

# COMPUTING & INFORMATION SCIENCE, PHD

College of Information, Science & Technology

## Vision Statement

The PhD program in computing and information science at the University of Nebraska Omaha (UNO) is a research-intensive, multidisciplinary program focused around the core areas of computer science, management information systems and interdisciplinary informatics.

## Program Contact Information

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Program Website (<http://phd.ist.unomaha.edu/>)

## Other Program Related Information

### Student Learning Outcomes

Upon completion of a PhD in Computing and Information Science:

- Students will be able to interpret and synthesize research literature from multiple areas of the IT discipline.
- Students will be able to identify open research questions and design appropriate approaches to investigate them.
- Students will demonstrate the ability to contribute to scholarly literature.
- Students will be able to effectively engage students in learning about IT content.

## Admissions

Applicants with an earned undergraduate or graduate degree in a computing discipline (e.g., computer science, management information systems, bioinformatics, cybersecurity or a closely related discipline) can apply for admission to the PhD program. Applicants whose prior degrees are outside of a computing discipline are encouraged to discuss their interests with the program director prior to application.

Admission decisions are based on a holistic review of application materials by the College of IS&T's Doctoral Program Committee (DPC). During this review process the committee is looking for candidates that demonstrate:

- **Technical Interest.** Our program is a PhD in computing & information science. As such, you will be expected to demonstrate an interest and aptitude in computing that fits with the nature of our program.
- **Prior Experience with Research.** A PhD is fundamentally a research degree. Highlight your involvement in existing research projects, thesis work, and/or publications. Be specific about the roles you played in various projects in your statement of purpose and seek reference letters from those who can speak to your research experience and potential.
- **Alignment with UNO Faculty Expertise.** Alignment of your research interests with the expertise of graduate faculty in the College of IS&T is an important consideration during admissions in order to ensure successful applicants will have access to appropriate research mentors

from the start of the program. Review IS&T faculty profiles on the web, identify specific research areas that interest you in your statement of purpose, and explicitly mention faculty names with whom you see a good match. Feel free to reach out via email to our faculty prior to submitting your application to discuss your interest.

- **Independence and Initiative.** A PhD is largely self-motivated and self-directed work. As such, successful PhD applicants should demonstrate a history of taking the initiative to perform beyond expectations and work independently.
- **Proficiency in Written and Verbal English Communication.** The ability to read, comprehend and write scholarly papers is key to success as a doctoral student.

General Application Requirements and Admission Criteria (<http://catalog.unomaha.edu/graduate/admission/>)

## Program-Specific Requirements

### Application Deadlines (Spring 2024 and Fall 2024)

- Fall: January 15
- Spring: September 15

NOTE: All materials, including recommendation letters, transcripts, and applicable test scores, must be received by the application deadline. Applications which are incomplete after the published deadline will not be reviewed.

## Other Requirements

- **Entrance Exam:** Graduate Record Examination (GRE) scores are required for most applicants but are only one component of a holistic admission decision. Successful applicants have typically had GRE scores of 150 verbal and 160 quantitative or better. The GRE requirement may be waived for exceptional applicants subject to the GRE waiver procedures documented below.
  - The GRE may be automatically waived for applicants holding a master's degree from an accredited US institution provided that (1) the degree is in a computing discipline and (2) that the graduate GPA for that degree is 3.3 or higher.
  - A GRE waiver may also be *requested* for candidates meeting one or more of the conditions below.
    - Those who hold a bachelor's degree in a computing discipline from an accredited US institution with a GPA of 3.6 or higher.
    - Those with a minimum of 5 years of professional experience in the IT industry in the United States.
    - Those with a history of high-quality, peer-reviewed publications in a computing field who have made significant contributions to the authorship of those papers.
    - GRE waiver requests must be submitted to the Doctoral Program Committee Chair using the form located on the program website along with supporting documentation. Requests must be received at least 1 month prior to the published application deadline for the applicable term. Note that eligibility to apply for a GRE waiver does not guarantee it will be granted, and waivers will only be approved by the DPC in cases where the candidate's record permits an evaluation of their research potential without reference to GRE scores.
- **English Language Proficiency:** Applicants are required to have a command of oral and written English. Those who do not hold a baccalaureate or other advanced degree from the U.S., **OR** a baccalaureate or other advanced degree from a predetermined country on the waiver list (<https://www.unomaha.edu/graduate-studies/prospective-students/Proof%20of%20English%20Proficiency-%20International.pdf>), must meet the minimum language proficiency score requirement in order to be considered for admission.
  - Internet-based TOEFL: 90, IELTS: 7.0, PTE: 61, Duolingo: 120

- **Statement of Purpose:** A written statement (not to exceed two single-spaced pages) which addresses the following:
  - How is a PhD in computing & information science going to advance your career?
  - Why is UNO the right place for you to pursue doctoral studies?
  - In answering the questions above the statement should:
    - Describe your research interests and how they align with the work of current IS&T faculty members.
    - Describe any relevant technical knowledge/skills or professional experiences that relate to the research you hope to conduct in computing and information science.
    - Describe your prior research experiences. If you have participated in collaborative research, what was your role on those projects?
    - Lastly, if you have included optional supporting materials as part of your application, explain them.
- **Current resume or CV:** In addition to listing prior academic accomplishments and professional positions, please include complete citations for all prior authored academic publications if applicable.
- **Letters of Recommendation:** Three letters of recommendation are required. The best recommendation letters are from those who can give an in-depth evaluation of your strengths and weaknesses with respect to academic work.
  - We strongly recommend that at least one letter writer be able to speak directly about your prior research experiences.
  - Letters must be submitted directly to the application system by the letter writers. The DPC reserves the right to verify the content of recommendation letters with their authors.
- **Transcripts:** Transcripts from all higher-education institutions previously attended are required.
- **Optional Supporting Materials:** Applicants are encouraged to include a PDF portfolio of supporting materials that may provide additional evidence of research potential. This may include:
  - Copies of academic papers, publications, theses or project reports done in an academic or industrial setting
  - Documentation of technical accomplishments like a portfolio of significant software development projects
  - Documentation of certifications or other forms of micro-credentials not otherwise reflected on transcripts
  - Other materials you would like to share with the committee

## Admission Process and Timeline

Eligible students who request a GRE waiver must do so no later than one month prior to the published program application deadline for the term. These requests will be reviewed by the DPC, and applicants will be notified via email of the GRE waiver outcome prior to the admission deadline.

Following the admission deadline, the DPC will begin review of all complete applications. It is the applicant’s responsibility to ensure all materials are available for review (including reference letters, transcripts, and others supporting materials) in the admission system by the deadline. Incomplete applications will not be considered by the committee.

Candidates identified for further consideration may be invited by the committee to take part in an interview with a small group of faculty to learn more. These interviews are usually conducted within 4-8 weeks following the application deadline. Final admission decisions are usually made within 2-3 weeks following those interviews.

## Degree Requirements Coursework

The PhD in computing & information science program requires 90 credit hours of graduate-level studies. The coursework taken by a student is entered into a plan of study that must be approved by the doctoral program committee before the beginning of the PhD student's second year of studies. The coursework consists of foundation courses, doctoral seminar and colloquia, a major field of study, and the dissertation. General rules applying to all plans of study include:

- Undergraduate course credits taken at UNO or another institution cannot be counted toward the PhD degree in computing & information science.
- Dual-listed undergraduate courses ending in 8xx5 cannot be counted as course credits in the PhD program.
- Only three courses ending in 8xx6 are allowed outside the Foundation Course section of a plan of study.
- Graduate internship credit (CSCI 8950, ISQA 8910, CYBR 8910, or equivalent) may not be used in a doctoral plan of study.
- A maximum of three directed study type courses may be counted in the plan of study, including CIST 9970, CIST 9980, masters-level independent study courses, or other equivalents.

The different categories of credit-hour requirements for the program are outlined below.

### Foundation Courses 24 credit hours

Foundation courses constitute any of the courses offered in the master's degree in a computing-related field (e.g.: computer science, management information systems, cybersecurity, IT innovation).

Credit for graduate computing-related coursework in a prior degree may only be used to satisfy foundation course hours in the plan of study. A grade of B- or better is required in all coursework from a prior degree applied to foundation requirements, and thesis, thesis-equivalent project, independent study credits, or their equivalents from a prior degree may not be counted towards foundation requirements.

### Core Courses 12 credit hours

Code	Title	Credits
CIST 9080	RESEARCH DIRECTIONS IN I.T.	3
CIST 9040	COLLOQUIUM ON IT RESEARCH	1
CIST 9050	COLLOQUIUM ON IT TEACHING	1
CIST 9060	COLLOQUIUM ON IT PROFESSION AND ETHICS	1

### A Graduate-Level Research Methods Course, selected from 3

ISQA 9150	RESEARCH IN INFORMATION TECHNOLOGY	
ITIN 9300	SOCIAL COMPUTING AND ITS APPLICATIONS	
or a concentration-designated research methods course for students in a concentration		
or an alternate course with faculty advisor and DPC approval (8xx0 or 9xxx level only)		

### A Graduate-Level Statistics Course, selected from 3

ISQA 8160	APPLIED DISTRIBUTION FREE STATISTICS	
ISQA 8340	APPLIED REGRESSION ANALYSIS	
ISQA 9130	APPLIED MULTIVARIATE ANALYSIS	
or an alternate course with faculty advisor and DPC approval (8xx0 or 9xxx level only)		

**Total Credits 12**

## Major Field of Study 18 credit hours

Coursework in the major field of study provides students the advanced study needed to develop an in-depth knowledge of their chosen field of research. For students who have indicated a concentration within their PhD in computing & information science plan of study, this comprises the concentration credit hours. At least three courses (9 hours) must be in 9000-level courses. The remaining courses should include at least one 8000-level graduate-only course.

## Electives 12 credit hours

Selected in consultation with your faculty advisor.

## Dissertation 24 credit hours

### 90 Total credit hours

## Comprehensive Examination & Admission to Candidacy

Comprehensive exams will typically be scheduled around the middle of the fall and spring semester, as needed. Students intending to take comprehensive exams must apply to do so at least one semester prior to the term in which they plan to take the exam. Comprehensive exams may not be taken without an approved plan of study in place and the student has completed all core coursework in the plan. Typically, the comprehensive exam will be administered between the fourth and sixth semesters of study in the PhD program (not including summers).

Comprehensive exams consist of three parts. Parts one and two must be completed within the same week, but may be scheduled on non-consecutive days.

- **Part 1: Written Breadth Examination (one day)**
  - When applying for the comprehensive examination, the student will select one area-of-interest on which to be tested from the list of available breadth examination areas published on the PhD in computing & information science program website. The area will specify a reading list of publications from which the student should prepare. Reading lists may be updated by faculty annually and must be updated after three years. Lists to be used in breadth exams the subsequent academic year will be posted online in April. Graduate faculty members responsible for each selected area of interest will prepare four essay style questions to be answered based on the published reading list.
  - Student responses to the breadth questions will be assessed by at least two graduate faculty members from each corresponding area of interest, excluding the student's direct faculty advisor.
- **Part 2: Written Depth Examination (one day)**
  - When applying for the exam, students without an approved dissertation committee must name a depth examining committee. This committee shall consist of the student's faculty advisor and at least two graduate faculty members from IS&T with relevant expertise in the student's intended area of research. For students with an approved dissertation committee on file, that committee will serve in this capacity.
  - The student and their faculty advisor will prepare a personal reading list of publications aligned with the student's intended dissertation research specialization. This reading list should be finalized no later than when the student applies to take the comprehensive exam.
  - The faculty advisor, in consultation with other depth examining committee members, will prepare a minimum of two essay questions that assess the student's depth of knowledge in their individual research trajectory.
  - Responses to depth questions will be assessed by the student's depth examining committee members.
- **Part 3: Oral Examination**

- Prior to taking either part of the written exam, the student will prepare and submit a research pre-proposal about their intended dissertation focus to their depth examining committee members. Details about the structure and content of the pre-proposal can be found on the PhD in computing & information science program website.
- Within two weeks of being notified of a passing result on parts one and two of the comprehensive examination, the student will give a brief presentation (approximately 20 minutes) of their research pre-proposal to their depth examining committee members, followed by a question and answer period.
- Students receiving a failing result on either part one or two of the exam may not proceed to the oral examination.

Faculty members assessing the different components of the exams will be responsible for communicating a strictly pass/fail result to the DPC. A student may not be asked to revise any part of their examination after submission. Should the student fail one or more part of the comprehensive exam, they may be allowed to re-take it during the following academic term upon specific recommendation by the DPC. For students who fail only one area of the breadth exam, retaking only the deficient area will be required with appropriate adjustments for breadth exam time limits. However, a student may only attempt comprehensive exams a maximum of two times.

Upon successfully completing all three parts of the comprehensive examination and meeting the general residency requirements outlined in the Graduate Catalog, the student will advance to candidacy and should file the necessary paperwork with graduate studies.

## Dissertation

### Dissertation Committee

Students must establish their full dissertation committee no later than the end of the semester when they complete their comprehensive examination. Makeup of the dissertation committee is subject to general Graduate College rules governing dissertation committees. For purposes of the computing and information science program, all graduate faculty members in the College of Information Science & Technology are considered internal to the student's academic program.

### Dissertation Credits

The dissertation of a PhD candidate is supervised by the chair or co-chairs of the student's dissertation committee in consultation with other members of the committee. While working on his or her dissertation, the candidate should take hours for the course CIST 9990. A minimum of 24 hours of this course is required for graduation. Dissertation course credits should be taken only after the PhD student has passed all elements of the comprehensive exam and advances to candidacy.

**IMPORTANT NOTE:** A minimum of seven months must elapse between the date of the PhD student's advancement to candidacy and the date of his or her dissertation defense.

### Dissertation Proposal

Students must formally propose their dissertation to their approved dissertation committee. A written proposal should be prepared under the guidance of the dissertation committee, and a public oral defense of the proposal should be scheduled with the committee members allowing for sufficient time to review the written document. The result of the proposal defense should be recorded on the appropriate form by the dissertation committee and submitted to DPC. To ensure timely progress in the program, the proposal milestone should be completed no later than when students have accumulated 12 hours of CIST 9900.

### Scheduling Dissertation Defense

When the dissertation committee deems it appropriate for the PhD candidate to defend their dissertation, the PhD candidate should prepare a dissertation and submit it to the dissertation committee members. While

submitting the dissertation to the dissertation committee, the candidate should also submit a final oral exam form to the Office of Graduate Studies. The final oral exam form requires the signatures of the dissertation committee members and the doctoral program committee chair, and should be submitted at least four weeks before the desired date of the public dissertation defense. Dissertation committee members should sign this form after receiving the final draft of the dissertation.

**IMPORTANT NOTE:** Before scheduling the dissertation defense, the student should refer to the Office of Graduate Studies website and/or the current Graduate Catalog for the graduation checklist, dissertation filing deadlines and commencement dates for the semester in which they plan to graduate. Be sure to apply to graduate in MavLINK prior to the deadline.

## Teaching Requirement

PhD students are encouraged to teach at least one course in the College of IS&T at the undergraduate level as instructors of record during their PhD studies. Students typically will complete this requirement in their second or third year of studies. Further information about qualifications, timing, and funding related to teaching assignments can be found on the program website.

## Concentrations

### Artificial Intelligence Concentration

Code	Title	Credits
<b>Required Courses *</b>		
CSCI 8456	INTRODUCTION TO ARTIFICIAL INTELLIGENCE	<b>12</b>
CSCI 8110	ADVANCED TOPICS IN ARTIFICIAL INTELLIGENCE	
ISQA 9130	APPLIED MULTIVARIATE ANALYSIS	
CSCI 9810	RESEARCH FOUNDATIONS IN THEORETICAL COMPUTING	
<b>Electives</b>		
CSCI 9410	ADVANCED TOPICS IN LOGIC PROGRAMMING	<b>6</b>
ISQA 9120	APPLIED EXPERIMENTAL DESIGN AND ANALYSIS	
CSCI 8300	IMAGE PROCESSING AND COMPUTER VISION	
CSCI 8360	MACHINE LEARNING FOR TEXT	
CSCI 8450	ADVANCED TOPICS IN NATURAL LANGUAGE UNDERSTANDING	
CSCI/MATH 8480	MULTI-AGENT SYSTEMS AND GAME THEORY	
ISQA 8160	APPLIED DISTRIBUTION FREE STATISTICS	
ISQA 8340	APPLIED REGRESSION ANALYSIS	
ISQA 8720	APPLIED STATISTICAL MACHINE LEARNING	
ITIN 8300	RESEARCH FOUNDATIONS	
MATH 8456	INTRODUCTION TO MACHINE LEARNING AND DATA MINING	
or STAT 8456	INTRODUCTION TO MACHINE LEARNING AND DATA MINING	
CSCI 8476	PATTERN RECOGNITION	
CSCI 8486	ALGORITHMS FOR ROBOTICS	
CSCI 8590	FUNDAMENTALS OF DEEP LEARNING	
BMI 8400	LINEAR ALGEBRA FOR ADVANCED COMPUTING AND AI	
<b>Total Credits</b>		<b>18</b>

\* Any required course completed while pursuing a master's degree may be substituted with any of the concentration electives.

### Computing Systems Concentration

Code	Title	Credits	
<b>Required Courses (select any three from the list below) *</b>			
CSCI 8150	ADVANCED COMPUTER ARCHITECTURE	<b>9</b>	
CSCI 8210	ADVANCED COMMUNICATIONS NETWORKS		
CSCI 8530	ADVANCED OPERATING SYSTEMS		
CYBR 9460	SECURITY OF EMBEDDED SYSTEMS		
<b>Electives</b>			
CIST 9100	SEMINAR ON READINGS IN IT	<b>9</b>	
CSCI 9420	INTELLIGENT AGENT SYSTEMS		
CSCI 8160	INTRODUCTION TO VLSI DESIGN		
CSCI 8410	DISTRIBUTED SYSTEMS AND NETWORK SECURITY		
CSCI 8390	ADVANCED TOPICS IN DATA BASE MANAGEMENT		
CSCI 8430	TRUSTED SYSTEM DESIGN, ANALYSIS AND DEVELOPMENT		
CYBR 8480	SECURE MOBILE DEVELOPMENT		
CSCI 8610	FAULT TOLERANT DISTRIBUTED SYSTEMS		
CSCI 8620	MOBILE COMPUTING AND WIRELESS NETWORKS		
CYBR 8436	QUANTUM COMPUTING AND CRYPTOGRAPHY		
CSCI 8446	INTRODUCTION TO PARALLEL COMPUTING		
CSCI 9810	RESEARCH FOUNDATIONS IN THEORETICAL COMPUTING		
Courses not used in concentration requirements may also satisfy concentration electives.			
Other courses may count as electives on a case-by-case basis with approval of the concentration faculty			
<b>Total Credits</b>			<b>18</b>

\* Any required course completed while pursuing a master's degree may be substituted with any of the concentration electives.

### Human-Centered Computing Concentration

Code	Title	Credits
<b>Required Courses *</b>		
ISQA 9030	BEHAVIORAL AND ORGANIZATIONAL ISSUES IN INFORMATION SYSTEMS	3
CSCI 8256	HUMAN COMPUTER INTERACTION	3
CIST 9100	SEMINAR ON READINGS IN IT (3 total hours required)	1
<b>Electives, selected from</b>		
CMST 8196	COMPUTER-MEDIATED COMMUNICATION	<b>9</b>
CSCI/ITIN 8266	USER EXPERIENCE DESIGN	
ISQA 9010	FOUNDATIONS OF INFORMATION SYSTEMS RESEARCH	
ITIN 8300	RESEARCH FOUNDATIONS <sup>1</sup>	
ITIN 8220	DESIGN PROCESS	

ITIN 9300	SOCIAL COMPUTING AND ITS APPLICATIONS	
SOC 8060	QUALITATIVE METHODS <sup>1</sup>	
Other elective courses can be considered with faculty advisor, concentration, and DPC approval.		
<b>Total Credits</b>		<b>18</b>

<sup>1</sup> If not used as an HCC elective, SOC 8060 or ITIN 8300 can satisfy the IT PhD core requirement for a research methods course for students in the HCC concentration.

\* Any required course completed while pursuing a master's degree may be substituted with any of the concentration electives.

## IT Project Management Concentration

Code	Title	Credits
<b>Required Courses *</b>		
ISQA 9010	FOUNDATIONS OF INFORMATION SYSTEMS RESEARCH	3
ISQA 8810	INFORMATION TECHNOLOGY PROJECT FUNDAMENTALS	3
CIST 9100	SEMINAR ON READINGS IN IT (1 cr to be taken multiple times for 3 credits total, ITPM designated section only)	3
<b>Electives</b>		
Select 9 elective hours from below, with at least one elective at 9xxx level		9
CIST 9900	SPECIAL TOPICS IN INFORMATION TECHNOLOGY	
ISQA 9020	TECHNICAL AND PROCESS ISSUES IN INFORMATION SYSTEMS RESEARCH	
ISQA 9030	BEHAVIORAL AND ORGANIZATIONAL ISSUES IN INFORMATION SYSTEMS	
PSYC 9070	PROSEMINAR: COGNITIVE PSYCHOLOGY	
PSYC 9630	LEADERSHIP THEORIES AND RESEARCH	
CSCI 8710	MODERN SOFTWARE DEVELOPMENT METHODOLOGIES	
CSCI 8790	ADVANCED TOPICS IN SOFTWARE ENGINEERING	
CSCI 8700	SOFTWARE SPECIFICATIONS AND DESIGN	
ISQA 8210	MANAGEMENT OF SOFTWARE DEVELOPMENT	
ISQA 8820	PROJECT RISK MANAGEMENT	

Other elective courses may be selected with the by approval of the student's supervisory committee

\* Any required course completed while pursuing a master's degree may be substituted with any of the concentration electives.

## Academic Performance Progress Report

Every doctoral student (full time or part time) and must complete an annual Progress Report in consultation with their faculty advisor. These forms must be submitted for review by the Doctoral Program Committee to assess the student's progress in the program and track program level Student Learning Outcomes. Students will report on their completion of program milestones, outcomes of teaching assignments, and publications or measures of scholarly output. An electronic copy of the current form is available on the IT PhD program website.

The DPC will review progress reports and provide the student and their faculty advisor with a written assessment of progress. Any items of concern identified in this written assessment should be addressed in a timely manner by the student and their faculty advisor to ensure continued satisfactory progress in the program. If the DPC deems progress as not satisfactory, the student will be placed on probationary status and the student will be ineligible for funding as a graduate assistant. Students placed on probation must complete an additional progress report in the next semester updating DPC of their progress. After one semester on probation, a student whose performance has not improved will be recommended for dismissal by the Graduate College.

If student progress reports are not completed by the specified deadline, an advising hold will be placed on the student record and the student will be contacted and given an opportunity to submit the progress report within five days of being notified. If no progress report is received, the student's progress will be considered unsatisfactory and they may lose their funding and be counseled out of the PhD program.

### CIST 9040 COLLOQUIUM ON IT RESEARCH (1 credit)

The purpose of the course is to provide a forum for interaction among doctoral students and faculty on topics of relevance to professional success as researchers. Topics to be discussed include: nature of research in information technology; research problem selection, development, and presentation with special emphasis on the doctoral dissertation; dissertation process; development and crafting of papers for journals; collaboration on research projects; and review process for journal papers.

**Prerequisite(s):** Admission to PhD program in Information Technology or permission of instructor.

### CIST 9050 COLLOQUIUM ON IT TEACHING (1 credit)

The purpose of the course is to provide a forum for interaction among doctoral student and faculty on topics of relevance to professional success as teachers/educators in university settings. Topics to be discussed include: issues and challenges of teaching; getting started in teaching; course preparation; teaching methods; assessment of students; on-going course development; diversity in the classroom; use of technology in teaching including online education; and developing and maintaining a teaching portfolio.

**Prerequisite(s):** Doctoral students in Information Technology and Biomedical informatics. Students from doctoral programs across the University of Nebraska are welcome to register with permission of instructor. Not open to non-degree graduate students.

### CIST 9060 COLLOQUIUM ON IT PROFESSION AND ETHICS (1 credit)

The purpose of this course is to provide a forum for interaction among doctoral students and faculty on topics of relevance to professional success as members of the academy. Some of the topics to be discussed will include: ethics and professional code of conduct; strategies for dealing with academic dishonesty/plagiarism; academic and professional organizations in the IT profession (e.g., IEEE, ACM, AIS, PMI, AITP); challenges of human subjects research; developing survival skills: balancing service, teaching and research, etc.; career development and progression; and role and nature of local, national, and international service.

**Prerequisite(s):** Any IS&T PhD student is eligible to attend; other Doctoral students can attend with permission of instructor. Not open to non-degree graduate students.

### CIST 9080 RESEARCH DIRECTIONS IN I.T. (3 credits)

The purpose of this course is to provide a forum for interaction among doctoral students and faculty on topics of relevance to IT research and make them familiar with current and future research directions in IT. Students will examine what constitutes a research contribution, gain hands-on experience with directed research, and explore the breadth of sub-disciplines within IT research.

**Prerequisite(s):** Doctoral standing in Information Technology or permission of course coordinators. Not open to non-degree graduate students.

**CIST 9100 SEMINAR ON READINGS IN IT (1 credit)**

Seminar focused on IT literature within a topic area aligned with PhD in IT concentrations, providing opportunity for in-depth review and discussion of materials in the concentration reading list. Provides exposure to current topics, research methods, and professional practice for the concentration.

**Prerequisite(s):** Open to all currently admitted PhD students and other graduate students by instructor permission. May be repeated up to 3 times for credit in Major Field of Study, and up to 3 times as an elective.

**CIST 9900 SPECIAL TOPICS IN INFORMATION TECHNOLOGY (3 credits)**

This course is designed to acquaint students with issues which are current to the field or emerging trends in the information technology area. Topics will vary across terms. This course may be repeated, but no topic may be taken more than once.

**Prerequisite(s):** Permission of the instructor. Additional prerequisite courses may be required for particular topic offerings.

**CIST 9970 RESEARCH OTHER THAN THESIS (1-3 credits)**

This is a directed research course enabling students to pursue a research topic individually under the direction of a graduate faculty member. Research problems should help introduce students to practical research methods in the field of computing, and they should be framed in such a way to enable the student to complete the work in the course of one semester.

**Prerequisite(s):** Requires instructor permission. Only open to doctoral students in the IT PhD program. Course cannot be taken for credit after candidacy nor count towards core/major field of study requirements in the IT PhD. Not open to non-degree graduate students.

**CIST 9980 INDEPENDENT STUDY IN INFORMATION TECHNOLOGY (1-3 credits)**

This course allows students to conduct an in-depth study of a specific topic of their interest that is not available in a formal course. The topic to be studied must be agreed upon by the student and the instructor, including a structured schedule and grading criteria, and should be distinct from students' thesis work or Research Other Than Thesis (CIST 9970) course credits.

**Prerequisite(s):** Requires instructor permission. Only open to doctoral students in the IT PhD program. Not open to non-degree graduate students.

**CIST 9990 DISSERTATION (1-12 credits)**

The dissertation is an original research project conducted and written under the direction of a faculty supervisory committee. The dissertation provides the student with an opportunity to do original research that contributes to advancing the body of knowledge in information systems and/or information technology.

**Prerequisite(s):** Admission to the Ph.D. program in Information Technology. Admission to candidacy for the Ph.D. degree. Prior to enrolling for dissertation hours, the students must have permission of the supervisory committee. Not open to non-degree graduate students.

**CSCI 8000 ADVANCED CONCEPTS IN PROGRAMMING LANGUAGES (3 credits)**

Logic/Declarative programming is an important programming paradigm in which problems are described in terms of the properties they possess. As a result, in this style of programming many algorithmic elements, which explicitly must be articulated when writing programs in other programming languages, can be omitted. Core elements of logic programming play important roles in AI.

**Prerequisite(s):** CSCI 3320; CSCI 3660; CSCI 4220. Not open to non-degree graduate students.

**CSCI 8010 FOUNDATIONS OF COMPUTER SCIENCE (3 credits)**

This is a foundational course for students enrolled in the graduate program in computer science. The objectives are to introduce students to a large body of concepts so that they are better prepared for undertaking the core courses in the graduate program. It is assumed that student would have programmed in a high-level language and have exposure to basic college level mathematical concepts such as logarithms, exponents, sequences, and counting principles.

**Prerequisite(s):** Students are expected to have written programs using a high-level programming language and should understand basic mathematical concepts including exponents, logarithms, sequences, and counting principles. Not open to non-degree graduate students.

**CSCI 8016 INTRODUCTION TO THE THEORY OF RECURSIVE FUNCTIONS (3 credits)**

This is a proof-oriented course presenting the foundations of Recursion Theory. We present the definition and properties of the class of primitive recursive functions, study the formal models of computation, and investigate partially computable functions, universal programs. We prove Rice's Theorem, the Recursion Theorem, develop the arithmetic hierarchy, demonstrate Post's theorem. Introduction to the formal theories of computability and complexity is also given. (Cross-listed with MATH 4010, MATH 8016, CSCI 4010).

**Prerequisite(s):** MATH 2230 or MATH 2030 with a C- or better or CSCI 3660 with a C- or better or instructor's permission.

**CSCI 8040 LARGE SCALE NETWORK ANALYSIS ALGORITHMS (3 credits)**

The course will provide a review of the properties of large complex network systems, such as those occurring in social networks, epidemiology and biological systems. We will discuss algorithms to analyze these properties, their implementations, their stability under information fluctuation and how information spreads through networks.

**Prerequisite(s):** Students should be comfortable w/ programming, have knowledge of data structures, preliminary graph algorithms, & linear algebra. Suggest Prep Courses: CSCI 4150 or CSCI 8156; CSCI 3320; MATH 4050 or Permission. Not open to non-degree graduate students.

**CSCI 8050 ALGORITHMIC GRAPH THEORY (3 credits)**

The overall of the goal is to introduce advanced concepts in graph theory, graph modeling, and graph algorithms and how they can be used to solve a wide range of problems in various application domains. The course introduces students to several applied path algorithms, clustering and partitioning techniques, network flow algorithms, and weighted matching algorithms. Other advanced concepts associated with complex networks include node centralities in graphs and community detection approaches. The course will also introduce students to key classes of graphs with a particular focus on the main classes of Perfect Graphs and their applications in scheduling, chip design, mobile computing, and Biomedical Informatics. (Cross-listed with MATH 8050).

**Prerequisite(s):** CSCI 3320 or CSCI 8325 and MATH 4150 or MATH 8156 or permission of instructor. Not open to non-degree graduate students.

**CSCI 8060 ALGORITHMIC COMBINATORICS (3 credits)**

This course includes classical combinatorial analysis graph theory, trees, network flow, matching theory, external problems, and block designs. (Cross-listed with MATH 8060).

**Prerequisite(s):** MATH 3100, CSCI 3100, MATH 8105 or CSCI 8105 or instructor's permission.

**CSCI 8080 DESIGN AND ANALYSIS OF ALGORITHMS (3 credits)**

The course provides students an understanding of advanced topics in algorithms. Main topics include: growth of functions, asymptotic notation, recurrences, divide and conquer, dynamic programming, greedy algorithms, graph algorithms, and the theory of NP-Completeness. (Cross-listed with MATH 8080).

**Prerequisite(s):** CSCI 3320 or CSCI 8325 or equivalent. Not open to non-degree graduate students.

**CSCI 8105 APPLIED COMBINATORICS (3 credits)**

Basic counting methods, generating functions, recurrence relations, principle of inclusion-exclusion. Polya's formula. Elements of graph theory, trees and searching network algorithms. (Cross-listed with MATH 8105, MATH 3100, CSCI 3100).

**CSCI 8110 ADVANCED TOPICS IN ARTIFICIAL INTELLIGENCE (3 credits)**

An in-depth study of one or more topics selected from: search techniques, knowledge representation, knowledge programming, parallel processing in Artificial Intelligence, natural language processing, image processing, current and future directions, etc. May be repeated with different topics, with permission of adviser.

**Prerequisite(s):** CSCI 4450 or CSCI 8456 or equivalent.

**CSCI 8150 ADVANCED COMPUTER ARCHITECTURE (3 credits)**

This course will provide an in-depth understanding of the key architectural concepts governing the design of state-of-the-art high-performance computers. It will introduce methods that are commonly used to trade-off the various architectural choices to design systems with the desired cost-performance requirements. The course will provide a systems level perspective to design. The emphasis will be on the cache, memory and I/O subsystems, system interconnects leading to distributed shared-memory multiprocessor systems. Multiprocessor clusters based on message passing and high-performance processor architecture will be covered. The course will also provide a brief overview of emerging system architectures including quantum computing and those used to facilitate machine learning applications.

**Prerequisite(s):** CSCI 4350, CSCI 4500 or equivalent with permission of the instructor. Not open to non-degree graduate students.

**CSCI 8156 GRAPH THEORY & APPLICATIONS (3 credits)**

Introduction to graph theory. Representations of graphs and graph isomorphism. Trees as a special case of graphs. Connectivity, covering, matching and coloring in graphs. Directed graphs and planar graphs. Applications of graph theory in several fields such as networks, social sciences, VLSI, chemistry and parallel processing. (Cross-listed with CSCI 4150, MATH 4150, MATH 8156).

**Prerequisite(s):** MATH 2030 or permission of instructor.

**CSCI 8160 INTRODUCTION TO VLSI DESIGN (3 credits)**

Introduction to the principal concepts of integrated circuits layout. Presentation of the hardware foundations, algorithmic mathematical and graph theoretical foundations of circuit layout. Topics discussed in digital design and computer architecture classes are studied at the actual layout design level such as datapath subsystems and array subsystems. Design methodology tools and testing. Hardware descriptions languages.

**Prerequisite(s):** CSCI 3320 (or CSCI 8325), CSCI 3710 and CSCI 4350 (or CSCI 8356). Not open to non-degree graduate students.

**CSCI 8206 NUMERICAL METHODS (3 credits)**

This course involves solving nonlinear algebraic equations and systems of equations, interpolation and polynomial approximation, numerical differentiation and integration, numerical solutions to ordinary differential equations, analysis of algorithms and errors, and computational efficiency. (Cross-listed with CSCI 4200, MATH 4200, MATH 8206).

**Prerequisite(s):** MATH 1970 and MATH 2050 and MATH 2350 with a C- or better or permission of instructor.

**CSCI 8210 ADVANCED COMMUNICATIONS NETWORKS (3 credits)**

Advanced study of communication networks, analysis of communication needs, special problems encountered in different types of networks, efficiency and traffic analysis and emerging hardware software technologies. Detailed "hands-on" study of the TCP/IP networking protocols.

**Prerequisite(s):** CSCI 3550 or 8555 or equivalent. Not open to non-degree graduate students.

**CSCI 8256 HUMAN COMPUTER INTERACTION (3 credits)**

Human computer interaction is concerned with the joint performance of tasks by humans and machines; human capabilities to use machines (including learnability of interfaces); algorithms and programming of the interface; engineering concerns that arise in designing and building interfaces; the process of specification, design, and implementation of interfaces; and design trade-offs. (Cross-listed with CSCI 4250).

**CSCI 8266 USER EXPERIENCE DESIGN (3 credits)**

User experience (UX) design is concerned with the application of user-centered design principles to the creation of computer interfaces ranging from traditional desktop and web-based applications, mobile and embedded interfaces, and ubiquitous computing. This course provides in-depth, hands-on experience with real world application of the iterative user-centered process including contextual inquiry, task analysis, design ideation, rapid prototyping, interface evaluation, and reporting usability findings. (Cross-listed with CSCI 4260, ITIN 4260, ITIN 8266).

**CSCI 8300 IMAGE PROCESSING AND COMPUTER VISION (3 credits)**

This course introduces the computer system structures and programming methodologies for digital image processing and computer vision. The course will cover the mathematical models of digital image formation, image representation, image enhancement and image understanding. Techniques for edge detection, region growing, segmentation, two-dimensional and three-dimensional description of object shapes will be discussed. The course will concentrate on the study of knowledge-based approaches for computer interpretation and classification of natural and man-made scenes and objects.

**Prerequisite(s):** CSCI 1620 and CSCI 3320. Not open to non-degree graduate students.

**CSCI 8306 DETERMINISTIC OPERATIONS RESEARCH MODELS (3 credits)**

This is a survey course of deterministic operations research models and algorithms. Topics include linear programming, network programming, and integer programming. (Cross-listed with CSCI 4300, MATH 4300, MATH 8306).

**Prerequisite(s):** MATH 2050 with a C- or better or permission of instructor.

**CSCI 8316 PROBABILISTIC OPERATIONS RESEARCH MODELS (3 credits)**

This is a survey course of probabilistic operations, research models and algorithms. Topics include Markov chains, queueing theory, inventory models, forecasting, and simulation. (Cross-listed with CSCI 4310, MATH 4310, MATH 8316).

**Prerequisite(s):** MATH 2050 and either MATH 4740 or MATH 8746 or STAT 3800 or STAT 8805 all with a C- or better or permission of instructor.

**CSCI 8325 DATA STRUCTURES (3 credits)**

This is a core that will cover a number of data structures such as tree, hashing, priority queues and graphs as well as different algorithm design methods by examining common problem-solving techniques. (Cross-listed with CSCI 3320)

**CSCI 8326 COMPUTATIONAL OPERATIONS RESEARCH (3 credits)**

Survey of computational methods used in the solution of operations research problems. Some topics may include scripting to guide optimization software, constraint programming, heuristics and metaheuristics for optimization, basic machine learning algorithms, and simulation. (Cross-listed with MATH 4320, MATH 8326, CSCI 4320).

**Prerequisite(s):** MATH 3200 or CSCI 1620, and MATH 4300 each with a grade of C- or better or permission of instructor.

**CSCI 8340 DATABASE MANAGEMENT SYSTEMS II (3 credits)**

This course is an in-depth coverage of database management systems. Students will learn important principles of query processing and query optimization, transaction processing, and various database systems architectures. After taking this course, students should also be able to identify useful resources to explore future developments in the area of database management systems.

**Prerequisite(s):** CSCI 4850 or CSCI 8856. Not open to non-degree graduate students.

**CSCI 8350 DATA WAREHOUSING AND DATA MINING (3 credits)**

This course is an in-depth coverage of data warehousing and data mining. This course starts with coverage of data warehousing (an enabling technology for data mining) and covers the entire data mining process and various data mining functionalities in detail. Students will get a chance to practice knowledge learned in the course to complete term projects related to data warehousing and/or data mining. After taking this course, students should also be able to identify useful resources to explore future developments in the area of data warehousing and data mining.

**Prerequisite(s):** CSCI 4850 or CSCI 8856. Not open to non-degree graduate students.

**CSCI 8360 MACHINE LEARNING FOR TEXT (3 credits)**

This course focuses on the fundamental techniques for extraction of various insights from text data which is ubiquitous on the Web, social media sites, emails, news articles, digital libraries, and other sources. The course topics will include concepts and techniques used by search engines to crawl, index, and rank web pages on the Web, machine learning techniques for categorization of news articles into different categories, sentiment and opinion analysis of social media chats, text summarization, and information extraction.

**Prerequisite(s):** Not open to non-degree graduate students.

**CSCI 8366 FOUNDATIONS OF CYBERSECURITY (3 credits)**

Contemporary issues in computer security, including sources for computer security threats and appropriate reactions; basic encryption and decryption; secure encryption systems; program security, trusted operating systems; database security, network and distributed systems security, administering security; legal and ethical issues. (Cross-listed with CYBR 4360, CYBR 8366)

**Prerequisite(s):** CSCI 3320 or CSCI 8325 OR ISQA 3400 OR By instructor permission

**CSCI 8390 ADVANCED TOPICS IN DATA BASE MANAGEMENT (3 credits)**

This course is an in-depth coverage of well-selected topic(s) in recent development of database management systems. Since new developments in DBMS are very diverse, when each time when this course is offered, it will focus on one or more specific topics, and the course can be taken multiple times for credit.

**Prerequisite(s):** CSCI 4850 or CSCI 8856. Not open to non-degree graduate students.

**CSCI 8400 ADVANCED COMPUTER GRAPHICS (3 credits)**

Computer graphics continues to play an important role in computer science. This course covers the mathematical foundations of three-dimensional representation and animation; ray tracing and path tracing rendering methods; using the graphical processing unit (GPU) for real time applications; and concludes with simulation of natural phenomenon.

**Prerequisite(s):** Bachelors degree or permission from the Graduate Program Committee. Not open to non-degree graduate students.

**CSCI 8410 DISTRIBUTED SYSTEMS AND NETWORK SECURITY (3 credits)**

The course aims at understanding the issues surrounding data security, integrity, confidentiality and availability in distributed systems. Further, we will discuss various network security issues, threats that exist and strategies to mitigate them. This course will cover topics in cryptography, public key infrastructure, authentication, hashing, digital signatures, ARP protection, IP and IPSEC, IP Tables, SSL/TLS, firewalls, etc. (Cross-listed with CYBR 8410)

**Prerequisite(s):** CSCI 8366 or equivalent(s). Not open to non-degree graduate students.

**CSCI 8420 SOFTWARE ASSURANCE (3 credits)**

Software assurance is a reasoned, auditable argument created to support the belief that the software will operate as expected. This course is an intersection of knowledge areas necessary to perform engineering activities or aspects of activities relevant for promoting software assurance. This course takes on a software development lifecycle perspective for the prevention of flaws. (Cross-listed with CYBR 8420)

**Prerequisite(s):** CSCI 8836 OR by permission of the Instructor. Not open to non-degree graduate students.

**CSCI 8430 TRUSTED SYSTEM DESIGN, ANALYSIS AND DEVELOPMENT (3 credits)**

This course examines in detail: the principles of a security architecture, access control, policy and the threat of malicious code; the considerations of trusted system implementation to include hardware security mechanisms, security models, security kernels, and architectural alternatives; the related assurance measures associated with trusted systems to include documentation, formal specification and verification, and testing, and approaches that extend the trusted system, into applications and databases and into networks and distributed systems.

**Prerequisite(s):** CSCI 8366 or equivalents, or instructor permission. Not open to non-degree graduate students.

**CSCI 8446 INTRODUCTION TO PARALLEL COMPUTING (3 credits)**

This course is an introduction to parallel computing, that is using multiple processors to execute algorithms. Topics discussed include: classification of parallel computers; shared-memory versus message passing; forms of parallelism; measures of performance; designing parallel algorithms; parallel programming and parallel languages; synchronization constructs; and operating systems for parallel computers. (Cross-listed with CSCI 4440)

**Prerequisite(s):** CSCI 4500, which may be taken concurrently, with C- or better.

**CSCI 8450 ADVANCED TOPICS IN NATURAL LANGUAGE UNDERSTANDING (3 credits)**

The course will provide in depth study of the topics in natural language processing and understanding, such as syntax, lexical and computational semantics, natural language ambiguities and their disambiguation, logical form construction and inference. The course will survey state-of-the-art natural language processing toolkits and knowledge bases that boost the development of modern language processing and understanding applications.

**Prerequisite(s):** CSCI 3320 OR CSCI 3660 OR CSCI 4450. Not open to non-degree graduate students.

**CSCI 8456 INTRODUCTION TO ARTIFICIAL INTELLIGENCE (3 credits)**

An introduction to artificial intelligence. The course will cover topics such as machine problem solving, uninformed and informed searching, propositional logic, first order logic, approximate reasoning using Bayesian networks, temporal reasoning, planning under uncertainty and machine learning. (Cross-listed with CSCI 4450).

**CSCI 8476 PATTERN RECOGNITION (3 credits)**

Structures and problems of pattern recognition. Mathematics model of statistical pattern recognition, multivariate probability, Bay's decision theory, maximum likelihood estimation, whitening transformations. Parametric and non-parametric techniques, linear discriminant function, gradient-descent procedure, clustering and unsupervised learning, and feature selection algorithms. (Cross-listed with CSCI 4470)

**Prerequisite(s):** CSCI 1620 with C- or better, and MATH 2050. Recommended: MATH 4740/8746 or STAT 3800/8805.

**CSCI 8480 MULTI-AGENT SYSTEMS AND GAME THEORY (3 credits)**

This course covers advanced topics in the area of coordination of distributed agent-based systems with a focus on computational aspects of game theory. The main topics covered in this course include distributed constraint satisfaction, distributed constraint optimization, and competitive and cooperative game theory. (Cross-listed with MATH 8480)

**Prerequisite(s):** CSCI 4450 or CSCI 8456. Suggested background courses: CSCI 4480 or CSCI 8486; CSCI 8080. Not open to non-degree graduate students.



**CSCI 8486 ALGORITHMS FOR ROBOTICS (3 credits)**

This course provides an introduction to software techniques and algorithms for autonomously controlling robots using software programs called controllers. Students will be taught how to program and use software controllers on simulated as well as physical robots. (Cross-listed with CSCI 4480).

**Prerequisite(s):** CSCI 3320 with C- or better. CSCI 4450/8456 is a recommended but not essential pre-requisite.

**CSCI 8500 NUMERICAL LINEAR ALGEBRA (3 credits)**

Topics covered in this course include error propagation, solutions of nonlinear equations, solutions of linear and nonlinear systems by various schemes, matrix norms and conditioning, and computation of eigenvalues and eigenvectors. (Cross-listed with MATH 8500).

**Prerequisite(s):** MATH 1960 and MATH 2050, or permission of instructor. Familiarity with computer programming is assumed.

**CSCI 8506 OPERATING SYSTEMS (3 credits)**

Operating system principles. The operating system as a resource manager; I/O programming, interrupt programming and machine architecture as it relates to resource management; memory management techniques for uni-multiprogrammed systems; process description and implementation; processor management (scheduling); I/O device, controller, and channel management; file systems. Operating system implementation for large and small machines. (Cross-listed with CSCI 4500).

**Prerequisite(s):** CSCI 3710, CSCI 3320/8325, MATH 1950, and CSCI 4350/8356 with C- or better.

**CSCI 8510 NUMERICAL DIFFERENTIAL EQUATIONS (3 credits)**

Topics covered in this course include interpolation and approximations, numerical differentiation, numerical integration, and numerical solutions of ordinary and partial differential equations. (Cross-listed with MATH 8510).

**Prerequisite(s):** MATH 1970, MATH 2350, or permission of instructor. Familiarity with computer programming is assumed.

**CSCI 8520 ADVANCED TOPICS IN OPERATIONS RESEARCH (3 credits)**

Advanced treatment of a specific topic in the area of operations research not available in the regular curriculum. Topics, developed by individual faculty members, will reflect their special interests and expertise. The course may be repeated for credit as topics differ. (Cross-listed with MATH 8520).

**Prerequisite(s):** MATH 4300 or MATH 8306 or CSCI 4300 or CSCI 8306 or permission of the instructor.

**CSCI 8530 ADVANCED OPERATING SYSTEMS (3 credits)**

State-of-the-art techniques for operating system structuring and implementation. Special purpose operating systems. Pragmatic aspects of operating system design, implementation and use.

**CSCI 8555 COMMUNICATION NETWORKS (3 credits)**

This course is designed to bring students up to the state of the art in networking technologies with a focus on Internet. It will cover the principles of networking with an emphasis on protocols, implementations and design issues. (Cross-listed with CSCI 3550)

**Prerequisite(s):** (CSCI 3320 or CSCI 8325 with grade of C- or better) AND (CSCI 2240 or CYBR 2250 with grade of C- or better)

**CSCI 8566 NUMBER THEORY & CRYPTOGRAPHY (3 credits)**

An overview of one of the many beautiful areas of mathematics and its modern application to secure communication. The course is ideal for any student who wants a taste of mathematics outside of, or in addition to, the calculus sequence. Topics to be covered include: prime numbers, congruences, perfect numbers, primitive roots, quadratic reciprocity, sums of squares, and Diophantine equations. Applications include error-correcting codes, symmetric and public key cryptography, secret sharing, and zero knowledge proofs. (Cross-listed with CSCI 4560, MATH 4560, MATH 8566).

**Prerequisite(s):** MATH 2230 with a C- or better or MATH 2030 with a C- or better or CSCI 2030 with a C- or better or permission of instructor

**CSCI 8590 FUNDAMENTALS OF DEEP LEARNING (3 credits)**

This course is an introduction to deep learning, a branch of machine learning concerned with the development and application of neural networks. Deep learning trains the machine to learn patterns that it is presented with rather than requiring the human operator to define the patterns that the machine should look for. Deep learning is behind many recent advances in artificial intelligence, such as face recognition, speech recognition and autonomous driving. This course will cover the foundations of deep learning, learning theory, basic/advanced neural networks and problem domains of many selected applications.

**Prerequisite(s):** CSCI 3320 or instructor permission

**CSCI 8610 FAULT TOLERANT DISTRIBUTED SYSTEMS (3 credits)**

This course is to study the theory and practice of designing computer systems in the presence of faulty components. Emphasizes the basics of how faults can affect systems and what is required to mask or compensate for their efforts.

**Prerequisite(s):** Not open to non-degree graduate students.

**CSCI 8620 MOBILE COMPUTING AND WIRELESS NETWORKS (3 credits)**

The objective of the course is to introduce contemporary issues in mobile computing and wireless networks. The course covers the differences between mobile computing and the traditional distributed computing paradigm, impediments of the mobile and wireless environments, problems and limitations due to such impediments, various network layers solutions, location management techniques, mobile IP, wireless LANs, wireless TCP, ad hoc networks, and sensor networks.

**Prerequisite(s):** CSCI 3550 or CSCI 8555. Not open to non-degree graduate students.

**CSCI 8626 COMPUTER GRAPHICS (3 credits)**

An introduction to the acquisition, manipulation and display of graphical information using digital techniques. Topics include discussion of the various hardware devices used for input and output, the classical algorithms and data structures used in manipulation of graphical objects, the user interface to the graphics system, and applicable standards. (Cross-listed with CSCI 4620).

**Prerequisite(s):** ISQA 3300 or CSCI 3320.

**CSCI 8656 INTRODUCTION TO CLOUD COMPUTING (3 credits)**

This course is an introduction to cloud computing. The students will learn about core concepts of cloud computing such as cloud models (IaaS, PaaS, SaaS, etc.), deployment models (public, private, hybrid), cloud infrastructures (compute, networking, storage), cloud services (VMs, serverless, object storage, cache, CDN, etc.), and big-data driven systems. This course will revisit essential topics in CS-related courses such as data structure, operating systems, and distributed systems and show how they are utilized and applied in diverse cloud computing technologies and systems including Hadoop, Spark, and distributed databases. After taking this course, students will have basic knowledge of cloud computing and hand-on experiences with diverse projects (including cloud system demos) that utilize diverse and heterogeneous cloud resources. (Cross-listed with CSCI 4650).

**Prerequisite(s):** Prior experience and background knowledge of networking and operating systems are preferred

**CSCI 8666 AUTOMATA, COMPUTABILITY, AND FORMAL LANGUAGES (3 credits)**

This course presents a sampling of several important areas of theoretical computer science. Definition of formal models of computation and important properties of such models, including finite automata and Turing machines. Definition and important properties of formal grammars and their languages. Introduction to the formal theories of computability and complexity. (Cross-listed with CSCI 4660, MATH 4660, MATH 8666).

**Prerequisite(s):** MATH 2030. Recommended: CSCI 3320/CSCI 8325.

**CSCI 8700 SOFTWARE SPECIFICATIONS AND DESIGN (3 credits)**

A continuation of the study of software engineering with an emphasis on early phases of software development, namely requirements engineering/specification and architectural design. Includes an in-depth study of practices for effective software requirements specification and architectural design, as well as formal specifications of software systems. Related topics such as metrics and support tools are also covered.

**Prerequisite(s):** CSCI 4830 or CSCI 8836. Not open to non-degree graduate students.

**CSCI 8706 COMPILER CONSTRUCTION (3 credits)**

Assemblers, interpreters and compilers. Compilation of simple expressions and statements. Analysis of regular expressions. Organization of a compiler, including compile-time and run-time symbol tables, lexical scan, syntax scan, object code generation and error diagnostics. (Cross-listed with CSCI 4700).

**CSCI 8710 MODERN SOFTWARE DEVELOPMENT METHODOLOGIES (3 credits)**

Designed to introduce students to advanced object technology and other modern methodologies for developing software systems. Intended for graduate students who have mastered the basic concepts and issues of software engineering. Course covers advanced object-oriented software development. The course also covers several offshoots of object technology, including: component-based software engineering, aspect-oriented software development, software product line engineering, service-oriented computing, etc.

**Prerequisite(s):** CSCI 4830 or CSCI 8836.

**CSCI 8760 FORMAL METHODS IN SOFTWARE ENGINEERING (3 credits)**

In the high consequence system domain, a primary objective of any construction technique employed is to provide sufficiently convincing evidence that the system, if put into operation, will not experience a high consequence failure or that the likelihood of such a failure falls within acceptable probabilistically defined limits. Systems for which such evidence can be provided are called high assurance systems. The objective of this course is to examine software-engineering techniques across the development life cycle that are appropriate for high assurance systems. The course will analyze the nature of the evidence provided by various techniques (e.g., does a given technique provide sufficiently strong evidence in a given setting).

**Prerequisite(s):** CSCI 8000 and CSCI 8836 or CSCI 4830

**CSCI 8766 TOPICS IN MODELING (3 credits)**

Selection of such topics as formulation and analysis of various models involving Markov chains, Markov processes (including birth and death processes), queues, cellular automata, difference and differential equations, chaotic systems and fractal geometries. (Cross-listed with CSCI 4760).

**Prerequisite(s):** MATH 2350 and MATH 4740 or MATH 8746.

**CSCI 8790 ADVANCED TOPICS IN SOFTWARE ENGINEERING (3 credits)**

The main objective of this course is (1) to introduce advanced topics in software engineering approaches and (2) to provide an overview and in-depth understanding of software development and maintenance techniques. Many well-known software implementation problems, associated programming tools, and analysis techniques are also covered. At the end of this course, the student should be able to apply the practical skills and approaches in solving non-trivial problems in diverse fields of study.

**Prerequisite(s):** CSCI 4830 or CSCI 8836. Not open to non-degree graduate students.

**CSCI 8836 INTRODUCTION SOFTWARE ENGINEERING (3 credits)**

Basic concepts and major issues of software engineering, current tools and techniques providing a basis for analyzing, designing, developing, maintaining and evaluating the system. Technical, administrative and operating issues. Privacy, security and legal issues. (Cross-listed with CSCI 4830).

**CSCI 8856 DATABASE MANAGEMENT SYSTEMS (3 credits)**

Basic concepts of data base management systems (DBMSs). The relational, hierarchical and network models and DBMSs which use them. Introduction to data base design. (Cross-listed with CSCI 4850).

**CSCI 8876 DATABASE SEARCH AND PATTERN DISCOVERY IN BIOINFORMATICS (3 credits)**

This required course for undergraduate bioinformatics majors provides foundational knowledge on database aspects used in the field and an overview of their applications in bioinformatics, biomedical informatics, and health/clinical informatics. The course begins with a brief review of key concepts in computational molecular biology related to database search/development, database management systems, the difference between primary and secondary databases, and bioinformatics-related aspects of modeling and theory in computer science. The major focus is on the multiple challenges and aspects of bio-database development, search, and pattern discovery. The course uses problem-based learning to help students develop database management skills as they apply to high throughput "-omics." data, the basics of data management, data provenance and governance, standards, and analysis through KDD-based workflows. This course will also consider the fundamentals of artificial intelligence and machine learning as they pertain to bioinformatics, from the perspective of database storage, I/O, and analysis. (Cross-listed with BIOI 4870)

**Prerequisite(s):** CSCI 3320 and BIOI 3500, or permission of instructor; BIOI 3500 can be taken concurrently. Prior completion of CSCI 4850 is strongly recommended but not required. Not open to non-degree graduate students.

**CSCI 8910 MASTER OF SCIENCE CAPSTONE (3 credits)**

The capstone course is to integrate coursework, knowledge, skills and experimental learning to enable the student to demonstrate a broad mastery of knowledge, skills, and techniques across the Master degree curriculum of Computer Science for a promise of initial employability and further career advancement. The course is designed to be in a student-centered and student-directed manner which requires the command, analysis and synthesis of knowledge and skills. Students may apply their knowledge and skill to a project which serves as an instrument of evaluation. Students are encouraged to foster an interdisciplinary research and cultivate industry alliances and cooperation in this course. This capstone course should be taken only after students have completed at least 3/4 of course requirements for the major.

**Prerequisite(s):** Master's degree of Computer Science with course-only option (program III). Not open to nondegree students.

**CSCI 8920 ADVANCED TOPICS COMPUTER SCIENCE (3 credits)**

An in-depth study, at the graduate level, of one or more topics that are not treated in other courses. May be repeated with different topics with permission of adviser.

**Prerequisite(s):** Permission of instructor; will vary with offering. Not open to non-degree graduate students.

**CSCI 8950 GRADUATE INTERNSHIP IN COMPUTER SCIENCE (1-3 credits)**

The purpose of this course is to provide students with opportunities to apply their academic studies in environments such as those found in business, industry, and other non-academic organizations. The student interns will sharpen their academic focus and develop better understanding of non-academic application areas.

**Prerequisite(s):** Permission of the graduate program chairperson and a minimum grade point average of 3.0 (B), with at most one grade below B, but not lower than C+ for all CS graduate classes. Not open to non-degree graduate students.

**CSCI 8960 THESIS EQUIVALENT PROJECT IN COMPUTER SCIENCE (1-6 credits)**

This course allows a graduate student to conduct a research project in computer science or a related area. The project is expected to place an emphasis on applied, implementations-based, or experimental research. The process for development and approval of the project must include: appointment of supervisory committee (chaired by project adviser), a proposal approved by the supervisory committee, monitoring of the project by the supervisory committee, an oral examination over the completed written product conducted by the supervisory committee, and final approval by the supervisory committee. The approved written project will be submitted to the Office of Graduate Studies by the advertised deadlines.

**Prerequisite(s):** Permission of Graduate Adviser. Not open to non-degree graduate students.

**CSCI 8970 INDEPENDENT STUDY (1-3 credits)**

Under this number a graduate student may pursue studies in an area that is not normally available in a formal course. The topics to be studied will be in a graduate area of computer science to be determined by the instructor.

**Prerequisite(s):** Permission of the Graduate Program Committee. Not open to non-degree graduate students.

**CSCI 8980 GRADUATE SEMINAR (1 credit)**

This course offers an up-to-date coverage of the contemporary and emerging concepts, models, techniques and methodologies, and/or the current research results in the fundamental areas of computer science. Topics to be covered by the course will vary in different semesters.

**Prerequisite(s):** Permission of the Instructor. Not open to non-degree graduate students.

**CSCI 8986 TOPICS IN COMPUTER SCIENCE (3 credits)**

This is a variable topic course in computer science at the senior/graduate level. Topics not normally covered in the computer science degree program, but suitable for senior/graduate-level students can be offered. (Cross-listed with CSCI 4980).

**Prerequisite(s):** Permission of instructor. Additional prerequisites may be required for particular topic offerings.

**CSCI 8990 THESIS (1-6 credits)**

A research project, designed and executed under the supervision of the chair and approval by members of the graduate student's thesis advisory committee. In this project the student will develop and perfect a number of skills including the ability to design, conduct, analyze and report the results in writing (i.e., thesis) of an original, independent scientific investigation.

**Prerequisite(s):** Permission of Graduate Adviser. Not open to non-degree graduate students.

**CSCI 9410 ADVANCED TOPICS IN LOGIC PROGRAMMING (3 credits)**

This course will examine some advanced topics in logic programming, in particular logic programming under stable model (or answer set) semantics. Answer set programming is a common name of the field. Formal syntax, semantics, and proofs of correctness for logic programs will be considered. Elements of inductive and Prolog programming will also be introduced. Each advanced topic will be followed by how it has been applied in practice. Advanced applications of logic programming will be covered in detail.

**Prerequisite(s):** CSCI 8000 and doctoral student standing in Information Technology or the permission of the instructor.

**CSCI 9420 INTELLIGENT AGENT SYSTEMS (3 credits)**

This course covers the principles of interaction between agents in multi-agent systems using game theory. Relevant topics studied in this course include competitive games, statistical Bayesian games, cooperative games, and mechanism design. Students will have to implement projects related to the material studied in the course.

**Prerequisite(s):** CSCI 3320 or CSCI 8325 and CSCI 4450 or CSCI 8456. Not open to non-degree graduate students.

**CSCI 9710 METHODS IN SOFTWARE ENGINEERING RESEARCH (3 credits)**

This course provides guidelines on how to conduct research in the field of software engineering by presenting the research methods, classic readings, and development of theories and their application to real life problems. The main emphasis of the course is to provide opportunity for in-depth study of topics such as contemporary methods for software development.

**Prerequisite(s):** CSCI 8836 or equivalent course and doctoral student standing in Information Technology or permission of the instructor. Not open to non-degree graduate students.

**CSCI 9810 RESEARCH FOUNDATIONS IN THEORETICAL COMPUTING (3 credits)**

This course offers an up-to-date coverage of the contemporary and emerging concepts, models, techniques, and methodologies, and/or the current research results in the fundamental areas of theoretic computing. The course will examine advanced research topics in computer science and engineering, including foundations of automata theory, computability, complexity analysis, computational logics and algorithmic analysis, hybrid dynamic systems theory, number theory, adaptation and learning theory, concepts and principles in computational geometry, stochastic processes, and random optimization. Each topic will be discussed with a perspective of research issues and directions. Active student participation in investigation of the research topics, survey of the current state-of-art, and identifying the future research insights is required. Students will take turn presenting their research results on specific topics. Topics to be covered by the course will vary in different semesters.

**Prerequisite(s):** The prerequisites of this course vary depending on the areas to be covered in the semester the course is offered. Good standing in Ph.D. program is required. Permission of the instructor may be required. Not open to non-degree graduate students.

**ISQA 8016 BUSINESS INTELLIGENCE (3 credits)**

This course intends to provide graduate students in-depth exposure to the growing field of business intelligence. Business intelligence (BI) consists of the set of concepts and techniques used to analyze business data in support of decision-making and planning. BI spans a number areas of management information systems, including Decision Support Systems (DSS), Enterprise Resource Planning (ERP), Data Warehousing, Knowledge Management, Customer Relationship Management, Data Mining, and others.

**Prerequisite(s):** (ISQA 4150 or ISQA 8156) and ISQA 8040 and ISQA 8050. Not open to non-degree graduate students.

**ISQA 8030 INFORMATION SYSTEMS AND ETHICS (3 credits)**

This course gives you an introduction to organizations and the role that information and information systems play in supporting an organization's operations, decision-making processes, quality management, and strategic activities. The course provides an introduction to the management of information systems function, the strategic and regulatory issues of telecommunications, and ethical and legal issues related to information systems.

**Prerequisite(s):** Admission into the MS in MIS program.

**ISQA 8040 AN OVERVIEW OF SYSTEMS DEVELOPMENT (3 credits)**

The course presents an overview of the systems development lifecycle and database development. The course will focus on theory, current tools and techniques that the system developer can use to develop and document information systems. The purpose of this course is to prepare the student for further graduate-level study of information systems. This course may not be used in a plan of study for any graduate program at UNO.

**ISQA 8050 DATA ORGANIZATION AND STORAGE (3 credits)**

The course will provide concepts of data organization, data storage, and data transfer through computer networks. The performance implications of various design decisions will be explored. The purpose of this course is to prepare the student for further graduate-level study of information systems. This course may not be used in a plan of study for any graduate program at UNO.

**ISQA 8060 RESEARCH IN MIS (3 credits)**

This course covers research methods and their application to the development and evaluation of management information systems. Also covered is the relationship between organization theory and IS research.  
**Prerequisite(s):** CIST 2500, CIST 2100, and ISQA 8040, or permission of the instructor.

**ISQA 8070 SEMINAR IN MANAGEMENT INFORMATION SYSTEMS (1 credit)**

This course is designed to acquaint students with issues which are current to the field or harbingers or emerging trends in the information systems area. Topics will vary across terms. This course may be repeated, but no topic may be taken more than once.

**Prerequisite(s):** Permission of the instructor. Additional prerequisite courses may be required for particular course offerings.

**ISQA 8080 SEMINAR IN MANAGEMENT INFORMATION SYSTEMS (3 credits)**

This course is designed to acquaint students with issues which are current to the field or harbingers or emerging trends in the information systems area. Topics will vary across terms. This course may be repeated, but no topic may be taken more than once.

**Prerequisite(s):** 1) Permission of the instructor. 2) Additional prerequisite courses may be required for particular course offerings.

**ISQA 8086 SPECIAL TOPICS: INFORMATION SYSTEMS & QUANTITATIVE ANALYSIS (1-5 credits)**

This course is designed to acquaint students with issues which are current to the field or harbingers or emerging trends in the information systems area. Topics will vary across terms. This course may be repeated, but no topic may be taken more than once. (Cross-listed with ISQA 4000)

**Prerequisite(s):** Permission of instructor. Additional prerequisites may be required for particular topic offerings.

**ISQA 8090 SEMINAR IN MANAGEMENT INFORMATION SYSTEMS (2 credits)**

This course is designed to acquaint students with issues which are current to the field or harbingers or emerging trends in the information systems area. Topics will vary across terms. This course may be repeated, but no topic may be taken more than once.

**Prerequisite(s):** Permission of the instructor. Additional prerequisite courses may be required for particular course offerings.

**ISQA 8106 INFORMATION SYSTEMS ARCHITECTURE AND ORGANIZATION (3 credits)**

This course examines the frameworks and tools used to develop an organization's information system architecture. It provides the analytical skills and conceptual frameworks with which to make recommendations and decisions regarding the integration of information technology components into an information system architecture. (Cross-listed with ISQA 4100)

**Prerequisite(s):** CIST 2100 and ISQA 3310

**ISQA 8136 INFORMATION TECHNOLOGY FOR DEVELOPMENT (3 credits)**

Information Technology for Development (ITD) is the implementation and evaluation of information technology infrastructures to stimulate economic, social and human development. In this service-learning course, students will learn and apply ITD concepts for developing and adding value through IT by working with small business entrepreneurs in Omaha or rural Nebraska. Students will evaluate micro-business technology needs, prepare business technology plans, provide training, and implement appropriate solutions, to the extent possible within a semester class. (Cross-listed with ISQA 4130)

**Prerequisite(s):** Though not required, the following courses or their equivalent would provide the necessary background : CIST 1100, CIST 1300, ISQA 3210, ISQA 3310, ISQA 3400. Not open to non-degree graduate students.

**ISQA 8156 ADVANCED STATISTICAL METHODS FOR IS&T (3 credits)**

This course emphasizes the application and interpretation of statistical methods including design of experiments, analysis of variance, multiple regression, and nonparametric procedures and the use of statistical computer packages. The intent is to develop quantitative abilities needed for quantitatively intensive jobs and for advanced study in management information systems, computer science and information technology. (Cross-listed with ISQA 4150)

**Prerequisite(s):** CIST 2500 or equivalent (at least one course in statistics)

**ISQA 8160 APPLIED DISTRIBUTION FREE STATISTICS (3 credits)**

The primary objective of this course is to expose students to methods of analyzing data from non-normal populations including binomial tests, contingency tables, use of ranks, Kolmogorov-Smirnov type statistics and other selected topics.

**Prerequisite(s):** Admission to MS program in Management Information Systems or permission of instructor. This course assumes prior knowledge with basic descriptive and inferential statistics from an introductory undergraduate course (e.g., CIST 2500).

**ISQA 8166 INTRODUCTION TO ENTERPRISE RESOURCE PLANNING (3 credits)**

Introduction to Enterprise Resource Planning (ERP) is designed to expose students to the primary enterprise application that forms the information systems (IS) infrastructure for most large organizations today. The primary purpose of this course is for students to gain an understanding of the enterprise wide, cross functional nature of ERP software. In the process of learning about ERPs, the students develop "hands on" experience with the largest and most well-known ERP application, SAP. (Cross-listed with ISQA 4160, SCMT 4160)

**Prerequisite(s):** CIST 2100 or equivalent. Not open to non-degree graduate students.

**ISQA 8176 DIGITAL SUPPLY CHAIN & LOGISTICS (3 credits)**

Global Supply Chains are being disrupted by digital transformation driven by emerging technologies such as IoT (internet of things) and AI/ML (Artificial Intelligence/Machine Learning). This course will take a closer look at global supply chains and logistics with an emphasis on the impact of digitalization. We will explore the typical global supply chain processes and how state-of-the-art and emerging technologies impact them. Thus, the class views global digital supply chains by integrating business and technological perspectives. The course will start with an overview of technologies relevant to digital supply chains. We will then discuss digitalization strategy and digital supply chains, fundamental GSCM (Global Supply Chain Management) processes and their potential for digitalization, and discussion of IT/software systems, IoT, AI/ML, Data Analytics/Visualization, and related facets that impact digital supply chains. The course will culminate with an integrated case study and/or research paper (graduate). (Cross-listed with ISQA 4170).

**Prerequisite(s):** Permission of instructor. It is preferable that students have taken an introductory supply chain class or have some experience in the transportation, logistics and supply chain management sector. Undergraduate students must have Junior standing.

**ISQA 8180 ELECTRONIC COMMERCE (3 credits)**

Electronic Commerce is the digital enablement of transactions between multiple parties. A multitude of technologies, tools and applications have brought about changes in business, and society that require careful consideration. Students are given an overview of electronic commerce business models and required to apply these to solve business problems or take on opportunities presented. They will cover topics such as social networking, electronic markets, and political and ethical issues associated with electronic commerce, and business plans for technology ventures. They will apply these concepts using Web 2.0 tools, mobile applications and website design assignments.

**ISQA 8196 PROCESS REENGINEERING WITH INFORMATION TECHNOLOGY (3 credits)**

Business process reengineering issues are examined. Reengineering concepts and methods are introduced. Additional special project(s) are required. SAP will be introduced. (Cross-listed with ISQA 4190)

**Prerequisite(s):** CIST 2500; prerequisite/co-requisite ISQA 4110.

**ISQA 8206 INFORMATION AND DATA QUALITY MANAGEMENT (3 credits)**

The course primarily focuses on developing an in-depth understanding of Data and Information Quality (DQ and IQ) concepts and issues. On completing this course students will be able to understand and use DQ and IQ Concepts in Information Systems projects, be able to recognize various patterns of Data and Design Deficiencies in Systems and be able to suggest appropriate DQ and IQ improvement plans in light of known deficiencies in systems. (Cross-listed with ISQA 4200)

**Prerequisite(s):** CIST 2500

**ISQA 8210 MANAGEMENT OF SOFTWARE DEVELOPMENT (3 credits)**

This course should encourage you to think critically about aspects of software development that make it difficult and strategies to mitigate these challenges. This course integrates concepts from software engineering, management science, psychology, and organizational behavior to identify, understand, and propose solutions to problems associated with software development. We examine and consider issues from various perspectives, such as the project manager, development team, senior management, and project sponsor. This course prepares students for various roles within a software development effort including leadership positions in software development. Students will practice software project management and agile methods of managing projects in a semester long team project using contemporary project and development methods.

**Prerequisite(s):** ISQA 8040 or equivalent. Not open to non-degree graduate students.

**ISQA 8220 ADVANCED SYSTEMS ANALYSIS AND DESIGN (3 credits)**

This course is a systems analysis and design course for systems and business analysts. The course presents an overview of object-oriented system analysis and design. The course will then focus on theory, best practices, and modern methodologies that analysts can use to analyze and design information systems.

**Prerequisite(s):** ISQA 8040 or (ISQA 4110 and ISQA 4120) or equivalent and ISQA 8050 or ISQA 3310 or equivalent

**ISQA 8306 DATABASE ADMINISTRATION (3 credits)**

This course is designed to give students an applied, practical introduction to database administration. Students will gain an understanding of the functioning of a database management system and its relationship to the computing environment in which it runs. They will learn the concepts, principles, and techniques necessary to carry out such functions as database object creation, storage management, capacity planning, performance tuning, backup and recovery, and security management. Each semester the course will focus on one commercial database management system (DBMS), such as Oracle. (Cross-listed with ISQA 4300)

**Prerequisite(s):** ISQA 8040 or ISQA 3310 or CSCI 4850. Not open to non-degree graduate students.

**ISQA 8310 IT INFRASTRUCTURE & CLOUD COMPUTING (3 credits)**

This course provides a graduate-level introduction to the business and technical decisions around technical infrastructure. It covers topics related to computer and systems architecture and communications networks, with a focus on the technical and business decisions around technology. Students completing the course will be able to understand and design network infrastructure, evaluate cloud computing offerings, and communicate their decisions. The course covers hardware, software, and cloud computing technologies.

**ISQA 8340 APPLIED REGRESSION ANALYSIS (3 credits)**

The primary objective of this course is to expose students to regression models and applications with particular emphasis on applying these concepts to IT research. Topics to be discussed include: Foundations of regression analysis using least squares procedures; model formulation, stepwise regression, transformations; graphical methods, estimation; inference; influence diagnosis; matrix formulation, multicollinearity, time series, and nonlinear models.

**Prerequisite(s):** ISQA 4150 or ISQA 8156, not open to non-degree graduate students.

**ISQA 8380 ENTERPRISE ARCHITECTURE AND SYSTEMS INTEGRATION (3 credits)**

This course is designed to give students grounding in the concepts, issues, and tools needed to manage enterprise architecture, distributed systems & Internet-based environments. The goal of the course is to equip students to make the architecture and infrastructure-related decisions needed for successful development and use of contemporary client/server and Internet-based systems. Topics include middleware, architecture, XML, JSON, web services, service-oriented architecture, enterprise application integration, distributed computing services, Model View Controller (MVC) development frameworks.

**Prerequisite(s):** ISQA 8310 and ISQA 8050 or equivalent; permit required.

**ISQA 8410 DATA MANAGEMENT (3 credits)**

The course provides in-depth coverage of such areas as: the relational model, SQL, data modeling, data quality management, database design, data warehousing, business intelligence, document and content management, NoSQL systems, and data governance. The course offers a mix of theoretical treatment and hands-on application. Current DBMS and data modeling software will be used.

**Prerequisite(s):** ISQA 8050 or equivalent, permit only.

**ISQA 8420 MANAGING THE I.S. FUNCTION (3 credits)**

The course provides a focus on the business management implications of the information explosion. The course is organized around a management audit of the information services activity to help present and future managers recognize and implement effective information services management.

**Prerequisite(s):** CIST 2100 and ISQA 8040. Not open to non-degree graduate students.

**ISQA 8450 NOSQL AND BIG DATA TECHNOLOGIES (3 credits)**

The course will cover topics in the area of NoSQL and Big Data management. The course is intended to get students familiarized with NoSQL and Big Data technologies, explore how these database technologies differ conceptually from traditional relational database technologies, understand their applications, uses, advantages, and disadvantages, and provide hands-on experience with NoSQL and Big Data databases. The course offers a mix of theoretical treatment and hands-on application of the discussed NoSQL and Big Data technologies.

**Prerequisite(s):** Prior exposure to data management is expected. The prereq is: ISQA 3310, ISQA 8040, CSCI 4850, or work experience that has given you a comparable grounding in database concepts and technologies; in this case permission by the instructor is needed.

**ISQA 8460 INTERNET OF THINGS (IOT), BIG DATA AND THE CLOUD (3 credits)**

This course introduces the Internet of Things (IoT). It provides an overview of a number of technologies and research disciplines that enable the Internet to reach out into the real world of physical objects. In the future, the "Things" in question may have identities and virtual personalities, operating in smart spaces using intelligent interfaces to connect and communicate with the social, environmental, and user context.

**Prerequisite(s):** Basic Web Development using HTML/CSS and some MVC framework. The equivalent of two semester exposure to programming.

**ISQA 8525 GRAPHICAL USER INTERFACE DESIGN (3 credits)**

This course is an introduction to interaction design with a primary emphasis on designing usable and useful computer interfaces. Students will learn the principles of interface design grounded in a fundamental understanding of human cognitive processes. They will learn how end-users develop and use mental models of interaction and will apply this knowledge to the design of interfaces for real-world applications. A design project will challenge students to plan their own designs, to develop interfaces and to integrate them into a working application prototype, to test their application with real users, and to effectively communicate the overall results. (Cross-listed with ISQA 3520)

**Prerequisite(s):** CIST 1300

**ISQA 8546 COMPUTER SECURITY MANAGEMENT (3 credits)**

The purpose of this course is to integrate concepts and techniques from security assessment, risk mitigation, disaster planning, and auditing to identify, understand, and propose solutions to problems of computer security and security administration. (Cross-listed with CIST4540, CYBR 4540, CYBR 8546)

**Prerequisite(s):** IASC 4360 or permission of the instructor.

**ISQA 8560 INFORMATION WARFARE AND SECURITY (3 credits)**

This course will study the nature of information warfare, including computer crime and information terrorism, as it relates to international, national, economic, organizational, and personal security. Information warfare policy and ethical issues will be examined.

**Prerequisite(s):** CIST 2100 or BSAD 8030 or ISQA 8030, or permission of instructor required.

**ISQA 8570 INFORMATION SECURITY POLICY AND ETHICS (3 credits)**

The course will cover the development and need for information security policies, issues regarding privacy, and the application of computer ethics. (Cross-listed with IASC 8570)

**Prerequisite(s):** CIST 2100 or BSAD 8030, or permission of instructor.

**ISQA 8580 SECURITY RISK MANAGEMENT AND ASSESSMENT (3 credits)**

The purpose of this course is to prepare the student for managing information security at the organizational level. This course will combine concepts from strategic management, decision science and risk analysis to prepare the student to integrate security issues into an organizational strategic planning process.

**Prerequisite(s):** CIST 2100 or ISQA 8030. Not open to non-degree graduate students.

**ISQA 8600 FROM DATA TO DECISIONS (3 credits)**

This course focuses on inquiry-driven data preparation and exploratory analysis skills for audience-driven, decision-oriented data analysis. Students gain experience in data evaluation, cleaning, documentation, and exploration with basic descriptive statistics and visualizations.

**ISQA 8700 DATA MINING: THEORY AND PRACTICE (3 credits)**

This course provides students theoretical issues as well as practical methods for conducting data mining process, including the implementation of a warehouse. After covering the essential concepts, issues, techniques to build an effective data warehouse, this course emphasizes the various techniques of data mining, such as association, classification, clustering and prediction for on-line analyses within the framework of data warehouse architectures. This course also promotes students to conduct a real-life data analyzing project in Big Data Era.

**Prerequisite(s):** ISQA 8050 and ISQA 8310 and ISQA 8040, not open to non-degree graduate students.

**ISQA 8720 APPLIED STATISTICAL MACHINE LEARNING (3 credits)**

This course focuses on advanced techniques in the analysis and evaluation of data, using both supervised and unsupervised methods. It covers the main types of statistical learning models needed for complex data analytics problems, as well as aspects of model development and optimization.

Topics include: Linear and Non-Linear Regression Models, Classification, Resampling Methods, Model Selection and Regularization, Decision Trees, Model Boosting and Bagging, Support Vector Machines, and Clustering methods. This is an applied, hands-on course that will use a state-of-the-art statistical tool to implement the discussed approaches in assignments and a course project and focuses on the understanding and application of the concepts.

**Prerequisite(s):** ISQA 8156 (B- grade or better) and the following topics: The equivalent of two classes of statistics and/or advanced mathematics and a minimum of one semester of applying R in courses and/or projects

**ISQA 8736 DECISION SUPPORT SYSTEMS (3 credits)**

This course examines a set of information systems which specifically support managerial decision makers: Decision Support Systems, Group Decision Support Systems, Executive Information Systems, Data Warehouses, Expert Systems, and Neural Networks. This course explores the development, implementation, and application of these systems, how these systems can be applied to current business problems, as well as how organizational issues impact the implementation and usage of these systems. (Cross-listed with ISQA 4730)

**Prerequisite(s):** ISQA 8030 or equivalent.

**ISQA 8750 STORYTELLING WITH DATA (3 credits)**

This course provides an in-depth study of how to build a compelling story using data for business professionals to make winning arguments, it provides an overview of a number of technologies and research disciplines that enabled the power of data visualization. Data visualization is critical to managing large volumes of data, and can be defined as the science (analytical) and art (design) of manipulating and presenting data for expression and cognitive recognition. Data visualization involves using data in a way that humans can clearly understand, supporting efforts by organization to gain competitive advantage by changing operations, decision-making, and strategic initiatives.

**Prerequisite(s):** CSCI 1620 or equivalent. Admission into the UNO graduate program, basic web development or work experience with comparable grounding in programing, scripting concepts & technologies and permission by the instructor is needed.

**ISQA 8810 INFORMATION TECHNOLOGY PROJECT FUNDAMENTALS (3 credits)**

The course will integrate concepts and techniques from management science, psychology, organizational behavior, & administration change to identify, understand & propose solutions to the problems of project management. The purpose of the course is to prepare the graduate for project participation and leadership.

**Prerequisite(s):** CIST 2100 and ISQA 8040. Not open to non-degree graduate students.

**ISQA 8820 PROJECT RISK MANAGEMENT (3 credits)**

This course will cover project risk management, i.e., the process of measuring or assessing risk in projects and then developing strategies to manage the risk. The topics covered will include: Risk Management Planning, Risk Identification, Quantitative Risk Analysis, Qualitative Risk Analysis, Risk Response Planning, and Risk Monitoring and Control will be covered in detail. Students will learn how to apply and use the tools and techniques needed to perform these project management tasks. A collection of readings on risk management from the empirical literature coupled with risk management standards from organizations such as IEEE and the Project Management Institute (PMI) will be used to provide the student with an excellent foundation in risk management and control.

**Prerequisite(s):** ISQA 8810 or permission of instructor.

**ISQA 8900 INDEPENDENT RESEARCH IN MANAGEMENT INFORMATION SYSTEMS (1-3 credits)**

The content of the course will vary. However, both the student and the faculty member must sign an Independent Research Agreement and file it with the Master of Science in Management Information Systems Graduate Program Committee before registration for the course. This agreement will detail the project, the schedule for its completion, the form of the output, the method of evaluation and other relevant information pertaining to the project.

**Prerequisite(s):** Permission of instructor, and at least 12 hours of course work toward a M.S. in MIS should be completed.

**ISQA 8910 INFORMATION SYSTEMS INTERNSHIP (1-3 credits)**

Information Systems Internship provides students with an opportunity for practical application and further development of knowledge and skills acquired in the MS MIS degree program. The internship gives students professional work experience and exposure to the challenges and opportunities faced by IT professionals in the workplace.

**Prerequisite(s):** Permission of the instructor required. Students must have completed a minimum of 18 credit hours towards the MS MIS program. Not open to non-degree graduate students.

**ISQA 8950 CAPSTONE MANAGEMENT INFORMATION SYSTEMS (3 credits)**

The course consists of a student executed Information Systems design project providing an in-depth practical experience. It typically covers system conceptualization, analysis, and design. It may also involve prototyping. The project will typically not include the actual implementation of the system. This course replaces the MS in MIS comprehensive exam requirement.

**Prerequisite(s):** Students must have 6 credit hours or fewer left in the program. Students must have completed all core classes. Not open to non-degree graduate students.

**ISQA 8990 THESIS (1-6 credits)**

This course is a research project designed and executed under supervision of a thesis supervisory committee. Student will develop skills, including the ability to design, conduct, analyze, and report results in writing (i.e., thesis) of an original, independent, scientific investigation. The student's thesis supervisory committee must approve the project plan.

**Prerequisite(s):** ISQA 8060 research methods or equivalent. Graduate major in MIS and approval of the thesis supervisory committee. Not open to non-degree graduate students.

**ISQA 9010 FOUNDATIONS OF INFORMATION SYSTEMS RESEARCH (3 credits)**

This course covers the following areas: (1) information systems as an academic discipline including classic readings in IS and its reference disciplines, (2) theory development and evaluation, (3) research methods applicability in IS.

**Prerequisite(s):** Doctoral student standing in the information systems areas or with the permission of the instructor; ISQA 8060 or equivalent. Not open to non-degree graduate students.

**ISQA 9020 TECHNICAL AND PROCESS ISSUES IN INFORMATION SYSTEMS RESEARCH (3 credits)**

This seminar is a survey course on the technical and process issues in information systems research. The course balances the acquisition of knowledge about the conduct of research in technical and process issues with the application of that knowledge to research on information systems. Major topics include: software engineering, programming, data base systems, decision support systems, data warehousing and mining systems, object-oriented systems, adaptive and expert systems, client-service systems, information filtering and multimedia systems, information agents, mobile computing, telecommunications, and electronic commerce.

**Prerequisite(s):** Doctoral student standing in the information systems area or with the permission of the instructor; ISQA 9010 is recommended. Not open to non-degree graduate students.

**ISQA 9030 BEHAVIORAL AND ORGANIZATIONAL ISSUES IN INFORMATION SYSTEMS (3 credits)**

This seminar is a survey course on behavioral and organizational issues in information systems research. The course balances the acquisition of knowledge about the conduct of research in behavioral and organizational issues with the application of that knowledge to research on information systems. The course is intended for doctoral students in Information Technology or related areas.

**Prerequisite(s):** Doctoral student standing in the information systems area or with the permission of the instructor; ISQA 9010 is recommended. Not open to non-degree graduate students.

**ISQA 9120 APPLIED EXPERIMENTAL DESIGN AND ANALYSIS (3 credits)**

Constructing and analyzing designs for experimental investigations; completely randomized, randomized complete block and Latin-square designs, split-plot designs, incomplete block designs, confounded factorial designs, nested designs, and treatment of missing data, comparison of designs. The course will use computer-assisted analysis and graphic techniques included in software such as Statistical Analysis Software (SAS) or Statistical Package for Social Sciences (SPSS) or R (a programming language that provides a wide variety of statistical and graphical techniques. Similar to the S language).

**Prerequisite(s):** ISQA 4150 or ISQA 8156 or consent of instructor. Not open to non-degree graduate students.

**ISQA 9130 APPLIED MULTIVARIATE ANALYSIS (3 credits)**

The use of multivariate analysis for solving business problems. Multivariate Analysis of Variance (MANOVA), factor, cluster, and discriminant analysis techniques in IT research. The course will use computer-assisted analysis and graphic techniques included in software such as Statistical Analysis Software (SAS) or Statistical Package for Social Sciences (SPSS) or R (A programming language that provides a wide variety of statistical and graphical techniques. Similar to the S language).

**Prerequisite(s):** ISQA 4150 or ISQA 8156 or consent of instructor. Not open to non-degree graduate students.

**ISQA 9150 RESEARCH IN INFORMATION TECHNOLOGY (3 credits)**

Research methods in Information Technology involves an overview of the research process specific to problems in IT. Students will learn about theories in IT relevant to their areas of research. They will identify key components of research problems in IT, understand different types of research processes, develop research questions, and design research projects. They will learn to construct research instruments that enable them to collect data. They will also learn about the different data collection and analysis tools and techniques. As part of this course, students will take the CITI training and achieve the research readiness they need to succeed in the PhD in IT program.

**Prerequisite(s):** Permission of the instructor. Not open to non-degree graduate students.

**ISQA 9900 ADVANCED RESEARCH IN INFORMATION SYSTEMS (3 credits)**

This course provides a format for exploration of advanced research areas that are of interest to doctoral students in the information systems and/or information technology area. The specific research area will vary from semester to semester, in keeping with research interests of faculty and students. Examples of areas include, but are not limited to, e-business technology, mobile commerce, intelligent agents e-enabled decision support, electronic collaboration, computer-mediated communications, human-computer interaction and information assurance.

**Prerequisite(s):** Admission to PhD program in Information Technology or permission of instructor