Re-Designing a Computer Science Program for Tomorrow's Leaders

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Abstract

Saint Mary's University of Minnesota includes a small, private liberal arts college that offers 58 majors at its Winona campus. It contains a department of Mathematics, Computer Science and Statistics that for many years has offered a bachelor's degree in computer science. The computer science program has undergone many changes over the years and was nearly eliminated a few years ago. Recently the administration has eagerly supported a renewal of the computer science major. This paper details the steps and processes undertaken to revise the computer science major to be current with industry trends and prepare graduates for a wide variety of positions in computer technology.

1. Introduction

Saint Mary's University of Minnesota includes a small, private liberal arts college that offers 58 majors at its Winona campus. It contains a department of Mathematics, Computer Science and Statistics that for many years has offered a bachelor's degree in computer science (1). The computer science program has undergone many changes over the years and was nearly eliminated a few years ago. Recently the administration has eagerly supported a renewal of the computer science major. They believe a solid computer science program will help support the university's vision of providing advanced knowledge, skills and critical thinking abilities to prepare tomorrow's leaders.

This paper details the steps and processes undertaken to revise the computer science major to be current with industry trends and prepare graduates for a wide variety of positions in computer technology. Early in the planning stages it was decided that the computer science major would maintain a sturdy foundation in computer programming yet align more closely with modern computing environments and devices. The redesign of the program also needed to be well supported by national standards, career outlooks and relevant research papers. The primary source of the revisions emanates from the Curriculum Guidelines for Undergraduate Degree Programs in Computer Science released in 2013 by The Joint Task Force on Computing Curricula which includes the Association for Computing Machinery (ACM) and IEEE Computer Society. The 2013 edition included four new knowledge areas which expanded the breadth of the possible computer science courses offerings, and these new areas greatly influenced this re-design. The second main source was provided by the United States Department of Labor in their Occupational Outlook Handbook for Computer and Information Technology Occupations. They list ten primary occupations, and from that list, the redesign of the computer science major is expected to prepare students for entry level positions in seven of them. Additional research from current literature and working groups focused on computing education in liberal arts colleges was utilized to bring clarity to the unique challenges and opportunities faced by Saint Mary's University in this endeavor.

2. Design Framework

This document presents a framework for the proposal to revise the Computer Science programs. These revisions are primarily guided by two sources: The Association for Computing Machinery (ACM) and IEEE-Computer Society and The Occupational Outlook Handbook for Computer and Information Technology Occupations.

2.1 ACM /IEEE Curriculum Guidelines

The Association for Computing Machinery (ACM) and IEEE-Computer Society sponsor efforts to establish international curricular guidelines for undergraduate programs in computer science (2). These guidelines set the standard across the country for undergraduate computer science programs. The latest revision to these guidelines was

published in December of 2013. The CS2013 guidelines include an expanded and redefined body of knowledge, a result of rethinking the essentials necessary for a Computer Science curriculum.

An overview of the number of core hours (both Tier-1 and Tier-2) by KA in the CS2013 Body of Knowledge is provided below. For comparison, the number of core hours from both the previous CS2008 and CC2001 reports are provided as well.

	CS2013		**CS2008**	**CC2001**
Knowledge Area	**Tier1**	**Tier2**	**Core**	**Core**
AL-Algorithms and Complexity	19	9	31	31
AR-Architecture and Organization	0	16	36	36
CN-Computational Science	1	0	0	0
DS-Discrete Structures	37	4	43	43
GV-Graphics and Visualization	2	1	3	3
HCI-Human-Computer Interaction	4	4	8	8
IAS-Information Assurance and Security	3	6	--	--
IM-Information Management	1	9	11	10
IS-Intelligent Systems	0	10	10	10
NC-Networking and Communication	3	7	15	15
OS-Operating Systems	4	11	18	18
PBD-Platform-based Development	0	0	--	--
PD-Parallel and Distributed Computing	5	10	--	--
PL-Programming Languages	8	20	21	21
SDF-Software Development Fundamentals	43	0	47	38
SE-Software Engineering	6	22	31	31
SF-Systems Fundamentals	18	9	--	--
SP-Social Issues and Professional Practice	11	5	16	16
Total Core Hours	**165**	**143**	**290**	**280**

Table 1: ACM/IEEE Knowledge Areas and Hours

The proposed curriculum changes represent an adoption of this new body of knowledge to better prepare students for modern positions while still maintaining a foundational core in computer programming. The bodies of knowledge new to the 2013 recommendations are described in the document as follows (2):

- Information Assurance and Security (IAS) is a new KA in recognition of the world's critical reliance on information technology and computing. IAS as a domain is the set of controls and processes, both technical and policy, intended to protect and defend information and information systems. IAS draws together topics that are pervasive throughout other KAs. Topics germane to only IAS are presented in depth in this KA, whereas other topics are noted, and cross referenced to the KAs that contain them. As such, this KA is prefaced with a detailed table of cross-references to other KAs.

- Platform-Based Development (PBD) is a new KA that recognizes the increasing use of platform-specific programming environments, both at the introductory level and in upper-level electives. Platforms such as the Web or mobile devices enable students to learn within and about environments constrained by hardware, APIs, and special services (often in cross-disciplinary contexts). These environments are sufficiently different from "general purpose" programming to warrant this new (wholly elective) KA.

- Systems Fundamentals (SF) - In previous curricular volumes, the interacting layers of a typical computing system, from hardware building blocks, to architectural organization, to operating system services, to application execution environments (particularly for parallel execution in a modern view of applications), were presented in independent knowledge areas. The new Systems Fundamentals KA presents a unified systems perspective and common conceptual foundation for other KAs (notably Architecture and Organization, Network and Communications, Operating Systems, and Parallel and Distributed Algorithms). An organizational principle is "programming for performance": what a programmer needs to understand about the underlying system to achieve high performance, particularly in terms of exploiting parallelism.

- Parallel and Distributed Computing (PD) - Previous curricular volumes had parallelism topics distributed across disparate KAs as electives. Given the vastly increased importance of parallel and distributed computing, it seemed crucial to identify essential concepts in this area and to promote those topics to the core. To highlight and coordinate this material, CS2013 dedicates a KA to this area. This new KA includes material on programming models, programming pragmatics, algorithms, performance, computer architecture, and distributed systems.

2.2 Occupational Outlook Handbook

The United States Department of Labor predicts employment of computer and information technology occupations is projected to grow 13 percent from 2016 to 2026 (3). Updates to the computer science programs were designed to better prepare graduates for the following positions as noted in table 2.

Computer and Information Technology Occupations				
Occupation	**Entry Level Education**	**2016 Median Pay**	**Job Growth 2016-26**	**Employment Change 2016-26**
Computer Programmer	Bachelor's Degree	$79,840	-21,300	-7%
Computer Systems Analyst	Bachelor's Degree	$87,220	54,400	9%
Database Administrator	Bachelor's Degree	$84,950	13,700	11%
Information Security Analyst	Bachelor's Degree	$93,600	28,500	28%
Network and Systems Administrator	Bachelor's Degree	$79,700	24,000	6%
Software Developers	Bachelor's Degree	$102,280	302,500	24%
Web Developers	Associate Degree	$66,130	24,400	15%

Table 2: Occupation Outlook

The outlook provides the following occupation descriptions (3):

- Computer programmers write and test code that allows computer applications and software programs to function properly. They turn the program designs created by software developers and engineers into instructions that a computer can follow.
- Computer systems analysts, sometimes called systems architects, study an organization's current computer systems and procedures, and design solutions to help the organization operate more efficiently and effectively. They bring business and information technology (IT) together by understanding the needs and limitations of both.
- Database administrators (DBAs) use specialized software to store and organize data, such as financial information and customer shipping records. They make sure that data are available to users and secure from unauthorized access.

- Information security analysts plan and carry out security measures to protect an organization's computer networks and systems. Their responsibilities are continually expanding as the number of cyberattacks increases.
- Computer networks are critical parts of almost every organization. Network and computer systems administrators are responsible for the day-to-day operation of these networks.
- Software developers are the creative minds behind computer programs. Some develop the applications that allow people to do specific tasks on a computer or another device. Others develop the underlying systems that run the devices or that control networks.
- Web developers design and create websites. They are responsible for the look of the site. They are also responsible for the site's technical aspects, such as its performance and capacity, which are measures of a website's speed and how much traffic the site can handle. In addition, web developers may create content for the site.

3. Program Design

The following courses were either added or re-designed to better meet the ACM/IEEE guidelines and prepare students for entry level positions as specified in section 2.2.

3.1 New Courses

- CS 310 Web Systems 1 - This course will introduce the essential topics of Internet programming. Students will design Interactive Web pages using HTML, CSS, JavaScript, and other client-side script technology. Concepts such as cookies, manipulating multimedia, and publishing and managing a remote site will be discussed.

- CS 360 Intro to Cybersecurity - This course provides an overview of modern security concepts. Topics covered will include security terminology, risk management, security policy and strategy, security awareness, cryptography, operating system security, network security, physical security and digital forensics. The course will contain a lab component where students will investigate current hardware and software tools for vulnerability analysis and penetration testing.

- CS 335 Networking - This course examines computer networks and data communication. Topics include: telecommunications history; transmission media; transmission characteristics; error detection and correction; local and wide

area networking applications; standard network models; industry standards; protocols; network management; wireless and mobile networks; network security.

- CS 305 Server Systems - This course will cover the basics of server operating systems. Topics will include installation, active directory, user management, file management, device management, data storage, group policies, data and system recovery, performance monitoring, and security. Students will complete hands on projects utilizing file servers, web servers, email servers, database servers, firewalls and network services.

- CS 315 Visual App Development - An introduction to a visual programming framework to develop applications for graphical operating system environments and internet applications. Topics include basic concepts of programming, problem solving, file I/O operations, programming logic, exception handling, and design techniques of an object-oriented language within a visual development environment.

3.2 Re-Designed Courses

- CS 320 – Computer Architecture - This course will introduce the function and design of the various components necessary to process information digitally. The study of computer organization focuses on how various electronic circuits and components fit together to create working computer systems. Concepts of machine level representation of data, assembly level machine organization, and memory system organization are also included.

- CS 485 Systems Design - This course introduces established and evolving methodologies for the analysis, design, and development of an information system. Emphasis is placed on system characteristics, managing projects, prototyping, object-oriented tools and techniques for describing process flows, data flows, data structures, file designs, input and output designs, program specifications, and systems development life cycle phases.

- CS 380 – Web Systems 2 - This course will advance the web site design and development skills introduced in Web Systems 1. Topics include web forms, database implementation, XML, server-side scripting, web server implementation and configuration, design frameworks and discussion of design and development issues.

- CS 490 Capstone Project - In this project-oriented course, students complete a capstone project, serving as a culmination of their studies within the major. The project entails the development of a significant piece of software or completion of technology project by a student and supervised by a designated faculty member within the department.

3.3 Proposed CS Major

Proposed CS Major 2018		
Course	**Description**	**Credits**
CS101	CS Fundamentals	3
CS110	Computer Science I	3
CS210	Computer Science II	3
CS220	Discrete Math	3
CS255	Database Management	3
CS305	Server Systems	3
CS310	Web Systems 1	3
CS320	Computer Architecture	3
CS325	Computer Science III	3
CS335	Networking	3
CS360	Intro to Cybersecurity	3
CS380	Web Systems 2	3
CS485	Systems Design	3
CS490	Capstone Project	3
Choose 6 credits from the following list		6
CS315	Visual App Development (3)	
CS288	Mobile Applications (3)	
CS290/CS390	Special Topics (3)	
CS496	Internship (3-6)	
Total Credits		**48**

Table 3: Revised Major

The knowledge areas from the 2013 curricular recommendations are mapped to the Saint Mary's University courses in figure 4.

Knowledge Area	SMU Courses
AL-Algorithms and Complexity	CS101, CS110
AR-Architecture and Organization	CS101, CS320
CN-Computational Science	CS220, CS255, CS355

DS-Discrete Structures	CS101, CS220, CS320
GV-Graphics and Visualization	CS325, CS315, CS380
HCI-Human-Computer Interaction	CS110, CS315
IAS-Information Assurance and Security	CS305, CS335, CS360
IM-Information Management	CS255, CS485
IS-Intelligent Systems	CS320
NC-Networking and Communication	CS335, CS360
OS-Operating Systems	CS101, CS305, CS 320
PBD-Platform-based Development	CS310, CS380, CS288
PD-Parallel and Distributed Computing	CS320, CS325
PL-Programming Languages	CS110, CS 210, CS325
SDF-Software Development Fundamentals	CS101, CS310, CS485
SE-Software Engineering	CS325, CS485, CS490
SF-Systems Fundamentals	CS305, CS335. CS485
SP-Social Issues and Professional Practice	CS101, CS490

Table 4: Knowledge Area Mapping

4. Conclusion

The paper details Saint Mary's University of Minnesota's steps and processes undertaken to revise the computer science major to be current with industry trends and prepare graduates for a wide variety of positions in computer technology. The proposal is set to be approved in the spring of 2018 and be available for students for the 2018 fall semester.

University administrators believe a solid computer science program will help support the university's vision of providing advanced knowledge, skills and critical thinking abilities to prepare tomorrow's leaders. The redesign of the program as demonstrated in this paper is well supported by national standards, career outlooks and relevant research.

References

[1] Saint Mary's University of Minnesota. (2018). *2017-2018 Academic Catalog.* Retrieved from: http://catalog.smumn.edu/index.php?catoid=25

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[3] Occupational Outlook Handbook, United States Department of Labor – Bureau of Labor Statistics. Retrieved from*:* https://www.bls.gov/ooh/computer-and-information-technology/home.htm