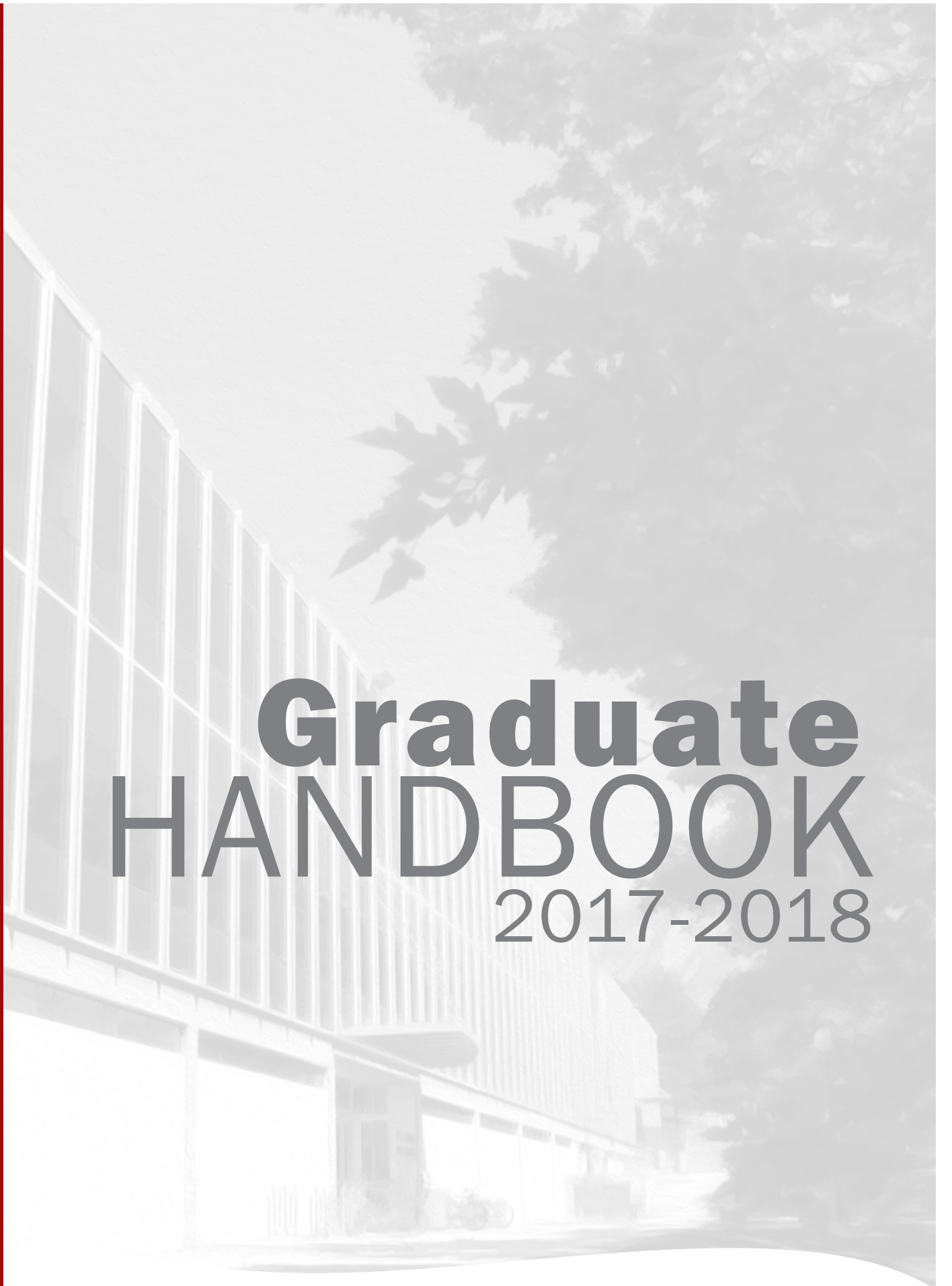

Graduate HANDBOOK 2017-2018

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 37 regular faculty members, 4 research faculty, 5 clinical faculty, and 19 adjunct faculty, and over 260 MS and PhD students in our 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 PhD 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 PhD graduate went on to teach at Brigham Young University and founded WordPerfect. Computer animation pioneer Ed Catmull, received both his BS and PhD 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.

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** 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
Ross Whitaker
Professor

ASSOCIATE DIRECTOR
Mike Kirby
Professor

DIRECTOR OF GRADUATE STUDIES (DGS)
Feifei Li
Associate Professor

DIRECTOR OF GRADUATE ADMISSIONS
Thomas Fletcher
Associate Professor

DIRECTOR OF BS/MS PROGRAM
Jason Wiese
Assistant Professor

DIRECTOR OF UNDERGRADUATE STUDIES
Jim de St. Germain
Associate Professor, Career-Line

TRACK DIRECTORS

COMPUTER ENGINEERING
Erik Brunvand
Associate Professor

COMPUTER SCIENCE PROGRAM
Jacobus Van der Merwe
Associate Professor

DATA MANAGEMENT & ANALYSIS
Jeff Phillips
Assistant Professor

GRAPHICS & VISUALIZATION
Cem Yuksel
Assistant Professor

HUMAN-CENTERED COMPUTING
Miriah Meyer
Associate Professor

IMAGE ANALYSIS
Tom Fletcher
Associate Professor

NETWORKED SYSTEMS
Sneha Kasera
Professor

TRACK DIRECTORS

ROBOTICS
John Hollerbach
Professor

SCIENTIFIC COMPUTING
Hari Sundar
Assistant Professor

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Computer architecture: clustered processors & memory hierarchy bottlenecks

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

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Assistant Professor
Theoretical computer science machine learning and statistics, distributed algorithms

Mahdi Bojnordi
Assistant Professor
Computer architecture, novel memory technologies, and energy-efficient computing

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

Erik Brunvand
Associate Professor
Computer architecture & VLSI systems

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Assistant Professor
Computational psychology, artificial intelligence, game design, interactive narrative

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

Tamara Denning
Assistant Professor
Security, privacy & human-centric computing

Matthew Flatt
Professor
Programming languages & systems

Thomas Fletcher
Associate Professor
Shape analysis, computer vision image analysis & image processing

Ganesh Gopalakrishnan
Professor
Formal analysis of concurrent systems (MPI, GPU, Threading), symbolic, dynamic, & run-time verification methods and tool frameworks

Mary Hall
Professor
Optimization, parallelization & compilers

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

Tom Henderson
Professor
Computer vision & mobile robotics

Tucker Hermans
Assistant Professor
Autonomous learning and perception for robot manipulation

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

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

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

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Assistant Professor
Computer graphics, modeling and animation

Bob Kessler
Professor
Systems software & software engineering, Entertainment Arts & Engineering (EAE)

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Scientific computing & visualization, High Performance Computing, Concurrent Programming

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Databases & large-scale data management

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Visualization & large multidimensional data

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Security, parallelism, verification & optimization

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Algorithms, big data analytics, geometric data analysis

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Data analysis and data visualization

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Formal methods & verification

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Computer vision, machine learning, and algorithms

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Embedded systems, sensor networks, static analysis & operating systems

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Natural language processing, information retrieval & artificial intelligence

Vivek Srikumar
Assistant Professor
Machine learning & natural language processing

Ryan Stutsman
Assistant Professor
Distributed Systems, Operating Systems, and Databases

Hari Sundar
Assistant Professor
Parallel algorithms, scientific computing & inverse problems

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

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

Suresh Venkatasubramanian
Professor
Algorithms, computational geometry & data mining

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

Jason Wiese
Assistant Professor
Human-computer interaction, mobile and ubiquitous computing

R. Michael Young
Professor
Artificial Intelligence, Video games, Interactive narrative

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

MASTER'S PROGRAM

MASTER'S IN COMPUTER SCIENCE & MS IN COMPUTING

MASTER'S DEGREE GUIDELINES

MS DEGREES OPTIONS

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

- MS in Computer Science
- MS in Computing

Degree programs may contain a thesis, a project, or a course-only option as specified. 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 director of the track to which they wish to enter.

Master's Degrees:
MS in Computer Science

MS in Computing
Tracks:
- Computer Engineering
- Data Management and Analysis
- Graphics and Visualization
- Human-centered Computing
- Image Analysis
- Networked Systems
- Robotics
- Scientific Computing

The Program of Study form must be submitted to the Graduate Records Office by the Graduate Advisor 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 Computer Science program, and Computing Degree programs. 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 required to register for 9 hours, 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 by the graduate school.

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 their degree program.

Students choosing the thesis option must be registered for at least three semester hours during the semester of their thesis defense. Once a student has passed the thesis defense, the student does not have to register the next term, and the student needs to turn in the final thesis draft to the thesis office within 90 days.

COURSE REQUIREMENTS

All degree programs have certain course requirements. 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 be a graduate level course having a course number of 5000 or above, and should

be directly related to the student's degree
- A grade of C or better
- The GPA over all courses in the program of study 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 School of Computing at the University of Utah. 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., successful completion of a similar course taken at another recognized University). This waiver is obtained by petitioning the DGS. The waiver procedure should be initiated by first contacting the Graduate Advisor. Waiving a required course does not reduce the 30 graduate credit-hour requirement.

MS SUPERVISORY COMMITTEE

The MS Supervisory Committee (SVC) consists of three members. The following two policies are in place for SVCs:

1. The chair of an SVC must be a regular faculty member (tenured/tenure track) from the SoC.
2. The majority of the SVC must be regular faculty members (tenured/tenure track) within the SoC.

Research or adjunct faculty may chair or may be members of supervisory committees if accorded that privilege by the SoC faculty and the Graduate School. However, exception to only one of the two policies listed above but not both simultaneously will be allowed.

MS COMPREHENSIVE EXAM

For the project and thesis options of this degree, the MS 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 opting for a project or thesis, the comprehensive exam will typically be passed by meeting the grade requirements in the courses required for completing their degree/track, but this can be modified at the discretion of the student's committee.

MS TRANSFER CREDIT

A student may only count up to nine semester hours of non-matriculated graduate work at the University of Utah 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 recognized institutions may transfer up to six semester hours to the University of Utah. The courses must be bona fide graduate-level classwork (e.g., independent study is excluded), with grade C 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 necessarily imply fulfillment of any specific required course.

MS PROJECT DOCUMENT (Project Option)

The project is done through an independent study (often formally as an independent study course) 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 is done). The student is responsible for arranging a time and place for the defense together with the committee.

MS THESIS DEFENSE AND 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 Advisor at least two weeks prior to the defense date agreed upon by the supervisory committee. A verification notice will be sent to all committee members asking if the student is ready to defend. Once positive responses are received, and no later than one week prior to defense, the defense will be announced to all students and faculty in the School of Computing. 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 emailed as a PDF to the Graduate Advisor two weeks prior to the announced time of defense. This copy will be made available for department acccess.

After successfully defending the thesis, the student must obtain approval that the thesis is satisfactory by obtaining signatures from their committee members and the chair of the department by using the Final Reading Approval form, and the Supervisory Committee Approval form. These forms will be submitted along with the final draft of the thesis manuscript to the thesis office. The majority of the signatures of the committee members are required for the thesis editors to start the format approval and the editing process. A student can defend a thesis until the day before the following semester starts. However, in order to graduate in a certain semester, please consult the thesis calendar for submission deadlines on the Graduate School's website.

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 Advisor 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, and one to the School of Computing library. Detailed policies and procedures concerning the thesis are contained in "A Handbook for Theses and Dissertations" published by the Graduate School.

RESIDENCY

At least 24 hours of the 30 MS course and thesis hours must be in resident study at the University of Utah. This does not refer to, or fulfill, State Residency Requirements. A full time student working on an MS program is expected to complete the degree requirements within two calendar years. The Graduate School limits MS programs to four years.

MASTER'S DEGREE GUIDELINES

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 Advisor for the proper form.

MONITORING OF PROGRESS

Annual meetings and reports: Each year the student will meet with the track director for review of their progress.

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.

GRADUATE STUDENT PROGRESS GUIDELINES FOR THE MS THESIS 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	4 Semesters	Program requirement: within three semesters
Defend proposal	3 Semesters	4 Semesters	U. requirement: one semester before defense
Thesis defense	4 Semesters	5 Semesters	
Final document			U. requirement: document finalized within three months of the defense

INDIVIDUAL MS TRACK SPECIFICATIONS

MS IN COMPUTER SCIENCE

A student may pursue an MS with (1) a thesis option, or (2) a project option, or (3) a course-only option, or (4) an MS/MBA option. The MS program requires 30 total semester hours of graduate coursework (including thesis hours for the thesis option). All students must take the following three required courses (for all options).

COURSE REQUIREMENTS Required courses:	
CS 6150	Advanced Algorithms
CS 6460	Operating Systems
CS 6810	Computer Architecture

Students must show proficiency in the three fundamental categories: theory, systems and hardware. Students can request approval from the Track director to substitute the required courses with other electives, or more advanced courses 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.

Up to six semester hours of graduate-level course may be taken outside of the School of Computing. In general, seminars cannot be used as part of the required 30 hours. The one allowable exception is CS 7930: Colloquium. This course may be taken for up to two credit hours at one time as part of the Program of Study.

THESIS OPTION

A minimum of six thesis research credits (CS 6970) are required for the thesis option, and a maximum of 10 thesis research credits can be used on the Program of Study. At least one additional CS 6000-level or higher course is required (excluding independent study, and seminars). Additional 6000-level courses may be needed to reach the 30 credit minimum. At most three independent study (CS 6950) credit hours may be used to fulfill the required 30 semester hours, but only when the project is self-contained and independent of thesis research.

PROJECT OPTION

A minimum of three Independent Study credits (CS 6950) are needed for the project option, and a maximum of six Independent Study credits can be used on the Program of Study. At least four additional CS courses must be taken excluding independent study, seminars, or thesis research credit (CS 6970). Additional 6000-level courses may be required to reach the 30 credit minimum.

COURSE-ONLY OPTION

At least six additional CS courses must be taken excluding seminars, or thesis research credit (CS 6970). Additional 6000-level courses may be required to reach the 30 credit minimum. At most three independent study (CS 6950) credit hours may be used to fulfill the required 30 semester hours.

MS/MBA OPTION

At least four additional CS courses must be taken excluding independent study, seminars, or thesis research credit (CS 6970). One independent study must be taken. The remaining courses needed for this option are specified by the Business School as part of the joint MS/MBA Program.

MS IN COMPUTING:
COMPUTER ENGINEERING

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

TRACK FACULTY

Rajeev Balasubramonian, **Erik Brunvand (Track Director),** Neil Cotter (ECE), Peter Jensen, Priyank Kalla (ECE), Sneha Kumar Kasera, Chris Myers (ECE), John Regehr, Ken Stevens (ECE)

COURSE REQUIREMENTS Required courses:
CS/ ECE 6810 Computer Architecture
CS/ ECE 6710 Digital VLSI Design

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

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

ELECTIVES Two courses must be taken by students doing the thesis option, three courses must be taken by students doing the project option, and four courses must be taken by students doing the coursework option, and 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 GPUs/Many Cores/Multi-Cores
CS 6460	Operating Systems
CS 6470	Compiler Principles and Techniques
CS 6475	Advanced Compilers
CS 6480	Advanced Computer Networks
CS 6490	Network Security
CS 6956	Wireless and Mobile Networks
ECE 5325	Wireless Communications Systems
ECE 5520	Digital Communications Systems

MS IN COMPUTING:
COMPUTER ENGINEERING

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

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 Study (CS/ECE 6950).

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 Study (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 Study (CS/ECE 6950) are allowed.

A maximum of two seminar hours will be permitted for any of the three options.

MS IN COMPUTING:
DATA MANAGEMENT & ANALYSIS

A student may pursue an MS with a (1) thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for any of the three options is 30 from graduate level classes. 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, Lajos Horvath (Math), Chris Johnson, Sneha Kumar Kasera, Mike Kirby, Alexander Lex, Feifei Li, Miriah Meyer, Baxton Osting (Math), Valerio Pascucci, Bei Wang Phillips, Jeff Phillips (Track Director), Vivek Srikumar, Hari Sundar, Suresh Venkatasubramanian

CORE CLASSES - Must take 4 core classes, at least one from each line.	
CS 6140	Data Mining /or/ CS 6350 Machine Learning
CS 6150	Advanced Algorithms
CS 6530	Database Systems
CS 6630	Visualization for Data Science (CS 6635 Visualization for Scientific Data may be taken as a subsitute)

A average grade of B or greater is required for core classes.

ELECTIVES: Three courses from the following list are required: (or CS 6140/CS 6350 if not counted above) Students may also subsitute most graduate classes taught by track faculty.

ALGORITHMICS

CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6180	Clustering

ANALYTICS

CS 6210	Advanced Scientific Computing
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6390	Probabilistic Learning
CS 6961	Structured Prediction
CS 6963	Distributed Systems

MANAGEMENT

CS 6230	High-Performance Computing and Parallelization
CS 6235	Parallel Programming for GPUs/Many Course/Multi-Cores
CS 6480	Advanced Computer Networks
CS 6490	Network Security

Students may substitute other SoC graduate-level courses for elective requirements with approval of the Track Director (especially those taught by track faculty). With approval of the supervisory committee, a student may take two elective courses (6 credit hours) 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 Track Director.

In all three options, seminar hours cannot be included to fulfill the 30 graduate level credits requirement. Independent study credit hours can only be used on the Program of Study for students who pursue the project based degree. However, once a student enters the project or the thesis option, his/her prior independent study or thesis research hours can be converted into project or thesis hours whichever is applicable, if the student's advisor deems these hours relevant to the student's project or thesis.

MS IN COMPUTING:
DATA MANAGEMENT & ANALYSIS

A student may pursue an MS with a (1) thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for any of the three options is 30 from graduate level classes. 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.

DATA SCIENCE OPTION

CORE CLASSES	
CS 5530	Database Systems /or/ CS 6965 Big Data Computer Systems
CS 6140	Data Mining
CS 6190	Probabilistic Learning
CS 6350	Machine Learning
CS 6630	Visualization
MATH 5080	Statistical Inference I
MATH 6010	Linear Models

SUGGESTED ELECTIVES	
CS 6150	Advanced Algorithms
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6530	Database Systems
CS 6961	Structured Prediction
MATH 5770	Introduction to Optimization
MATH 6030	Multivariate Models
MATH 6070	Mathematical Statistics

A average grade of B or greater is required for core classes.

Students may place out of the above requirements by substituting or transferring courses from other institutions at the discretion of the Track Director. Students may complete the required 30 credits with SoC graduate-level courses or Math graduate-level courses, or from other departments with approval of the Track Director.

In all three options, seminar hours cannot be included to fulfill the 30 graduate level credits requirement. Independent study credit hours can only be used on the Program of Study for students who pursue the project based degree. However, once a student enters the project or the thesis option, his/her prior independent study or thesis research hours can be converted into project or thesis hours whichever is applicable, if the student's advisor deems these hours relevant to the student's project or thesis.

MS IN COMPUTING:
GRAPHICS & VISUALIZATION

A student may pursue an MS with (1) a 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

Martin Berzins, Elaine Cohen, Charles Hansen, Chris Johnson, Ladislav Kavan, Mike Kirby, Alexander Lex, Miriah Meyer, Valerio Pascucci, Bei Wang Phillips, Bill Thompson, **Cem Yuksel (track director)**

COURSE REQUIREMENTS **(COURSE ONLY OPTION)** Four of the following regular courses are required in addition to the seminar.	
CS 6610	Interactive Computer Graphics
CS 6630	Visualization for Data Science
CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
A minimum of a B- or greater is required for any of the required courses.	

Three courses from the following list are required:	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
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 and research credit.

MS IN COMPUTING:
GRAPHICS & VISUALIZATION

COURSE REQUIREMENTS **(PROJECT OPTION)** Four of the following regular courses are required in addition to the seminar.	
CS 6610	Interactive Computer Graphics
CS 6630	Visualization for Data Science
CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
A minimum of a B- or greater is required for any of the required courses.	

Three courses from the following list are required:	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
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. Thesis research hours are not counted toward the degree in the project option.	

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.

MS IN COMPUTING:
GRAPHICS & VISUALIZATION

COURSE REQUIREMENTS **(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	Visualization for Data Science
CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design
CS 7933 Graphics Seminar (or) CS 7942 Visualization Seminar (one credit hour maximum)	
A minimum of a B- or greater is required for any of the required courses.	

Three courses from the following list are required:	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-based Animation
CS 6665	Character Animation
CS 6680	Computer-Aided Geometric Design II
Elective courses (to equal 30 total credit hours):	
For the thesis option, students can take up to 9 thesis hours and no independent study.	
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.

MS IN COMPUTING:
HUMAN-CENTERED COMPUTING

In human-centered computing (HCC) the design and development of technology is motivated by the needs of people. HCC focuses on understanding how people use technology, creating new and accessible technology that enables novel interactions, and evaluating how technology impacts and supports people in the world. The core methods and techniques in HCC are grounded in computer science, but are also draw on social science and design. Current HCC focus areas in the School of Computing include personal informatics, mobile interaction, visualization, games, and privacy.

TRACK FACULTY

Erik Brunvand, Rogelio E. Cardona-Rivera, Tamara Denning, Alexander Lex, **Miriah Meyer (track director),** Jason Wiese, R. Michael Young

CORE CLASSES: Required courses:	
CS 6540	HCI
CS 6xxx	Advanced HCI
CS 6630	Visualization for Data Science
ED PS 6010	Introduction to Statistics and Research Design

ELECTIVES: 6 electives in total.
Pre-approved course list from within CS and across campus (1) Up to 3 electives can be taken from outside CS (2) Other electives require director approval

PRE-APPROVED CS ELECTIVES

Data Science

CS 6140	Data Mining
CS 6160	Computational Geometry
CS 6190	Probalistic Modeling
CS 6340	Natural Language Processing
CS 6350	Machine Learning
CS 6530	Database Systems

Visualization

CS 6635	Visualization for Scientific Data

Robotics

CS 6300	Artifiial Intelligence
CS 6310	Robotics
CS 6320	3D Computer Vision

Computer Graphics

CS 6610	Interactive Computer Graphics
CS 6640	Introduction to Digital Imaging

Embedded Systems

CS 6780	Embedded System Design
CS 6785	Advanced Embedded Software

MS IN COMPUTING:
HUMAN-CENTERED COMPUTING

PRE-APPROVED NON-CS ELECTIVES

Design

DES 5320	Typographic Communication
DES 5370	Digital Fabrication
DES 5710	Product Design and Development

Ed Psychology

ED PSY 6030	Introduction to Research Design

Psychology

PSY 6120	Advanced Human Cognition
PSY 6140	Cognitive Neuroscience Approaches to Research
PSY 6420	Methods in Social Psychology
PSY 6700	Neuropsychology

Anthropology

ANTH 6169	Ethnographic Methods

Sociology

SOC 6110	Methods of Social Research

Entertainment Arts and Engineering

EAE 6900	Games User Research
EAE 6900	A.I. For Games

MS IN COMPUTING: IMAGE ANALYSIS

A student may pursue an MS with (1) a thesis option, or (2) a project option, or (3) a course-only option. The minimum number of credits for any of three options is 30 from graduate level classes. 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 (Track Director), Tom Henderson, Sarang Joshi, Srikumar Ramalingam, Tolga Tasdizen, Bill Thompson, Ross Whitaker

COURSE REQUIREMENTS Required courses:	
CS 6640	Image Processing
CS 7640	Advanced Image Processing and/or BIOEN 6500 Mathematics of Imaging
Students are also required to complete two out of the following three courses. The third can be taken as elective.	
CS 6150	Advanced Algorithms
CS 6320	3D Computer Vision
CS 6350	Machine Learning

The Program of Study must be courses at the 6000 level or above and research credits. Of the required 30 semester hours, up to 24 credit hours must be graduate courses within the SoC or on the following list of recommended electives.

ELECTIVES Recommended elective courses within the School of Computing and other departments are listed below:	
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 6500	Mathematics of Imaging
COMPUTATIONAL METHODS	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6550	Foundations of Algorithms in Computer Graphics and Visualization
STATISTICS & LEARNING	
CS 6300	Artificial Intelligence
CS 6390	Probabilistic Modeling
CS 6560	Computational Statistics
ECE 6540	Estimation Theory

Students may place out of required courses or electives 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, and they must be approved by the Track Director.

MS IN COMPUTING:
NETWORKED SYSTEMS

A student may pursue an MS with (1) a thesis option, (2) a project option, or (3) a course-only option. The minimum number of credit hours required for all the three options is 30. These credit hours must be from graduate level courses only. Students must take all of the three required courses listed below, and any four courses from the elective list below.

Students selecting the thesis option must include a minimum of 6 (up to a maximum of 9) MS Thesis Research (CS 6970) credits in their program of study. Students selecting the thesis option may include at most 3 credits of Independent Study (CS 6950) on their program of study, and may only do so if the work done in the Independent Study does not overlap with the student's thesis work, as determined by the student's supervisory committee. If work done for an independent study turns into thesis work, the Independent Study credits can be converted to MS Thesis Research (CS 6970) credits.

For students selecting the project option, exactly 6 credits of Independent Study (CS 6950), covering the student's project work, must be included in the program of study. For students selecting the coursework option, Independent Study (CS 6950) can be included in the program of study for at most 3 hours.

TRACK FACULTY

Tamara Denning, Eric Eide, Ganesh Gopalakrishnan, Mary Hall, **Sneha Kasera (Track Director),** Feifei Li, Neal Patwari, John Regehr, Robert Ricci, Ryan Stutsman, Jacobus Van der Merwe, Suresh Venkatasubramanian

COURSE REQUIREMENTS The following 3 courses are required:	
CS 6480	Advanced Computer Networks
CS 6490	Network Security
CS 6956	Wireless and Mobile Networks

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

ELECTIVES At least 4 elective courses must be taken from the following list:	
CS 6110	Formal Methods in Systems Design
CS 6150	Advanced Algorithms
CS 6235	Parallel Programming for GPUs/Many Cores/Multi-Cores
CS 6460	Operating Systems
CS 6530	Database Systems
CS 6810	Computer Architecture
CS 6957	Software Defined Network Architecture
CS 6963	Distributed Systems
CS 6964	Computer Security Research

MS IN COMPUTING: ROBOTICS

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

Two additional elective courses, directly related to the student's degree, at the 6000-level or higher (not including independent study, seminars, or thesis research hours) from any department are required. Depending on whether a student is pursuing a thesis MS, a project MS, a course-only MS or 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, Tucker Hermans, **John Hollerbach (Track Director),** Steve Mascaro (ME), Vivek Srikumar, Ross Whitaker

COURSE REQUIREMENTS The following three courses are required:	
CS 6310 / ME EN 6220	Introduction to Robotics
CS 6370 / ME EN 6225	Motion Planning
CS 6330 / ME EN 6230	Introduction to Robot Control (pre-requisite for CS 7310 & CS 7320)
CS 7939 / ME EN 7960-001*	Robotics Seminar (Fall 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
CS 6380	Multi-agent systems
ACTION	
ME EN 6240	Advanced Mechatronics
CS 6360	Virtual Reality
CS 7310 / ME EN 7230	Robot Mobility and Manipulation
CS 7320 / ME EN 7220	System Identification for Robotics
ME EN 7960-07	Haptics
Two additional 6000-level courses are required (excluding independent study, seminars, or thesis research credit).	

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

MS IN COMPUTING:
SCIENTIFIC COMPUTING

A student may purse an MS in Scientific Computing with a thesis option or a project-based option. A minimum of 30 credit hours is required for either option. In addition to six required courses, students must take two elective courses that involve the themes of Scientific Computing or are directly applicable to the student's dissertation research. Students are also required to take two courses of independent study (for projects) or MS thesis hours (for thesis) for a total of six hours.

TRACK FACULTY

Martin Berzins, Mary Hall, Chuck Hansen, Tom Henderson, Chris Johnson, Mike Kirby, Valerio Pascucci, **Hari Sundar (Track Director),** Ross Whitaker

COURSE REQUIREMENTS The following six courses are required:	
CS 6150	Advanced Algorithms
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6230 CS 6235	High-Performance Computing and Parallelization and/or Parallel Programming for GPUs/Many Cores/Multi-Cores
CS 6630	Visualization
MATH 6870	Math Modeling

Two additional elective courses must be selected from the following list. Students can possibly take other 6000-level and above courses within the School of Computing as electives; permission of the track director (the student's committee) is necessary in such cases.	
CS 6100	Foundations of Computer Science
CS 6530	Database Systems
CS 6610	Interactive Computer Graphics
CS 6650	Image Synthesis
CS 6810	Advanced Computer Architecture
CS 7120	Information-Based Complexity
CS 7210	Advanced Topics in Scientific Computing
CS 7450	Simulation Methods
Additional 6000-level and above courses may be required to reach a 30-credit minimum (excluding independent study, seminars, or thesis research credit hours).	

PHD PROGRAM

PHD IN COMPUTER SCIENCE & PHD IN COMPUTING

PHD GUIDELINES

PHD DEGREES OPTIONS

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

- PhD in Computer Science
- PhD in Computing

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

A PhD 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 director of the track to which they wish to enter. 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.

PhD Degrees:
PhD in Computer Science

PhD in Computing
Tracks:
- Computer Engineering
- Data Management and Analysis
- Graphics and Visualization
- Human-centered Computing
- Image Analysis
- Networked Systems
- 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 the DGS should be understood to mean "DGS and/or the track directors".

REGISTRATION REQUIREMENTS

Full-time graduate students in the School of Computing are required to register for 9 hours, 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 also required to take nine hours to be classified as full-time by the graduate school.

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 dissertation defense. Once a student has passed the dissertation defense, the student does not have to register the next term, but the final dissertation should be turned in within the 90-day period.

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 be a graduate level course having a course number of 5000 or above, and should be directly related to student's degree

- 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 School of Computing at the University of Utah. 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 MS degree to a PhD 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. The number of hours is specified on a track/program basis. Each track/program determines the number of hours allowed that may count. 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, the track director, and the DGS.

PhD 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 PhD requirements, and can be used to satisfy some or all of the PhD 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 PhD 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 course requirements,
- passes the written portion of the qualifying examination, and
- passes the oral portion of the qualifying examination (i.e. proposal defense).

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 PhD Supervisory Committee (SVC) conducts the student's written qualifying examination, oral qualifying examination, and dissertation defense. This committee consists of five faculty members, at least one member must be from outside the SoC. The following two policies are in place for SVCs:

1. The chair of an SVC must be a regular faculty member (tenured/tenure track) from the SoC.
2. The majority of the SVC must be regular faculty members (tenured/tenure track) within the SoC.

Research or adjunct faculty may chair or may be members of supervisory committees if accorded that privilege by the SoC faculty and the Graduate School. However, exception to only one of the two policies listed above but not both simultaneously will be allowed. For Computing degrees, further restrictions on committee makeup may apply. All official decisions of the committee are decided by majority vote.

RESEARCH ENGAGEMENT REQUIREMENT FOR FELLOWSHIP STUDENTS

All fellowship students are required to take a total of 4 credit hours of research seminar classes offered by the SoC, essentially four (1) credit hour classes, in their first two semesters (could be divided as two seminar classes each semester). These research seminar classes will help the students explore different research areas and identify one that they would like to pursue for their PhD research.

Students must engage in seminars from different research areas in order to qualify for this requirement.

Alternately, the fellowship students can choose to enroll in 2 seminars and one independent study of 2 hours (with an SoC faculty member) to meet the research engagement requirement. A student cannot count a single offering of a seminar in a semester as more than one even if the students enrolls in the seminar for more than one credit hour. The research engagement requirement can be waived by the DGS or the Director of SoC if a student can demonstrate some other "significant research activity", such as working as an RA in a research group. Research colloquium **cannot** be counted towards meeting this research seminar requirement, but research boot-camp class for PhD students is counted and required.

The research engagement requirement applies only to the fellowship students.

TEACHING MENTORSHIP

All PhD students will be required to complete 4 credit hours of Teaching Mentorship with a "Pass" grade. Teaching mentorship will involve working with one or more faculty members (Teaching mentors) on tasks including but not limited to the following:

- Holding student contact hours
- Developing teaching resources (e.g., web pages)
- Lecturing
- Developing and grading assignments

The Teaching Mentorship must be spread across two semesters (2 credit hours each semester). The required tasks will be laid out by the Teaching Mentors before the start of the mentorship each semester. A Pass/Fail grade will be assigned for each semester by the Teaching Mentors based on how well the mentee performs the required tasks. The Teaching Mentorship must be completed before the written qualifying examination (described below). The Teaching Mentorship hours cannot be used to replace course requirements.

The mentorship assignment will be made in conjuction with your advisor and the Undergraduate Faculty Advisor (Jim de St. Germain). The mentorship should be fulfilled by the end of the 6th semester. In very special cases, the Teaching Mentorship requirement can be waived by the Director of the School of Computing if the student has significant prior teaching experience (e.g., having taught at a recognized US university).

PhD QUALIFYING EXAMINATION

All PhD students must pass a Qualifying Examination, as specified by the Graduate School. The Qualifying Exam consists of two parts, a written examination covering the candidate's chosen area of specialization and an oral examination involving a defense of the candidate's written thesis proposal.

The written portion of the Qualifying Examination will cover the candidate's general area of specialization in sufficient depth to demonstrate his/her preparation for conducting PhD level research. Each member of the student's supervisory

committee will contribute one or more questions to this exam. The supervisory committee will provide a written evaluation of this portion of the exam, including an indication of whether or not the student will be allowed to proceed to the oral portion of the Qualifying Examination. Specific details of the written qualifying exam procedures appear below.

The oral portion of the Qualifying Exam involves a defense of the candidate's dissertation proposal. At the supervisory committee's option, it may also include follow up questions relating to the written portion of the exam. All members of the candidate's committee should certify that the proposal is ready to be defended prior to conducting the oral portion of the Qualifying Exam.

There are two forms required to be filled out; these forms are available on-line or from the Graduate Coordinator. The first is a report on the written portion of the Qualifying Exam. The second is a report for the complete Qualifying Exam, both written and oral. These forms plus the written examination questions and student answers, will be retained in the student's School of Computing file. Consistent with the requirements of the Graduate School, the Qualifying Examination must be completed at least one semester prior to defense of the thesis.

Guidelines on PhD Written Qualifying Exams Question Submission

Each member of the student's supervisory committee who holds a faculty rank in the University of Utah School of Computing must submit at least one question. Other committee members may each submit a question at their option.

Question Format

The format of each question can be chosen by the committee member posing the question. Possibilities include (but are not limited to):

- "Take home" question, to be researched by the student using library, web, and other publicly available resources;
- A "closed book sit down" examination, to be written during a fixed period without use of background materials;
- An "open book sit down" examination, similar to (2), but permitting use of reference materials.

* Note that in all cases, the examination will be written, not oral.

Exam Administration and Grading

The entire exam should be completed in no more than seven days from initial question assignment to completed answers. Grading should be completed within seven days after the student delivers his/her answers. Each committee member contributing a question will grade that question and provide a specific, written evaluation of the quality and correctness of the answer. Allowable grades on individual questions are:

HP - high pass
P - pass
F - fail

A grade of P signifies the minimal acceptable performance expected from a PhD student. An F grade indicates an answer that is partially correct, but not up to the standards we expect from our PhD students.

The members contributing questions will each cast a Pass / Fail vote on the examination as a whole. An overall passing grade should be given to candidates who, through their answers, demonstrate that they are well prepared to conduct PhD level research in their specialty area of computer science. The overall exam Pass / Fail grade will be determined by majority vote of those contributing questions. In the event of equal numbers of Pass and Fail votes, the deciding vote will be cast by the Director of Graduate Studies.

Repeating the Exam

A student who fails his/her first attempt may retake the exam once. No conditional pass grades will be given. However, the supervisory committee can at their discretion include fewer questions on repeated exams.

PHD GUIDELINES

PhD 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 Advisor. 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 sent by email as a pdf to the Graduate Advisor two weeks prior to the announced time of defense. This copy will be made available for department access.

After successfully defending the dissertation, the student must obtain approval that the thesis is satisfactory by obtaining signatures from their committee members and the chair of the department by using the Final Reading Approval form, and the Supervisory Committee Approval form. These forms will be submitted with the final draft of the thesis manuscript to the thesis office. The majority of the signatures of the committee members are required for the thesis editors to start the format approval and the editing process. The Dean of the Graduate School signs the Final Reading Approval form after all editing is completed and before the thesis release. While a student can defend a thesis until the day before the following semester starts, in order to graduate in a certain semester, please see the thesis calendar for submission deadlines on the Graduate School's website.

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 Advisor 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, and one to the School of Computing library. 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

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, however, the full committee may consist of the same faculty members as the initial 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."

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. Students not in good standing can face consequences including loss of funding or expulsion from the PhD program.

PHD GUIDELINES

All PhD students are required to submit a duly filled and signed due progress form in the Fall semester every year. The deadline each year, typically in October, will be announced on the graduate students mailing list. Those students who fail to submit their due progress forms by the announced deadline can face consequences including loss of funding or expulsion from the PhD program.

GRADUATE STUDENT PROGRESS GUIDELINES FOR THE PhD PROGRAM

Milestone	Good Progress	Acceptable Progress	Comments
Choose advisor and initial committee	1 Semesters	2 Semesters	
Program of study approved by advisor and initial committee	4 Semesters	5 Semesters	
Complete Teaching Mentorship	4 Semesters	6 Semesters	
Complete required courses	5 Semesters	6 Semesters	
Full committee formed	6 Semesters	7 Semesters	
Program of study approved by committee	6 Semesters	7 Semesters	U. requirement: one semester before defense
Written qualifier	5 Semesters	6 Semesters	U. requirement: one semester before defense
Oral qualifier (proposal)	7 Semesters	8 Semesters	U. requirement: After written qualifier and one semester before defense
Dissertation defense	10 Semesters	12 Semesters	
Final document			U. requirement: document finalized within three months of the defense

PHD IN COMPUTER SCIENCE

At least 50 hours of graduate coursework is required for the PhD 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. 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 hours may be graduate-level courses outside of the School of Computing. 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 Track director. PhD students must demonstrate core knowledge in computer science by fulfilling the following requirements:

COURSE REQUIREMENTS Required courses:	
CS 6150	Advanced Algorithms
CS 6460	Operating Systems
CS 6810	Computer Architecture

Students must show proficiency in the three fundamental categories: theory, systems and hardware. Students can request approval from the Track director to substitute the required courses with other electives, or more advanced courses 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. Additional 6000-level courses and above may be required to reach a 50-credit hour minimum (excluding independent study, seminars, or dissertation research credit hours).

PHD IN COMPUTING:
COMPUTER ENGINEERING

A PhD student must either already have an MS degree or complete all of the requirements for a course, project, or thesis-based MS degree in CE. The supervisory committees may require additional coursework hours above that required for the MS degree. Also, all students must complete at least 7 hours of coursework at the University of Utah. All students must complete at least 14 hours of dissertation research (CS 7970).

TRACK FACULTY

Rajeev Balasubramonian, **Erik Brunvand (Track Director),** Neil Cotter (ECE), Peter Jensen, Priyank Kalla (ECE), Sneha Kumar Kasera, Chris Myers (ECE), John Regehr, Ken Stevens (ECE)

COURSE REQUIREMENTS
Required courses for students not already having an MS degree: Same as the requirements for the M.S. in Computer Engineering listed on Page 11 of this handbook.
Required courses for students who already have an MS degree: At least 7 hours of coursework at the University of Utah determined in consultation with the student's committee.

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 PhD committee consists of five members. The majority of the committee must consist of CE faculty from either SoC or ECE. PhD 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 SoC or ECE 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.**

PHD IN COMPUTING:
DATA MANAGEMENT & ANALYSIS

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 track director. Students may place out of the following requirements by substituting or transferring courses from other institutions at the discretion of the track director.

TRACK FACULTY

Tom Fletcher, Lajos Horvath (Math), Chris Johnson, Sneha Kumar Kasera, Mike Kirby, Alexander Lex, Feifei Li, Miriah Meyer, Baxton Osting (Math), Valerio Pascucci, Bei Wang Phillips, Jeff Phillips (Track Director), Vivek Srikumar, Hari Sundar, Suresh Venkatasubramanian

CORE CLASSES: Must take 4 core classes, at least one from each line.	
CS 6140	Data Mining /or/ CS 6350 Machine Learning
CS 6150	Advanced Algorithms
CS 6530	Database Systems
CS 6630	Visualization for Data Science (CS 6635 Visualization for Scientific Data may be taken as a subsitute)

A student must take four elective courses (twelve hours) which involve the areas related to data, 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, the students needs to take 6000 level courses and above when available/appropriate. In addition to the following electives, other 6000 level and above classes taught by track faculty are also typically allowed as electives. All courses taken by a track student to fulfill the elective requirements must be approved by the student's committee and the track director.

ELECTIVES

Three courses from the following list are required: (or CS 6140/CS 6350 if not counted above.) Students may also substitute most graduate courses taught by track faculty.

ALGORITHMICS

CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6180	Clustering

ANALYTICS

CS 6210	Advanced Scientific Computing
CS 6300	Artificial Intelligence
CS 6340	Natural Language Processing
CS 6390	Probabilistic Learning
CS 6961	Structured Prediction
CS 6963	Distributed Systems

MANAGEMENT

CS 6230	High-Performance Computing and Parallelization
CS 6235	Parallel Programming for GPUs/Many Course/Multi-Cores
CS 6480	Advanced Computer Networks
CS 6490	Network Security

PHD IN COMPUTING:
GRAPHICS & VISUALIZATION

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 MS degree may be included. At least 14 semester hours of dissertation research (CS 7970) and 27 semester hours of graduate course work must be included. Up to 20 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 required courses, 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 required courses greater than 3.5.

TRACK FACULTY

Martin Berzins, Elaine Cohen, Charles Hansen, Chris Johnson, Ladislav Kavan, Mike Kirby, Alexander Lex, Miriah Meyer, Valerio Pascucci, Bei Wang Phillips, Bill Thompson, **Cem Yuksel (track director)**

COURSE REQUIREMENTS Three of the following four courses are required:	
CS 6610	Interactive Computer Graphics
CS 6630	Visualization for Data Science
CS 6635	Visualization for Scientific Data
CS 6640	Image Processing
CS 6670	Computer-Aided Geometric Design

PHD IN COMPUTING:
GRAPHICS & VISUALIZATION

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 27 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 6160	Computational Geometry
CS 6170	Computational Topolgy
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6320	3D Computer Vision
CS 6360	Virtual Reality
CS 6540	Human/ Computer Interaction
CS 6600	Mathematics of Computer Graphics
CS 6620	Ray Tracing for Graphics
CS 6650	Perception for Graphics
CS 6660	Physics-Based Animation
CS 6680	Computer-Aided Geometric Design II
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.

PHD IN COMPUTING:
HUMAN-CENTERED COMPUTING

In human-centered computing (HCC) the design and development of technology is motivated by the needs of people. HCC focuses on understanding how people use technology, creating new and accessible technology that enables novel interactions, and evaluating how technology impacts and supports people in the world. The core methods and techniques in HCC are grounded in computer science, but are also draw on social science and design. Current HCC focus areas in the School of Computing include personal informatics, mobile interaction, visualization, games, and privacy.

TRACK FACULTY

Erik Brunvand, Rogelio E. Cardona-Rivera, Tamara Denning, Alexander Lex, **Miriah Meyer (track director),** Jason Wiese, R. Michael Young

CORE CLASSES: Required courses:	
CS 6540	HCI
CS 6xxx	Advanced HCI
CS 6630	Visualization for Data Science
ED PS 6010	Introduction to Statistics and Research Design

ELECTIVES: 5 electives in total
Pre-approved course list from within CS and across campus (1) Up to 3 electives can be taken from outside CS (2) Other electives require director approval

PRE-APPROVED CS ELECTIVES

Data Science

CS 6140	Data Mining
CS 6160	Computational Geometry
CS 6190	Probalistic Modeling
CS 6340	Natural Language Processing
CS 6350	Machine Learning
CS 6530	Database Systems

Visualization

CS 6635	Visualization for Scientific Data

Robotics

CS 6300	Artifiial Intelligence
CS 6310	Robotics
CS 6320	3D Computer Vision

Computer Graphics

CS 6610	Interactive Computer Graphics
CS 6640	Introduction to Digital Imaging

Embedded Systems

CS 6780	Embedded System Design
CS 6785	Advanced Embedded Software

PHD IN COMPUTING:
HUMAN-CENTERED COMPUTING

PRE-APPROVED NON-CS ELECTIVES

Design

DES 5320	Typographic Communication
DES 5370	Digital Fabrication
DES 5710	Product Design and Development

Ed Psychology

ED PSY 6030	Introduction to Research Design

Psychology

PSY 6120	Advanced Human Cognition
PSY 6140	Cognitive Neuroscience Approaches to Research
PSY 6420	Methods in Social Psychology
PSY 6700	Neuropsychology

Anthropology

ANTH 6169	Ethnographic Methods

Sociology

SOC 6110	Methods of Social Research

Entertainment Arts and Engineering

EAE 6900	Games User Research
EAE 6900	A.I. For Games

Mechanical Engineering

ME EN 7240	Haptics for Virtual Reality, Teleoperation, and Physical Human-Robot Interaction

PHD IN COMPUTING:
IMAGE ANALYSIS

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 MS degree may be included. **Seminars may be used as part of the required 50 hours, but independent study cannot.**

TRACK FACULTY

Tom Fletcher (Track Director), Tom Henderson, Sarang Joshi, Srikumar Ramalingam, Tolga Tasdizen, Bill Thompson, Ross Whitaker

COURSE REQUIREMENTS Required courses:	
CS 6640	Image Processing
CS 7640	Advanced Image Processing and/or BIOEN 6500 Mathematics of Imaging
Students are also required to complete two out of the following three courses: The third can be taken as elective.	
CS 6150	Advanced Algorithms
CS 6320	3D Computer Vision
CS 6350	Machine Learning

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:	
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 6500	Mathematics of Imaging
COMPUTATIONAL METHODS	
CS 6160	Computational Geometry
CS 6170	Computational Topology
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6550	Foundations of Algorithms in Computer Graphics and Visualization
STATISTICS & LEARNING	
CS 6300	Artificial Intelligence
CS 6390	Probabilistic Modeling
CS 6560	Computational Statistics
ECE 6540	Estimation Theory

Students may place out of required courses or electives 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, and they must be approved by the Track Director. Up to 12 approved credit hours may be transferred from other institutions, and up to 20 credit hours may be used from a previous MS degree at the University of Utah.

PHD IN COMPUTING:
NETWORKED SYSTEMS

Course work listed on the approved Program of Study form must comprise at least 50 semester hours of graduate course work and dissertation research. Up to 3 credit hours of an Independent Study (CS 6950) can be included in the Program of Study. At least 14 semester hours of dissertation research (CS 7970) and 27 semester hours of graduate course work must be included. Up to 20 hours of graduate level course work already applied to other degrees may be used in the program of study as approved by the track director.

TRACK FACULTY

Tamara Denning, Eric Eide, Ganesh Gopalakrishnan, Mary Hall, Feifei Li, **Sneha Kasera (Track Director),** Neal Patwari, John Regehr, Robert Ricci, Ryan Stutsman, Jacobus van der Merwe, Suresh Venkatasubramanian

COURSE REQUIREMENTS The following 3 courses are required:	
CS 6480	Advanced Computer Networks
CS 6490	Network Security
CS 6956	Wireless and Mobile Networks

PhD students must demonstrate core knowledge in networked systems by passing three specied courses, 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 specied courses of at least 3.5.

A student must take five elective courses (fifteen hours) which are related to the general area of networking or are directly applicable to the student's dissertation research. Up to two courses (six 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. All courses taken by a track student to fufilll the elective requirements must be approved by the student's committee and the track director.

ELECTIVES At least 4 elective courses must be taken from the following list:	
CS 6110	Formal Methods in Systems Design
CS 6150	Advanced Algorithms
CS 6235	Parallel Programming for GPUs/Many Cores/Multi-Cores
CS 6460	Operating Systems
CS 6530	Database Systems
CS 6810	Computer Architecture
CS 6957	Software Defined Network Architecture
CS 6963	Distributed Systems
CS 6964	Computer Security Research
Additional CS graduate level courses may be required to meet the 50 credit hour program of study requirement.	

PHD IN COMPUTING: **ROBOTICS**

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 must be taken 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, Tucker Hermans, **John Hollerbach (Track Director),** Steve Mascaro (ME), Vivek Srikumar, Ross Whitaker

COURSE REQUIREMENTS Required courses:	
CS 6310 / ME EN 6220	Introduction to Robotics
CS 6370 / ME EN 6225	Motion Planning
CS 6330 / ME EN 6230	Introduction to Robot Control (pre-requisite for CS 7310 & CS 7320)
CS 7939 / ME EN 7960-001*	Robotics Seminar (Fall 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
CS 6380	Multi-agent systems
ACTION	
ME EN 6240	Advanced Mechatronics for Mechanical Engineers
CS 6360	Virtual Reality
CS 7310 / ME EN 7230	Robot Mobility and Manipulation
CS 7320 / ME EN 7220	System Identification
ME EN 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.

PHD IN COMPUTING:
SCIENTIFIC COMPUTING

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 track director.

TRACK FACULTY

Martin Berzins, Mary Hall, Chuck Hansen, Tom Henderson, Chris Johnson, Mike Kirby, Valerio Pascucci, **Hari Sundar (Track Director),** Ross Whitaker

COURSE REQUIREMENTS The following four courses are required:	
CS 6210	Advanced Scientific Computing I
CS 6220	Advanced Scientific Computing II
CS 6230 CS 6235	High-Performance Computing and Parallelization and/or Parallel Programming for GPUs/Many Cores/Multi-Cores
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. Students can possibly take other 6000-level and above courses within the School of Computing as electives; advising and permission of the track director (or mentor and committee) is necessary in such cases.	
CS 6100	Foundations of Computer Science
CS 6530	Database Systems
CS 6610	Interactive Computer Graphics
CS 6650	Image Synthesis
CS 6810	Advanced Computer Architecture
CS 7120	Information-Based Complexity
CS 7210	Advanced Topics in Scientific Computing
CS 7450	Simulation Methods
Additional 6000-level and above courses may be required to reach a 50-credit minimum (excluding independent study, seminars, or dissertation research credit hours).	