduate Financial Assistance

The School of Computing has several financial assistance awards available. Applications are available on the web¹. These scholarships are awarded based upon academic performance, rather than financial need. Most are awarded to Computer Science and Computer Engineering full majors or those students who will become full majors during the following academic year. The following scholarships are available. All applications must be submitted to the School's office by March 15.

Special Departmental Scholarships. These awards are available to students majoring in Computer Science and Computer Engineering who are residents of the state of Utah. They are for resident tuition for two semesters. To be eligible, students must take at least 12 credit hours per semester.

School of Computing Scholarships. A few awards are available each year to Computer Science and Computer Engineering majors. These are unrestricted cash awards of \$500 to \$2,500, made possible in part by generous donations from the School of Computing faculty and the Eccles Foundation. To be eligible, students must take at least 9 credit hours per semester. Use the same application as for the Continuing Student Scholarship.

¹http://www.cs.utah.edu/info/forms/scholarship_form.pdf

College of Engineering Scholarships. These scholarships are awarded to students majoring in Computer Science and Computer Engineering. These are unrestricted cash awards of \$500 to \$2000. To be eligible, students must take at least 12 credit hours per semester. Use the same application as for the Continuing Student Scholarship.

Students may also apply for financial aid from the College of Engineering, which each year awards about 25 Josephine Beam Educational Scholarships. These scholarships are worth approximately \$500 and are based on need. Obtain an application from the Office of the Dean of Engineering in Kennecott 214. Applications must be submitted by February 15.

1.9 Employment Opportunities

The University Office of Career Services offers an internship program which allows qualified students to work in their fields of interest for all or part of their junior and/or senior years. This can be done on a full or part time basis, either in Salt Lake City or elsewhere. *Students are paid for their work, but no credit is granted.* The benefits of such experience include exposure to ideas which could help with career decisions, making contacts which may be useful in the future, and valuable experience in an area that is pertinent to current studies. Corporations participating include IBM, 3M, Hewlett Packard, Microsoft, Evans & Sutherland, Novell, Intel, and Unisys. Many of our majors take advantage of this valuable opportunity.

The School employs a number of junior and senior students as computer operators and as teaching assistants. These jobs involve no more than 20 hours of work per week at an appropriate hourly wage. Appointments are made each semester based on student applications, which should be submitted prior to the start of each term. These applications are available on the web². In addition, general inquiries are received periodically from local industry and from University research groups for students who are interested in working part or full time. These are posted on a computer bulletin board which is accessible to majors. More information may be obtained from the Academic Counselor.

Students seeking employment upon graduation should contact the University Office of Career Services in order to be included on a list supplied to employers. Students not planning to work towards an advanced degree should register with Career Services at the beginning of their senior year, since most companies begin interviewing in the fall semester.

1.10 Student Participation in School Affairs

Opportunities for students to develop their organizational and leadership abilities are available through participation in the Undergraduate Student Advisory Committee (UgSAC), which plays an active role in the School by coordinating the following:

1. Course and faculty teaching evaluations.
2. Representation (one student) at faculty meetings.
3. Announcements to all declared pre-majors and majors.
4. Representation on the College Student Advisory Committee.
5. Organization of Engineering Week activities in February.
6. Organization of lunch meetings for pre-majors and majors.
7. Organization of university and high school programming contests.
8. Feedback on School issues affecting students, such as scheduling, curriculum changes, and graduation requirements.
9. GRE preparation classes.

Anyone interested in joining this organizations should contact UgSAC at ugsac@cs.utah.edu. Participation, suggestions, and criticisms are solicited.

²<http://www.cs.utah.edu/dept/webforms/current/ugrad-TA.html>

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Computing Facilities

The School of Computing provides state of the art computing facilities for both instructional and research use. Both facilities share a common network infrastructure that is based on an ATM fabric running at OC-12 (622 Mbps) and that provides desktop connections at speeds ranging from Fast Ethernet (100 Mbps) up to Gigabit Ethernet where necessary. The School's network attaches via an OC-12 connection directly to the campus OC-48 ATM mesh, which in turn routes traffic to Abilene (Internet 2), vBNS, and the Internet.

In addition to the shared network infrastructure, the core School of Computing facility supplies many centralized services, including shared disk space (4 Terrabytes), time, web/cgi, ftp, firewall, backups, printing resources, and email. Most services run on Solaris-based hosts, ranging from Ultra 10's to an Enterprise 5000. Several large-scale Solaris and Linux machines are also made available for general use.

The instructional computing facility includes over 180 Unix, Linux, and Windows-based machines. Most of these machines are organized into three laboratories and the remainder are situated in graduate student offices. The NT Lab in EMCB 210 includes approximately 90 Pentium II-based PCs. The electronic classroom in MEB 3225 contains 30 Pentium III-based PCs arranged into a classroom configuration. The CES/Grad Lab in MEB 3161 contains nine SGI workstations. Students in the School of Computing also have access to the College of Engineering Workstation Laboratory, which consists of five servers, more than 100 Sun workstations, and approximately 10 Linux workstations.

The research computing facility is a heterogeneous mix of over 300 machines, including SGI, HP, Sun and Intel-based hardware. The research computing facility includes major laboratories devoted to computer-aided design and graphics, computer systems, asynchronous digital systems and VLSI, robotics and vision, scientific computing and imaging, and information retrieval and natural language processing. These research laboratories contain a wide array of specialized equipment, including

- an SGI Origin 3800 (32 processors);
- an SGI Origin 2000 Reality Monster (96 processors, 8 IR heads);
- a 200-node network testbed and emulation facility;
- an SGI Power Onyx (14 processors, 2 RE2 heads);
- a multi-source nonlinear video editing environment;
- a real-time signal processing lab;

- an image analysis lab;
- equipment for various types of custom hardware design;
- a Sarcos Dextrous Arm, Utah/MIT Dextrous Hand, and PUMA 560 robots; and
- a Sarcos Treadport locomotion interface, several SensAble Phantom haptic interfaces, Fakespace Responsive Workbench, nVision Datavisor HiRes, and a variety of position trackers.

The College of Engineering operates a research-scale integrated circuit (IC) fabrication facility that is used extensively by the School of Computing. Equipment for testing and debugging both internally and externally fabricated circuits is housed in an integrated circuit testing facility that contains state-of-the-art HP, Tektronix and Micromanipulator automated IC testing equipment.

3

Computer Science Courses

The number and title of each course is followed by the number of semester hours it carries, the semester(s) during which it is taught (F=fall, S=spring, U=summer), its prerequisites, its corequisites, and any courses with which it is cross-listed.

Where a course has both a 5000- and 6000-level number, the 5000-level version is intended for undergraduate and the 6000-level version for honors and graduate students. The two versions of the class will meet together, but extra work will be expected of honors and graduate students.

Current class schedules and registration information¹ are available on line.

1000 Engineering Computing (3, FS) Coreq.: CP SC 1010, MATH 1210

Meets with CP SC 1001. Introduction to programming principles and engineering problem solving via computational means using MATLAB (during the first half of the semester) and C (during the second half of the semester). Decomposition of programs into data representations, functions, and control structures. Clean programming practices are emphasized. The MATLAB portion of the course focuses on the implementation of physically-based models, data visualization via plotting, and selected numerical techniques. The C portion of the course introduces basic syntax and special features of the language for engineering implementations.

1001 Engineering Computing using MATLAB (1.5, FS) Coreq.: CP SC 1010, MATH 1210

Meets with CP SC 1000. Introduction to programming principles and engineering problem solving via computational means using MATLAB. Decomposition of programs into data representations, functions, and control structures. Focus on the implementation of physically-based models, data visualization via plotting, and selected numerical techniques. Clean programming practices are emphasized. (This is a half-semester course that meets with CP SC 1000.)

1010 Introduction to Unix (0.5, FSU)

An introduction to the Unix workstations used in the College of Engineering CADE Lab. Topics include the X Windows system, Unix shell commands, file system issues, text editing with Emacs, accessing the World Wide Web with Netscape, and electronic mail. Self-paced course using online teaching aids.

¹<http://www.acs.utah.edu/prod/bin/student>

1020 Introduction to Programming in C++ (3, U)

An introduction to essential programming concepts using C++. Laboratory practice.

1021 Introduction to Programming in Java (3, FSU)

An introduction to essential programming concepts using Java. Laboratory practice emphasizes object-oriented techniques and web-based application design.

1040 Creating Interactive Web Content (3, FSU)

Introduction to the essentials of web page design and object-oriented programming through the use of HTML and JavaScript to create interactive web pages. It is appropriate for any student who is comfortable using a computer to write a paper and browse the Web. This is a 100% online course that can be completed on any computer equipped with a recent version of Netscape Communicator or Internet Explorer.

1050 Social Aspects of a Digital World (2, S)

Social and policy aspects of computing, beginning with a review of the history and technology of the Internet. Privacy, intellectual property, ethics, electronic commerce, and computer crime. Concurrent enrollment in a companion 1000-level discussion course (such as CP SC 1051) is required.

1051 Introductory Discussion of Social Aspects (1, S)

The combination of CP SC 1050/1051 is appropriate for any student who is already comfortable using a computer to write papers and explore the Web.

1950 Independent Study (1 to 4)**1960 Special Topics (1 to 4)****2000 Introduction to Programming in C (4, F) Coreq.: CP SC 1010**

Introduction to essential programming concepts using C. Decomposition of programs into functional units; control structures; fundamental data structures of C; recursion; dynamic memory management; low-level programming. Some exposure to C++. Laboratory practice. (Intended for non-CS majors).

2010 Introduction to Computer Science I (4, FS) Coreq.: MATH 1210, CP SC 1010

The first course required for students intending to major in computer science and computer engineering. Introduction to the engineering and mathematical skills required to effectively program computers, and to the range of issues confronted by computer scientists. Roles of procedural and data abstraction in decomposing programs into manageable pieces. Introduction to object-oriented programming. Extensive programming exercises that involve the application of elementary software engineering techniques.

2020 Introduction to Computer Science II (4, FS) Prereq.: CP SC 2010

The second course required for students intending to major in computer science and computer engineering. Introduction to the problem of engineering computational efficiency into programs. Classical algorithms (including sorting, searching, and graph traversal) and data structures (including stacks, queues, linked lists, trees, hash tables, and graphs). Analysis of program space and time requirements. Extensive programming exercises that require the application of elementary techniques from software engineering.

2100 Discrete Structures (3, FS) Prereq.: CP SC 2010

Introduction to propositional logic, predicate logic, formal logical arguments, finite sets, functions, relations, inductive proofs, recurrence relations, graphs, and their applications to Computer Science.

2950 Independent Study (1–4)**2960 Special Topics (1–4)**

3050 Social Aspects of a Digital World (2, F) Prereq.: Programming proficiency

Social and policy aspects of computing, beginning with a review of the history and technology of the Internet. Privacy, intellectual property, ethics, electronic commerce, and computer crime. Concurrent enrollment in a companion 3000-level discussion course (such as CP SC 3051) is required. (Not offered 2002–03.)

3051 Intermediate Discussion of Social Aspects (1, F) Prereq.: Programming proficiency

The combination of CP SC 3050/3051 is appropriate for students who have an understanding of computing technology comparable to that of a newly-admitted computer science major. (Not offered 2002–03.)

3100 Models of Computation (3, F) Quantitatively Intensive B.S. Course. Prereq.: CP SC 2020, CP SC 2100

Models of sequential computation, including finite-state automata, push-down automata, and Turing machines.

3200 Scientific Computation (3, S) Prereq.: CP SC 2020, MATH 2250

Scientific computation relevant to computer science and engineering; floating-point arithmetic, systems of linear equations (direct and iterative techniques), nonlinear equations (univariate and multivariate), interpolation and differentiation (divided differences), integration (mechanical and Gaussian quadratures, optimal quadratures), approximation by spline functions (natural splines and B-splines, optimality of splines).

3500 Software Practice (4, FS) Prereq.: CP SC 2020

Meets with CP SC 5010. Practical exposure to the process of creating large software systems, including requirements specifications, design, implementation, testing, and maintenance. Emphasis on software process, software tools (debuggers, profilers, source code repositories, test harnesses), software engineering techniques (time management, code and documentation standards, source code management, object-oriented analysis and design), and team development practice. Much of the work will be in groups and will involve modifying preexisting software systems.

3505 Honors Software Practice (4, F) Prereq.: CP SC 2020

Practical exposure to the process of creating large software systems, including requirements specifications, design, implementation, testing, and maintenance. Emphasis on software process, software tools (debuggers, profilers, source code repositories, test harnesses), software engineering techniques (time management, code and documentation standards, source code management, object-oriented analysis and design).

3510 Advanced Algorithms and Data Structures (4, FS) Quantitatively Intensive B.S. Course. Prereq.: CP SC 2100, CP SC 3500

Meets with CP SC 5020. Study of algorithms, data structures, and complexity analysis beyond the introductory treatment from CP SC 2020. Balanced trees, heaps, hash tables, string matching, graph algorithms, external sorting and searching. Dynamic programming, exhaustive search. Space and time complexity, derivation and solution of recurrence relations, complexity hierarchies, reducibility, NP completeness. Laboratory practice. (Not offered Fall 2002.)

3520 Programming Language Concepts (3, F) Prereq.: CP SC 3500

Ideas behind the design and implementation of programming languages. Syntactic description; scope and lifetime of variables; runtime stack organization; parsing and abstract syntax; semantic issues; type systems; programming paradigms; interpreters and compilers.

3700 Fundamentals of Digital System Design (4, S) Quantitatively Intensive B.S. Course. Cross-listed as ECE 3700. Prereq.: CP SC 2010, PHYCS 2220

Techniques for minimizing logic functions and designing common combinational circuits such as decoders, selectors, and adders. Synchronous and asynchronous sequential circuits, state diagrams, Mealy and Moore circuits, state minimization and assignment. Use of software tools for design, minimization, simulation, and schematic capture. Implementation with MSI, LSI, and field programmable gate arrays. Laboratory included.

- 3710 Computer Design Laboratory** (3, F) Cross-listed as ECE 3710. Prereq.: CP SC/ECE 3700, CP SC/ECE 3810
Student groups design, build, and test a programmable device such as a computer or calculator.
- 3720 Analog & Digital Interfacing with Microprocessors & Microcontrollers** (4, S) Cross-listed as ECE 3720. Prereq.: CP SC/ECE 3700
Fundamentals of digital-to-analog (D-to-A) and analog-to-digital (A-to-D) circuits, relays, stepper motors, and digital switches. Interfacing digital and analog circuits to computers and micro-controllers. Laboratory included.
- 3810 Computer Architecture** (4, FS) Quantitatively Intensive B.S. Course. Cross-listed as ECE 3810. Prereq.: CP SC 2020
An in-depth study of computer architecture and design, from digital logic to operating systems, including topics such as pipelining, memory systems, parallel and serial communication, and interrupts. Performance measures and compilation issues. Computer architectures including RISC, CISC, stack, and parallel.
- 3950 Independent Study** (1–4)
- 3960 Special Topics** (1–4)
- 3991 Computer Engineering Junior Seminar** (0.5, F) Cross-listed as ECE 3991. Prereq.: CE major status
Presentation from faculty and industry representatives to discuss trends in computer engineering, professionalism, ethics, the impact of engineering in global and societal contexts, lifelong learning, and contemporary issues.
- 3992 CE Prethesis** (0.5, S) Cross-listed as ECE 3992. Prereq.: CP SC/ECE 3991, CE major status
Students do necessary library research, develop writing and speaking skills, and prepare and present a senior thesis proposal.
- 4010 Teaching Introductory Computer Science** (1, FS) Prereq.: Permission of instructor
Issues confronted by undergraduate teaching assistants in introductory computer science courses, including leading lab sections, conducting office hours, grading assignments, communicating with students. Each student must currently be an undergraduate teaching assistant in the School of Computing. May be taken for credit up to three times.
- 4400 Computer Systems** (3, FS) Prereq.: CP SC 3500, CP SC 3810; CP SC 3510 recommended
Introduction to computer systems from a programmer's point of view. Machine level representations of programs, optimizing program performance, memory hierarchy, linking, exceptional control flow, measuring program performance, virtual memory, concurrent programming with threads, network programming. *Not offered Fall 2003.*
- 4500 Software Engineering Laboratory** (3, S) Prereq.: CP SC 3510, senior standing in Computer Science
Development of significant software systems by small student groups, with emphasis on applying sound, disciplined software engineering practice.
- 4540 Web Software Architecture** (3, S) Prereq.: CP SC 3510
Software architectures, programming models, and programming environments pertinent to developing web applications. Topics include client-server model, multi-tier software architecture, client-side scripting (JavaScript), server-side programming (Servlets and JavaServer Pages), component reuse (JavaBeans), database connectivity (JDBC), and web servers.
- 4550 Simulation** (3, F) Prereq.: CP SC 3510
Basic simulation modeling, modeling complex systems, basic probability and statistics for simulation, building valid simulations, random numbers, and output data analysis. Both discrete event and continuous simulation may be covered.

4710 Computer Engineering Senior Project (3, F) Cross-listed as ECE 4710. Prereq.: CP SC/ECE 3710, CP SC/ECE 3720, senior standing in Computer Engineering

Students design a microcomputer system that includes RAM, EPROM, and I/O devices. Capstone project for computer engineering majors. Formal written reports, one or more oral presentations.

4950 Independent Study (1–4)

4960–4964 Special Topics (1–4)

4970 Bachelor's Thesis (3) Prereq.: Senior standing in computer science

Only students who have previously worked with a faculty member in a research group may register for Bachelor's Thesis credit, and then only with the permission of the faculty member. An undergraduate thesis is a publication-quality description of work done in previous semesters. At a minimum a thesis must be published as a technical report; ideally, it should be submitted to a conference or journal. A Bachelor's Thesis is intended as an alternative to the senior Software engineering Laboratory for students who are headed for graduate school.

4991 CE Senior Thesis I (2, F) Cross-listed as ECE 4992. Prereq.: CP SC/ECE 3992 and approved senior thesis proposal

Students work on original senior thesis project.

4992 CE Senior Thesis II (2, S) Cross-listed as ECE 4992. Prereq.: CP SC/ECE 4991

Students work on original senior thesis project, make an oral presentation at the annual student technical conference, and prepare and submit their senior thesis for approval.

4999 Honors Thesis/Project (3) Upper-division Communications/Writing

Restricted to students in the Honors Program working on their Honors degree.

5010 Software Practice (4, FS) Prereq.: CP SC 2020 and permission of instructor

Meets with CP SC 3500. This course is for graduate students from other than the School of Computing. Practical exposure to the process of creating large software systems, including requirements specifications, design, implementation, testing, and maintenance. Emphasis on software process, software tools (debuggers, profilers, source code repositories, test harnesses), software engineering techniques (time management, code and documentation standards, source code management, object-oriented analysis and design), and team development practice. Much of the work will be in groups and will involve modifying preexisting software systems.

5020 Advanced Algorithms and Data Structures (3, FS) Prereq.: CP SC 5010 and permission of instructor

Meets with CP SC 3510. This course is for graduate students from other than the School of Computing. Study of algorithms, data structures, and complexity analysis beyond the introductory treatment from CP SC 2020. Balanced trees, heaps, hash tables, string matching, graph algorithms, external sorting and searching. Dynamic programming, exhaustive search. Space and time complexity, derivation and solution of recurrence relations, complexity hierarchies, reducibility, NP completeness. (Not offered Fall 2002.)

5050 Social Aspects of a Digital World (2, F) Prereq.: Permission of instructor

Social and policy aspects of computing, beginning with a review of the history and technology of the Internet. Privacy, intellectual property, ethics, electronic commerce, and computer crime. Concurrent enrollment in a companion 5000-level discussion course (such as CP SC 5051) is required. (Companion discussions may also be offered by other departments.) (Not offered 2002–03.)

5051 Advanced Discussion of Social Aspects (1, F) Prereq.: Permission of instructor

The combination of CP SC 5050/5051 is appropriate for students who have a graduate-level background in issues related to the social aspects of computing (e.g., intellectual property or electronic commerce). (Not offered 2002–03.)

5060 Legal Protection of Digital Information (2, F)

Ways of protecting digital information—computer software and databases—using intellectual property law. Copyrights, patents, trade secrets, and contracts as ways of protecting digital information.

5100 Foundations of Computer Science (3, S) Prereq.: CP SC 3100, CP SC 3510

Meets with CP SC 6100. Finite Automata and related topics (BDDs, Presburger Arithmetic, and decidable fragments of first-order logic). Automata on Infinite Words, connections with Specification and Verification of Systems. Push Down Automata, Turing Machines, Proofs by Reduction, Diagonalization, Problems in Computability. First-order Logic and Decidability. NP Completeness, P-space Completeness.

5210 Advanced Scientific Computing I (3, F) Prereq.: CP SC 3200, CP SC 3510, MATH 3160

Meets with CP SC 6210. An introduction to existing classical and modern numerical methods and their algorithmic development and efficient implementation. Topics include: numerical linear algebra, interpolation, approximation methods and parallel computation methods for nonlinear equations, ordinary differential equations, and partial differential equations.

5300 Artificial Intelligence (3, S) Prereq.: CP SC 3510

Meets with CP SC 6300. Introduction to field of artificial intelligence, including heuristic programming, problem-solving, search, theorem proving, question answering, machine learning, pattern recognition, game playing, robotics, computer vision.

5310 Robotics (3, F) Cross-listed as ME EN 5220. Prereq.: CP SC 1000, MATH 2250, PHYCS 2220

Meets with CP SC 6310. The mechanics of robots, comprising kinematics, dynamics, and trajectories. Planar, spherical, and spatial transformations and displacements. Representing orientation: Euler angles, angle-axis, and quaternions. Velocity and acceleration: the Jacobian and screw theory. Inverse kinematics: solvability and singularities. Trajectory planning: joint interpolation and Cartesian trajectories. Statics of serial chain mechanisms. Inertial parameters, Newton-Euler equations, D'Alembert's principle. Recursive forward and inverse dynamics.

5320 Computer Vision (3, S) Prereq.: CP SC 3510, MATH 2210, MATH 2270

Meets with CP SC 6320. Basic pattern-recognition and image-analysis techniques, low-level representation, intrinsic images, "shape from" methods, segmentation, texture and motion analysis, and representation of 2-D and 3-D shape. (Not offered 2002–03.)

5340 Natural Language Processing (3, F) Prereq.: CP SC 3510

Meets with CP SC 6340. Computational models and methods for understanding written text. Introduction to syntactic analysis, semantic analysis, discourse analysis, knowledge structures, and memory organization. A variety of approaches are covered, including conceptual dependency theory, connectionist methods, and statistical techniques. Applications include story understanding, fact extraction, and information retrieval.

5350 Machine Learning (3, F) Prereq.: CP SC 3510; CP SC 5300/6300 recommended

Meets with CP SC 6350. Techniques for developing computer systems that can acquire new knowledge automatically or adapt their behavior over time. Topics include concept learning, decision trees, evaluation functions, clustering methods, explanation-based learning, language learning, cognitive learning architectures, connectionist methods, reinforcement learning, genetic algorithms, hybrid methods, and discovery.

5460 Operating Systems (3, F) Prereq.: CP SC 3510, CP SC/ECE 3810, CP SC 4400

Characteristics, objectives, and issues concerning computer operating systems. Hardware/software interactions, process management, memory management, protection, synchronization, resource allocation, file systems, security, and distributed systems. Extensive systems programming.

5470 Compiler Principles and Techniques (3, S) Prereq.: CP SC 3100, CP SC 3510, CP SC/ECE 3810, CP SC 4400

Lexical analysis, top-down and bottom-up parsing, symbol tables, internal forms and intermediate languages, run-time environments, code generation, code optimization, semantic specifications, error detection and recovery. Use of software tools for lexical analysis and parsing.

5480 Data Communications and Networks (3, F) Prereq.: CP SC 3510, CP SC/ECE 3810, CP SC 4400

Meets with CP SC 6480. A comprehensive study of the principles and practices of data communication and networks. Topics include: transmission media, data encoding, local and wide area networking architectures, internetwork and transport protocols (e.g., IPv4, IPv6, TCP, UDP, RPC, SMTP), networking infrastructure (e.g., routers, name servers, gateways), network management, distributed applications, network security, and electronic commerce. Principles are put into practice via a number of programming projects.

5520 Anatomy of a Modern Programming Language (3, S) Prereq.: CP SC 3520

Requirements, challenges, and techniques for designing a modern programming language, currently focusing on Java as a case study. Syntactic and lexical issues, semantic specification, modularity concepts, support for object-oriented programming, types and subtypes, type safety and security, portability, compilability, dynamic linking and loading, program evolvability, use of meta data (reflection), multi-threading, native code generation and linkage, generic types, persistence.

5530 Database Systems (3, F) Prereq.: CP SC 3500

Meets with CP SC 6530. Representing information about real world enterprises using important data models including the entity-relationship, relational and object-oriented approaches. Database design criteria, including normalization and integrity constraints. Implementation techniques using commercial database management system software. Selected advanced Topics such as distributed, temporal, active, and multi-media databases.

5540 Human/Computer Interaction (3, F) Prereq.: CP SC 3510

Meets with CP SC 6540. Fundamentals of input/output devices, user interfaces, and human factors in the context of designing interactive applications.

5600 Introduction to Computer Graphics (3, S) Prereq.: CP SC 3500, MATH 2250; Coreq.: CP SC 3510 recommended

Basic display techniques, display devices, and graphics systems. Homogeneous coordinates, transformations, and clipping. Introduction to lighting models. Introduction to raster graphics and hidden-surface removal.

5605 Honors Introduction to Computer Graphics (3, S) Prereq.: CP SC 3505

Basic display techniques, display devices, and graphics systems. Homogeneous coordinates, transformations, and clipping. Introduction to lighting models. Introduction to raster graphics and hidden-surface removal.

5610 Advanced Computer Graphics I (3, F) Prereq.: CP SC 5600

Meets with CP SC 6610. Interactive 3D computer graphics, polygonal representations of 3-D objects. Interactive lighting models. Introduction to interactive texture mapping, shadow generation, image-based techniques such as stencils, hidden-line removal, and silhouette edges. Introduction to image-based rendering, global illumination, and volume rendering.

5630 Scientific Visualization (3, F) Prereq.: CP SC 3510; CP SC 3200 or CP SC 5210 or MATH 5600

Meets with CP SC 6630. Introduction to the techniques and tools needed for the visual display of data. Students will explore many aspects of visualization, using a "from concepts to results" format. The course begins with an overview of the important issues involved in visualization, continues through an overview of graphics tools relating to visualization, and ends with instruction in the utilization and customization of a variety of scientific visualization software packages.

5710 Advanced Integrated Circuit Design I (3, F) Cross-listed as ECE 5710. Prereq.: CP SC/ECE 3700

Meets with CP SC 6710. Introduction to basic concepts of the design of CMOS integrated circuits for students with a wide range of backgrounds. Static and dynamic properties of CMOS circuits, composite layout of CMOS circuits, and modeling of transistors for use in SPICE simulations. Commonly encountered CMOS circuits. Introduction to CMOS analog/digital circuits. Students complete design, composite layout, and digitization of a simple integrated circuit using computer-aided design tools.

5720 Advanced Integrated Circuit Design II (3) Cross-listed as ECE 5720. Prereq.: CP SC/ECE 5710/6710, ECE 2100

Meets with CP SC 6720. Design of mixed signal (analog/digital) CMOS integrated circuits. Fundamental building blocks for analog circuits, including the basic principles of opamp, current mirror and comparator design. Basics of discrete-time signals and filters. Implementation of switched capacitor circuits and discussions of various implementations of D/A and A/D converters, oversampled converters and phase locked loops. (Not offered 2002–03.)

5740 Computer-Aided Design of Digital Circuits (3) Cross-listed as ECE 5740. Prereq.: CP SC/ECE 3700, CP SC 3510

Meets with CP SC 6740. Introduction to theory and algorithms used for computer-aided synthesis of digital integrated circuits. Topics include algorithms and representations for Boolean optimization, hardware modeling, combination logic optimization, sequential logic optimization and technology mapping. (Not offered 2002–03.)

5750 Synthesis and Verification of Asynchronous VLSI Systems (3, F) Cross-listed as ECE 5750. Prereq.: CP SC/ECE 3700, CP SC 3510

Meets with CP SC 6750. Introduction to systematic methods for the design of asynchronous VLSI systems from high-level specifications to efficient, reliable circuit implementations. Topics include specification, controller synthesis, optimization using timing information, technology mapping, data path design, and verification. (Not offered 2002–03.)

5810 Advanced Computer Architecture (3, F) Cross-listed as ECE 5810. Prereq.: CP SC/ECE 3700, CP SC/ECE 3810

Meets with CP SC 6810. Principles of modern high performance computer and micro architecture: static vs. dynamic issues, pipelining, control and data hazards, branch prediction and correlation, cache structure and policies, cost-performance and physical complexity analyses.

5830 VLSI Architecture (3) Cross-listed as ECE 5830. Prereq.: CP SC/ECE 3700, CP SC/ECE 3810

Meets with CP SC 6830. Project-based study of a variety of Topics related to VLSI systems. Use of field programmable gate arrays to design, implement, and test a VLSI project. (Not offered 2002-03.)

5940 Seminar (1-3)

Current Topics in computer science. May be repeated for credit.

5950 Independent Study (1–4)**5960–5969 Special Topics** (1–4)

The following special topics courses are currently scheduled for the 2003–04 academic year. Contact the faculty member in charge for details. Check the on-line schedule for a more current listing of offerings.

- **CP SC 5960 Computational Geometry** (3,F). Prof. Praun.
- **CP SC 5961 Parallel Programming** (3,S). Prof. Berzins.
- **CP SC 5962 Games Graphics** (3,S). Prof. Hansen.
- **CP SC 5963 Advanced Manufacturing** (3, F). Prof. Drake.

6010 Writing Research Proposals (2, S) Prereq.: Graduate standing in Computer Science

Fundamental aspects of writing computer science research proposals, including thesis, dissertation, and grant proposals. Form, style, substance, and marketing of effective proposals will be considered. Emphasis is placed on developing and presenting clear and compelling ideas. Substantial writing and class presentations is required of all participants. (This is a half-semester course.)

6020 Conducting, Publishing, and Presenting Early-Career Research (3) Prereq.: Graduate standing in Computer Science

This is an independent study offering designed to encourage beginning graduate students to conduct, publish, and present original research early in their graduate careers. A graduate student can earn credit for CP SC 6020 by having a first-authored paper accepted for publication in a top-tier journal or conference and by subsequently presenting the published work in a one-hour research colloquium. The research must be conducted while a graduate student at Utah; the paper must be accepted within two years of enrolling in the graduate program; the journal or conference must be approved by the student's graduate committee; the colloquium must be presented as soon as possible after the acceptance of the paper; and the student must complete these requirements and register for CP SC 6020 within three years of enrolling in the graduate program. CP SC 6020 may not be repeated for credit.

6100 Foundations of Computer Science (3, S) Prereq.: CP SC 3100, CP SC 3510

Meets with CP SC 5100. Graduate and honors students only. Extra work required.

6110 Formal Methods for System Design (3, S) Prereq.: CP SC 5100/6100 and CP SC 6520

Study of methods for formally specifying and verifying computing systems. Specific techniques include explicit state enumeration, implicit state enumeration, automated decision procedures for first-order logic, and automated theorem proving. Examples selected from the areas of superscalar CPU design, parallel processor memory models, and synchronization and coordination protocols. (Not offered 2002–03.)

6210 Advanced Scientific Computing I (3, F) Prereq.: CP SC 3200, CP SC 3510, MATH 3160

Meets with CP SC 5210. Graduate and honors students only. Extra work required.

6220 Advanced Scientific Computing II (3, S) Prereq.: CP SC 5210/6210 or MATH 5600

A study of the numerical solution of two and three dimensional partial differential equations that arise in science and engineering problems. Topics include: finite difference methods, finite element methods, boundary element methods, multigrid methods, mesh generation, storage optimization methods, and adaptive methods.

6300 Artificial Intelligence (3, S) Prereq.: CP SC 3510

Meets with CP SC 5300. Graduate and honors students only. Extra work required.

6310 Robotics (3, F) Cross-listed as ME EN 6220. Prereq.: CP SC 1000, MATH 2250, PHYCS 2220

Meets with CP SC 5310. Graduate and honors students only. Extra work required.

6320 Computer Vision (3, S) Prereq.: CP SC 3510, MATH 2210, MATH 2270

Meets with CP SC 5320. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

6340 Natural Language Processing (3, F) Prereq.: CP SC 3510

Meets with CP SC 5340. Graduate and honors students only. Extra work required.

6350 Machine Learning (3, F) Prereq.: CP SC 3510; CP SC 5300/6300 recommended

Meets with CP SC 5350. Graduate and honors students only. Extra work required.

6360 Virtual Reality (3, S) Prereq.: CP SC 5310/6310

Human interfaces: visual, auditory, haptic, and locomotory displays; position tracking and mapping. Computer hardware and software for the generation of virtual environments. Networking and communications. Telerobotics: remote manipulators and vehicles, low-level control, supervisory control, and real-time architectures. Applications: manufacturing, medicine, hazardous environments, and training. (Not offered 2002–03.)

6470 Advanced Topics in Compilation (3, F) Prereq.: CP SC 5470

Compilation of modern languages. Optimization techniques, register allocation and instruction scheduling, garbage collection, exception handling. Linkers and late-stage compilation and optimization. (Not offered 2002–03.)

6480 Data Communications and Networks (3, F) Prereq.: CP SC 3510, CP SC/ECE 3810

Meets with CP SC 5480. Graduate and honors students only. Extra work required.

6520 Programming Languages and Semantics (3, S) Prereq.: CP SC 3520, CP SC 3100

Examination of the formal and pragmatic ideas behind programming language design. Imperative, functional, logic, object-oriented, and multi-paradigm languages. Lambda calculus, fixpoints, type systems, and predicate logic. Denotational semantics and models of concurrency.

6530 Database Systems (3, F) Prereq.: CP SC 3510

Meets with CP SC 5530. Graduate and honors students only. Extra work required.

6540 Human/Computer Interaction (3, F) Prereq.: CP SC 3510

Meets with CP SC 5540. Graduate and honors students only. Extra work required.

6610 Advanced Computer Graphics I (3, S) Prereq.: CP SC 5600 or CP SC 3610

Meets with CP SC 5610. Graduate and honors students only. Extra work required.

6620 Advanced Computer Graphics II (3, S) Prereq.: CP SC 5610/6610

Introduction to ray-tracing. Intersection methods for 3-D objects, reflection and refraction. Introduction to surface and solid texturing. Introduction to continuous-tone pictures and the aliasing problem. Special effects such as soft shadows, depth-of-field, motion-blur, and indirect lighting.

6630 Scientific Visualization (3, F) Prereq.: CP SC 3510; CP SC 3200 or CP SC 5210/6210 or MATH 5600

Meets with CP SC 5630. Graduate and honors students only. Extra work required.

6650 Image Synthesis (3, F) Prereq.: CP SC 5620/6620, CP SC 6670, MATH 5010

Using camera and sensor simulation along with physical simulation to generate realistic synthetic images. (Not offered 2002–03.)

6670 Computer-Aided Geometric Design I (3, F) Prereq.: MATH 2210, MATH 2250, CP SC 3510; Coreq.: CP SC 5600/6600**6680 Computer-Aided Geometric Design II** (3) Prereq.: CP SC 6670

Introduction to current concepts and issues in CAGD systems with emphasis on free-form surface design; mathematics of free-form curve and surface representations, including Coons patches, Bezier method, B-splines, triangular interpolants, and their geometric consequences; classical surface geometry; local and global design tradeoffs and explicit and parametric tradeoffs; subdivision and refinement as techniques in modeling; current production capabilities compared to advanced research. Laboratory experiments with current CAD systems. (Not offered 2002–03.)

6710 Advanced Integrated Circuit Design I (3, F) Cross-listed as ECE 6710. Prereq.: CP SC/ECE 3700

Meets with CP SC 5710. Graduate and honors students only. Extra work required.

6720 Advanced Integrated Circuit Design II (3) Cross-listed as ECE 6720. Prereq.: CP SC/ECE 5710/6710, ECE 2100
Meets with CP SC 5720. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

6740 Computer-Aided Design of Digital Circuits (3) Cross-listed as ECE 6740. Prereq.: CP SC/ECE 3700, CP SC 3510
Meets with CP SC 5740. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

6750 Synthesis and Verification of Asynchronous VLSI Systems (3, F) Cross-listed as ECE 6750. Prereq.: CP SC/ECE 3700, CP SC 3510
Meets with CP SC 5750. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

6770 Advanced Digital VLSI Systems Design (3) Cross-listed as ECE 6770. Prereq.: CP SC/ECE 5710/6710
Full custom, high speed, high performance CMOS circuit design issues, methodologies, and techniques. Failure modes, modeling techniques, testing, clock skew analysis, clock distribution, power analysis, power line distribution, electrical rules checking, megacell design flow, and other important design issues. (Not offered 2002–03.)

6810 Advanced Computer Architecture (3, F) Cross-listed as ECE 6810. Prereq.: CP SC/ECE 3700, CP SC/ECE 3810
Meets with CP SC 5810. Graduate and honors students only. Extra work required.

6820 Parallel Computer Architecture (3) Cross-listed as ECE 6820. Prereq.: CP SC/ECE 5810/6810
Architecture, design, and analysis of parallel computer systems: vector processing, data vs. control concurrency, shared memory, message passing, communication fabrics, case studies of current high performance parallel systems. (Not offered 2002–03.)

6830 VLSI Architecture (3) Cross-listed as ECE 6830. Prereq.: CP SC/ECE 3700, CP SC/ECE 3810
Meets with CP SC 5830. Graduate and honors students only. Extra work required. (Not offered 2002–03.)

6930–6944 Seminar (1-3)
Current Topics in Computer Science. May be repeated for credit.

6950 Independent Study (1–4)

6960–6969 Special Topics (1–4)
The following special topics course is currently scheduled for the 2003–2004 academic year. Contact the instructor for details. Check the on-line schedule for a more current listing of offerings.

- **CP SC 6963 Numerical Linear Algebra** (3,S). Prof. Sikorski.

6970 Masters Thesis Research (1–12)

6980 Faculty Consultation Masters (1–12)

7120 Information-Based Complexity (3) Prereq.: CP SC 3200, MATH 2270, MATH 3210
Analysis of optimal computational methods for continuous problems. Introduction to the general worst case theory of optimal algorithms, linear problems, and spline algorithms as well as selected nonlinear problems. Examples include optimal integration, approximation, nonlinear zero finding, and fixed points. (Not offered 2002–03.)

7240 Sinc Methods (3, S) Prereq.: CP SC 5210/6210 or MATH 5600 or MATH 5610
Sinc methods for solving difficult computational problems, such as partial differential and integral equation problems, that arise in science and engineering research. Emphasis on parallel computation. Applications vary, depending on participants in the class. Students are given projects—whenever possible in their areas of research—that lead to publishable research articles. (Not offered 2002–03.)

7310 Advanced Robotics (3, S) Cross-listed as ME EN 7230. Prereq.: CP SC/ME EN 5310/6310 5220/6220

Covers the kinematics, dynamics, and control of robotic manipulators. Projects controlling robots will be an integral part of the course.

7460 Advanced Operating Systems (3) Prereq.: CP SC 5460, CP SC 5480/6480

Practical distributed operating systems concepts from basics through the state of the art. Topics include interprocess communication, client-server systems, distributed shared memory, distributed file systems, distributed databases, portable computing, software fault tolerance, and wide-area (e.g. web) applications. Work includes individual oral presentations, a group project, and a written research report. (Not offered 2002–03.)

7940 Seminar (1–3)

May be repeated for credit.

7950 Independent Study (1–4)**7960 Special Topics** (1–4)

No special topics courses are currently scheduled for the 2003–2004 academic year. Check the on-line schedule for a current listing of offerings.

7970 PhD Dissertation Research (1–12)**7980 Faculty Consultation PhD** (1–12)**7990 Continuing Registration: PhD** (0)

4

School of Computing Faculty and Their Research Interests

Rajeev Balasubramonian

Assistant Professor, School of Computing
Ph.D., University of Rochester, 2003

Professor Balasubramonian¹ joins the faculty in Fall 2003. His research interests include high-performance and low-power computer architecture. Broadly, he is interested in employing large transistor budgets in a complexity-effective manner to solve a diverse set of problems. The primary focus of his research has been the evaluation of technology trends and their impact on the design of next-generation microprocessors. He is especially concerned with problems involving long on-chip wire delays and memory latencies, which represent two of the most important bottlenecks in the future. Among other things, his dissertation studied scalability issues in clustered processors, which are designs that incorporate many processing units on a single die at low complexity. His future research goals include evaluations of multi-threaded workloads, heterogeneity within a clustered system, on-chip interconnect networks, power, and thermal issues.

Martin Berzins

Professor, School of Computing
Ph.D., University of Leeds, 1981

Professor Berzins² joined the faculty in 2003. His research area is the study of novel computational algorithms for the numerical solution of partial differential equations on both serial and parallel computers. In particular, his interests are in devising new adaptive mesh algorithms, exploiting new parallel computing techniques to reduce computing times, and to investigate novel applications in the areas of environmental and other complex systems.

¹<http://www.cs.utah.edu/~rajeev/>

²<http://www.cs.utah.edu/~mb/>

Erik Brunvand

Associate Professor, School of Computing
Ph.D., Carnegie Mellon University, 1991

Professor Brunvand³ joined the faculty in 1990. He has interests in computer architecture and VLSI systems in general, and self-timed and asynchronous systems in particular. One aspect of his research involves compiling concurrent communicating programs into asynchronous VLSI circuits. The current system allows programs written in a subset of Occam, a concurrent message-passing programming language based on CSP, to be automatically compiled into a set of self-timed circuit modules suitable for manufacture as an integrated circuit. He is also interested in investigating the effects of asynchrony on computer systems architecture at a higher level. To explore these ideas he is building a series of prototype asynchronous computer systems out of FPGA and custom VLSI chips.

John Carter

Associate Professor, School of Computing
Ph.D., Rice University, 1992

Professor Carter⁴ joined the faculty in January 1993. His research interests include computer architecture, operating systems, distributed systems, and computer networks. Of particular interest are novel memory system designs, both hardware and software. Dr. Carter is co-leading two research projects: the Impulse Adaptable Memory Systems project and the Khazana project. The goal of the Impulse project is to attack the primary problem limiting performance in future computer systems – the inability of conventional memory systems to supply data fast enough to avoid processing stalls – by developing a main memory controller and associated software that allows applications to dynamically change the way that the processor’s memory hierarchy is managed. Khazana makes it easier for programmers to develop sophisticated distributed applications by addressing the shared state management problem faces by most such applications. Khazana exports the abstraction of a distributed secure persistent globally shared store that applications can use to store their shared state. It is responsible for performing many of the common operations needed by distributed applications, including replication, consistency management, and fault recovery.

Elaine Cohen

Professor, School of Computing
Adjunct Associate Professor of Mathematics
Ph.D., Syracuse University, 1974

Professor Cohen⁵ has held a faculty position since 1974. Currently she is co-head of the School’s Computer-Aided Geometric Design Group. Present research is centered around representational and algorithmic problems associated with geometric modeling, graphics, scientific visualization physically based modeling, process planning, CAD/CAM and CAE. Dr. Cohen received a B.A. in Mathematics from Vassar College in 1968 and M.S. and Ph.D. degrees in mathematics from Syracuse University in 1970 and 1974, respectively.

³<http://www.cs.utah.edu/~elb/>

⁴<http://www.cs.utah.edu/~retrac/>

⁵<http://www.cs.utah.edu/~cohen/>

Al Davis

Professor, School of Computing
Ph.D., University of Utah, 1972

Professor Davis⁶ joined the faculty in 1993. His research interests involve high performance computer architectures and digital system design methodologies. More specifically he is interested in parallel processor architectures, high performance uniprocessor I/O architecture, VLSI, VLSI CAD, high performance communication, and asynchronous circuits. Prior to his joining the faculty in the fall of 1993, he spent the previous 12 years as a research scientist working on the design and implementation of parallel processing systems at Schlumberger Palo Alto Research and subsequently at Hewlett-Packard Laboratories. Recent accomplishments include 1) the development of an automatic asynchronous circuit synthesis system called STETSON; 2) the design and implementation of an asynchronous scalable parallel communication fabric VLSI component called FEDEX which is capable of supporting 500 MB/sec sustained bandwidth on each of its 7 ports; and 3) the development of an extensible and scalable parallel processing system called MAYFLY and 4) the development of a very low latency message passing protocols called Direct Deposit. He is currently involved in the DARPA sponsored Impulse project (Prof. John Carter is the PI) which is developing an adaptive memory controller that is capable of dynamically organizing cache lines to suit the applications needs. During the 1999-2000 academic year, Professor Davis was on sabbatical at Intel in Austin, Texas where he lead the I/O and memory architecture efforts for the IA32 processor which is expected to be in production in 2003.

Matthew Flatt

Assistant Professor, School of Computing
Ph.D., Rice University, 1999

Professor Flatt's⁷ research interests cover all practical and theoretical aspects of programming languages, systems, and environments. As part of the Programming Languages Team (PLT), he is one of the principal architects of the DrScheme programming environment and a co-author of the *How to Design Programs* textbook. His current research topics include module languages for software components, object-oriented languages for classes and mixins, and high-level operating systems for cooperating applications.

Ganesh C. Gopalakrishnan

Professor, School of Computing
Ph.D., State University of New York at Stony Brook, 1986

Professor Gopalakrishnan's⁸ primary research is in verification methods for concurrent systems such as shared memory systems, microprocessor busses, multithreaded software, and message passing networks. He also maintains active interest in self-timed design. Today's concurrent systems employ complex protocols that are expected to guarantee properties such as in-order arrival of messages, deadlock freedom, and liveness. In modern design approaches, these systems are subject to a battery of conventional tests, and when all these pass, model-checking methods are brought to bear to tracking down elusive bugs that may cripple the system well after field deployment. The effectiveness of conventional model-checking methods is limited by their inability to handle large state spaces, deal with parameterized designs, or provide guidelines for writing a comprehensive list of properties to check. Our group's recent efforts have addressed these problems using realistic driving problems such as generalized multi-level PCI I/O busses, the Intel Itanium Shared Memory Model, and the Java Shared Memory Model for Multithreading. Professor Gopalakrishnan was a general co-Chair of the Internal Symposium on Formal Methods in Computer-Aided Design (FMCAD) in November 1998, the International Symposium on Advanced Research in Asynchronous Circuits and Systems (Async) in November 1994. He organized the Workshop on Advances in Verification (WAVE) as well as the workshop on Formal Specification and Verification Methods for Shared Memory Systems, both in year 2000.

⁶<http://www.cs.utah.edu/~ald/>

⁷<http://www.cs.utah.edu/~mflatt/>

⁸<http://www.cs.utah.edu/~ganesh/>

David H. Hanscom

Clinical Professor, School of Computing
Ph.D., Case Western Reserve University, 1970

Professor Hanscom's⁹ background is in the field of communications processor design at Sperry Univac, where he worked from 1970 to 1982. Since then he has been responsible for administering the undergraduate Computer Science and Computer Engineering programs at the University of Utah. In that capacity he teaches core computer science classes, serves as faculty advisor for individual students and for the Student Chapter of the Association for Computing Machinery, participates in student recruiting activities, and serves as director of the High School Computing Institute. His interests are in the areas of undergraduate education, computer architecture, and data communications.

Charles Hansen

Associate Professor, School of Computing
Ph.D., University of Utah, 1987

Professor Hansen¹⁰ joined the faculty in 1998. His research interests span scientific visualization, computer graphics, and high performance computing. Scientific visualization of large scale problems is of key interest and recent work involves taking into consideration time-varying data and exploiting this for speeding up the visualization process. Other methods for visualizing large amounts of data are multiresolution models and view dependent algorithms. The interest in computer graphics is driven from the scientific visualization perspective but includes parallel algorithms for speeding up global illumination.

Thomas C. Henderson

Professor, School of Computing
Ph.D., University of Texas, 1979

Professor Henderson's¹¹ professional interests include autonomous agents, multisensor systems, and simulation. Major areas of current research are robot behavior specification, simulation, multisensor integration, and bio-based computational models. Prior to his arrival at Utah, he was a visiting professor at the Institut National de Recherche en Informatique et en Automatique (INRIA), France, and a Research Associate at the Institut fuer Nachrichtentechnik, Deutsche Forschungs und Versuchsanstalt fuer Luft und Raumfahrt (DFVLR), Germany.

Lee A. Hollaar

Professor, School of Computing
Ph.D., University of Illinois at Urbana-Champaign, 1975

Professor Hollaar's¹² primary interest is in legal issues regarding computers, particularly the intellectual property protection of software and information. As a Fellow with the Committee on the Judiciary, he has advised the United States Senate on computer-related issues such as encryption, copyright and patent, and regulation of the internet. He was one of the drafters of the Utah Digital Signature Act, the first law in the world to legally recognize digital signatures, and is active in the implementation of the required infrastructure. He directed the Utah Retrieval System Architecture (URSA) project, which developed hardware and software systems to support large information retrieval systems, including a special-purpose VLSI processor for the rapid searching of text and one of the first workstation-based client-server distributed systems for information retrieval. He was also the University's director of campus networking, and continues to work in communications networks and distributed systems.

⁹<http://www.cs.utah.edu/~hanscom/>

¹⁰<http://www.cs.utah.edu/~hansen/>

¹¹<http://www.cs.utah.edu/~tch/>

¹²<http://www.cs.utah.edu/~hollaar/>

John M. Hollerbach

Professor, School of Computing
Ph.D., Massachusetts Institute of Technology, 1978

Professor Hollerbach's¹³ interests include robotics and virtual reality. The focus in virtual reality is on improving the transparency and sense of immersion through better mechanical interfaces and their control, better visual and auditory displays, and sensorimotor integration. Haptic interfaces are being employed for virtual manipulation of mechanical CAD models and for scientific visualization. The Treadport locomotion interface is being employed for walk-through synthetic environments such as outdoor terrain.

Wilson C. Hsieh

Associate Professor, School of Computing
Ph.D., Massachusetts Institute of Technology, 1995

Professor Hsieh¹⁴ joined the faculty in September 1997. His research interests are in compilers and programming languages, operating systems, and architecture.

Christopher R. Johnson

Professor, School of Computing
Research Associate Professor of Physics and Bioengineering
Ph.D., University of Utah, 1989

Professor Johnson's¹⁵ research interests are in the area of scientific computing. Particular interests include inverse and imaging problems, adaptive methods for partial differential equations, numerical analysis, problem solving environments, computational problems in medicine, and scientific visualization. In 1992, Professor Johnson was awarded a Young Investigator's Award from the NIH, in 1994 he was awarded the National Young Investigator (NYI) Award from the NSF, and in 1995 he was awarded the Presidential Faculty Fellow (PFF) Award from the NSF. In 1996 he received a DOE Computational Science Award and in 1997 received the Par Excellence Award from the University of Utah Alumni Association and the Presidential Teaching Scholar Award. In 1999, Professor Johnson was Awarded the Governor's Medal for Science and Technology from Utah Governor Michael Leavitt. He directs the Scientific Computing and Imaging Institute.

Robert Kessler

Professor, School of Computing
Ph.D., University of Utah, 1981

Professor Kessler's¹⁶ current research interests are in agents, software engineering, distributed systems, and visual programming. In the early 90's, he founded the Center for Software Science, a state of Utah Center of Excellence. He has also founded several startup companies and is currently involved with an Internet startup company, emWare, as a member of the board. He has served as member-at-large of ACM SIGPLAN and Vice Chairman for Conferences for SIGPLAN. He recently completed a seven year assignment as co-editor-in-chief of the International Journal of Lisp and Symbolic Computation.

Mike Kirby

Assistant Professor, School of Computing
Ph.D., Brown University, 2002

Professor Kirby¹⁷ joined the faculty in 2002. His research focus is on large-scale scientific computation and visualization, with an emphasis on the scientific cycle of mathematical modeling, computation, visualization, evaluation, and understanding. His primary research interests include computational science and engineering, high-order numerical methods, concurrent programming, scientific visualization, and high performance computing.

¹³<http://www.cs.utah.edu/~jmh/>

¹⁴<http://www.cs.utah.edu/~wilson/>

¹⁵<http://www.cs.utah.edu/~crj/>

¹⁶<http://www.cs.utah.edu/~kessler/>

¹⁷<http://www.cs.utah.edu/~kirby/>

Arthur H. Lee

Clinical Associate Professor, School of Computing
Ph.D., University of Utah, 1992

Professor Lee¹⁸ joined the faculty in 2001. His interests revolve around object-oriented programming. Of particular interest are software design, software architecture, and software evolution. These are being experimented in areas such as programming languages, database systems, and distributed systems. He is also interested in improving computer science curricula. He tries to bring emerging ideas from research and industry into the classroom, always looking for new ones to incorporate into the CS curricula. Some of the emerging ideas that Professor Lee is investigating include aspect-oriented programming, web programming, and embedded programming. He is also interested in finding innovative and effective ways to use computers and other technologies in teaching.

Jay Lepreau

Research Associate Professor, School of Computing
B.S., University of Utah, 1983

Professor Lepreau's¹⁹ research interests focus on operating systems, but expand into many other areas including security, networking, component software, programming and domain-specific languages, compilers, distributed systems, and software assurance. As head of the Flux Research Group, he currently leads three DARPA and NSF-sponsored research projects. The "Alchemy" project is developing a new model of component programming for embedded and other low-level systems. Utah's Active Networks effort is attempting to develop a router OS that can safely and speedily "execute" Java bytecode-carrying packets. Finally, in a related effort his group is constructing a unique research instrument: a remotely configurable 1000-node network testbed and emulation facility. In these efforts, his group has developed much software, including the "Janos" active network OS, the "Knit" component composition language, the OSKit, the Flick IDL compiler, the Fluke/Flask OS, and the "Alta" and "KaffeOS" Java operating systems. In 1994 he founded the prestigious *Usenix/ACM/IEEE Symposium on Operating Systems Design and Implementation* (OSDI) conference series, and served as its first program chair.

Gary E. Lindstrom

Professor, School of Computing
Ph.D., Carnegie-Mellon University, 1971

Professor Lindstrom's²⁰ research interests include programming languages, databases, and scientific data management. He is on the editorial board of *International Journal of Parallel Programming*, and was Editor-in-Chief from its founding until 1993. With Doug DeGroot, he co-edited the book *Logic Programming: Functions, Relations and Equations* published by Prentice-Hall. Professor Lindstrom has been a member of the National Science Foundation Computer and Computation Research Advisory Committee, and served as a Distinguished Visitor of the IEEE Computer Society. In 1981 he received the College of Engineering Outstanding Teaching Award.

Emil Praun

Assistant Professor, School of Computing
Ph.D., Princeton University, 2002

Professor Praun²¹ joined the faculty in 2002. His main interests are in computer graphics. In particular, he has been working on applications of local parameterizations of triangle meshes: dividing 3D-embedded surfaces into collections of patches and "unfolding" each of the patches into the plane. He is also interested in combining direct acquisition of 3D surfaces with procedural detail generation methods. He is a recipient of the John E. and Marva M. Warnock Presidential Endowed Chair for Faculty Innovation in Computer Science.

¹⁸<http://www.cs.utah.edu/~alee/>

¹⁹<http://www.cs.utah.edu/~lepreau/>

²⁰<http://www.cs.utah.edu/~gary/>

²¹<http://www.cs.utah.edu/~emilp/>

John Regehr

Assistant Professor, School of Computing
Ph.D., Virginia, 2001

Professor Regehr's²² background is in operating systems and real-time systems, and his current research focuses on techniques and tools that make it easier and faster to develop efficient, reliable embedded software. He joined the faculty in 2003, having received his Ph.D. from the University of Virginia in 2001. Professor Regehr was previously a postdoc in the School of Computing from 2001-2003 and an adjunct assistant professor in the School of Computing during 2002-2003.

Richard F. Riesenfeld

Professor, School of Computing
Ph.D., Syracuse University, 1973

Professor Riesenfeld²³ has been involved in research in the areas of computer graphics, animation, computer aided geometric design and CAD/CAM since joining the faculty in 1972. Recently he has been investigating a broad spectrum of research problems in computer graphics, geometric modeling, and manufacturing within an integrated experimental testbed system motivated by the unifying principles of spline theory.

Ellen M. Riloff

Associate Professor, School of Computing
Ph.D., University of Massachusetts at Amherst, 1994

Professor Riloff²⁴ joined the faculty in 1994. Her research interests are in natural language processing, machine learning, and artificial intelligence. She is particularly interested in techniques for automatically generating dictionaries and knowledge bases for natural language processing. Most of her work revolves around the task of *information extraction*, which involves extracting information from text. The NLP research group at Utah has built its own NLP system called Sundance, which is a partial parser that activates and instantiates case frames for information extraction. Current research projects include bootstrapping techniques for learning extraction patterns, corpus-based techniques for learning semantic dictionaries, and corpus-based methods for coreference resolution.

Peter Shirley

Associate Professor, School of Computing
Ph.D., University of Illinois, 1991

Professor Shirley²⁵ joined the faculty in 1996. He is interested in creating highly realistic images of virtual environments, and visualization of complex data. The former involves explicit and procedural generation of geometric models with realistic optical characteristics, light transport simulation to determine the outgoing light distribution from surfaces, and tone reproduction to create images displayable on low dynamic range media such as paper and CRTs. The latter involves issues of visual representation of complex data, as well as strategies for navigation and interaction that help the user extract local and global information about the data. In 2000 Professor Shirley received the University of Utah Student's Choice Teaching Award and in 1998 he received the College of Engineering Outstanding Teacher Award.

²²<http://www.cs.utah.edu/~regehr/>

²³<http://www.cs.utah.edu/~rfr/>

²⁴<http://www.cs.utah.edu/~riloff/>

²⁵<http://www.cs.utah.edu/~shirley/>

Kris Sikorski

Professor, School of Computing
Ph.D., University of Utah, 1982

Professor Sikorski's²⁶ current research interests are in the areas of distributed parallel scientific computation and computational complexity with emphasis on information based complexity. Of specific interest are applied problems in geophysics (3-D modeling of earthquakes), combustion (fluid mechanics), and electromagnetic wave propagation (Maxwell equations). Various parallel explicit and implicit algorithms are being studied and implemented on massively parallel machines. Information based complexity is a study of optimal algorithms for problems which are approximately solved, because of partial and contaminated information. Optimal algorithms for solving nonlinear problems with use of various error criteria are of special interest to Professor Sikorski.

Claudio Silva

Associate Professor, School of Computing
Ph.D., SUNY Stonybrook, 1996

Professor Silva²⁷ joined the faculty in 2003. His main research interests are in graphics, visualization, applied computational geometry, and high-performance computing. His current research focuses on architectures and algorithms for building scalable displays, rendering techniques for large datasets, 3D scanning, and algorithms for graphics hardware, and includes recent work on 3D compression and multi-resolution techniques for point-sets and polygonal surfaces, large-scale 3D photography, visibility culling and volume rendering.

Konrad Slind

Assistant Professor, School of Computing
Ph.D., TU Munich, 1999

Professor Slind²⁸ joined the faculty in 2001. His research interests are in logic and functional programming. He is particularly interested in higher order logic, its implementation, and its application to deductive verification of system properties. Recent research has investigated the modeling of generic and functional programming. Before coming to Utah, he participated in a European project that developed middleware for applications that require a theorem proving component.

Frank Stenger

Professor, School of Computing
Ph.D., University of Alberta, 1965

Professor Stenger's²⁹ research interests include the development of new methods of computation and the computer solution of computationally difficult problems from science and engineering, such as inverse problems, crack problems, flow problems and heat problems. He developed the Sinc methods, which provide optimal algorithms in all areas of engineering computation. He is currently writing, jointly with Michael O'Reilly and Tao Zhang, a *Sinc Tool Box* computer-based tutorial package to make these methods accessible to users. One of his students (Kenneth Parker) has recently completed his Ph.D. dissertation *PTOLEMY: A Sinc-Collocation Mapping Sub-System*, which is a computer sub-package of *Maple* that automates the solution of partial differential equations. Several of his students have recently written or are presently writing computer packages for solving a broad range of difficult engineering problem—such as Navier-Stokes equations (Barkey and Vakili, Narasimhan), Maxwell equations (Naghsh-Nilchi) based on his recently discovered Sinc method of approximating indefinite convolutions, which leads to a unified approach for solving elliptic, parabolic, and hyperbolic differential equations. Another student (Ross Schmittlein) is writing a package based on Sinc, constructing conformal maps. Stenger and his former student O'Reilly have been developing methods which make it possible to invert the Helmholtz equation without computing the forward solution. During the next few academic years he expects to extend these inversion methods so that they can be applied to rendering, to visualization, to the determination of paths for robots, and to the inversion of heat and electromagnetic problems for medical and geophysical applications. Seven of his papers have been accepted for publications during this past academic year.

²⁶<http://www.cs.utah.edu/~sikorski/>

²⁷<http://www.cs.utah.edu/~csilva/>

²⁸<http://www.cs.utah.edu/~slind/>

²⁹<http://www.cs.utah.edu/~stenger/>

Cynthia A. Thompson

Assistant Professor, School of Computing
Ph.D., University of Texas, 1998

Professor Thompson³⁰ joined the faculty in 2000. Her research interests are in machine learning, natural language processing, and artificial intelligence. She is especially interested in applying machine learning to complex, relational tasks such as language processing and adaptive interfaces. After receiving her Ph.D., she spent two years at the Center for the Study of Language and Information at Stanford University, building and studying conversational interfaces that adapt themselves over the course of several interactions with a user.

William B. Thompson

Professor, School of Computing
Ph.D., University of Southern California, 1975

Professor Thompson's³¹ primary research interest is in the area of visual perception. Currently, he is exploring how an understanding of computational vision can aid in improving the spatial information conveyed by graphical displays. He is also active in the exploration of techniques for analyzing visual motion, sensing for manufacturing, and vision-based navigation. Professor Thompson joined the faculty in 1991 after 16 years in the Computer Science Department at the University of Minnesota.

Ross Whitaker

Associate Professor, School of Computing
Ph.D., University of North Carolina, 1993

Professor Whitaker³² joined the faculty in 2000. He has interests in computer vision, visualization, and image processing. In the area of medical image processing, Dr. Whitaker is a codeveloper of the "Insight" toolkit for segmenting and visualization the 3D color data associated with the Visible Human Project. Dr. Whitaker is also working on new, statistics-based methods for building surface models from noisy range measurements, such as those from laser radar and ultrasound. In the area of visualization, Dr. Whitaker is developing new methods for visualizing biological volume datasets and for processing the surface models that are derived from these datasets.

Joseph L. Zachary

Clinical Professor, School of Computing
Ph.D., Massachusetts Institute of Technology, 1987

Professor Zachary³³ joined the faculty in 1987. He is interested in finding ways to use computers in teaching science and engineering in general, and computer science in particular. He is currently developing Web-based tools and curricula for teaching introductory programming, computer science, and scientific computing courses. The author of two textbooks in scientific programming, Professor Zachary received the 1999 IEEE Computer Science and Engineering Undergraduate Teaching Award, won the University of Utah Distinguished Teaching Award in 1997, was named a Department of Energy Undergraduate Computational Science Education Award winner in 1996, was a University of Utah Presidential Teaching Scholar in 1995, and received the College of Engineering Outstanding Teaching Award in 1990.

³⁰<http://www.cs.utah.edu/~cindi/>

³¹<http://www.cs.utah.edu/~thompson/>

³²<http://www.cs.utah.edu/~whitaker/>

³³<http://www.cs.utah.edu/~zachary/>