Artificial Intelligence and IT Professionals

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As "self-programming techniques" manifest in the form of artificial intelligence (AI), many are wondering how AI will affect IT professionals. For example, some predict that AI could reduce the number of jobs for software developers by 70 percent in India, which accounts for 65 percent of global IT offshore work and 40 percent of IT-enabled business process work.[1]

However, such dire predictions are not new. It is helpful to recall a similar prediction almost 60 years ago when Herbert Simon, a Nobel Prize winner sometimes called 'the founding father of AI,' predicted that 'self-programming techniques' would lead to the extinction of the computer programming occupation by 1985. Simon noted:[2]

> *"...we can dismiss the notion that computer programers [sic] will become a powerful elite in the automated corporation. It is far more likely that the programing occupation will become extinct (through the further development of self-programing techniques) than that it will become all powerful. More and more, computers will program themselves…."*

While massive industrial and technical developments—including personal computers in the 1980s; the World Wide Web in the 1990s; outsourcing and offshoring in the 2000s; and social media, mobile computing, and cloud computing in the 2010s—created some peaks and valleys, the computer programming occupation has continued its inexorable growth, belying the initial pessimism.

Rather than attempt a blunt prediction of future decades, we approach the question of how AI will affect IT professionals by first identifying the factors that influence the demand for software programmers, then discussing how these factors relate to AI, and finally articulating the likely impact of AI on IT professionals.

FACTORS THAT INFLUENCE THE DEMAND FOR PROGRAMMERS AND IT PROFESSIONALS

We begin by delving into what software programmers do and how those activities are affected by technical developments. To 'program' is to develop a series of instructions or operations to be performed by a mechanism such as a computer. The personal computer revolution of the 1980s and the advent of the World Wide Web in the 1990s greatly increased the information intensity of industrial activity by allowing numerous occupational tasks to be codified and standardized.[3] The ability to access world-class intra-firm efficiencies through the personal computer and inter-

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firm efficiencies through the World Wide Web drove demand for software such as enterprise resource planning (ERP) software. In turn, this demand for software accelerated the number of computer science degrees during the mid-1980s and late 1990s, as shown in Figure 1. In this way, the codification and standardization enabled by IT created significant new demand for IT and the software programming profession during the 1980s and 1990s.

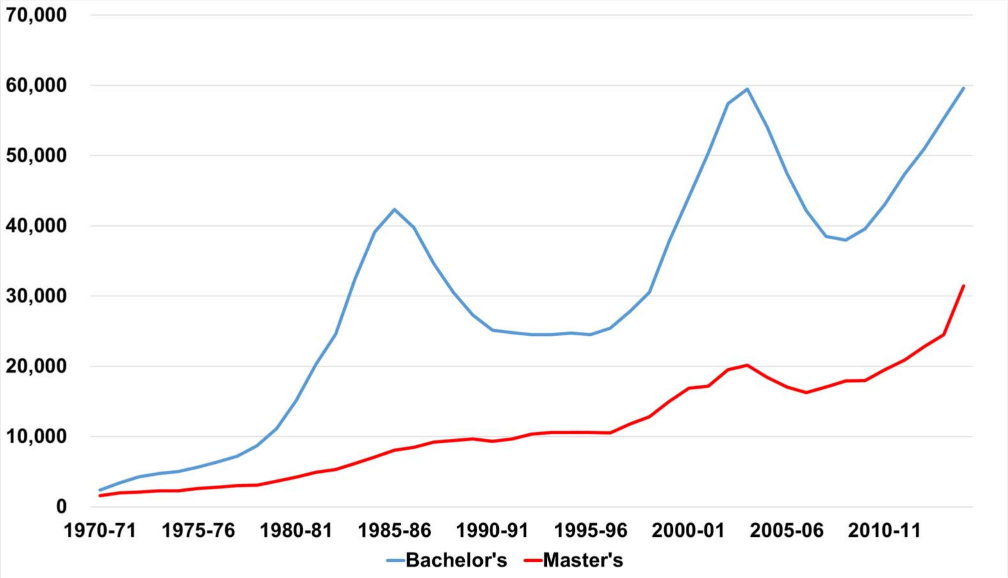

Figure 1. Degrees in computer and information sciences conferred by US postsecondary institutions. (Source: Digest of Education Statistics, 2016, US National Center for Education Statistics, https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2017094)

While the increase of outsourcing and the advent of offshoring during the 2000s might not have changed the overall demand for software programming, it certainly shifted and reallocated that demand across firms and geographies. Outsourcing and offshoring of software development and other occupations during the past two decades was enabled by higher levels of modularization. Modularization is the decomposition of a product or service into components, such that the components can be performed independently by separate people in different firms or geographies, and later be reintegrated. We find evidence of the impact of modularization on software programmers in developed economies by noting the relatively flat level of employment for software programmers in the US (see Figure 2) and of information and communication technology (ICT) specialists in the European Union during the 2000s. Meanwhile, India's National Association of Software and Service Companies (NASSCOM) reports that the number of IT and business process outsourcing (BPO) professionals in India increased almost ten-fold from 430,000 in 2001 to 3,860,000 in 2017.

To place these figures in context, the research firm IDC estimates that the number of global software development professionals was 11,000,000 in 2014. Combining this IDC estimate with the US Census Bureau data in Figure 2 and the NASSCOM data above suggests that about 15 percent of software development professionals are in the US, and about 30 percent of software development professionals are in India.

Figure 1 shows that the number of bachelor's degrees in computer and information science declined by 26 percent from 2004-2005 to 2009-2010, but then increased sharply from 2009-2010 to reach an all-time high in 2014-2015. The sharp decline in computer and information science degrees might have been due to concerns about offshoring because we do not see a decline in two related fields (business and engineering/engineering technologies) from 2004-2005 to 2009-2010, where the number of bachelor's degrees in business increased by 15 percent, and the number of bachelor's degrees in engineering and engineering technologies increased by 12 percent.

Note that the number of computer and information science bachelor's degrees surged by 50 percent from 2009-2010 to 2014-2015 as concerns about offshoring subsided, an increase far greater than the 2 percent increase in business degrees and 30 percent increase in engineering/engineering technologies degrees during the same timeframe.

It is important to note that the impacts of offshoring vary for different types of IT occupations. For example, in our related research we found that information-intensive and high-skill occupations experienced higher employment growth, despite a slight decline in salary growth in the US from 2000-2004, suggesting that many information-intensive service occupations have a tacit component that make them more difficult to relocate offshore. In one of our research papers, we note that total employment for computer and information systems managers (a more tacit and less codifiable occupation) increased 20 percent from 283,480 in 2000 to 341,250 in 2015, while wages increased 76 percent from $80,250 to $141,000 during the same timeframe. In contrast, employment for computer programmers (a more codifiable occupation) declined 45 percent from 2000 to 2015, and wages for computer programmers increased 38 percent from 2000 to 2015, only half the rate of increase for manager positions. More recently, firms are using crowdsourcing or micro-sourcing through platforms such as Amazon Mechanical Turk or upwork.com to outsource or offshore some activities. However, the extent to which these platforms will negatively impact the work of software programmers that involves complex workflows remains debatable.[4]

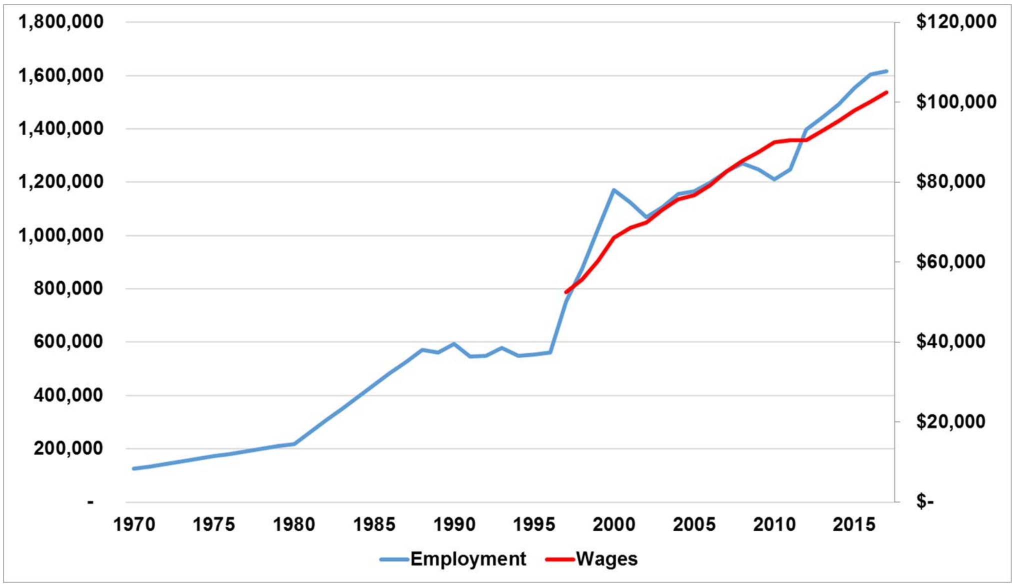

Figure 2. Computer programmer employment and wages in the US. (Sources: 1970 data from US Census Bureau supplementary report number PC(S1)-32, https://www.census.gov/library/publications/1973/dec/population-pc-s1-32.html; 1980 data from US Census Bureau supplementary report number PC80(S1)-8, https://www.census.gov/content/dam/Census/library/publications/1983/demo/pc80-s1-8.pdf; 1987-1996 data from US General Accounting Office report GAO/HEHS-98-159R, https://www.gao.gov/products/HEHS-98-159R; 1997-2017 data from US Bureau of Labor Statistics Occupational Employment Statistics, https://www.bls.gov/oes/tables.htm)

In addition to the offshoring of information-intensive activities, another factor that facilitated the disaggregation of business processes is the global movement of labor. The cross-border movement of IT professionals continues to attract significant debate on immigration, visa issues, and employment and wages of IT professionals in developed economies.[5] Even firms that offshored and outsourced realized the limits of outsourcing, and progressive firms kept at least some critical IT capabilities and programmers onshore and in-house for strategic reasons.

The above findings in the context of technological and organizational developments during the 1980s, 1990s, and 2000s can inform the discussion of 'extinction' or 'substitution' for the software programming occupation, because activities that can be codified, standardized, and modularized are also more likely to be automated through AI.

While the modularization of software development has reduced the complexity of individual activities, complexity is increased by the need to coordinate work across software teams and integrate individual modules to create a product that is Apple-simple, Google-fast, and SAP-reliable at the same time.[6] The complexity of software programming jobs has also increased due to changes in system development methodologies and the rise of agile methods that call for closer collaboration among software developers and customers integrating design thinking and related approaches.[7]

For example, given the difficulty to elicit precise requirements from clients upfront, agile software development insists on constant customer feedback and collaboration, which might be difficult to achieve in a disaggregated work mode.[8] Because of the need for innovation and closer collaboration between software developers and users, firms are realizing the value of investing in their internal technical capabilities and digital transformation by bringing more software development in-house, sometimes moving toward a hybrid model that includes both on-premise and cloud computing.[9]

There is a need to take a more thoughtful perspective on how AI is likely to influence the software development profession.

The foregoing discussion suggests that Simon's 1960 prediction about computer programmers becoming extinct needs to be seen in the context of major industrial and technical developments. Simon made his prediction before the advent of the personal computer and the World Wide Web, changes in software development methodologies and the role of IT departments in firms, and many other wider trends in technology, business, and society.[10] As part of these developments, the demand for computer programmers has increased (see Figure 2) and the IT profession, which consisted mostly of code development in the 1960s, has now diversified into many different job descriptions and responsibilities.[11] For example, in addition to computer programmers, software developers, and web developers, current US Bureau of Labor Statistics computer occupations include information security analysts, network and computer systems administrators, computer network architects, computer user support specialists, and computer network support specialists.

SOFTWARE DEVELOPMENT IN THE AGE OF ARTIFICIAL INTELLIGENCE

While Simon wrote that "more and more, computers will program themselves" during a time of great anticipation for AI, this anticipation did not come to fruition at that time. Now that we are again at a time of enthusiasm based on recent advances in AI and machine learning, there is a need to take a more thoughtful perspective on how the factors discussed above fit into AI, and on how AI is likely to influence the software development profession.

We consider two different roles of AI for software development: (1) AI as a tool to program software, and (2) AI as the software itself—sometimes referred to as Software 2.0.[12] Making some cautious but informed predictions, it is likely that both of these roles will be relevant for software development in the future, and that there will be a place for human software developers in both of these AI roles.

The first role of AI as a tool to program software means that AI directly writes program code or indirectly helps human programmers to write program code—in the sense of instructions for computers. Consequently, the tasks of human software developers will follow the general trajectory of automation and outsourcing, where high-level tasks carried out by human programmers will move to even higher levels of value creation, while lower-level programming tasks will increasingly be performed by AI.[13] This is in line with earlier conjectures that emerging technologies can destroy some jobs, and in this case, it will replace jobs that involve lower-level programming. Thus, AI will substitute for humans by simplifying the entire job (robots replacing workers) or substituting some activities within a job that are amenable to rule-based logic (similar to automated teller machines taking over some functions of a human teller). These trends have been underway for some time and are already visible across industries.

However, technologies also create new jobs (for example, data scientists), change the mix of jobs in the economy, and alter the nature of activities within jobs.[14] For example, AI might complement humans in jobs that require pattern recognition or case-based reasoning. In the case of software development, recent discussions on the role of AI suggest that AI assistance might help human programmers avoid errors and strategic mistakes when coding.[15] For example, AI could act as a pair programming partner, reducing the resource needs for the established agile practice of pair programming. Agile practices could also be useful in test-driven development, where humans could focus on writing test cases and AI would create code that satisfies the test.[15] In this way, software development would be conducted through human–machine interaction.[16] Going beyond software development, other occupations that are menial and/or prone to error, and therefore good candidates for AI-enabled displacement, include cashiers, laboratory technicians, accountants, auditors, and tax preparers.

The second role of AI as the software itself suggests that we would not use traditional programming code—in the sense of instructions as to what the computer should do—but would replace program code with AI (Software 2.0).[12] However, we believe that traditional program code will continue to be relevant. For example, Brynjolfsson and Mitchell[17] suggest that AI/Software 2.0 is particularly useful for stable tasks. Thus, traditional programming might still be needed in more dynamic environments such as the case of frequently changing customer requests or the context of more exploratory research projects.

It seems feasible that some code will be replaced by AI and that new problems will be addressed through AI instead of traditional code. For example, traditional instructions could be replaced by the weights in a neural network. We see this already in the context of translation services, speech recognition, and video gaming.[12] But even in such a context, we would likely still need software developers. The work of software developers might shift away from traditional coding and toward designing and developing the architecture that brings together AI modules to solve a problem, to development tasks related to data governance, and/or to activities requiring judgment rather than activities requiring rule-based decisions. Furthermore, the omnipresence of AI in ubiquitous or experiential computing[18] will create a continuing need for software developers. Relatedly, recent efforts to create explainable AI (XAI) or to address ethical questions related to AI, such as bias and discrimination, will likely continue to require software programmers.[19]

To further explore the potential impacts of AI on various IT occupations, Table 1 shows US Bureau of Labor Statistics 2016-2017 data for the average wage and current number of positions, and 2016-2026 projections for the growth of each occupation. These seven IT occupations each include at least 100,000 employees, and reasonably represent the range of average wages among IT professionals.

The Bureau of Labor Statistics classifies the growth of each occupation into one of four categories: decline, average growth (5 to 9 percent), faster than average growth (10 to 14 percent), and much faster than average growth (15 percent and up). The projected growth for each IT occupation provides some clues for how AI could affect various IT occupations, considering these Bureau of Labor Statistics projections at face value.

The projection that software developer (applications) and web developer occupations are expected to grow much faster than average from 2016-2026 suggests that AI is expected to complement (not displace) traditional programming over the next decade. Similarly, the much faster than average growth projection for information security analysts suggests that AI could create demand for IT professionals who can address both cybersecurity and privacy considerations when bad actors use AI capabilities to design more sophisticated attacks.[20]

Table 1. 10-year projected growth for various IT occupations. Source: Digest of Education Statistics, 2016, US National Center for Education Statistics, available at https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2017094.

Position	2016-2017 wages	2016-2017 employment	2016-2026 projected employment growth
Software developers (applications)	$101,790	831,000	Much faster than average (15%+)
Web developers	$67,990	163,000	Much faster than average (15%+)
Information security analysts	$95,510	100,000	Much faster than average (15%+)
Computer user support specialists	$50,210	637,000	Faster than average (10-14%)
Database administrators	$87,020	120,000	Faster than average (10-14%)
Network and computer systems administrators	$81,100	391,000	Average (5-9%)
Computer network support specialists	$62,340	199,000	Average (5-9%)
Computer network architects	$104,650	163,000	Average (5-9%)

The projection that the computer user support specialist occupation is expected to grow faster than average also suggests a complementary role for AI over the next decade, as additional applications and functionality will draw additional users. Similarly, the need for effective management of additional data that results from additional applications and functionality is consistent with the projection that the database administrator occupation is expected to grow faster than average, reinforcing a complementary role for AI over the next decade. However, the projection that the occupations of network and computer systems administration, computer network support specialists, and computer network architects will grow at only an average rate suggests that AI is expected to automate computation-intensive tasks such as managing the flow of network traffic. It will be interesting to examine the extent to which these projections map to reality as capabilities of AI unfold over time and reveal the extent to which AI complements or substitutes activities in IT occupations.

CONCLUSION

AI will bring many changes to the IT profession. While it is difficult to predict precisely how these changes will unfold, just as it was difficult for Simon to predict six decades ago, there are reasons to believe that software development will change and that with appropriate investments in human capital, software programmers should be able to respond to the changes in technologies and customer needs.[21]

For computer science students, we do not expect any major short-term changes in curricula as students still need to learn the basics of computer programming. However, over time we expect that more entry-level computer programming concepts will trickle down into high school curricula and coding boot camps, and more advanced concepts such as AI and machine learning will extend beyond computer information and science degrees into other majors such as business and the natural sciences. On the whole, there are reasons to be optimistic about the future of software programmers and IT professionals because the seamless integration of "human and computer intelligence to solve interesting and important problems that impact the future of work, organizations, and broader society" will continue the high demand for their talents and creativity.[22]

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