2006-1079: COMPUTING CURRICULA: THE HISTORY AND CURRENT STATUS OF 4-YEAR COMPUTING PROGRAMS

Michael Bailey, Brigham Young University

Barry Lunt, Brigham Young University

Gordon Romney, Brigham Young University

Computing Curricula: The History and Current Status of 4-Year Computing Programs

Abstract

The invention and creation of the digital computer in the mid-20th century gave rise to a host of new industries and dramatic changes in some of the programs offered at 4-year academic institutions. The first of these was the discipline of computer science, followed by the disciplines of information systems, computer-based library science, computer engineering, software engineering, and information technology. Additionally, there are newly-emerging programs in disciplines that are heavily computer-dependent, such as animation, industrial design, bioinformatics, and others.

The purpose of this paper is to present the history and current status of the five core computing academic disciplines as described in the Computing Curriculum document: computer science, information systems, computer engineering, software engineering, and information technology. The information summarized includes the number of programs in existence, the development of a standardized curriculum for each, and the development and implementation of accreditation standards for each.

Introduction

The closing of the Second World War brought great change to society in the developed world. In addition to the upheavals resulting from retooling industries from militarily dominated economics to more peaceful pursuits, from the unemployment problems resulting from disbanded armies, and from reconstruction of destroyed industries, other revolutions were forming in the intellectual landscape of society. Much has been written about the competing economic and political competitions that arose among the survivors, but less notice is given to the technological capital that was produced during the war and its transfer to the peacetime economy. Notable technologies that were largely developed during this dark time include nuclear energy, radar, spread-spectrum communications, and of course, the computer.

Over time, these technologies flowed from the defense research labs to industrial and academic institutions. Inevitably, as the research progressed in these technologies, a body of knowledge was built up which began to be transferred to bright students. At the time of this writing, academic courses are being taught in Universities all around the world in each of these subjects, and in the case of computers, several distinct degree programs have formed around the technology.

There is little doubt that computer technologies have had great impact on society. It is difficult to find a workplace without a computer, from the corporate offices teaming with computer-laden cubicles to the plumbing contractor who keeps her books in a home office. In the home, computers have penetrated all but the poorest neighborhoods of America. From an even broader perspective, it can be observed that computers are involved in most aspects of our lives, from the dozen or two that control our cars' systems to the processors in our cell phones and electronic planners. How did our modern computer society evolve from the post-war behemoths of 60 years ago? One aspect of this technological revolution can be observed from the perspective of colleges and universities, and the topics that they have been providing for student study. From small beginnings, computational topics have come to be a significant part of most institutions' courses of study. Even in courses and programs not thought of as technological, computerized databases aid research, computer projectors aid presentations, and spreadsheets aid calculations. It may be said that computers permeate post-secondary academia.

Of greater concern to this research are the academic disciplines that have arisen more directly from the computational revolution, namely: Computer Science, Information Systems, Computer Engineering, Software Engineering, and Information Technology. Other disciplines exist which also have significant computational aspects, such as Library Sciences, Bioinformatics, and Computer Animation. These other disciplines will not be examined in this paper, not because they are not worthy, but because they are not included in the Computing Curricula 2005 report developed by the Joint Task Force for Computing Curricula 2005 of the ACM, AIS, and the IEEE-CS[1]. This is the document that is being used by ABET in conjunction with computer-oriented program accreditation.

In studying the history of academic computing programs, it is interesting to see that these disciplines did not appear ready-formed, but that they usually emerged first within existing departments as new sub-topics, and eventually found it necessary to separate from their parent organizations. This paper will examine the motivations for forming the new disciplines.

As the programs went through the formative stages, certain milestones were passed. This paper examines the following milestones for the computational disciplines: the point at which courses that would later become associated with a discipline began to be taught, the point at which degree programs began to be offered, the point at which separate academic departments began to be formed, and when programs began to seek accreditation. From this study, it is hoped that a sense of the academic computing revolution may be found. Using this perspective, academics can obtain a perspective on our time and place in technology, and anticipate future trends.

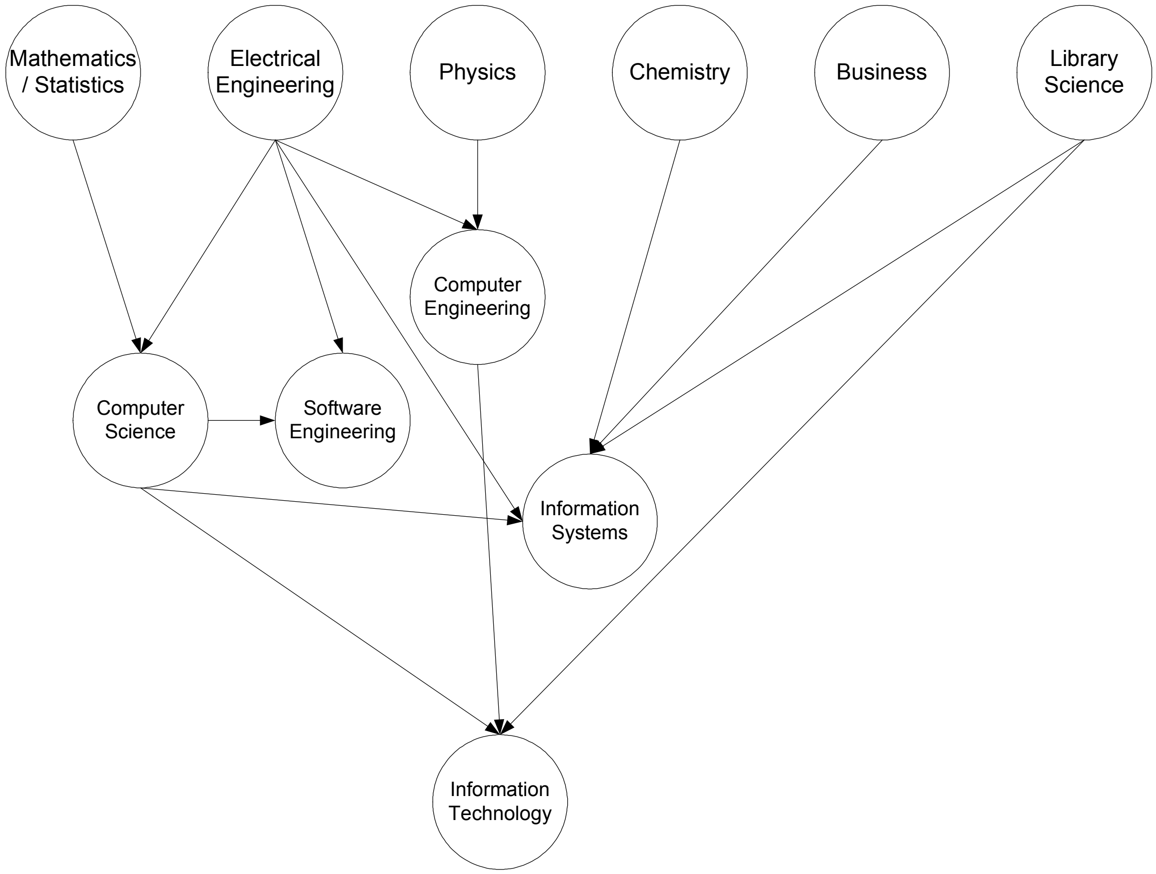

Figure 1. Overall trends in the antecedents of the programs, as gleaned from various historical sources.

Chronology

In the beginning was Mathematics; and it was good. Electrical Engineering was also an established, although much less widespread, discipline at the dawn of the computer age. These two can be considered as either the parents or the grandparents of most academic computer programs today. The primary exceptions to this rule are Information Systems programs, many of which arose in business schools. The first distinguishable offspring to arise from its Mathematics and Electrical Engineering parents was Computer Science, followed in order by Information Systems, Computer Engineering, Software Engineering, and Information Technology. Not all of these programs exist at all institutions, nor were they necessarily formed in this order everywhere, rather, this is the order in which they appeared in the literature and in the public perception as a whole. The genesis of each category of program will be considered individually.

In undertaking a history such as this, it is inevitable that there will be some disagreement over some of the terms and definitions used. This is due primarily to a lack of unity among practitioners and even of entire departments at various universities as to the precise definition of their discipline. The Computing Curricula 2005 Overall Report, as well as those that have preceded it, have helped to alleviate this problem, but differences remain. For example concerning Information Systems, William Aspray stated: “Indeed, information scientists have a long tradition, continuing to the present, of lively debate concerning the nature of their discipline."[2] The same could be said about each of the other disciplines discussed here. The approach used herein is to use the definitions as stated in the literature of the epochs examined.

Computer Science

Computers first began appearing in US universities in the 1930's and early 40's at MIT (differential analyzer), Harvard (Mark 1) and Penn (ENIAC and EDVAC). At first these were mechanical, followed by electro-mechanical, analog, and finally by digital as the computational research of the second world war filtered back into the university laboratories.[3] It is interesting to note that academic departments devoted to the studies of computers did not form in this era, even among the early adopters of the technology. Rather, computer laboratories were formed, usually within electrical engineering departments. Computer access was reserved for graduate students and faculty. Interesting enough, several of the early computer adopters were not among the first to form academic computer science departments. For example, Harvard's early research into mechanical devices may have delayed its adoption of the more capable digital electronic devices when they later became available. In addition, several of the first universities with computers were from the Ivy League, and such institutions are often reluctant to support applied science rather than liberal arts, as was illustrated by Harvard president Nathan Pusey's statement concerning funding for a computer laboratory: "Harvard did not get to be where it is by spending old money on new things."[3]

It is possible that the Second World War delayed the academic progress of computing by diverting academics such as Vannevar Bush and John von Neumann into national service; however the government resources that continued to be poured into computing following the war followed these scholars and others back to university laboratories upon their return. The result was thriving university research at facilities that were well connected.

The first academic computer activity consisted of course offerings to graduate students following the war. At MIT, Caldwell began teaching a course in digital computers in the electrical engineering department in 1947. Penn began teaching a course in digital computing in 1949. Columbia claims to have "the first such courses in the world fully integrated into a university curriculum and continuing year after year"[4] beginning in 1947. This emphasis on graduate courses preceding any undergraduate offerings was not confined to just the early computer programs. For example, Purdue had no appreciable computer content until 1962, when a computer science department was begun from scratch, but it was not until 1968 when its first undergraduate computer-oriented degree program began.[5]

There are exceptions to the rule that graduate curriculum preceded the undergraduate. For example, at Utah State, the opposite ordering occurred with an undergraduate computer science degree being offered in 1964, followed by a master's degree program in 1980 and PhD in 2002.[6] In like manner, one author's colleague, Joseph J. Ekstrom, was Brigham Young University's first awarded doctorate in Computer Science in 1992, having previously earned his undergraduate CS degree there.

In a process that was frequently difficult, these programs usually arose from pre-existing academic programs: often mathematics, electrical engineering, or both. In many cases territorial battles ensued as the popularity of the CS curriculum with students became evident. In addition, the large resource demands of computing laboratories caused contention with other faculty. These contentions, along with large student populations, pushed CS departments to become independent of their erstwhile hosts. Purdue's computer curriculum began in the mathematics department of the college of sciences, education and humanities. Jealousies and academic politics soon required that the mathematics department move to the School of Engineering. The computer science department was later formed as a component of the newly formed Division of Mathematical Sciences. The separation pains were even more pronounced at Harvard where computer studies were relegated to the lowly-esteemed applied sciences division. Here, where university support was wanting, competition for resources was fierce. As a result the CS faculty members, who were in the minority in the division, were consistently outvoted by their peers on issues of budgets and manpower. Additionally, attempts to separate from the applied sciences faculty were blocked. It was not until the 1970's that the faculty load imbalance between CS and the rest of the division began to be rectified.[3]

As computer science programs began to be widespread and recognizable as members of a distinct discipline, efforts to define a computer science body of knowledge and core curriculum began. Beginning in 1964, a committee under the auspices of the ACM began meeting, culminating in the renowned "Curriculum 68" document.[7] This standardization of curriculum did not immediately lead to the next logical step – accreditation. It was not until 1984 that the Computing Sciences Accreditation Board (CSAB) was formed by the ACM and the IEEE-CS.[8] The following year 31 pilot accreditation visits were performed. By 2004, the most recent year for which statistics have been released, there were 204 CS programs in the US accredited by the Computing Accreditation Commission (CAC) of ABET, which administers CS accreditation for CSAB.[9] Of course, not all programs are accredited, but these numbers are indicative of a strong, thriving discipline.

Information Systems

Like computer science, information systems was one of the early computer disciplines to emerge. The core guiding interests of IS as it emerged as a discipline were information storage, retrieval, and analysis, rather than on the CS interest in advancing computation technology. "The field is the product of the convergences of various disparate disciplines and activities: library science, computer science (and its antecedent punched-card technology), documentation of research and development, abstracting, indexing, communications science, behavioral science, micro- and macro-publishing, and video and optical science, among others."[10] In the years since this has been written, this perspective of the inclusiveness of IS has perhaps become even broader.

The origins of these programs reflect the discipline's breadth. For example, a 1972 paper from Ohio State speaks of the Computer and Information Science department existent at that time there. The description of topics of the department's studies matches what one would expect of such a hybrid: psychology, business, accounting, digital logic, systems programming, linguistics, and indexing, grouping and searching of information.[11] Like other early CS programs, this hybrid was formed out of the mathematics and electrical engineering departments, with graduate offerings preceding undergraduate ones. A glance at the current Ohio State catalog shows that CS has remained in the engineering college, while IS has migrated to business.[12]

At the University of Pittsburgh, IS emerged from library science in 1968 as a part of the newly formed Graduate School of Library and Information Science, and then became independent in 1973.[2] Once again, the original program was graduate in nature.

More surprisingly, information science also had its genesis in sciences such as chemistry. As one of the founders of the program at Western Reserve University, Allen Kent, stated: "In the early days, many people in information science were chemists, because for a long time they'd had a system for indexing and abstracting their literature. This information was very amenable to computer processing. Thus there was already a model in place for handling chemists' literature, which led to the organizing of literature in other fields along the same lines." [13]

Even though information systems began emerging as a discipline in the 60's and early 70's, there was no effort to standardize the curricula between programs until CSAB was formed in 1985. By 1987 draft accreditation criteria were being circulated by an ACM panel, but there was little interest, and accreditation was put on hold.[14] The diversity of the many IS programs may have led to this postponement, but it is more likely that it is due to the fact that many IS programs were in AACSB accredited business schools, and felt no need for an IS program accreditation. By the turn of the millennium, about 50% of IS programs were located outside of Business schools, so interest in IS program accreditation was renewed. In the Fall of 2001 CAC of ABET conducted the first IS program accreditation visits.[15] By the year 2004, 11 information systems programs were ABET accredited[9], which is still a small proportion of the 251 member institutions listed by ISWorld Net.[16]

Computer Engineering

In the earliest days of computing, what would later divide into computer science and computer engineering were generally combined, usually within electrical engineering. With time, the software-oriented body of knowledge of computer science was recognized as distinct and CS departments were spun-off or formed. Since the hardware-oriented aspects of computing were less distinct from electrical engineering, computer engineering has been far slower to separate from its parent. In fact, at most institutions today, computer engineering remains within a renamed electrical and computer engineering department, sometimes as an emphasis, more often as a degree program.

Computer engineering may, at least in spirit, be the oldest of the computing disciplines, in that much of the early history detailed in the computer science section of this report is actually more hardware than software oriented. For example, at about the same time that the ACM was producing "Curriculum '68", the COSINE committee of the Commission on Engineering Education was producing a report with recommendations under the following headings[17]:

1. "Some specifications for a computer-oriented first course in electrical engineering,"
2. "Some specifications for an undergraduate course in digital subsystems,"
3. "An undergraduate electrical engineering course on computer organization,"
4. "Impact of computers on electrical engineering education-a view from industry,"
5. "An undergraduate computer engineering option for electrical engineering,"
6. "Digital systems laboratories,"
7. "Computer-aided circuit design,"
8. "Computers in electrophysics."

Thus, from the earliest days of computers in academia, there was a strong impetuous to create computer engineering specializations within electrical engineering. By 1971, 87 of 203 electrical engineering departments responding to a survey indicated that they had an undergraduate computer engineering option or program.[18]

One of the earliest to formalize computer engineering was the University of Illinois at Urbana-Champaign. Beginning in 1969, an option in the electrical engineering department called EE&CS became available. Over time, the department changed its name from the Department of Electrical Engineering to Electrical and Computer Engineering, and the computer program was renamed to Computer Engineering.[19] This is quite typical of the progression in many universities over the next three decades. Accreditation first fell under the electrical engineering umbrella, but by 1990 a separate computer engineering accreditation was becoming an option for US institutions. In the decade from 1994-2004, the number of accredited computer engineering programs nearly doubled to 227 programs, with the trend continuing upward.

Software Engineering

While the origins of the software engineering discipline can be traced back to its first international conference in 1968, it still is less well-defined than the other disciplines discussed here. In fact, even within the past decade there have been seminars with presentations with titles such as "Software Engineering-why it did not work," and "Software Engineering-An Unconsummated Marriage."[20]

The motivation for the software engineering movement can be seen in this statement on the state of the software development art taken from the first NATO conference on software engineering[21]: "We build systems like the Wright brothers built airplanes-build the whole thing, push it off the cliff, let it crash, and start over again." Or consider this statement from M.D. McIlroy: "We undoubtedly produce software by backward techniques. We undoubtedly get the short end of the stick in confrontations with hardware people because they are the industrialists and we are the crofters. Software production today appears in the scale of industrialization somewhere below the more backward construction industries. I think its proper place is considerably higher, and would like to investigate the prospects for mass-production techniques in software."

Putting aside the hand-wringing, there has been recent significant progress in establishing a discipline in software engineering. There is now hope that with new software engineering tools such as the Rational Unified Process (RUP) and the Unified Modeling Language (UML) that engineering principles may yet be applied to software engineering.

The accreditation activities for software engineering have been equally slow to congeal. A model curriculum for it is now included in CC 2005, and the first accreditation visits were performed in 2003. At this time ABET has accredited 10 software engineering programs, scattered about the country.

Information Technology

Information Technology is undoubtedly the newest of the ABET-recognized computer disciplines. The explosion of the Internet and the world-wide web, beginning in about 1992 with the advent of web browsers such as Mosaic and Navigator, created a rapidly growing community of online computer users who wanted to communicate with each other easily and who wanted to access information of all sorts from their own computer. This dramatic growth in personal and corporate use of the Internet, along with web systems, databases, and networking, gave rise to information technology (IT) programs which specifically taught these topics.

As with the other computing disciplines, IT programs arose from various backgrounds at their institutions. Some, such as that at BYU, emerged from electronics programs. Others, such as the one at Georgia Southern, emerged from a technically-oriented IS background. The most common parent of all was CS. Since IT is particularly new, each program retains some flavor of its origins, while adhering to the core pillars of the IT curriculum: networks, web systems, programming, databases, and human-computer interaction.

In late 2001, many of these IT programs met together and formed a Society for Information Technology Education (SITE), which in 2003 became SIGITE, a special-interest group of the ACM (Association for Computing Machinery). Work formally began on defining accreditation criteria at that time. In 2004, three IT programs were accredited by the CAC of ABET under the new general computing criteria; in 2005, another IT program was accredited by the CAC of ABET under the new IT-specific criteria. Many other IT programs are presently preparing for accreditation.

SIGITE also began work on defining a model curriculum, after the model of the CC 2001 Computer Science volume. The IT volume of the 4-year curriculum is in its final review stage, and is available at http://www.acm.org/education/curricula.html#IT2005. SIGITE also participated in the creation of the Computing Curricula 2005: The Overview Report[1], making IT the fifth computing discipline to have a formally defined curriculum and to be included in The Overview Report.

Presently there are over 50 four-year IT programs in the United States, as taken from the rolls of the SIGITE membership. Most of these programs are experiencing vigorous enrollment and excellent placement. The authors are also aware of other countries, such as China, that are looking at implementing the IT curriculum.

Conclusions

As shown in this paper, across computer education history there are a few trends that stand out. First, computing principles are being taught ever earlier to students. Uniformly among the early adopters, computing curricula was for graduate students. Later, it became available to undergraduates, and some programming is now being taught in High Schools.

We can also observe that historically new computing disciplines arise to meet new computing demands. Often, existing programs have resisted this, claiming that they could do everything, and do it well, but increasing specialization has followed increasing capability and complexity. As in the history of academic computing related in this paper, the demands of the future will determine future specializations and future academic disciplines.

Bibliography

1. The Joint Task Force for Computing Curricula 2005, Computing Curricula 2005, ACM, IEEE-CS, 30 September 2005, http://www.acm.org/education/curric_vols/CC2005_Final_Report2.pdf

2. Aspray, William, Command and Control, Documentation, and Library Science: The origins of Information Science and the University of Pittsburgh, IEEE Annals of the History of Computing, Vol. 21, No. 4, 1999, pp. 4-20

3. Aspray, William, Was Early Entry a Competitive Advantage?: US Universities that Entered Computing in the 1940's, IEEE Annals of the History of Computing, Vol. 21, No. 4, 1999, Vol. 22, No. 3, 2000, pp. 42-87

4. Columbia University Computing History http://www.columbia.edu/acis/history/

5. Rice, John R., Rosen, Saul, Computer Sciences at Purdue University-1962 to 2000, IEEE Annals of the History of Computing, Vol. 26, No. 2, 2004, pp 48-61

6. History, http://www.cs.usu.edu/history.html

7. Report of the ACM Curriculum Committee on Computer Science, Curriculum 68, Recommendation for Academic Programs in Computer Science, Communications of the ACM, vol. 11, No. 3, March 1968, pp. 151-197

8. Booth, Taylor, and Miller, Raymond E., Computer Science Program Accreditation: The First Year Activities of the Computing Sciences Accreditation Board, Communications of the ACM, vol. 30, no. 5, May 1987, pp. 376-388

9. Accreditation Statistics, http://www.abet.org/statistics.shtml

10. Herner, Saul, Brief History of Information Science, Journal of the American Society for Information Science, vol. 35 no. 3, 1984, pp. 157-163

11. Mathis, Robert F., Kerr, Douglas S., Development of a Multifaceted Undergraduate Program in Computer and Information Science, ACM SIGCSE Bulletin, vol. 4, no. 1, 1972, pp. 8-12

12. Colleges and Schools, http://www.osu.edu/academics/a-z.php

13. Conklin, C., Birth of a New Age, Pitt magazine, March 1992, p. 34

14. Gorgone, John T., Information Systems Accreditation: Revisited, ACM SIGCSE Bulletin, vol. 31 no. 2, June 1999, pp. 17-18

15. Lidtke, Doris K., Feinstein, David, Gorgone, John, Yaverbaum, Gayle, Preparing for Information Systems Accreditation, Proceedings of SIGCSE'02, Feb. 2002, Covington Kentucky, USA, pp. 169-170

16. Information Systems Departments and ISWorld Net Members in North America, http://juliet.stfx.ca/~rmackinn/infosys/na.htm#usa

17. COSINE committee, Commission on Engineering Education, Computer Science in Electrical Engineering, IEEE Spectrum, March 1968, pp. 96-103

18. Coates, Clarence L. Jr., Arden, Bruce, Bartee, Thomas C., Bell, C. Gordon, Kuo, Franklin F., McCluskey, Edward J. Jr., Surber, William H. Jr., An Undergraduate Computer Engineering Option for Electrical Engineering, Proceedings of the IEEE, vol. 59, no. 6, June 1971, pp.854-860

19. Loui, Michael C., Computer Engineering at the University of Illinois at Urbana-Champaign, IEEE Transactions on Education, vol. 37, no. 3, August 1994 pp. 322-327

20. Position Papers for Dagstuhl Seminar 9635 on History of Software Engineering, August 1996, http://www.dagstuhl.de/9635/Report/

21. Mahoney, Michael S., Finding a History for Software Engineering, IEEE Annals of the History of Computing, vol. 26, no. 1, 2004, pp. 8-19