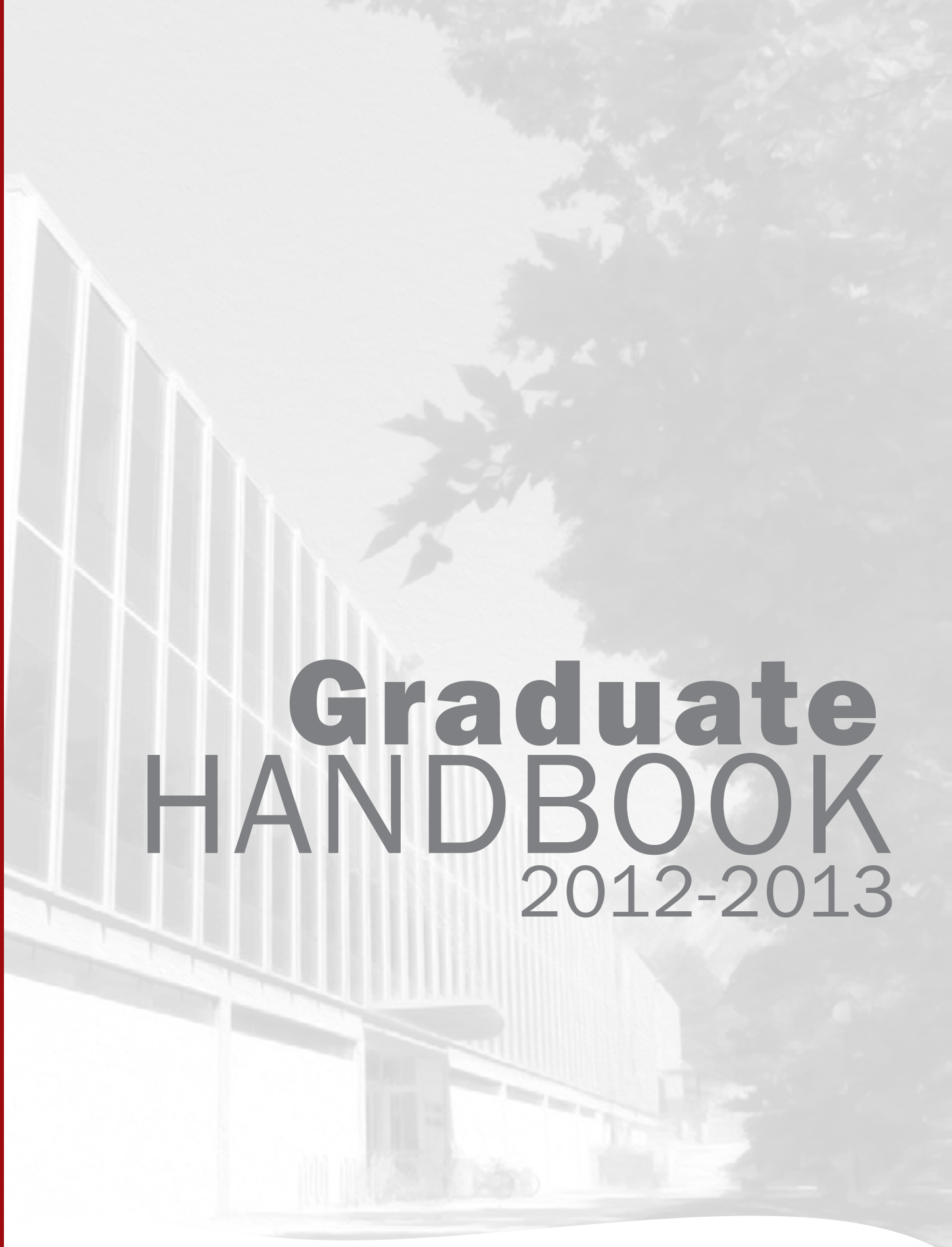

Graduate HANDBOOK 2012-2013

SCHOOL OF COMPUTING
UNIVERSITY OF UTAH

Welcome

The School of Computing was originally founded as the Computer Science Department at the University of Utah in 1965 by David C. Evans (In 2000, the department officially became the School of Computing). In 1985, the department reached 10 full-time faculty members. By 1996, it had doubled to 20. Today the School of Computing boasts 35 regular faculty members, four research faculty, and twenty adjunct faculty, with more than 396 CS undergraduate students, 110 CE undergrads, 94 enrolled in the M.S. program and 123 enrolled in the CS Ph.D. program.

The School of Computing at the University of Utah has a long history of distinguished faculty and alumni who have made substantial contributions to research and industry. SoC Ph.D. graduate John Warnock (1969) developed the Warnock recursive subdivision algorithm for hidden surface elimination, and later founded Adobe Systems, which developed the Postscript language for desktop publishing. Alan Ashton, 1970 Ph.D. graduate went on to teach at Brigham Young University and founded WordPerfect. Computer animation pioneer Ed Catmull, received both his B.S. and Ph.D. degrees in computer science from the University of Utah. Today he is the co-founder and president of Walt Disney and Pixar Animation Studios. He received a technical Academy Award in 1996 from the Academy of Motion Picture Arts and Sciences for "pioneering inventions in Digital Image Compositing".

Today's School of Computing faculty and students continue to carry the tradition of innovative research and technological advancements at the University of Utah.

Research Areas

Applied Computation, including Image Analysis, Scientific Computing, and Visualization

Artificial Intelligence, including Autonomous Systems, Natural Language Processing, Machine Learning and Robotics

Computer Graphics, including Geometric Design and Computation, Perception, Simulation & Electronic Animation and Game Engineering

Computer Systems, including Architecture and VLSI, Parallel Computing, Mobile and Embedded Systems, Networking and OS, Programming Languages, Compilers and Educational Software

Program Analysis and Formal Methods, including Static Analysis and Verification

Data Management, Analysis and Visualization, including Algorithms, Computational Geometry, Databases, Data Mining, and Data Visualization in large scale data

TABLE OF CONTENTS

The official copy of the handbook is the printed one on file at the SoC office, and controls if there are any differences between it and any other statement of rule or policy.

ADMINISTRATION

DIRECTOR
Al Davis
Professor

ASSOCIATE DIRECTOR
Ellen Riloff
Associate Professor

ASSOCIATE DIRECTOR
Ross Whitaker
Professor

DIRECTOR OF GRADUATE STUDIES (DGS)
Mike Kirby
Associate Professor

DIRECTOR OF GRADUATE ADMISSIONS
Sneha Kasera
Associate Professor

DIRECTOR OF BS/MS PROGRAM
Thomas Fletcher
Assistant Professor

DIRECTOR OF CES PROGRAM
Martin Berzins
Professor

TRACK DIRECTORS

COMPUTER ENGINEERING
Erik Brunvand
Associate Professor

DATA MANAGEMENT & ANALYSIS
Feifei Li
Assistant Professor

DIGITAL MEDIA
Erik Brunvand
Associate Professor

GAME ENGINEERING
Bob Kessler
Professor

GRAPHICS & VISUALIZATION
Charles Hansen
Professor

IMAGE ANALYSIS
Thomas Fletcher
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ROBOTICS
John Hollerbach
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Computer architecture: clustered processors, memory hierarchy bottlenecks

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Assistant Professor
Computer graphics and animation

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Professor
Adaptive numerical methods, parallel algorithms, computational fluid & solid mechanics applications

Richard Brown
Dean of Engineering and Professor
Microprocessor design, circuits to minimize leakage, solid-state chemical sensors

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Associate Professor
Computer architecture & VLSI systems

Elaine Cohen
Professor
Computer graphics, scientific visualization, geometric modeling, mechanical design

Al Davis
Director and Professor
Embedded/multi-core architecture, auto. domain specific architecture synthesis, VLSI, asynchronous circuits

Matthew Flatt
Associate Professor
Programming languages & systems

Thomas Fletcher
Assistant Professor
Shape analysis, computer vision image analysis, image processing

Guido Gerig
Professor
Medical image analysis

Ganesh Gopalakrishnan
Professor
Formal Analysis of Concurrent Systems (MPI, GPU, Threading), Symbolic, Dynamic, and Runtime Verification Methods and Tool Frameworks

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Optimization, parallelization & compilers

Charles Hansen
Professor
Visualization, computer graphics, parallel computation, computer vision

Tom Henderson
Professor
Computer vision, mobile robotics

Lee Hollaar
Professor
Digital intellectual property law

John Hollerbach
Professor
Robotics, teleoperation, virtual reality, & human motor control

Chris Johnson
Distinguished Professor
Scientific computing, visualization, imaging, & problem solving environments

Sneha Kasera
Associate Professor
Computer networks/systems, mobile systems and wireless networks, network security

Bob Kessler
Professor
Systems software & software engineering

Mike Kirby
Associate Professor
Scientific computing & visualization, High Performance Computing, Concurrent Programming

Feifei Li
Assistant Professor
Databases, large-scale data management

Miriah Meyer
Assistant Professor
Visualization & large multidimensional data

FACULTY

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Assistant Professor
Security, parallelism, verification & optimization

Valerio Pascucci
Professor
Computer graphics, computational geometry, geometric programming, & solid modeling

Jeff Phillips
Assistant Professor
Algorithms, data mining & machine learning

Zvonimir Rakamaric
Assistant Professor
Formal methods & verification

John Regehr
Associate Professor
Embedded systems, sensor networks, static analysis, operating systems

Rich Riesenfeld
Professor
Computer graphics, geometric modeling, & design

Ellen Riloff
Associate Professor
Natural language processing, information retrieval, & artificial intelligence

William Thompson
Professor
Visual perception, computer graphics, virtual environments, & computer vision

Jur van den Berg
Assistant Professor
Robotics & virtual environments

Kobus van der Merwe
Associate Professor
Networked systems, network management, mobile networking, network security and cloud computing.

Suresh Venkatasubramanian
Assistant Professor
Algorithms, computational geometry & data mining

Ross Whitaker
Professor
Image processing, medical image analysis, data analysis and visualization & geometry processing

Cem Yuksel
Assistant Professor
Physically-based simulation, image synthesis, GPU algorithms

MASTER'S PROGRAM

MASTER'S IN COMPUTER SCIENCE & MS IN COMPUTING

M.S. DEGREES OPTIONS

There are two Master's degree programs within in the School of Computing (SoC) at the University of Utah:

- MS in Computer Science
- MS in Computing

Transfers between degree programs will be considered between semesters and will occur only once per academic year.

An MS in Computing is earned within a particular track. Students are, in part, admitted based upon the track that they have selected during the admissions process. If students wish to switch tracks, they should seek approval from DGS and from the track directors of the tracks between which they wish to switch. Some flexibility will be allowed in terms of switching tracks; however, to remain in good standing, a student has to reach certain due progress milestones as determined by their degree/track required course specifications.

Master's Degrees:
Master's in Computer Science

Master's in Computing
Tracks:
- Computer Engineering
- Data Management and Analysis
- Digital Media
- Game Engineering
- Graphics and Visualization
- Image Analysis
- Robotics

The Program of Study form should be filed with the School of Computing in the second semester of study and with the Graduate School prior to taking the qualifying examination. The Program of Study form must be submitted to the Graduate Records Office no later than the last day of the semester proceeding the semester of graduation.

The Director of Graduate Studies (DGS) is the responsible entity for all graduate degree related issues. He/she will act in consultation with the track directors for administration of the Computing Degree program. In the information that follows: statements stating that something will be done/approved by DGS should be understood to mean "DGS and/or the track directors".

REGISTRATION REQUIREMENTS

Full-time graduate students in the School of Computing are ordinarily requested to register for 10 hours for TAs and 10 hours for RAs, which includes regular courses, seminars, and research credits as appropriate. This is especially the case for students being supported via research or teaching assistantships. Students who are not being supported by the school are required to take nine hours to be classified as full- time.

Graduate School policy dictates that a graduate student who receives a full tuition waiver during any semester in which he or she holds an assistantship, fellowship or traineeship is required to register for at least nine semester hours, including thesis research and seminars. Students must be registered for at least three hours per semester, exclusive of summer semester, to remain in a graduate degree program. Students who do not maintain continuous registration and who have not been granted a leave of absence by the Graduate School are subject to being discharged from the degree program.

Students doing theses must be registered for at least three semester hours during the semester of the student's thesis defense. Once a student has passed the thesis defense, the student does not have to register the next term if within the 90-day period to turn in the final thesis.

COURSE REQUIREMENTS

All degree programs have certain course requirements. However, these represent a necessary, rather than sufficient, set of courses for graduation. To graduate, this coursework must appear on a student's approved program of study, a customized course plan developed by the student in conjunction with their committee.

Courses that count toward graduation must be on the program of study. The following default restrictions apply to these courses:

- CS courses must have a course number of 6000 or above (CS 5470: Compiler Principles and Techniques will also be allowed)

- Non-CS courses must have a course number of 5000 or above
- A grade of B- or better
- The GPA for all required courses must be at least 3.0

In the subsequent pages of this document, each degree program and/or track may specify modifications and/or additions to these restrictions. Students should also consult the Graduate School Handbook concerning any University requirements.

A student may register for CS 6020 if that student writes and publishes a peer-reviewed article based on research performed in the University of Utah School of Computing (SoC). The contribution of the student to the article should be equivalent to that conferred by first authorship. The paper should be published in a respectable outlet. It is the responsibility of the student's advisor to determine whether the student has made such a contribution, and whether the outlet is of sufficient quality. This paper must be accepted for publication prior to the end of the second year of study.

COURSE WAIVERS

A student may obtain a waiver for any of the required courses by demonstrating prior knowledge (e.g., completion of a similar course taken at another University). This waiver is obtained by petitioning the DGS. The waiver procedure should be initiated by first contacting the Graduate Coordinator. Waiving a required course does not reduce the 30 graduate credit hour requirement.

M.S. SUPERVISORY COMMITTEE

The M.S. Supervisory Committee consists of three members. At least two members must be SoC faculty. Any SoC regular faculty member may serve as a supervisory committee chair. Research or adjunct faculty may chair supervisory committees if accorded that privilege by the regular faculty. All official decisions of the committee are decided by majority vote.

M.S. COMPREHENSIVE EXAM

For the project and thesis options of this degree, the M.S. comprehensive exam will be administered by the student's supervisory committee and can be coupled with (i.e. satisfied by) a project or thesis proposal defense, and/or meeting a specified level of performance on a set of classes.

For students not doing a project or thesis, the comprehensive exam will typically be passed by meeting the grade requirements in required courses for their degree/track, but this can be modified at the discretion of the student's committee.

M.S. TRANSFER CREDIT

A student may not count more than nine semester hours of non-matriculated graduate work toward any graduate degree unless the student's registration for more than nine semester hours is specifically approved in advance by the SoC Director and the Dean of the Graduate School. Graduate courses taken as an undergraduate at the University of Utah cannot be counted towards a degree program unless a petition for graduate credit was filed with the University's Registrar at the time the course was taken.

Students who have done graduate study at other institutions may transfer up to six semester hours to the University of Utah. The courses must be bona fide graduate level class work (e.g., independent study is excluded), with grade B- or better. Students must be able to show that the course work was not used toward any other degree.

Approval of each course is granted by the student's supervisory committee and the DGS. Course appropriateness is determined by consideration of course content and the student's declared research area. Approved courses are certified by a transfer credit form. Approval of a course taken elsewhere for transfer credit does not imply fulfillment of any specific required course.

M.S. PROJECT DOCUMENT (Project Option)

The project is done through an independent study with a professor in the School of Computing. The parameters for the scope of the project is set forth at the onset of the independent study, and the defense of the project will be done before the student's entire committee plus the professor in charge of the independent study (normally with the chairperson of the committee being the professor with whom the independent study was done). The student is responsible for arranging a time and place for the defense together with the committee.

M.S. THESIS DOCUMENT (Thesis Option)

The supervisory committee must give preliminary approval of the thesis prior to the defense. The defense can be scheduled after this approval. To schedule the defense, contact the Graduate Coordinator. Students are strongly encouraged to schedule the defense during a regular colloquium slot.

The student must provide one copy of the thesis to the chair of the supervisory committee at least three weeks before the defense, and one copy to each of the other committee members at least two weeks prior to the defense. A complete draft of the thesis must be delivered to the Graduate Coordinator two weeks prior to the announced time of defense. This copy will be made available for public access. Students are encouraged to place an additional copy on the SoC web pages at least one week prior to the announced time of defense.

After successfully defending the thesis, the student must obtain approval from the Final Reader (typically the supervisory committee chair), School Director, and Dean of the Graduate School. A draft of the final thesis must then be presented to the Thesis Editor. Successful completion of the defense must be reported to the Graduate School at least four weeks before the last day of examinations in the final semester.

Students should also read the document regarding copyright notices provided by the School and declare their intentions regarding granting the School the right to photocopy the thesis before notifying the Graduate Coordinator of completion of the defense.

The student has one month after the defense to make any revisions prior to submitting the thesis to the Graduate School Thesis Editor. There will be at most two additional months to complete any changes required by the Thesis Editor before final acceptance. If either of these deadlines are not met, the candidate must redo the oral defense. The final thesis must be filed one week before the end of the semester of graduation.

Students are expected to offer each committee member a bound copy of the thesis once it is completed. Detailed policies and procedures concerning the thesis are contained in "A Handbook for Theses and Dissertations" published by the Graduate School.

RESIDENCY

One year of study must be spent in full-time residency at the University (i.e., the student must enroll for a minimum of nine hours per semester for two consecutive semesters, summer optionally excluded). After the residency requirement is fulfilled, registration for three semester hours of CS 6970 (M.S. Thesis Research) is considered a full load. At least 24 semester hours must be in resident study at the University of Utah.

LEAVE OF ABSENCE

If a student does not plan to take classes during a Fall or Spring semester, a leave of absence must be requested. Contact the Graduate Coordinator for the proper form.

MONITORING OF PROGRESS

Annual meetings and reports: Each year the student will prepare a one-page summary of their progress and submit it to the advisory committee in preparation for a meeting that includes the student and advisory committee. The advisory committee will meet with the student and hear a presentation from the student and engage the student in a discussion about their progress in the program. A "meeting" in this context is

GRADUATE STUDENT PROGRESS GUIDELINES FOR THE M.S. PROGRAM

Milestone	Good Progress	Acceptable Progress	Comments
Choose advisor	1 Semester	2 Semesters	
Full committee formed	2 Semesters	3 Semesters	
Program of study	2 Semesters	3 Semesters	
Complete required courses	3 Semesters	3 Semesters	Program requirement: 3 semesters
Defend proposal	3 Semesters	4 Semesters	U. requirement: 1 semester before defense
Thesis defense	4 Semesters	5 Semesters	
Final document			U. requirement: document finalized within three months of the defense

some form of interactive communication between the student and the committee. The important aspect of this meeting is that the student and the committee be able to ask questions of one another and respond to those questions. In this document advisory committee refers to either the initial committee or full committee, depending on which committee is active during that particular part of the program.

The advisor will prepare a short report (approved by the advisory committee), which includes a checklist of milestones (using a form provided by the School). This report will comment on any milestone that is not met within the time frame denoted as "good." In the event that students have unmet milestones that have passed the "acceptable" time frame (as indicated in the guidelines), the advisory committee can either request an exception to keep the student in good standing (and justify the exception) or recommend that the student not be considered in good standing.

The advisory committee will also give an overall evaluation of the student's progress as acceptable, unacceptable, or borderline and make recommendations of what (if any) actions should be taken by the student and the department.

Actions by the DGS and the School: In the event that a student is found not to be in good standing (a decision made by the DGS based on reports from the advisory committee) one or more actions may be taken. For example, the School may assign the DGS to counsel the student, deny opportunities to serve as departmentally funded TA, discontinue tuition waiver benefits, or remove the student from the program. In the event that a faculty member fails to meet with advisory committees and report on their students, the DGS may elect to disallow this faculty to advise new students.

DEFENSE (Thesis Option)

Within three months of the thesis defense, the student must receive final reading approval from the thesis committee and the thesis editor. Failure to do so will result in probationary status and will require that the student re-defend the thesis.

A student may pursue an M.S. with a (1) thesis option, or (2) a project option, or (3) a course-only option. The M.S. program requires 30 total semester hours of graduate coursework (including thesis hours for the thesis option).

COURSE REQUIREMENTS: M.S. IN COMPUTER SCIENCE

Students should select one course from each of the three categories. Three of these courses are required for students in both the thesis and non-thesis tracks.

CATEGORY #1	
CS 6100	Foundations of Computer Science
CS 6150	Algorithms
CATEGORY #2	
CS 6460	Operating Systems *
CS 6480	Advanced Computer Networks
CS 7460	Advanced Operating Systems
CATEGORY #3	
CS 6810	Advanced Computer Architecture *
CS 6710	Digital VLSI Design
CS 6720	Advanced Integrated Circuit Design
CS 6740	CAD of Digital Circuits
CS 6770	Advanced Digital VLSI Systems Design
CS 6830	VLSI Architecture
CS 7820	Parallel Computer Architecture

* Suggested course

At most, six semester hours can be courses outside of computer science. **Seminars may not be counted.**

For students completing a thesis: at least one non-required CS course must be taken excluding independent study, seminars, or thesis research credit; independent study (CS 6950) can be included in the required 30 semester hours only when the project is self-contained and independent of thesis research.

For students not completing a thesis, at most three of the required 30 semester hours can be independent study (CS 6950 and CS 7950).

Students **not** doing a thesis must also take at least two courses from the following six choices:	
CS 5470	Compiler Principles and Techniques
CS 6210	Advanced Scientific Computing
CS 6300	Artificial Intelligence
CS 6480	Advanced Computer Networks
CS 6530	Database Systems
CS 7520	Programming Languages and Semantics

The following may also be used to fulfill this requirement:	
CS 6220	Advanced Scientific Computing II
CS 6350	Machine Learning
CS 6470	Advanced Topics in Compilation
CS 6510	Functional Programming
CS 6785	Advanced Embedded Systems
CS 7120	Information Based Complexity
CS 7460	Advanced Operating Systems
CS 7820	Parallel Computer Architecture

A student may pursue an M.S. with a (1) thesis option, or (2) a project option, or (3) a course-only option. The M.S. program requires 30 total semester hours of graduate coursework (including thesis hours for the thesis option).

TRACK FACULTY

Al Davis, Rajeev Balasubramonian, **Erik Brunvand (Track director),** Priyank Kalla (ECE), Chris Myers (ECE), John Regehr, Thomas Schmid (ECE), Ken Stevens (ECE)

COURSE REQUIREMENTS: M.S. IN COMPUTING, COMPUTER ENGINEERING Required courses:
CS/ ECE 6810 Computer Architecture
CS/ ECE 6710 Digital VLSI Design

Thesis option: 2 required, 2 electives from restricted list
Project option: 2 required, 3 electives from restricted list
Course-only option: 2 required, 4 electives from restricted list

* Additional courses on the program of study must be approved by the student's committee.

At least 24 hours of the 30 M.S. course and thesis hours must be in resident study at the University of Utah. A full time student working on an M.S. program is expected to complete the degree requirements within two calendar years. The Graduate School limits M.S. programs to four years.

ELECTIVES:
Four courses must be taken by students doing the coursework option, three courses must be taken by students doing the project option, and two courses must be taken by students doing the thesis option. Courses selected should be in an area of specialization selected by the student.

CS 6110	Formal Methods in System Design
CS 6150	Advanced Algorithms
CS 6235	Parallel Programming for Many Cores
CS 6460	Operating Systems
CS 6470	Compiler Principles and Techniques
CS 6475	Advanced Compilers
CS 6480	Advanced Computer Networks
CS 7460	Distributed Operating Systems
ECE 5325	Wireless Communications Systems
ECE 5520	Digital Communications Systems

Computer Engineering Track Elective courses: Continued	
ECE 6530	Digital Signal Processing
ECE 6531	Advanced Digital Signal Processing II
ECE 6580	Implementation of Digital Signal Processing
CS/ ECE 6720	Analog Integrated Circuit Design
CS/ ECE 6740	Computer-Aided design of Digital Circuits
CS/ ECE 6745	Testing and Verification of Digital Circuits
CS/ ECE 6750	Synthesis and Verification of Async VSLI Systems
CS/ ECE 6770	Advanced Digital VLSI Systems Design
CS/ ECE 6780	Embedded Systems Design
CS/ ECE 6785	Advanced Embedded Software
CS/ ECE 6830	VLSI Architecture
CS/ ECE 7810	Advanced Architecture
CS/ ECE 7820	Parallel Architecture

Thesis Option:
This option involves research on a thesis area and a written thesis submitted to the graduate school. A minimum of six thesis hours are required, and there must be at least 20 classroom hours in the program of study. A maximum of three hours of Independent/Special Studies (CS/ECE 6950) is permitted only when it is self-contained and not related to the thesis.

Project Option:
Similar to the coursework option with an independent/special study on a project topic required with a project report submitted to the independent/special study advisor. A minimum of three hours and maximum of six hours of Independent/Special Studies (CS/ECE 6950) are allowed.

Course-only Option:
In this option all the course requirements are fulfilled through graduate courses (no thesis hours). No more than three hours can be Independent/ Special Studies (CS/ECE 6950).

A maximum of two seminar hours will be permitted.

A student may pursue an M.S. with a (1) thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for either option is 30 graduate level classes (this includes 5000 and 6000 level courses as designated by departments). A maximum of 6 project hours or 9 thesis hours is allowed to be included in the program of study for students in the project or the thesis option. A minimum of 6 hours of thesis research is required for the thesis option.

TRACK FACULTY

Tom Fletcher, Mike Kirby, **Feifei Li (Track director)**, Miriah Meyer, Valerio Pascucci, Jeff Phillips, Suresh Venkatasubramanian

COURSE REQUIREMENTS Required courses: must take 4 required courses.	
CS 6150	Algorithms
CS 6350 Machine Learning / CS 6955 Data Mining / CS 6960 Non-Parametric Statistics	
CS 6530	Database Systems
CS 6630	Scientific Visualization

A minimum of a B or greater is required for any of the required courses.

ELECTIVES Three courses from the following list are required:	
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6230	High Performance Parallel Computing
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6640	Image Processing
CS 6963	Parallel Programming for GPUs
CS 6964	Applications of NLP
CS 5610	Interactive Computer Graphics
CS 6610	Advanced Computer Graphics I

In addition to the electives list, students may take any graduate-level courses taught by any track committee faculty members to fulfill the elective requirements. With approval of the supervisory committee, a student may take two elective courses at the graduate level or higher from other departments, excluding independent study, seminars and research credit. Students may place out of the above requirements by substituting or transferring courses from other institutions at the discretion of the TCF Chair.

In all three options, neither directed independent study (DIS) nor seminar hours can be included to fulfill the 30 graduate level credits requirement. However, once a student enters the project or the thesis option, his/her prior DIS hours can be converted into project or thesis hours if the student's advisor deems these DIS hours relevant to the project or the thesis the student will be working on.

A student may pursue an M.S. with a(1) thesis option, or (2) a project option, or (3) a course-only option. The M.S. program requires 30 total semester hours of graduate coursework (including thesis hours for the thesis option).

Thesis option: 4 required courses (12 credits), **Project option:** 4 required courses (12 credits), **Course-only option:** 4 required courses (12 credits)

TRACK FACULTY

Roger Altizer, **Erik Brunvand (Track director),** Adam Bargteil, Craig Caldwell, Bob Kessler, Miriah Meyer, Mark van Langeveld, Cem Yuksel

COURSE REQUIREMENTS Choose two of the following MGS course sequences (each sequence=2 courses)	
CS 6070/6071	Game Design I, II
CS 6080/6081	Game Arts I, II
CS 6090/6091	Game Engineering I. II

The remaining 18 credit hours (6 classes) should be 6000/7000 courses in CS, or other courses as approved by the student's committee, and can include the III class in a series above. For a course-only MS in Digital Media, at most 3 credit hours may be independent study. For a project-based MS, at least 3 and at most 6 hours should be independent study with the project being in a digital media area (as defined by the student and committee). For a thesis MS, at least 6 hours of Thesis Research (CS6970) should be included.

Theme Groupings for Electives: Students are also required to define a theme for at least three of their electives and have that theme (and those courses) approved by their committee. The theme can be negotiated between the student and their committee. The idea is to have them plan and defend how their electives fit into a coherent Digital Media theme.

Example theme groupings: Each grouping is three courses for 9 hours or half of the elective hours. Note that these are example course groupings, but it is not guaranteed that a Digital Media track student will automatically be able to take the suggested courses that are offered in other departments. Individual negotiation will be required for entry into upper division courses in other departments, and especially for courses in other colleges.

GRAPHICS	
CS 6610	Interactive Computer Graphics
CS 6620	Advanced Graphics II : Ray Tracing
CS 6640	Image Processing for Graphics
EMBEDDED/ART	
CS 5789	Kinetic Art and Embedded Systems
CS 6420	Grad Projects, Sculpture
CS 6780	Kinetic Art and Embedded Systems
CHARACTER DESIGN	
CS 6050	3D Modeling for VGA & M
CS 6964	Digital Figure Sculpting
CS 6967	Character Animation

HCI	
CS 6050	Perception for Graphics
CS 6360	Virtual Reality
CS 6540	HCI
ART DIRECTION	
CS 6620	Grad Projects, Graphic Design
CS 6720	Grad Projects, Photo
CS 6964	Digital Figure Sculpting
INFO VIS	
CS xxxx	
CS 6630	Scientific Visualization
CS 6961	Fundamentals of Visual Computing
LIGHTING DIRECTION	
CS 6050	Perception for Graphics
FILM 6905-04	Grip and Lighting
THEATER 6xxx	Grad hour in Theatrical Lighting
COMPUTER ANIMATION	
FILM 6610	Grad Computer Animation
FILM 6810	Grad Screenwriting
FILM 6905-03	Digital Cinema Workflows
CS 6967	Character Animation
EXPERIMENTAL MEDIA	
CS 5742	Kinetic Art
MUSIC 6360	Electronic Music Composition
ART 6xxx	Grad hours for sculpture or photo
SOUND DESIGN FOR DIGITAL MEDIA	
CS 6360	Virtual Reality
FILM 6420	Sound for Film and Digital Media
MUSIC 6538	Instrumentation
PHOTO-BASED DIGITAL MEDIA	
CS 6050	Image Processing
CS 6640	Perception for Graphics
ART 6720	Grad Projects, Photo

A student may pursue an M.S. Computing: Game Engineering with a project option only. The program requires a minimum of 43 credit hours of graduate coursework. Of those 43 credits, 6 credits are electives.

TRACK FACULTY

Roger Altizer, Adam Bargteil, Craig Caldwell, **Bob Kessler (Track director),** Mark van Langeveld, Cem Yuksel

COURSE REQUIREMENTS Required courses:	
CS 6070	Game Design I
CS 6071	Game Design II
CS 6080	Game Arts I
CS 6081	Game Arts II
CS 6082	Game Arts III
CS 6083	Game Arts IV
CS 6090	Game Engineering I
CS 6091	Game Engineering II
CS 6092	Game Engineering III
CS 6093	Game Engineering IV
CS 6095	Internship
Elective courses (to equal 43 total credit hours):	
Graduate level CS or affiliated courses from other relevant departments as approved by your supervisory committee.	

The internship can be taken any semester after the first semester.

Game Engineering I should be taken by most students, however especially well prepared students may take an elective instead. Permission of the Game Engineering I instructor must be obtained to replace the class with an elective.

A student may pursue an M.S. with a (1) course-only option, (2) a project option, or (3) a thesis option. The minimum number of credits for any option is 31 with 30 from graduate level (6000 level for CS courses) and 1 hour of either CS 7942 Visualization Seminar or CS 7933 Graphics Seminar. Seminars may not replace required or elective courses.

TRACK FACULTY

Adam Bargteil , Martin Berzins, Elaine Cohen, **Charles Hansen (Track director),** Chris Johnson, Mike Kirby, Miriah Meyer, Valerio Pascucci, Rich Riesenfeld, Bill Thompson, Cem Yuksel

COURSE REQUIREMENTS: M.S. IN COMPUTING, GRAPHICS AND VISUALIZATION TRACK (COURSE ONLY OPTION) Required courses:	
CS 6610	Interactive Computer Graphics
CS 6630	Scientific Visualization
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
Three courses from the following list are required:	
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Advanced Graphics II : Ray Tracing
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
CS 6960	Computational Geometry
Elective courses (to equal 30 total credit hours):	
Graduate level CS courses and independent study (a maximum of three hours of independent study is allowed). Thesis research hours are not counted toward the degree in the course-only option.	

COURSE-ONLY OPTION

With approval of the supervisory committee, a student may take two elective courses at the graduate level or higher from other departments including 5000 or 6000 level courses, excluding independent study, seminars, research credit.

COURSE REQUIREMENTS: M.S. IN COMPUTING, GRAPHICS AND VISUALIZATION TRACK (PROJECT OPTION) Required courses:	
CS 6610	Interactive Computer Graphics
CS 6630	Scientific Visualization
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
Three courses from the following list are required:	
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Advanced Graphics II : Ray Tracing
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
CS 6960	Computational Geometry
Elective courses (to equal 30 total credit hours):	
Students must take at least 3 and up to 6 credits (no more than 6 credits) of independent study for their MS project.	

PROJECT OPTION

With approval of the supervisory committee, a student may take two elective courses at the graduate level or higher from other departments including 5000 or 6000 level courses, excluding independent study, seminars, research credit.

COURSE REQUIREMENTS: M.S. IN COMPUTING, GRAPHICS AND VISUALIZATION TRACK (THESIS OPTION) Minimum 21 hours classroom courses and six hours of thesis research are required. Three of the following regular courses are required in addition to the seminar:	
CS 6610	Interactive Computer Graphics
CS 6630	Scientific Visualization
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
Three courses from the following list are required:	
CS 6320	Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Computer Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
CS 6960	Computational Geometry
Elective courses (to equal 30 total credit hours):	
Graduate level CS courses and independent study (a maximum of three hours of independent study is allowed). Thesis research hours are not counted toward the degree in the project option.	
A minimum of six hours of thesis research (CS 6970) is required.	

THESIS OPTION

With approval of the supervisory committee, a student may take two elective courses at the graduate level or higher from other departments including 5000 or 6000 level courses, excluding independent study, seminars, research credit.

Students may complete a thesis or non-thesis option. Both options have the same course requirements. A minimum of 30 credits is required. Independent study and seminars cannot be used as part of the required 30 hours. MS Residency Requirement: At least 24 semester hours must be in resident study at the University of Utah.

TRACK FACULTY

Tom Fletcher (Track director), Guido Gerig, Tom Henderson, Marcel Prastawa, Tolga Tasdizen, Bill Thompson, Ross Whitaker

COURSE REQUIREMENTS Required courses:	
CS 6640	Image Processing
CS 7640	Advanced Image Processing
Students are also required to complete two out of the following three courses:	
CS 6150	Algorithms
CS 6320	3D Computer Vision
CS 6350	Machine Learning

Students may place out of any of the above required courses by substituting or transferring courses from other institutions. Substitute courses must be regular classes with exams and/or assignments, not seminar, readings, or independent study classes.

ELECTIVES The Program of Study must be courses at the 6000 level or above and research credits. Independent studies should not be included. Of the required 30 semester hours, up to 24 credit hours must be graduate courses within the School of Computing or on the following list of recommended electives. Recommended elective courses within the School of Computing and other departments are listed below (organized into general topic areas):	
IMAGING, VISUALIZATION & GRAPHICS	
CS 6630	Scientific Visualization
CS 6650	Perception for Graphics
CS 6670	Computer-Aided Geometric Design I
BIOEN 6330	Principles of Magnetic Resonance Imaging
BIOEN 6330	Mathematics of Imaging
COMPUTATIONAL METHODS	
CS 6160	Computational Geometry
CS 6210	Advanced Scientific Computing
CS 6220	Advanced Scientific Computing II
CS 6550	Foundations of Algorithms in Computer Graphics and Visualization
CS 6967	Computational Topology
STATISTICS & LEARNING	
CS 6300	Artificial Intelligence
CS 6560	Computational Statistics
CS 6960	Nonparametric Statistics
ECE 6540	Estimation Theory

A student may pursue an M.S. with a course-only option, a project option, or a thesis option. The minimum number of credits is 30. Three courses are required, plus an additional three courses from a restricted selection as described in Robotics Track Courses.

Two additional elective courses at the 6000-level or higher (not including independent study, seminars, or thesis) from any department are required. Depending on whether a student is pursuing a course-only M.S., a project M.S., or a thesis M.S., additional 6000-level or higher courses can be chosen, this time including independent study, seminars, and research credit, in order to reach a 30-credit minimum.

TRACK FACULTY

Jake Abbott (ME), Tom Henderson, **John Hollerbach (Track director),** Steve Mascaro (ME), William Provancher (ME), Jur van den Berg, Ross Whitaker

COURSE REQUIREMENTS The following three courses are required:	
CS 6310 / ME EN 6220	Introduction to Robotics
CS 6330 / ME EN 6230	Introduction to Robot Control
CS 6370 / ME EN 6225	Geometric Computation for Motion Planning
One course from each of these three areas are required:	
PERCEPTION	
CS 6320	3D Computer Vision
CS 6640	Image Processing
COGNITION	
CS 6300	Artificial Intelligence
CS 6350	Machine Learning
ACTION	
ME 5240/ 6240	Advanced Mechatronics for Mechanical Engineers
CS 6360	Virtual Reality
CS 7310 / ME 7230	Robot Mobility and Manipulation
CS 7320 / ME 7960-05	System Identification
ME 7960-07	Haptics
Two additional 6000-level courses are required (excluding independent study, seminars, or thesis research credit).	

PHD PROGRAM

PHD IN COMPUTER SCIENCE & PHD IN COMPUTING

PH.D. DEGREES OPTIONS

There are two Ph.D. degree programs within in the School of Computing (SoC) at the University of Utah:

- Ph.D. in Computer Science
- Ph.D. in Computing

Transfers between degree programs will be considered between semesters and will occur only once per academic year.

A Ph.D. in Computing is earned within a particular track. Students are, in part, admitted based upon the track that they have selected during the admissions process. If students wish to switch tracks, they should seek approval from DGS and from the track directors of the tracks between which they wish to switch. Some flexibility will be allowed in terms of switching tracks; however, to remain in good standing, a student has to reach certain due progress milestones as specified.

Ph.D. Degrees:
Ph.D. in Computer Science

Ph.D. in Computing
Tracks:
- Computer Engineering
- Data Management and Analysis
- Graphics and Visualization
- Image Analysis
- Robotics
- Scientific Computing

The Director of Graduate Studies (DGS) is the responsible entity for all graduate degree related issues. He/she will act in consultation with the track directors for administration of the Computing Degree program. In the information that follows: statements indicating that something will be done/approved by DGS should be understood to mean "DGS and/or the track directors".

REGISTRATION REQUIREMENTS

Full-time graduate students in the School of Computing are ordinarily requested to register for 10 hours for TAs and 10 hours for RAs, which includes regular courses, seminars, and research credits as appropriate. This is especially the case for students being supported via research or teaching assistantships. Students who are not being supported by the school are required to take nine hours to be classified as full- time.

Graduate School policy dictates that a graduate student who receives a full tuition waiver during any semester in which he or she holds an assistantship, fellowship or traineeship is required to register for at least nine semester hours, including dissertation research and seminars. Students must be registered for at least three hours per semester, exclusive of summer semester, to remain in a graduate degree program. Students who do not maintain continuous registration and who have not been granted a leave of absence by the Graduate School are subject to being discharged from the degree program.

Students doing dissertations must be registered for at least three semester hours during the semester of the student's thesis defense. Once a student has passed the thesis defense, the student does not have to register the next term if within the 90-day period to turn in the final dissertation.

COURSE REQUIREMENTS

All degree programs have certain course requirements. However, these represent a necessary, rather than sufficient, set of courses for graduation. To graduate, this coursework must appear on a student's approved program of study, a customized course plan developed by the student in conjunction with their committee.

Courses that count toward graduation must be on the program of study. The following default restrictions apply to these courses:

- CS courses must have a course number of 6000 or above (CS 5470: Compiler Principles and Techniques will also be allowed)
- Non-CS courses must have a course number of 5000 or above
- A grade of B or better
- The GPA for all required courses must be at least 3.5

In the subsequent pages of this document, each degree program and/or track may specify modifications and/or additions to these restrictions. Students should also consult the Graduate School Handbook concerning any University requirements.

A student may register for CS 6020 if that student writes and publishes a peer-reviewed article based on research performed in the University of Utah School of Computing. The contribution of the student to the article should be equivalent to that conferred by first authorship. The paper should be published in a respectable outlet. It is the responsibility of the student's advisor to determine whether the student has made such a contribution, and whether the outlet is of sufficient quality. This paper must be accepted for publication prior to the end of the second year of study.

RESIDENCY

At least one year (i.e., two consecutive semesters) of the doctoral program must be spent in full-time academic work at the University of Utah. When a student proceeds directly from an M.S. degree to a Ph.D. degree with no break in the program of study (except for authorized leaves of absence), the residency requirement may be fulfilled at any time during the course of study.

CREDIT FOR PREVIOUS COURSES

PhD students may count some hours of coursework from other graduate degrees toward the coursework requirements associated with the program of study. Unlike for the MS programs, credit for previous courses for PhD students is administered by the DGS so these courses do not need to be officially transferred to the University. Approved courses are certified by inclusion of the appropriate SoC form in the student's file. All coursework on the program of study is subject to approval by the student's supervisory committee and the DGS.

Ph.D. students with a masters-level degree in a closely related discipline should work with their initial committee to create a program of study that can include graduate courses taken as part of their previous degree program. Unless explicitly specified by a degree/track, the program of study can include up to twenty total hours to be counted toward their Ph.D. requirements, and can be used to satisfy some or all of the Ph.D. required courses. Like all programs of study, it must then be approved by the DGS and the graduate school.

A student who has been accepted by the Graduate School is formally admitted to candidacy for the Ph.D. by the University at the recommendation of the student's supervisory committee. Admission to candidacy occurs after the student:

- forms a supervisory committee,
- files an approved Program of Study form,
- completes the core course requirements,
- passes the written portion of the qualifying examination, and
- passes the oral portion of the qualifying examination

An application for candidacy must be submitted to the Graduate School no later than two months prior to the semester of graduation. For the degree to be conferred, the approved Program of Study form must be completed and the dissertation completed and publicly defended.

A Ph.D. Supervisory Committee conducts the student's written qualifying examination, oral qualifying examination, and dissertation defense. This committee consists of five faculty members, at least three of whom must be from the SoC, and at least one member from outside the SoC. Any SoC regular faculty member may serve as a supervisory committee chair. Research or adjunct faculty may chair supervisory committees if accorded that privilege by the regular faculty. Individuals who are not faculty members may serve on supervisory committees if nominated by the regular faculty on the committee, and endorsed by the Graduate Studies Committee and School Director. For Computing degrees, further restrictions on committee makeup may apply. All official decisions of the committee are decided by majority vote.

QUALIFYING EXAMINATION

All Ph.D. students must pass a Qualifying Examination, as specified by the Graduate School. The Qualifying Exam consists of a written part, to be conducted first, and an oral part. The written part of the Qualifying Examination will cover the candidate's general area of specialization in sufficient depth to demonstrate their preparation for conducting Ph.D. -level research. Each internal member of the student's supervisory committee will contribute one or more questions to this exam. The external member(s) of the committee can provide question(s) if they wish to. The supervisory committee will provide a written evaluation of this part of the exam, including an indication of whether or not the student will be allowed to procede to the oral part of the Qualifying Examination. More details on the procedures for the written part are available on the Graduate School web page.

The oral part comprises the dissertation proposal defense. At the supervisory committee's option, it may also include follow-up questions relating to the written part of the exam. A majority of the supervisory committee should certify that the proposal is ready to be defended prior to conducting the oral part of the Qualifying Exam.

PH.D. DISSERTATION

The supervisory committee must give preliminary approval of the dissertation prior to the defense. The defense can be scheduled after this approval. To schedule the defense, contact the Graduate Coordinator. Students are strongly encouraged to schedule the defense during a regular colloquium slot.

The student must provide one copy of the dissertation to the chair of the supervisory committee at least three weeks before the defense, and one copy to each of the other committee members at least two weeks prior to the defense. A complete draft of the dissertation must be delivered to the Graduate Coordinator two weeks prior to the announced time of defense. This copy will be made available for public access. Students are encouraged to place an additional copy on the School of Computing web pages at least one week prior to the announced time of defense.

After successfully defending the dissertation, the student must obtain approval from the Final Reader (typically the supervisory committee chair), School Director, and Dean of the Graduate School. A draft of the final dissertation must then be presented to the Thesis Editor. Successful completion of the defense must be reported to the Graduate School at least four weeks before the last day of examinations in the final semester.

Students should also read the document regarding copyright notices provided by the School and declare their intentions regarding granting the School the right to photocopy the dissertation before notifying the Graduate Coordinator of completion of the defense.

The student has one month after the defense to make any revisions prior to submitting the dissertation to the Graduate School Thesis Editor. There will be at most two additional months to complete any changes required by the Thesis Editor before final acceptance. If either of these deadlines are not met, the candidate must redo the oral defense. The final dissertation must be filed one week before the end of the semester of graduation.

Students are expected to offer each committee member a bound copy of the dissertation once it is completed. Detailed policies and procedures concerning the dissertation are contained in "A Handbook for Theses and Dissertations" published by the Graduate School.

The completed dissertation must be published either in its entirety (through a legitimate publisher of the student's choice or through University Microfilms) or as one or more articles accepted for publication in approved scholarly journals. An abstract of each dissertation must be published in University Microfilms' Dissertation Abstracts International.

STUDENT PROGRESS: TERMINOLOGY

Initial committee: This consists of two University of Utah faculty members and an advisor, who must meet the School of Computing requirements for advising. The initial committee is different from the full committee, who will ultimately administer the qualifier and evaluate the dissertation. The full committee must be chosen to

conform to program requirements. The initial committee is automatically dissolved when the student forms a full committee.

Good versus acceptable progress: Students completing milestones within the time frame denoted as "good" are generally considered to be in good standing in the program. Students completing milestones within the time frame denoted as "acceptable" are considered to be making acceptable progress in the program and are encouraged to continue on and attempt to meet successive milestones within the time frames denoted as "good."

Such students may or may not be considered in good standing, depending upon evaluation of the director of graduate studies (DGS) with input from their advisor and advisory committee. Students not completing milestones within the time frame denoted as "acceptable" are not considered in good standing.

GRADUATE STUDENT PROGRESS GUIDELINES FOR THE PH.D. PROGRAM

Milestone	Good Progress	Acceptable Progress	Comments
Choose advisor and initial committee	2 Semesters	2 Semesters	
Program of study approved by advisor and initial committee	2 Semesters	3 Semesters	
Complete required courses	3 Semesters	5 Semesters	Program requirement: 5 semesters
Full committee formed	4 Semesters	5 Semesters	
Program of study approved by committee	4 Semesters	5 Semesters	U. requirement: 1 semester before defense
Written qualifier	5 Semesters	6 Semesters	U. requirement: 1 semester before defense
Oral qualifier (proposal)	5 Semesters	7 Semesters	U. requirement: After written qualifier and 1 semester before defense
Dissertation defense	9 Semesters	12 Semesters	
Final document			U. requirement: document finalized within three months of the defense

At least 50 hours of graduate coursework is required for the Ph.D. degree in computer science. This must be composed of at least 27 hours of regular graduate coursework, and at least 14 semester hours of dissertation research.In general, Independent study and seminars cannot be used as part of the required 50 hours. The one allowable exception is CS 7930 : Colloquium. This course may be taken for one credit hour as part of the Program of Study. Of the required 27 semester hours of regular courses, up to six may be graduate courses outside of CS. Up to 20 hours of coursework taken elsewhere or counted toward previous degrees can be counted toward the 27 hour regular course requirement with the approval of the GSC. Ph.D. students must demonstrate core knowledge in computer science by fulfilling the following requirements:

COURSE REQUIREMENTS: PH.D. IN COMPUTER SCIENCE
Students should select one course from each of the three categores.

CATEGORY #1	
CS 6100	Foundations of Computer Science
CS 6150	Algorithms
CATEGORY #2	
CS 6460	Operating Systems *
CS 6480	Computer Networks
CS 7460	Advanced Operating Systems
CATEGORY #3	
CS 6810	Advanced Computer Architecture *
CS 6710	Digital VLSI Design
CS 6720	Advanced Integrated Circuit Design
CS 6740	CAD of Digital Circuits
CS 6770	Advanced Digital VLSI Systems Design
CS 6830	VLSI Architecture
CS 7820	Parallel Computer Architecture

* Suggested course

Students must also take at least two courses for a total of 5 required courses:	
CS 5470	Compiler Principles and Techniques
CS 6210	Advanced Scientific Computing
CS 6220	Advanced Scientific Computing II
CS 6300	Artificial Intelligence
CS 6350	Machine Learning
CS 6470	Advanced Topics in Compilation
CS 6480	Computer Networks
CS 6510	Functional Programming
CS 6530	Database Systems
CS 6785	Advanced Embedded Systems
CS 7120	Information Based Complexity
CS 7520	Programming Languages and Semantics
CS 7460	Advanced Operating Systems
CS 7820	Parallel Computer Architecture

Students may not place out of these requirements by substituting or transferring courses from other institutions. However, with approval of the Graduate Studies Committee, a student may replace one or more of these courses with a more advanced course offered by the School of Computing in the same or related subject areas. Substitute courses must be regular classes with exams and/or assignments, not seminar, readings, or independent study classes. Each advanced course can be offered as a substitute for only one required course. At most nine credits of the 27 semester hours of regular graduate course work required of Ph.D. candidates can consist of CS5460, CS6100, CS6810, CS5470, CS6210, CS6480, CS7520, i.e., the seven courses listed above. Substitute courses are not subject to this nine credit limit.

A Ph.D. student must either already have an M.S. degree or complete all of the requirements for a course, project, or thesis-based M.S. degree in CE. The supervisory committees may require additional coursework hours above that required for the M.S. degree.

All students must complete at least seven hours of coursework at the University of Utah. All students must complete at least 14 hours of dissertation research (CS or ECE 7970). At least one year (i.e. two consecutive semesters) of the doctoral program must be spent in full-time academic work at the University of Utah. A student must be registered for at least three hours of credit in the semester that they defend their dissertation.

TRACK FACULTY

Al Davis, Rajeev Balasubramonian, **Erik Brunvand (Track director),** Priyank Kalla (ECE), Chris Myers (ECE), John Regehr, Thomas Schmid (ECE), Ken Stevens (ECE)

COURSE REQUIREMENTS Required courses:	
CS/ ECE 6710	Digital VLSI Design
CS/ ECE 6780	Embedded System Design
CS/ ECE 6810	Computer Architecture
Two additional courses are required from the following list:	
CS 6110	Formal Methods in System Design
CS 6470	Advanced Topics in Compilation
CS 6490	Network Security
CS/ ECE 6770	Advanced Digital VLSI Systems Design
CS/ ECE 6785	Advanced Embedded System Design
CS 7460	Distributed Operating Systems
CS/ ECE 7810	Advanced Architecture

Each CE graduate student must form a supervisory committee whose members approve the student's program of study and guides the student's research program. A Ph.D. committee consists of five members. The majority of the committee must consist of CE faculty from either ECE or SoC. Ph.D. students are strongly encouraged to have a member of the committee who is outside the University of Utah whenever it is feasible. The committee should be formed by the end of the second semester of enrollment in the graduate program, although a committee may be revised later by petition to the CE committee.

Any ECE or SoC regular faculty member may serve as a supervisory committee chair. Auxiliary faculty may chair supervisory committees if accorded that privilege by the regular faculty and the Dean of the Graduate School. Individuals who are not faculty members may serve on supervisory committees if nominated by the regular faculty on the committee, and endorsed by the CE Committee. The Dean of the Graduate School must grant final approval of all supervisory committees. **A maximum of two seminars hours will be permitted.**

Course work listed on the approved Program of Study form must comprise at least 50 semester hours of graduate course work and dissertation research, exclusive of independent study. At least 14 semester hours of dissertation research (CS 7970) and 24 semester hours of graduate course work must be included. Up to 12 hours of graduate level course work already applied to other degrees may be used in the program of study as approved by the TCF Chair.

TRACK FACULTY

Tom Fletcher, Mike Kirby, **Feifei Li (Track director)**, Miriah Meyer, Valerio Pascucci, Jeff Phillips, Suresh Venkatasubramanian

COURSE REQUIREMENTS Required courses: must take 4 required courses.	
CS 6150	Algorithms
CS 6350 Machine Learning / CS 6955 Data Mining / CS 6960 Non-Parametric Statistics	
CS 6530	Database Systems
CS 6630	Scientific Visualization

A minimum of a B or greater is required for any of the required courses.

A student must take five elective courses (fifteen hours) which involve the areas related to information, or are directly applicable to the student's dissertation research. Up to three courses (nine hours) may be taken from other departments at the University of Utah. All elective courses on the Program of Study must be taught at the graduate level. For those classes taken within the School of Computing, it is advised that students take 6000 level courses and above when available/appropriate. All courses taken by a track student to fulfill the elective requirements must be approved by the student's committee and the TCF Chair.

ELECTIVES Three courses from the following list are required:	
CS 5610	Interactive Computer Graphics
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6230	High Performance Parallel Computing
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6610	Advanced Computer Graphics I
CS 6640	Image Processing
CS 6963	Parallel Programming for GPUs
CS 6964	Applications of NLP

ADDITIONAL ELECTIVES

- MATH 5010 Introduction to Probability
- MATH 5080 Statistical Inference I
- MATH 5090 Statistical Inference II
- MATH 5250 Matrix Analysis
- MATH 6010 Linear Models
- MATH 6020 Multilinear Models
- MATH 7870 Methods of Optimization
- ECE 5510 Random Processes
- ECE 6540 Estimation Theory
- ECE 6520 Information Theory and Coding
- ECE 6551 Survey of Optimization Techniques
- IS 6481 Data Warehousing
- IS 6482 Data Mining
- BMI 6010 Foundations of Medical Informatics
- BMI 6020 Foundations of Bioinformatics and Genetic Epidemiology
- BMI 6105 Statistics for Biomedical Informatics
- BMI 6300 Medical Decision-Making

Course work listed on the approved Program of Study form must comprise at least 50 semester hours of graduate course work and dissertation research, exclusive of independent study. Graduate course work applied toward an M.S. degree may be included. At least 14 semester hours of dissertation research (CS 7970) and 30 semester hours of graduate course work must be included. Up to 12 hours of graduate level course work already applied to other degrees may be used in the program of study.

PhD students must demonstrate core knowledge in computer graphics and visualization by passing three courses from a choice of four, prior to the start of their fifth semester of study, with grades of B or better in each course and an overall GPA in the specified courses greater than 3.5. Students may place out of this requirement by substituting or transferring courses from other institutions.

TRACK FACULTY

Adam Bargteil , Martin Berzins, Elaine Cohen, **Charles Hansen (Track director),** Chris Johnson, Mike Kirby, Miriah Meyer, Valerio Pascucci, Rich Riesenfeld, Bill Thompson, Cem Yuksel

COURSE REQUIREMENTS

Required courses:

CS 6610	Interactive Computer Graphics
CS 6630	Scientific Visualization
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design

Substitute courses must be "regular" classes with exams and/or assignments, not seminar, readings, or independent study classes. Satisfactorily completing the three courses as described constitutes completion of the Comprehensive exam; this must be completed by the the end of the fourth semester.

ELECTIVE COURSES

School of Computing Computer Science courses on the Program of Study must be at the 6000 level or above, excluding independent study, and research credits. Of the required 30 semester hours, up to nine credit hours may be graduate courses outside of the School of Computing. Admissible elective courses within the School of Computing are the following:

CS 6620	Advanced Graphics II : Ray Tracing
CS 6310	Introduction to Robotics
CS 6360	Virtual Reality
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6960	Computational Geometry
CS 6540	Human/ Computer Interaction
CS 6650	Perception for Graphics
CS 6660	Physics-Based Animation
CS 6680	Computer-Aided Geometric Design II
CS 7320	3D Computer Vision
CS 7650	Realistic Image Synthesis

Courses not on the list above must be approved by the student's committee to count toward the elective requirements. Independent study (CS 6950 and CS 7950) can not be included in the Program of Study for the PhD degree.

A minimum of 50 credits is required, of which at least 27 credits must be graduate course work, and at least 14 credits must be dissertation research (CS 7970). Graduate course work applied toward an M.S. degree may be included. **Independent study and seminars cannot be used as part of the required 50 hours.**

TRACK FACULTY

Tom Fletcher (Track director), Guido Gerig, Tom Henderson, Marcel Prastawa, Tolga Tasdizen, Bill Thompson, Ross Whitaker

COURSE REQUIREMENTS

Required courses:

CS 6640	Image Processing
CS 7640	Advanced Image Processing
Students are also required to complete two out of the following three courses:	
CS 6150	Algorithms
CS 6320	3D Computer Vision
CS 6350	Machine Learning

Students may place out of any of the above required courses by substituting or transferring courses from other institutions. Substitute courses must be regular classes with exams and/or assignments, not seminar, readings, or independent study classes.

ELECTIVES

Computer Science courses on the Program of Study must be courses at the 6000 level or above and research credits. Of the required 27 semester hours, up to 12 credit hours may be graduate courses outside of the School of Computing. Recommended elective courses (organized into general topic areas):

IMAGING, VISUALIZATION & GRAPHICS	
CS 6630	Scientific Visualization
CS 6650	Perception for Graphics
CS 6670	Computer-Aided Geometric Design I
BIOEN 6330	Principles of Magnetic Resonance Imaging
BIOEN 6330	Mathematics of Imaging
COMPUTATIONAL METHODS	
CS 6160	Computational Geometry
CS 6120	Advanced Scientific Computing
CS 6220	Advanced Scientific Computing II
CS 6550	Foundations of Algorithms in Computer Graphics and Visualization
CS 6967	Computational Topology
STATISTICS & LEARNING	
CS 6300	Artificial Intelligence
CS 6560	Computational Statistics
CS 6960	Nonparametric Statistics
ECE 6540	Estimation Theory

A minimum of 50 credits is required, of which at least 27 credits must be graduate course work, and at least 14 credits must be dissertation research. Of the graduate course work, three are required courses, plus an additional three courses from the restricted electives as described in Robotics Track Courses.

Two additional elective courses at the 6000-level or above (not including independent study, seminars, or thesis) from any department are required. Remaining credits to fill the 50-credit minimum may be chosen from other 6000-level or higher courses or from seminars or dissertation research, but not independent study.

TRACK FACULTY

Jake Abbott (ME), Tom Henderson, **John Hollerbach (Track director),** Steve Mascaro (ME), William Provancher (ME), Jur van den Berg, Ross Whitaker

COURSE REQUIREMENTS Required courses:	
CS 6310 / ME 6220	Introduction to Robotics
CS 6370 / ME 6225	Geometric Computation for Motion Planning
CS 6960 / ME 6230	Introduction to Robot Control (pre-requisite for CS 7310 & CS 7320)
CS 7939 / ME 6225*	Robotics Seminar (Fall semester & Spring semester)
One course from each of these three areas are required:	
PERCEPTION	
CS 6320	3D Computer Vision
CS 6640	Image Processing
COGNITION	
CS 6300	Artificial Intelligence
CS 6350	Machine Learning
ACTION	
ME 5240/ 6240	Advanced Mechatronics for Mechanical Engineers
CS 6360	Virtual Reality
CS 7310 / ME 7230	Robot Mobility and Manipulation
CS 7320 / ME 7960-05	System Identification
ME 7960-07	Haptics

* The fall session deals with research: current student and faculty presentations, readings, and enrollee presentations. The spring session deals with professional development.

50 hours of graduate coursework is required, composed of at least 24 hours of regular graduate coursework, and at least 14 semester hours of dissertation research. Of the required 24 semester hours of regular courses, up to six hours may be graduate courses outside of CS. Up to 12 hours of coursework taken elsewhere or counted toward previous degrees can be counted toward the 24 hour regular course requirement with the approval of the GSC.

TRACK FACULTY

Adam Bargteil, Martin Berzins, Guido Gerig, Mary Hall, Chuck Hansen, Tom Henderson, Chris Johnson, **Mike Kirby (Track director),** Valerio Pascucci, Ross Whitaker

COURSE REQUIREMENTS: PH.D. IN COMPUTING, SCIENTIFIC COMPUTING TRACK

The following four courses are required:

CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6230 CS 6963	High-Performance Computing and Parallelization and/or Parallel Programming for GPUs
CS 6630	Scientific Visualization

In addition, a student must take four elective courses which involve the themes of scientific computing or are directly applicable to the student's dissertation research. The following is the list of those classes which will apply:

CS 6100	Foundations of Computer Science
CS 6530	Database Systems
CS 6650	Image Synthesis
CS 6610	Advanced Computer Graphics
CS 6810	Advanced Computer Architecture
CS 7120	Information-Based Complexity
CS 7210	Advanced Topics in Scientific Computing
CS 7450	Simulation Methods

Additional 6000-level courses may be required to reach a 50-credit minimum (excluding independent study, seminars, or thesis research credit).