



Early Adopter – Parallel Computing: Keys to *a* Future in Computing

An Undergraduate to Graduate Student
Curriculum / Concentration

MS Program in Computer Science

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Overview



- Brief History, CpS & Motivation
- Course Map & Description
 - Course map
 - CS UG Common Courses
 - CS UG Core & Foundations
 - MS Concentration in Parallel Computing
- < Two year Master's plan in concert w/ established plan A or plan B
- Thesis topics (plan A) w/ research faculty
- Comprehensive Examination (plan B)



History



- Hampton University's MS Program in CS
- Emphasis on AI, SE and CpS
- Subset of established facilities
 - Robotics lab created and courses run
 - IA lab created and UG courses run
- Update of program required
 - CpS facility missing, emerging field in CS
 - Many institutions already have CpS (i.e. A&T, W&M)



CpS



- Computational Science (CpS) facility under construction & expansion
- Summer 2008, Department awarded NSF MRI CNS-0821475
- Summer 2009, NSF REU supplement CNS-0941150
- Fall 2009, Department installed 400 core nVIDIA™ Tesla™ GPU/ Intel™ Xeon™ CPU cluster
- Spring 2010, research in CpS begins, courses run



Motivation



- Early experience institutionalizing MS and PhD program in Computational Science at NCAT
 - after PI departure, program faltered
 - want to do the same at HU and remain
- Three graduate courses:
 - COMP 732 – Advanced Software Tools
Spring 2004, 2006
 - COMP 733 – Parallel Computing Applications
Fall 2003
 - COMP 770 – Computer Organization and Programming for Scientific Computing
Fall 2004, Fall 2005
- Cps entails parallel computing and HPC on clusters on up to supercomputers



Motivation



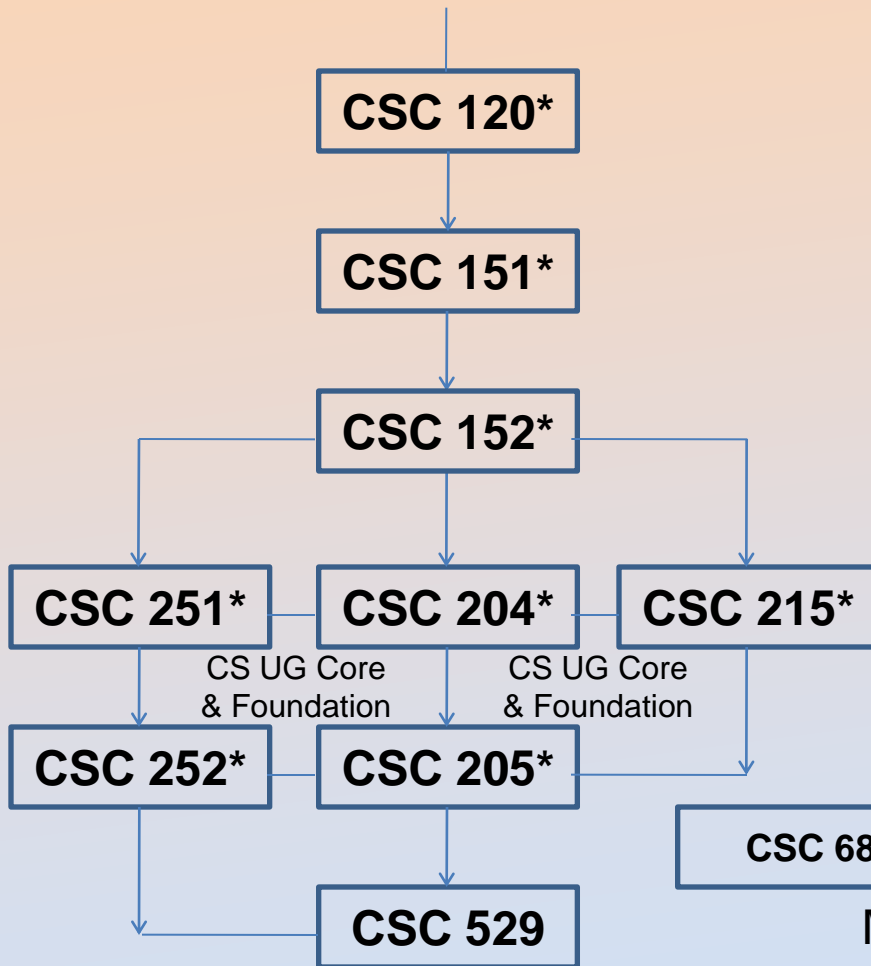
- HU CpS research begins
- Intel™ has donated Parallel Studio software suite
- AI, SE have established curricula
- CpS does not have an established curriculum
- We are proposing to NSF HBCU RISE to increase PhD production in SMET areas
- Hardware and Software are in place at HU
- Parallel computing abilities are now required of UG and Grad students
 - Parallel systems are now widely available
 - Many applications in simulation & modeling, data analysis, image and signal analysis, data visualization
 - Many sectors: medical, scientific, academic, industrial, commercial, governmental
 - Wide range:
 - small scale department project (< 32 nodes)
 - large scale government project (> 10⁵ = 100,000 nodes)
 - New tools are widely available: OpenMP, MPI, CUDA, OpenCL



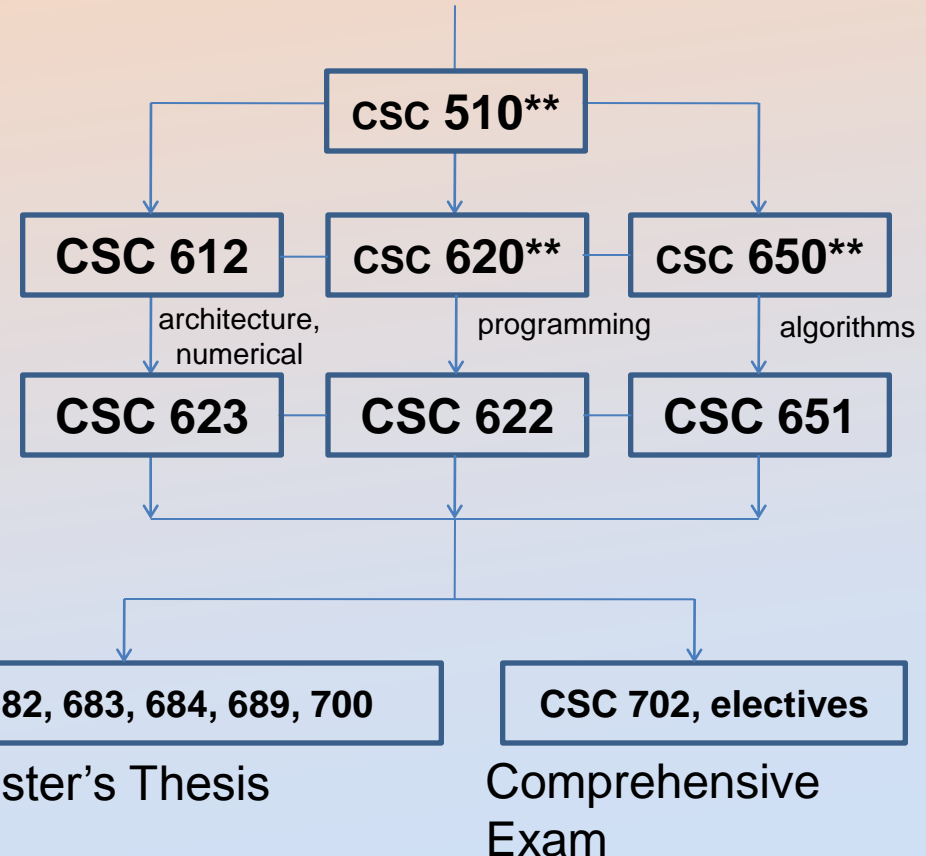
Undergraduate and Graduate Computational Science†



All CS UG Programs



Master's of Science Concentration in Computational Science



†cf. HU Acad. Cat. 2008-2010

*core UG

**core Grad + CSC 630, 640, 660



All CS UG Program Courses†



- **CSC 120*** – Introduction to Computers
This course helps the student understand how computers can be used to enhance his or her personal, academic or professional life. A hands-on approach is used to introduce students to various software packages for word processing, spreadsheet applications, and database management.
- **CSC 151*** – Computer Programming I
Computer basics; goals of quality software concepts of input/output, constants, variables, expressions; program control structures including iterations, sequence, selection; concepts of object oriented programming; use of a high level language; concepts of event-driven programming; introduction to Graphical User Interface components; introduction to input/output for files; introduction to arrays; ethical principles in computing.
- **CSC 152*** – Computer Programming II
Problem solving techniques. Principles of good programming style, documentation, and robustness. Introduction to Data Structures. Object-based and Object-Oriented Programming. Exception handling files and streams. Ethical issues in computing. Prerequisite: CSC 151

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*core UG

**core Grad + CSC 630, 640, 660



CS UG Core & Foundations†



- **CSC 204*** – Computer Architecture, Systems and Organization I
Binary number representation and arithmetic. Computer structure. Addressing techniques. Storage allocation. Subroutine linkage. Relocatability and program segmentation, bit manipulation. Operating system supplied I/O routines and interface using a systems programming language and assembly language. Macros.
Prerequisites: CSC 152, MAT 117
- **CSC205*** – Computer Architecture, Systems and Organization II
Intermediate logic design including truth tables, logic diagrams, Boolean functions and K-maps. Computer architecture including CPU design, memory organization, I/O processing including programmed I/O, interrupt I/O, and direct memory access. (Multi-computers, Flynn's taxonomy, MESI cache coherence, UMA & NUMA multiprocessing, Spring 2010) Coding. Prerequisite: CSC 204
- **CSC 529** – Topics in Parallel Programming
A treatment of topics not routinely covered by other courses. (foundations parallel programming in MPI & OpenMP, Spring 2010)
Prerequisite: Permission of the instructor

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*core UG

**core Grad + CSC 630, 640, 660



CS UG Core & Foundations†



- **CSC 215*** – Discrete Structures
Set theory, logic and combinatorics. Relations and functions. Proof techniques, including mathematical induction. Introduction to graph theory. Ethical principles in computing.
Prerequisites: CSC 152, MAT 117 (pre-calculus)
- **CSC 251*** – Data Structures and Algorithm Analysis I
Representation of compiler related data structures. Contiguous linked and hashed representations. Empirical and abstract analysis of time and space of competing representation. Space optimization. Specification, design, implementation, and verification of linear and hierarchical; abstract data types, including stacks, lists, queues and trees. Basic techniques to algorithm design and analysis; ethical principles in computing.
Prerequisite: CSC 152, Co-requisite: CSC 215
- **CSC252*** – Data Structures and Algorithm Analysis II
An in-depth survey of data structures and algorithms, exploring their design, running efficiency, and applications. Advanced methods for interval and external sorting and searching. Implementation of relational data types including directed and undirected graphs. Advanced algorithms, which may include parsing, breadth-first and depth-first graph traversals, minimum weighted paths and information, flow analysis, (parallel algorithms), ethical principles in computing. Prerequisites: CSC 204, 215, 251

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Master's of Science Concentration in Computational Science†



- **CSC 510** – Mathematical Foundations**
Propositional and Predicate Calculus. Proof techniques. Queuing theory. Mathematical formulations of data structures. Basic models of computation expressions and grammars. Prerequisites: CSC 215, 252
- **CSC 612 – Numerical Computation**
Numerical and optimization methods useful for simulation, graphics, and image processing. Computation statistics and Monte Carlo methods. Signal analysis foundations. Prerequisite: CSC 510 or permission of the instructor
- **CSC 620** – Operating Systems**
Relation between architectures and operating systems. Multiprogramming timesharing, multiprocessing, distributed processing and real time processing. Inter-process communication and synchronization. Resource allocation and related problems.
- **CSC 622 – Parallel Processing**
Parallel processing models and architectures. Concurrent processes and controls. Parallel algorithms and their analysis. Prerequisite: CSC 620 or permission of the instructor

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Master's of Science Concentration in Computational Science†



- **CSC 623 – Architecture**
Principles of computer design. Architecture of sequential and parallel computers.
Prerequisite: CSC 620 or permission of the instructor
- **CSC 650** – Theory of Computation**
Chomsky hierarchy. Turing machines, decidability and computational complexity.
- **CSC 651 – Algorithms and Complexity**
Turing machines and equivalent computational models. Church's thesis. Complexity classes. (Parallel algorithms, PRAMs and parallel complexity classes, TBA)
Prerequisites: CSC 510, 650 or permission of the instructor
- **Required:**
 - CSC 630** - Artificial Intelligence
 - CSC 640** - Software Engineering Foundations
 - CSC 660** - Programming Languages
- **Thesis option A**
 - CSC 681 – Research Seminar I / CSC 682 – Teaching Seminar I, CSC 683 – Research Seminar II,
 - CSC 684 – Thesis Research, CSC 689 – Thesis, CSC 700 – Thesis Registration
- **Comprehensive Exam option B**
 - Electives (2)
 - CSC 702 – Master's Comprehensive Exam

†cf. HU Acad. Cat. 2008-2010

*core UG

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Plan A†



- Research is conduct w/ research faculty on topics among the strengths of the Department
 - AI, SE (cf. w/ Boonthum, Mohammad, Hu)
 - CpS (cf. w/ Providence)
 - serial & parallel algorithms
 - multi- & many-core, distributed and parallel architectures
 - simulation & modeling, process-oriented, message-passing languages
 - numerical & algebraic computation, data analysis, data visualization
- At least one year of research & thesis writing
 - Concentration + CSC 681/682, 683, 684, 689, 700

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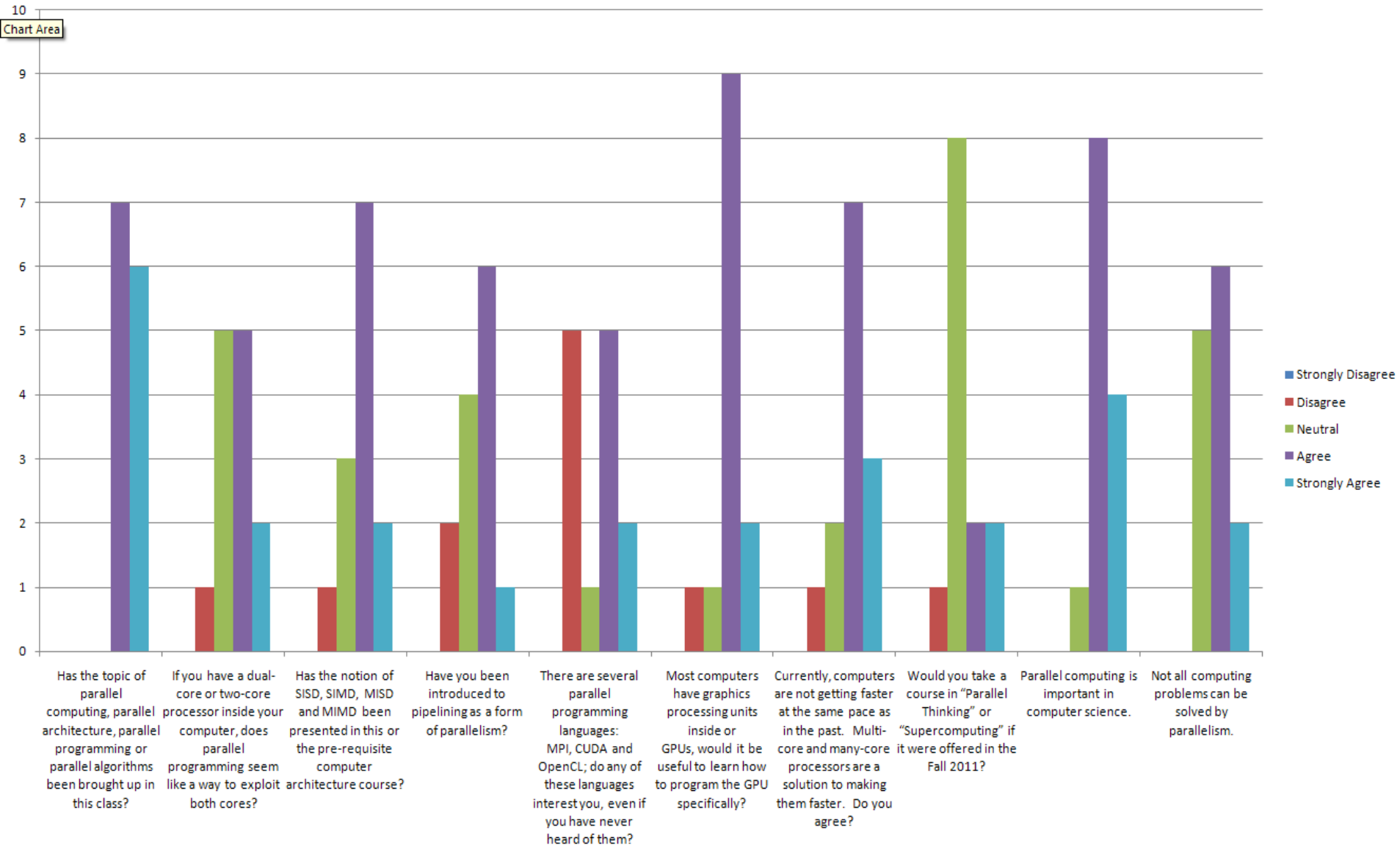
Plan B†



- Comprehensive Examination CSC 702
 - Currently multiple choice questions chosen at by pseudo-random generator from general CS, AI, SE, & CpS questions.



CSC 205 Interest Results





Future

Supported by:
NSF MRI CNS-0821475,
NSF REU supp. CNS-0941150



- Procure Grad support funding
 - NSF REU supplement and DoD Fall 2011 for UG
 - NSF HBCU RISE proposal April 2012
- Increase pubs quantity
- Form pipelines to R1 institutions
 - Broaden research base and funding (NSF BPC)
- Increase pub quantity
- Plan PhD program
 - Curriculum expansion (NSF CCLI)
- Procure Doctoral support funding
- Start Doctoral program
 - UG research & education (NSF REU Site)
 - NSF HBCU RISE



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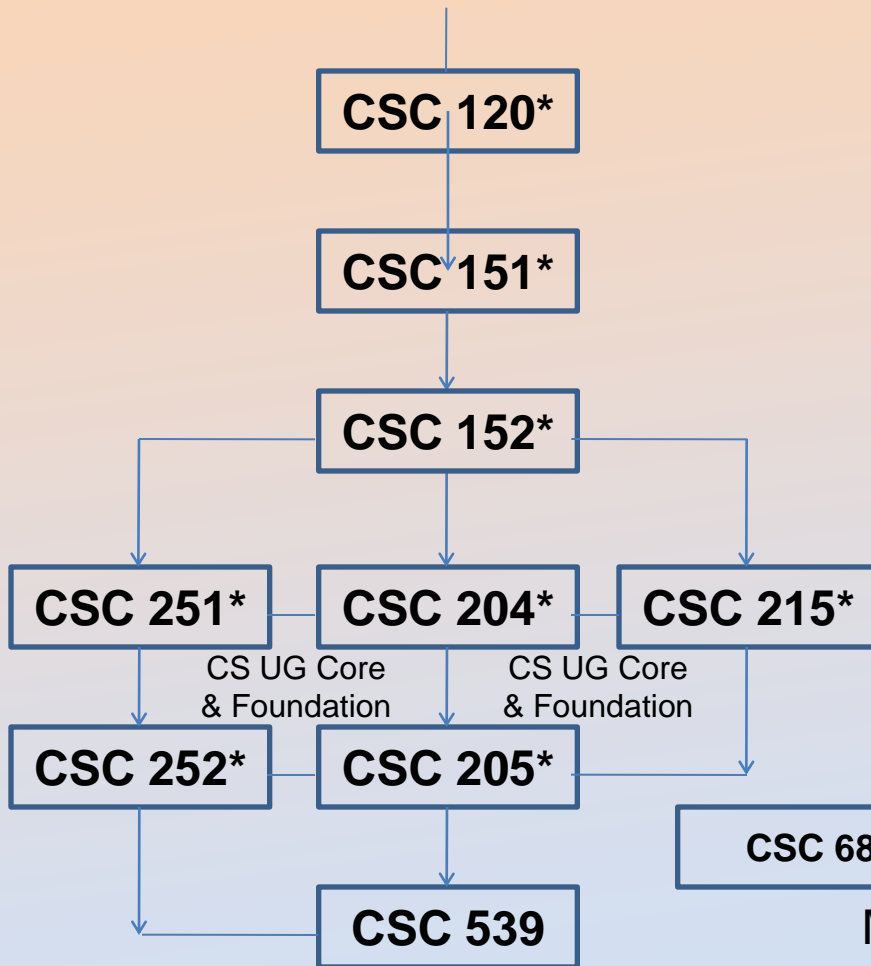
First NSF/TCPP Workshop on Parallel and Distributed Computing Education, 2011



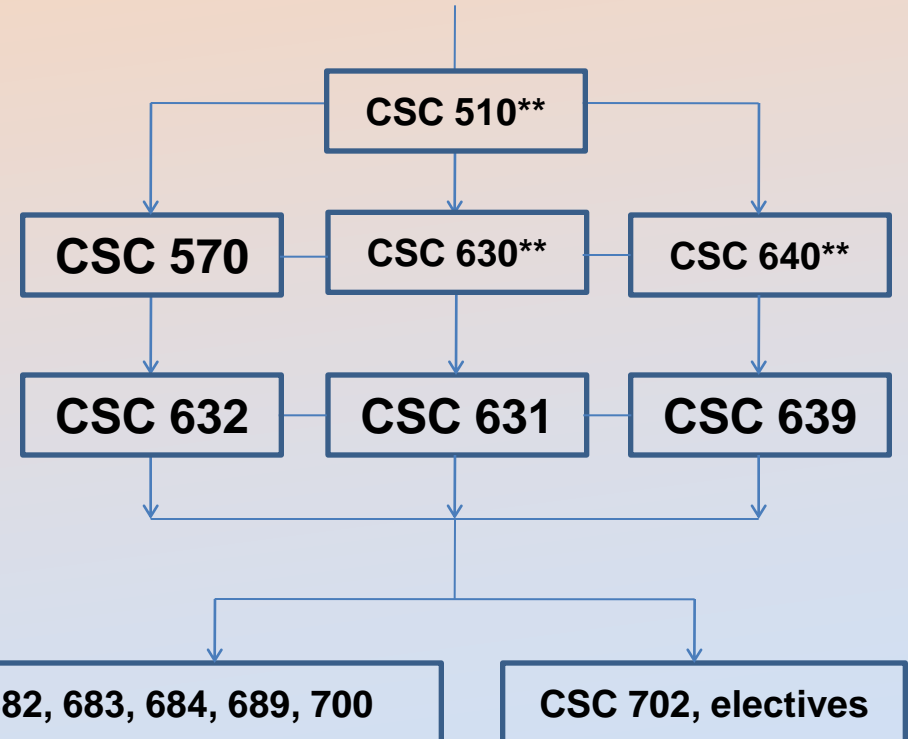
Undergraduate and Graduate Artificial Intelligence†



All CS UG Programs



Master's of Science Concentration in Artificial Intelligence



Master's Thesis

Comprehensive Exam

†HU Acad. Cat. 2008-2010

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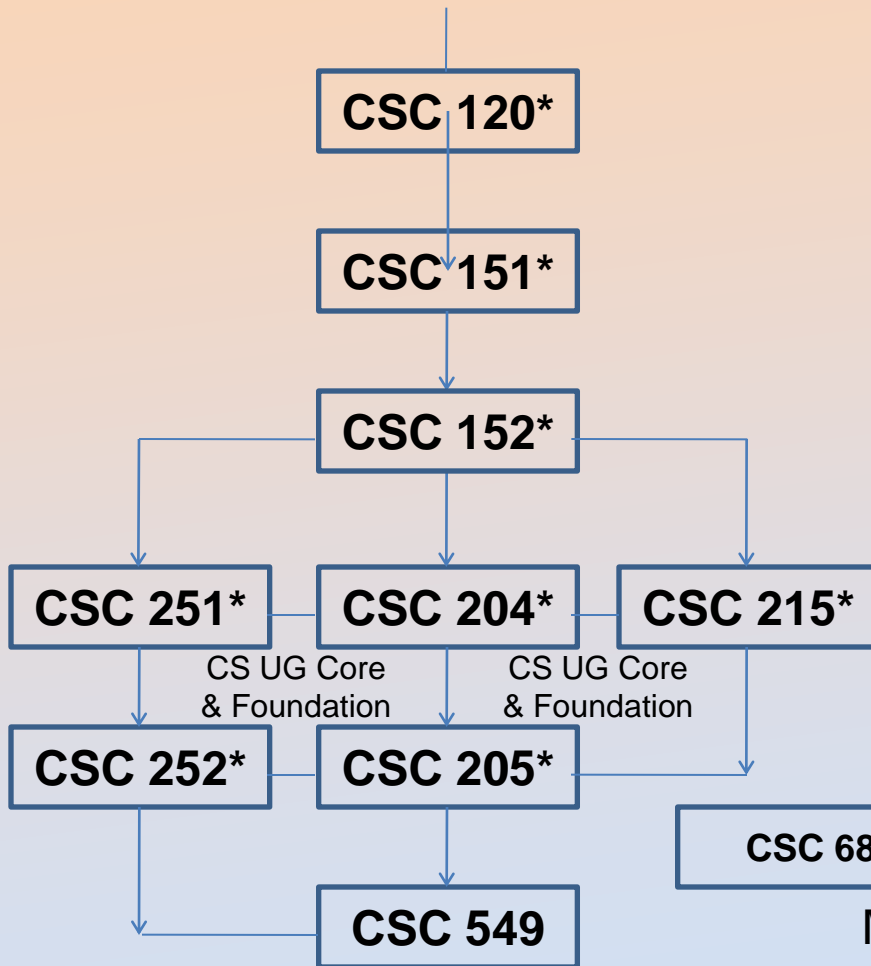
**core Grad + CSC 620, 650, 660



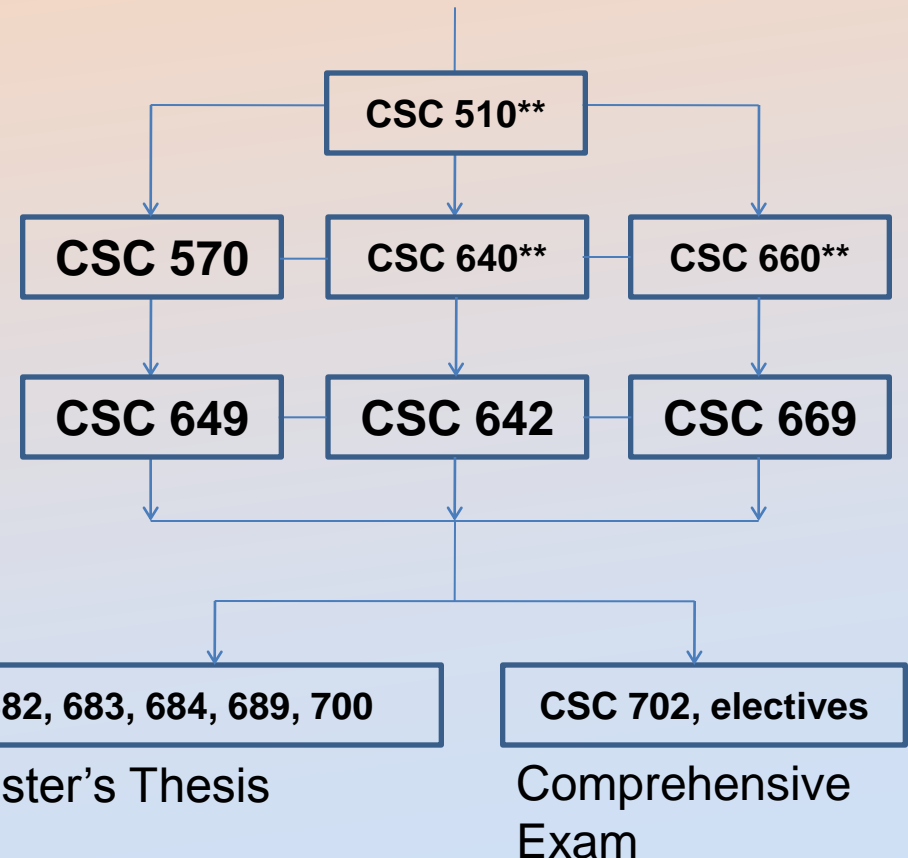
Undergraduate and Graduate Software Engineering†



All CS UG Programs



Master's of Science Concentration in Software Engineering



†HU Acad. Cat. 2008-2010

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