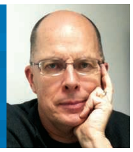
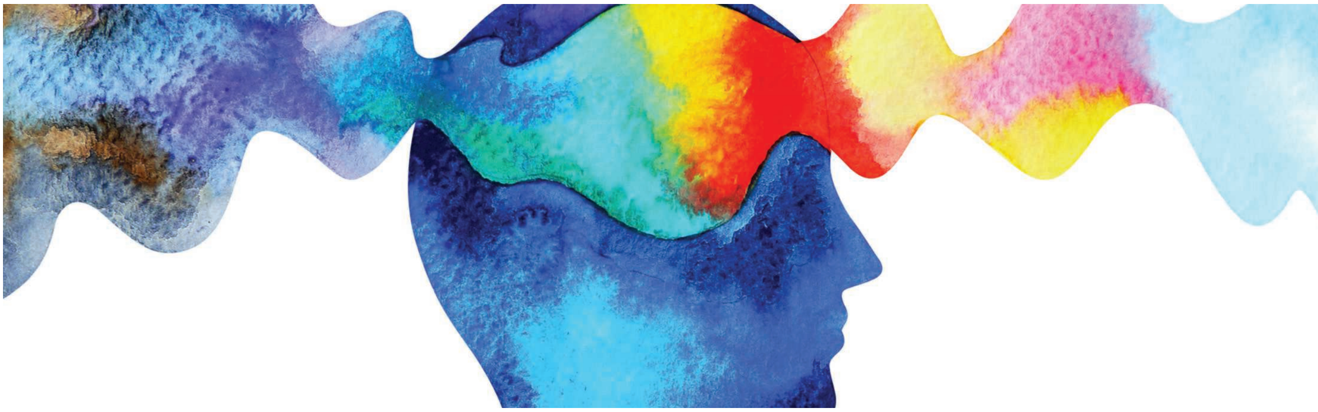
EDITOR DAVID ALAN GRIER
Djaghe; LLC; grier@gwu.edu





Value by Squares

David Alan Grier, Djaghe, LLC

Most times our articles teach us something about technology. Sometimes they teach us about business and society. In this article, Robert Metcalfe may give us insight that helps explain the growth of computer science.

As an academic discipline, would computer science have been possible without the invention of computer networks? Furthermore, would such networks have been built unless a small group of people believed that the value of such networks would grow faster than the cost of linking computers? This month's contribution to the *Computer* "Body of Knowledge" column begs us to consider such questions.

Even though we date the origins of computer science back to the 1940s (or when we are emboldened, back to 1821 when Charles Babbage demonstrated a machine that could interpolate mathematical functions), the modern form of computer science came to be in the mid-1960s, when universities such as the Massachusetts Institute of Technology (MIT); University of California, Los Angeles; University of Maryland; University of Michigan; Cambridge University; and Stanford University created computer science departments. Prior to that point, computer science had an ambiguous place in universities. For the most part, it was viewed as a service discipline—a field that supported research in physics or chemistry. In the United States, the major scientific funding agency, the National Science Foundation, had a substantial fund to support the purchase of computers by universities, but it had almost no funds for computer research.[1]

Computer science began to take shape in the early 1960s as researchers began to identify interesting computing

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- Article: "Metcalfe's Law After 40 Years of Ethernet"
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problems beyond numerical analysis and algorithm complexity. To those two traditional subjects, researchers began to add questions in artificial intelligence, graphics, natural language recognition, and, finally, timesharing and interactive computing.[6] Timesharing was the topic for one of the first grants that the National Science Foundation made for computing research. That grant funded the development of the Compatible Time-Sharing System at MIT.

Networking came directly out of the work on timesharing. The early-network researchers not only faced the problem of connecting different computers but also the problem of getting two different operating systems to communicate with each other over the network.[2] Robert Metcalfe, for whom "Metcalfe's law" is named (see "Article Facts"), came out of that MIT environment. He was an undergraduate while researchers were starting to build the Arpanet network and finished a doctorate shortly after that network became operational. He then moved to the Palo Alto Research Center, where he developed the Ethernet local area network technology.[3,4]

It was while working with Ethernet that Metcalfe made the observation that is now known as *Metcalfe's law*. He had left Xerox and founded the networking company 3Comm. He was trying to explain to the company's sales people how they might explain the value of a network. He argued that if there were N nodes on the network, each node could communicate with $N - 1$ other nodes. Hence, the amount of communication was proportional to $N*(N - 1)$ or N^2. From this observation, he noted any network would need a minimum number of nodes before it had enough value to justify the initial investment. However, once it crossed that threshold, the value of the network would grow rapidly.[5]

Metcalfe's law is not really a technical truth but an economic observation. It asserts value, not functionality. As an economic statement, it has been criticized. Some economists have suggested that it needs to account for the law of diminishing returns. Each new node may not bring the same value as its predecessor. Some have noted that the value of the network might be more accurately described as being proportional to $N*log(N)$, where N (again) is the number of nodes.[7] But the specific form of Metcalfe's observation is less important than the greater truth: all networks need a certain number of nodes before they justify the investment.[4]

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Metcalfe's law has been applied to every form of network, from generic local area networks to massive social networks. It rightly deserves to be in the "Body of Knowledge" column, which covers the important articles that *Computer* has presented to the field. However, does it give any insight into the question posited at the start of this article? "Was the development of academic computer science possible without the support of computer networks?" Strictly speaking, the answer is probably "no." More universities were becoming interested in computing during the 1960s. We see no evidence that these schools were making investments in the field, because they anticipated that all computer science departments would be linked by networks by the mid-1970s.

However, it is possible to argue that computer science grew quickly because of the power of networks. In the 1960s, the dominant scientific research field was physics. It had a position that was matched by no other field. Computing, by contrast, was a small field that was torn between two other fields: electrical engineering and mathematics. Networks helped pull computing together, gave it a common voice, and helped amplify the work of each individual contributor. By 1975, networks connected most computer science departments in North America and many in Europe. Five years later, it was rare that a university had a computer science department that lacked a network connection. It is difficult to tease cause from effect with computer science networks. Did computer science become big because of networks, or was it the other way around? However, as Metcalfe observed in his law, there was a point when the networks connecting computer science departments exceeded the cost of their investments. At that point, they started to become valuable. Very valuable. C

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DAVID ALAN GRIER is a principal with Djaghe, LLC. He is a Fellow of IEEE. Contact him at grier@gwu.edu.

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