Another View on Computer Architecture

Wilson G., Kenneth (1982 Nobel Laureate)

The coming of the computer has created a revolution as profound as the change from the Middle Ages to the Renaissance. Many of the changes that took place around the time of the Renaissance - the invention of printing, the development of systematic experimental science, the invention of oil painting - have analogs today, made possible by the computer. We are moving from printed media communication, with time delays of a year or more for professional publications, to instantaneous communication via computer networks. Computers are revolutionizing the capability of scientific instruments. Supercomputers are enabling man to “see” phenomena not even accessible to experiment - from tomorrow’s weather, to the complete billion-year history of a star, to the deep interior of the earth. The ability of computers to sort information is giving mankind unprecedented capability to find needles in our rapidly growing haystack of knowledge.

In the past forty years, the power of computers has advanced by a factor of a million or so. Nevertheless, the computer revolution has only just begun. The technological opportunities for further advances seem almost limitless. Since the bit carries no weight or other mechanical burdens, one can expect the volume assigned to a single bit in processors, communications, and memory, to continue to shrink dramatically, vastly increasing the number of bits that can be handled at a time. The needs for computing power are likely to keep pace with any technological advances that come along, due to the many problems of exponential or close to exponential complexity that computers must deal with - from economic forecasting to probing the secrets of molecules.

Unfortunately, there is one constraint from the discipline of physics which is limiting and shaping computer architectures of today and into the future. There is a maximum speed with which bits can travel, namely the speed of light, and today’s computer designs already suffer from this limitation - forcing supercomputers to become smaller and smaller as their speed increases. The speed of light limitation is forcing architects to achieve new levels of processing capabilities mostly through parallelism rather than speed. As silicon chips (or whatever replaces silicon in future) become three-dimensional and the bit continues to shrink, the number of bits that can be processed in parallel could increase in spectacular fashion - is Avogodro’s number (the number of atoms in a few grams, or 10^{23}) out of reach? Clearly the challenge to computer architects is to harness the capabilities of bits processed in parallel for the benefits of man- and womankind.

Finally, I remind all readers already deep into the jargon of silicon circuits that the brain puts all silicon circuits that the brain puts all silicon to shame. The brain has cycle times of milliseconds, and a size smaller than even a desktop computer, yet it recognizes patterns, analyzes speech, and stores and sorts through databases, all at rates that are untouchable even by supercomputers. Its programming system is natural and user-friendly. Only its fault-tolerance does not meet engineering standards.