Fourth LACCEI International Latin American and Caribbean Conference for Engineering and Technology (LACCET'2006)
"Breaking Frontiers and Barriers in Engineering: Education, Research and Practice"
21-23 June 2006, Mayagüez, Puerto Rico.

Options in Computing Education in the United States

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Abstract

The past several decades have seen the emergence of the computer and its pervasive integration into the developed world. Computers have evolved dramatically, and now can be found in nearly everything electrical. The early 1990s saw the explosive growth in the use of the Internet. These dramatic technological changes in our society demanded knowledgeable professionals and associated academic disciplines to prepare them, which gave rise first to computer science and information systems programs, starting in the early 1960s. More recently, this continued integration of computing into the fabric of society has given rise to academic programs in computer engineering, software engineering, and information technology.

Each of these disciplines has completed a formal curriculum definition and has also participated in a task force to define these five computing disciplines with respect to each other. This paper provides an overview of these efforts and provides details of the differences and similarities among these five computing disciplines, and gives an update on the status of these national developmental efforts.

Keywords

Information technology, curriculum, computing, information systems, computer science

Introduction

In the early 1960s, the impact of the computer began to be wide enough that academia recognized the need to educate students in this discipline. Two disciplines quickly arose to address this need, computer science (CS) and information systems (IS).

Most CS programs arose from mathematics or engineering programs, and most early professors in CS had degrees in these parental fields. The emphasis was on the programming of computers, the development of algorithms, the theory of computing, and closely related topics. The applications of the computer were only minimally addressed.

Most IS programs arose within schools of business, particularly programs in accounting. One of the earliest and most widespread applications of computers was in accounting, and there was a great need to train students in this area. The emphasis was on the application of computers in the accounting field, including IS design, systems operation and maintenance, IS management, information technology, and accounting programs.

In the late 1980s, two additional programs began to emerge: computer engineering and software engineering. Electrical engineering had long been teaching students the particulars of digital circuits and logic design, and many EE graduates had been going to work for computer hardware giants such as IBM and Intel. As the need for such skills continued to grow, many EE programs around the nation began to formally define a program in computer engineering (CpE). It should be pointed out that these CpE programs were not created *ex nihilo*, but were rather formalization and renaming of an option within EE which had existed for many years.

Software engineering (SE) grew out of the need for more rigorous methods of creating software, driven by the creation of continually larger and more complex programs. Examples of these very large and very complex programs include military command and control systems, avionics, digital telephone switches, aerospace and launch control, ballistic missile defense, and more recently operating systems and increasingly realistic computer games. The creation of the discipline of SE is facilitating the application of rigorous and proven engineering design methods to the relatively new field of computer programming as a component of large system integration projects.

Information technology, the newest of the computing disciplines discussed in this paper, grew out of the explosive growth in the use of the Internet as a result of the emergence of the world-wide web (WWW), which occurred in the early and mid-1990s. This discipline has grown very rapidly, due to the rate of expansion of the field of networked computing.

It should be acknowledged here that there are other programs in computing that are presently emerging, including programs such as informatics, bio-informatics, networking, and others. Since this paper cannot hope to include a discussion of all computing programs, we chose to focus on the five computing disciplines that have formally-defined curricula, as outlined by the ACM (Association for Computing Machinery), and as available at the ACM website (http://www.acm.org/education/curricula.html)[1].

The Overview Report

Since *Curriculum '68*[2], the Association for Computing Machinery (ACM) and the Computer Society of the Institute of Electrical and Electronic Engineers (IEEE-CS) have endeavored to maintain a current and formally defined recommended curriculum for computer science programs[3,4]. Similar work has taken place since the early 1970s in the field of information systems, under the auspices of the ACM, the Association for Information Systems (AIS), and the Association of Information Technology Professionals

(AITP). The 2001 update for the computer science curriculum (Computing Curricula 2001 – Computer Science[5]) pointed out the need for formal curriculum documents from CpE and SE, and also stated, "Once the individual reports have been completed, representatives from all the [computing] disciplines will come together to produce an overview volume that links the series together. That overview volume will contain definitions of the various computing disciplines along with an assessment of the commonalities that exist in the curricular approaches."

This overview report has been several years in the making, but is now available in draft form as Computing Curricula 2005[1]. It represents a great deal of working together by leaders in each of the five computing disciplines and is very useful in defining and differentiating each of the computing disciplines.

The remainder of this paper provides a brief look into the five disciplines covered in The Overview Report. Since this brief look has been compiled by academicians in the field of IT, it will have an IT bias. Every attempt will be made to fairly represent the information, but this IT bias should be acknowledged from the start.

Accreditation

In the academic world of computing as a whole, accreditation is quite fragmented. This section will discuss accreditation for each of the five computing disciplines, starting with computer science.

Computer science has generally been "a loosely organized network of scientists, researchers, and programmers", rather than "a tightly organized body of practicing professionals." (P 48, The Overview Report). Accordingly, most computer science programs have had little need or interest in accreditation. Today, only about 10% of CS programs in the U.S. are accredited. Those that are accredited have, in the past, been accredited through the Computer Science Accreditation Board (CSAB). In the year 2000, CSAB transferred accrediting responsibilities to the Computing Accreditation Commission (CAC) of ABET (formerly the Accreditation Board for Engineering and Technology; now just ABET).

Information Systems programs, generally being strongly affiliated with business schools or colleges, have had their own tradition of accreditation in association with their respective schools or colleges[6]. This tradition has been quite separate from accreditation in computer science, and has often been through The Association to Advance Collegiate Schools of Business (AACSB).

The more recent disciplines of CpE and SE are also somewhat disparate. Most engineering disciplines have had a very strong tradition and need for professional accreditation; since computer engineering has emerged from within EE, this tradition has been maintained. Most CpE programs are accredited, or are seeking accreditation. This accreditation is through the Engineering Accreditation Commission (EAC) of ABET.

Software engineering programs have few formal ties to traditional engineering programs, but since they are an engineering discipline, they are being accredited through the EAC of ABET. The first of these accreditations took place in 2003; since then, a total of ten SE programs have received accreditation.

In 2001, at the time work was begun on The Overview Report, there was no official body of IT programs, nor any formal IT curriculum. However, December of 2001 saw this change as the first Conference on Information Technology Curriculum was held, which resulted in the creation of the Society for Information Technology Education (SITE), as well as committees for defining IT accreditation and an IT curriculum.

IT accreditation standards progressed quickly, and outcomes were posted for public review in 2004. These outcomes have been approved for use in a pilot accreditation visit which took place in November 2005. Additionally, general outcomes were approved for accrediting of general computing programs; these outcomes have been used for accreditation of three IT programs in November 2004, and it is apparent that when the IT-specific outcomes are fully approved for accreditation, more IT programs will seek to be accredited. The IT outcomes can be found at www.**abet**.org/images/Criteria/C001 04-05 CAC Criteria 2011-18-03.pdf

It should be noted here that, in the lead author's experience, what happens in accreditation for CpE, SE, and IT programs is being and will be looked to by many people outside the U.S. as an example. Many countries are looking into accreditation for their relatively new computing programs, and one of the models most often looked to is ABET. Of the five computing programs being discussed in this paper, only IS programs are sometimes not accredited through ABET.

Brief Descriptions

Each of the five computing disciplines discussed in this paper has developed a brief description of their discipline. These are:

"*Computer engineering* is concerned with the design and construction of computers and computer-based systems. It involves the study of hardware, software, communications, and the interaction among them. Its curriculum focuses on the theories, principles, and practices of traditional electrical engineering and mathematics, and applies them to the problems of designing computers and computer-based devices." (The Overview Report, p. 13)

"*Computer science* spans a wide range, from its theoretical and algorithmic foundations to cutting-edge developments…." "While other [computing] disciplines can produce graduates better prepared for specific jobs, computer science offers a comprehensive foundation that permits graduates to adapt to new technologies and new ideas." (The Overview Report, p. 13)

"*Information systems* specialists focus on integrating information technology solutions and business processes to meet the information needs of businesses and other enterprises, enabling them to achieve their objectives in a effective, efficient way." "All IS degrees combine business and computing coursework." (The Overview Report, p. 14)

"*Information technology* … refers to undergraduate degree programs that prepare students to meet the technology needs of business, government, healthcare, schools, and other kinds of organizations." (The Overview Report, p. 14) "IT, as an academic discipline, focuses on meeting the needs of users within an organizational and societal context through the selection, creation, application, integration and administration of computing technologies." (Computing Curricula: Information Technology Volume, p. 5)

"*Software engineering* is the discipline of developing and maintaining software systems that behave reliably and efficiently, [and] are affordable to develop and maintain….It seeks to integrate the principles of mathematics and computer science with the engineering practices developed for tangible, physical artifacts." (The Overview Report, p. 15)

Knowledge Areas: Differences

Each of the five computing disciplines discussed in this paper have included in their model curriculum a one- or two-page list of *knowledge areas* that constitute their body of knowledge. In an effort to graphically portray these disciplines juxtaposed against each other, the detailed descriptions of each of these knowledge areas were compiled into pie charts that can assist in understanding the differences between these programs. There are 83 total knowledge areas. Many of them overlap or have much similarity, so these 83 knowledge areas were reduced to 15 emphasis areas for this paper. Additionally, since each formal curriculum also gives an idea how much time should be spent on each knowledge area, it was possible to combine subtopics within some knowledge areas. It is acknowledged that the graphs derived from this analysis (Figures 1-5) are somewhat oversimplified, but this was essential in order to reduce the complexity of the graphs as a whole.

In general, the graphs give great insight into each discipline. Computer engineering has a very strong emphasis on computer hardware (Figure 1); CS has a strong emphasis on algorithms & complexity, computer hardware, programming, and software life cycle (Figure 2). Information systems has a strong emphasis on developing information systems (Figure 3), and IT has emphases in human-computer interaction, information management (databases), development of information systems, networks, programming and security. Software engineering has their major emphasis in the area of the software life cycle.

Additionally, each computing discipline has a substantial body of knowledge that could not be adequately compared to the other computing disciplines. This is shown in the graphs under Other; details can be found by consulting the individual knowledge areas for each computing discipline.

Figure 1: Knowledge areas for Computer Engineering

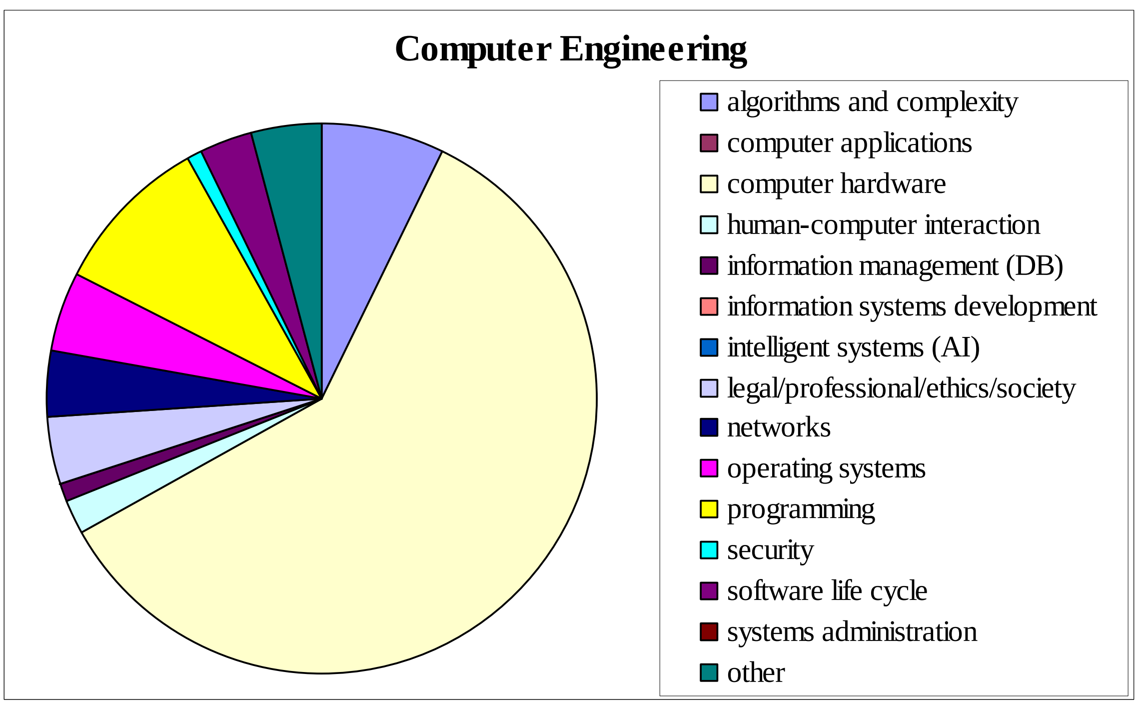


Figure 2: Knowledge areas for Computer Science

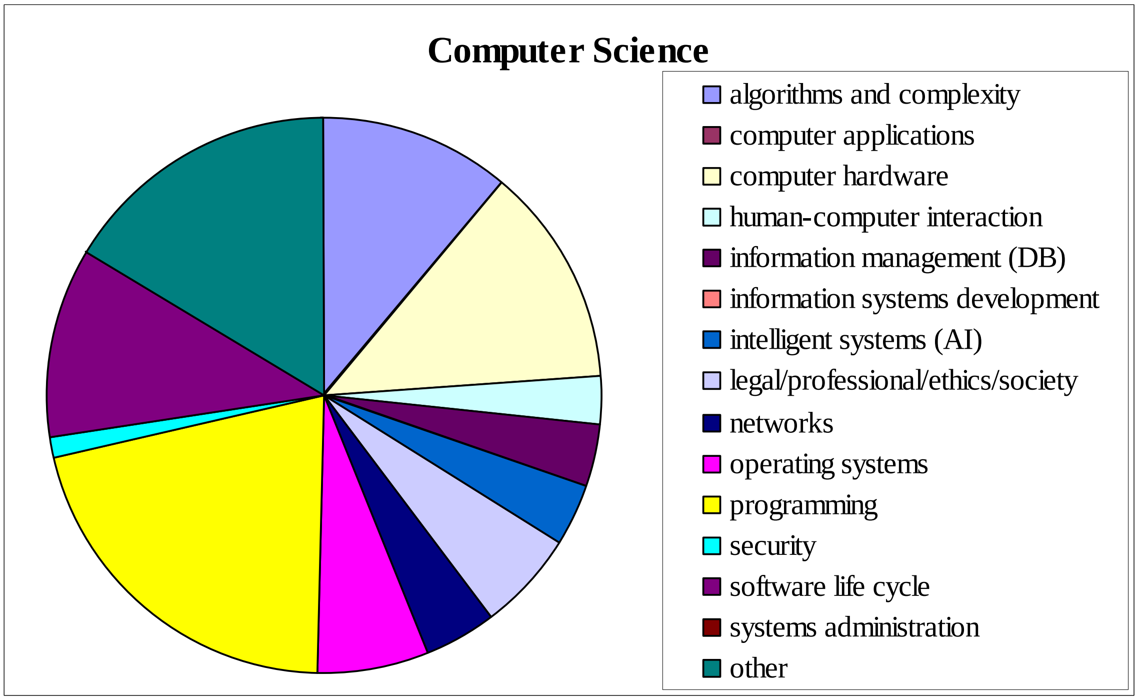


Figure 3: Knowledge areas for Information Systems

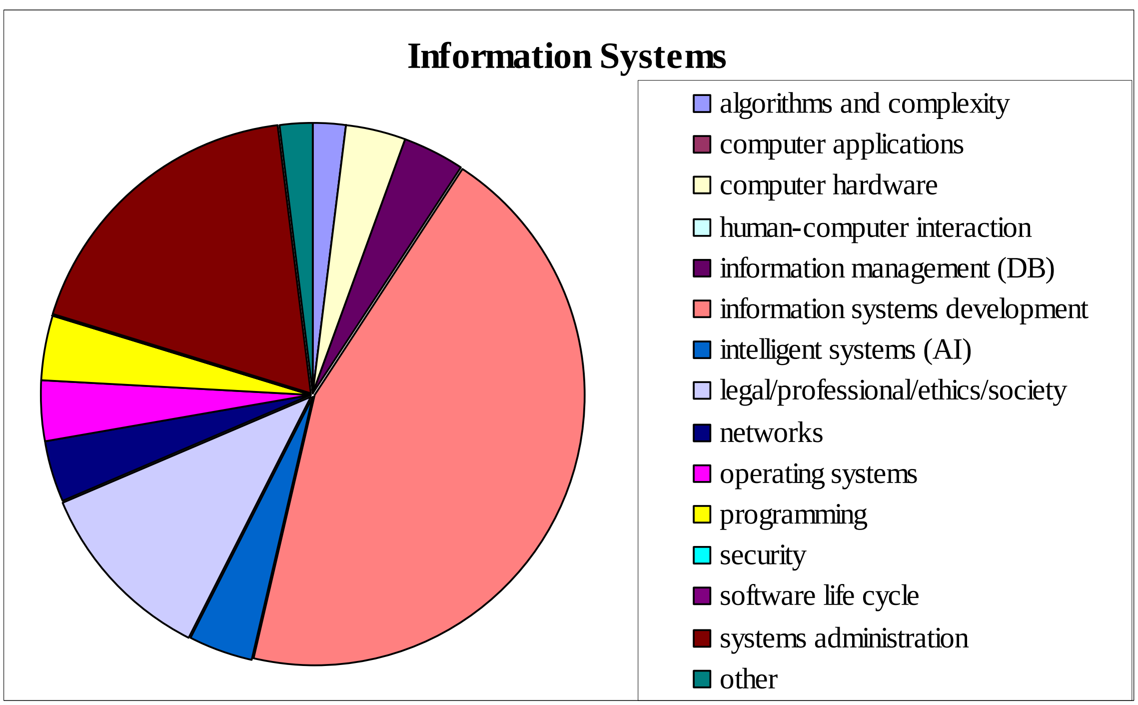


Figure 4: Knowledge areas for Information Technology

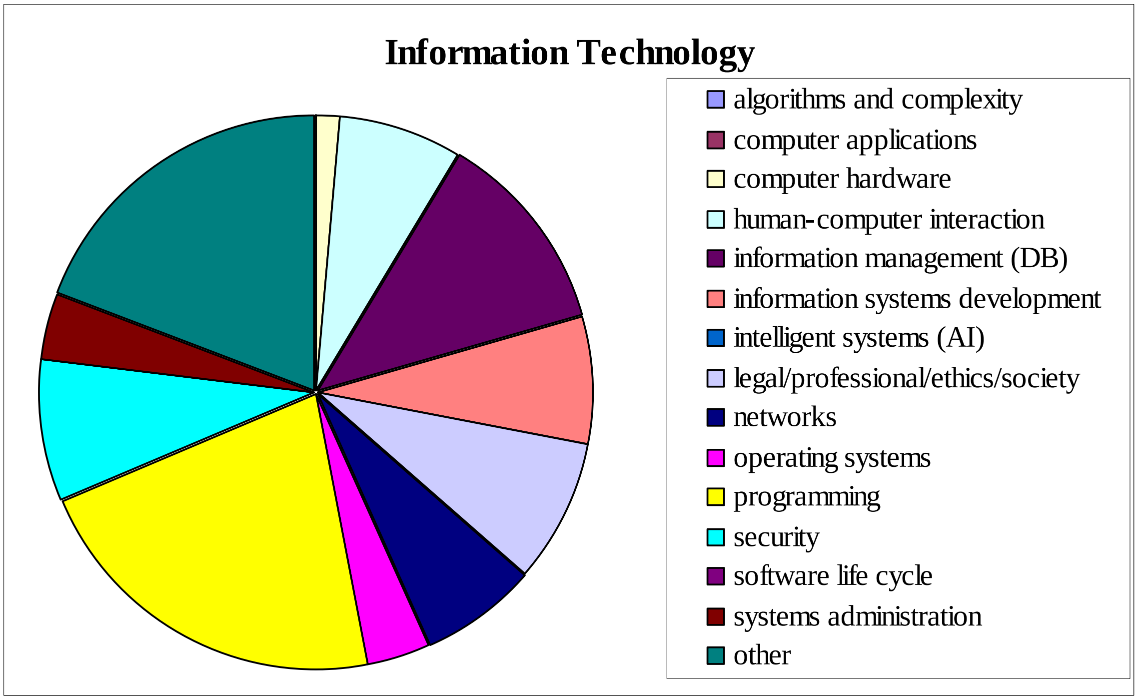
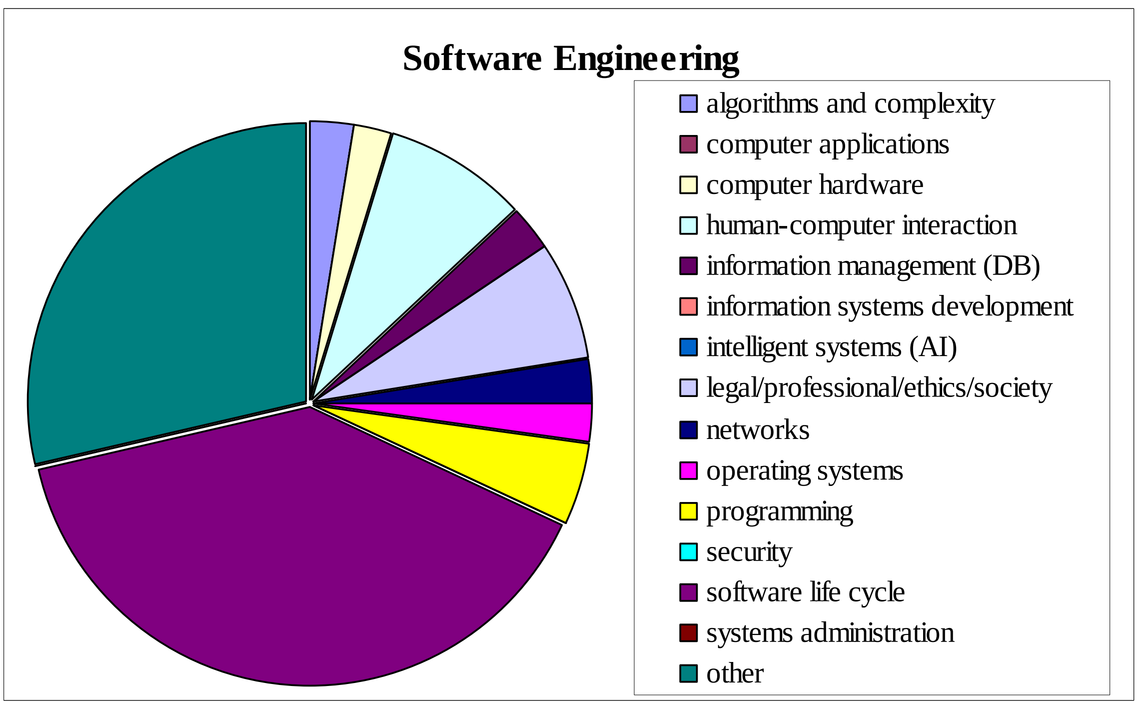


Figure 5: Knowledge areas for Software Engineering



Knowledge Areas: Commonalities

It is not a surprise that there are substantial differences among these five computing disciplines. Nevertheless, it would be very surprising if there were not some commonalities, since they all claim to be a computing discipline. Analysis of the formal curricula shows that all five programs cover:

- Computer foundational topics
- Computer programming (including algorithms, implementation, and software quality)
- Capabilities and limitations of computers (including societal impact)
- Software lifecycle issues
- Processes, both computing and professional
- Advanced computing topics
- Professionalism (including interpersonal communications, teamwork, management, ethics, and legal constraints)
- Applications to join theory and skills (including labs, assignments, projects, etc.)
- Capstone projects

Conclusion

Since the emergence of the computer in the 1950s, computing devices have exponentially dropped in cost, size, and power consumption, while exponentially growing in speed, storage, and capability. These dramatic changes have made computing elements the most versatile and widely adopted electronic devices ever created. In turn, this versatility and wide adoption for diverse application domains have created the need for more subdisciplines within computing. Over the last 15 years this need has driven the creation of the computing disciplines of computer engineering, software engineering, and information technology. Each of these relatively new computing disciplines has completed accreditation standards, has had some programs already accredited, and has formally defined a model curriculum. These three new computing disciplines now take their place alongside the older and more familiar computing disciplines of computer science and information systems. This study of their accreditation and model curricula has described the character of each discipline in terms of their differences and similarities.

It is expected that there will yet be other computing disciplines in the years and decades to come. When that happens, we shall look forward to learning their place in the expanding field of computing.

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