The Future of Computers as Moore's Law's Ceiling is Approached: A Literature Review

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Literature Review

This review examines many researchers' analyses of Moore's Law in the 21st century and the possibilities to extend it, or ways we can maximize computing power in its place. The scholarship suggests Moore's Law's ceiling can extend, but planning computer systems around other forms of efficiency should be brought to the forefront of Computer Science.

What is Moore's Law, and Will it Reach a Ceiling?

Moore's Law is not necessarily a set-in-stone 'law,' but rather a prediction of how the development of computers increases roughly every 18-24 months. As transistors get smaller and smaller, there may reach a point soon at which we cannot physically fit more into microchips. John Shalf notes this push for smaller transistors (more computation power per unit area) is possible because of influence in the market surrounding computers.[1] In short, Moore's law is simply a framework that lets the market double computing power every two years while keeping the cost relatively the same.[1] Shalf believes that this doubling every two years will flatten out by 2025.[1] Similarly, other researchers would agree that Moore's Law will flatten out soon.[2] They note that production of new technology has stalled; the 'room at the bottom' (amount of innovation left of computer efficiency regarding hardware) is running out as the size of atoms is the sole limiting factor.[2] John Loeffler believes the methods of packing even more transistors into the same amount of silicon will eventually reach its physical limits.[7] Similarly, Liming Xiu believes that, as we approach nanometers in the single digits, it will not be possible to find more ways to load up more transistors onto computing chips.[3] The research indicates Moore's Law will eventually reach a ceiling, but it does not have to be anytime soon like some have predicted; by implementing new technologies, we can continue to find ways that provide more computing power per unit area.

How Could Moore's Law be Extended?

The prolonging of Moore's Law can be achieved by creative innovation of what space transistors can exist in. According to Liming Xiu, moving in other dimensions that are not in the horizontal plane could provide new opportunities to the amount of computing power that can fit into one space (so long as they do not easily overheat).[3] The architectural approach of stacking these silicon wafer circuits on top of each other could raise Moore's Law's ceiling. Max Slater-Robins agrees with this but adds the fact that Intel has claimed a patent on this three-dimensional CMOS architecture.[4] Similar to cities, expanding vertically creates more surface area that can be used without having to expand further horizontally. According to Paolo Gargini, 3D power scaling (vertical expansion) will probably allow for Moore's Law to continue for up to 15 more years.[8] On the contrary, some researchers would argue that it might not even be possible to expand into new dimensions with semiconductors, but they agree that expanding into a new dimension of space would be one of the best candidates for prolonging Moore's Law.[5] Max Slater-Robins does briefly touch on this point as Intel has not brought their patent to fruition.[4] On the other hand, John Shalf would argue that to develop a new transistor, there would need to be a breakthrough in which a whole new material would need to be used.[1] Overall, there are theoretical ideas that are being discussed regarding the increase in processing power per unit area, extending Moore's Law.

What New Technology (Not Hardware) Addresses The End of Moore's Law?

With the predicted end of Moore's Law around the corner, new technology will have to adapt to find greater computing speeds in other ways than cramming more transistors onto a microchip. Adapting the way software/the computer can interpret machine language will allow better performance without having to upgrade hardware. Addressing software fragmentation can improve the performance of all hardware by unifying the underlying infrastructure that computers run on. Researchers would argue that a compiler infrastructure such as Multi-Level Intermediate Representation (MLIR) addresses the long-term implications of Moore's Law; by attempting to remove as much software fragmentation as possible, improving compile times of similar hardware and connecting existing compilers, MLIR can unify systems already put into place.[6] Researchers also suggest that having new MLIR technology will demystify the concept of what a compiler is to people who are new to the computing industry.[6] With more people working under a unified system, the producer of these systems and the consumers will both benefit from more efficient production. Other researchers have pointed out that, with the end of Moore's Law closing in, the specialization of processing units will probably rise.[2] Instead of developing general-purpose processors, making processors with more specific uses will be more commonplace. For example, graphics processing units (GPUs) are common for gaming computers, as they can do vector and graphics based calculations quickly. General purpose processors (general CPUs) can do the same calculations, but they do not specialize them to do nearly as many imagery-based-calculations per second as a GPU. Interestingly, John Loeffler suggests that the "answer" to Moore's Law may be our use of existing or soon to exist computers; whether large-scale quantum computing, artificial intelligence or something we have yet to discover is the next big thing, we will always try to find new ways to use and improve computers.[7] As a whole, Moore's Law is close enough to its likely end where people have thought of realistic new technologies to address the "lack of new power."

What Else Can We Expect to See in The Future Regarding Moore's Law?

As the ceiling of Moore's Law is practically inevitable, the implications go further beyond just how hardware and software systems will be affected; jobs surrounding the computational sciences and the consumer market will have to change with the technological differences that Moore's Law presents. The markets will also try to meet the needs of consumers as they have expected increases in performance over time. According to DJ Wardynski, engineers and computer scientists are hardly out of ideas for the future, and just as computers and computer systems have changed so drastically over the past 50 years, there is not much stopping them from changing just as wildly over the next 50 years.[9] In the early 90s no one expected anything like virtual reality or technological advancements such as the iPhone; everyone has a supercomputer in their pocket compared to computers then. Similarly, David Vellante and David Floyer believe that the market for hardware and software engineers especially will boom even higher than they currently are because of the capabilities of computers at the end of Moore's Law.[10] Being able to have extremely powerful computers that can simulate intelligence and can process data so fast will lend way to powerful innovation.

Concluding Statement

Overall, the scholarship suggests Moore's Law to be a model that shows computing power doubling every 18-24 months while maintaining market cost that has stayed fairly consistent until recently. The scholarship recommends that, as Moore's Law reaches its final years, the innovation to strengthen computer power has to become more creative to keep up with market demands.

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