On the Brink of Disconnection

By Candy Xu

On April 19, 1965, Gordon Moore presented an article that revolutionized the entire computer industry. He pointed out that due to the falling cost of circuit components, we would be able to squeeze more and more of them onto silicon chips over the next several decades. One effect of this increase in components is an increase in speed, a core characteristic that determines the functionality of a computer. Computing speed is highly related to the arrangement of components and communication between signals and code. These design mechanisms all belong to the field of computer architecture. Vital elements of computer architecture include the central processing unit (CPU), random access memory (RAM), read-only memory (ROM), Input and Output (I/O), and system bus. Together, these components construct a path for software and hardware to communicate with each other. If a computer is like a human body, then computer architecture would be the ways in which the brain and the rest of the body, namely the mental and physical components, interact. While existing architecture has already matured greatly since its genesis, the next decade will likely bring about efforts to revise the current architectural design further so as to continue increasing computing speed.
MOORE’S LAW

Computing speed is important for computer architects to consider, and improving chips is one way to achieve speedup. Most chips depend on complementary metal-oxide-semiconductor (CMOS) transistors, a type of semiconductor used in integrated circuits and digital logic design. For more than 30 years, we enjoyed “free” computer speedup by brutally adding more and more transistors on chips. This is the idea that Moore presented in his 1965 article. He predicted that the number of transistors would double every year, later revising the statement to every two years.

With this wonderful physical capability, the era of the “lazy software engineer” had begun. The speed of computers did not need to rely on code efficiency or runtime. All that programmers had to do was to wait for microchips to gain more transistors in order for their computers to run faster. This effortless speedup continued until we finally approached the physical limits of the technology. The time frame in which transistors double has increased tremendously because the transistors simply cannot get any smaller (Fig. 1). Currently, the smallest dimension of CMOS on electronic device is close to 10-20 atomic diameters. As a result, computer scientists began to explore other venues to accelerate computer performance.

LANGUAGE DECODING

With a stagnation in speed, we would lose the ability to implement more powerful programs or enhance the performance of existing ones. The slowing down of Moore’s Law thus poses a pressing issue to the whole industry: how can we get computers to operate on a faster timescale?

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industry: how can we get computers to operate on a faster timescale? Now that we cannot rely solely on hardware improvements, the solution probably lies in software or the intersection of software and hardware.

Computer scientists have already discovered an area with high potential for increasing computing speed—decoding from high-level programming languages to low-level ones. Languages that are more abstract can be thought of as higher level since they are more readable to humans and easier to use when programming. However, they are thus more structurally complicated and have longer runtimes. Languages that are less abstract can be thought of as lower level, as they usually refer to assembly code or machine code, which can communicate directly with hardware without the need for a compiler. Python is one of the most popular examples of a high-level programming language, while the language C is a great example of a language that is less abstract and lower level than Python.

Jun and Ling once performed recursion, a function that calls on itself, to a Fibonacci series calculation using both Python and C to illustrate the significant runtime difference in the two languages: the computation took Python 3.0 about 2.5396 seconds and took C <<0.0001 seconds. This hints at the great potential in speeding up high-level languages like Python by using more efficient techniques to decode them into low-level ones. Currently, JIT is working in that area by directly converting real-time Python models to machine code execution and using cache, a smaller but more accessible storage area for disk data, to temporarily store recently used data, respectively.

**DOMAIN-SPECIFIC LANGUAGES**

Turing Award winner and Professor at University of California, Berkeley, David Patterson also suggests that another emerging field which may significantly increase computing speed is domain-specific languages. Unlike general languages, such as Java and Python, which can be used in a variety of applications, domain-specific languages are customized for a certain field of interest. For example, Matlab is primarily for numerical computing.

Schaumont and Verbauwhede once ran a 128-bit key Advanced Encryption Standard algorithm using a completely customized program involving application-specific integrated circuit (ASIC) and Java. It turns out the customization increased the performance by a factor of nearly 3 million. Therefore, in order to support domain-specific computing, we would need greater customizable computer architecture. It is not
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QUANTUM COMPUTING

Other newly emerging ideas are also trying to break through the barrier of speed limits. Quantum computing is one that gained a huge amount of attention recently. Instead of calculating information based on binary systems, which consist only of two levels (0 or 1), quantum systems can distinguish between multiple levels and enable data access to many parts of the computer simultaneously. They rely on qubits, superposition, and entanglement, which together allow us to manipulate combinations of individual states (Fig. 2).

Although methods such as harnessing entanglement for computation have boosted quantum computing speed, this technology is so new and powerful that a real-world application has not been found yet. Professor Patterson and others suggest that a tangible application of quantum computing is most likely not going to take effect within the next decade.8,10

Thus, these ten years of disconnection in the speed up of computers would likely rely on re-architecturing the way that software languages communicate with each other and their hardware counterparts. If developed correctly, we can achieve as great of an increase in computing speed as we saw in the era of the “lazy software engineer.”

Living in this era of great technological advancement, we have the opportunity to join the battle and get involved with the next golden decade of computer re-architecture. In order to reconstruct the current system, we must redefine the means of interaction between software and hardware. Collectively, such efforts could not only power development in newly emerging technologies, but could in turn push past the boundaries that are currently preventing the next generation of advancements in computing.

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REFERENCES