20th Century vs. 21st Century C&C: The SPUR Manifesto

As technologists, we must confront the current weaknesses and deliver on the potential opportunities of computer and communication technologies in the 21st century. Consider this a call to arms for tackling that challenge.

My friend John Hennessy and I recently traveled to Japan to accept the Computer and Communication (C&C) Prize from NEC Corporation. The ceremony prompted me to reflect about the past priorities for C&C, and whether those priorities still make sense in the 21st century.

When ARPANET was created 35 years ago, there was little concern about security. The focus was connecting as many computers as possible, and then on making the communication faster and cheaper.

Personal computers were invented about a dozen years later. The argument was since a PC is used by only one person, we didn't need the protection found in traditional operating systems, there was no need to separate administrators from users. The focus was making many PCs, and then on making them faster and cheaper.

After about another dozen years, the ARPANET morphed into the Internet, and the World Wide Web made it easy to connect PCs together. A PC user could then access information from millions of computers around the world.

Over those years we excelled at our goal, as we improved the cost and performance of 20th century C&C by at least a factor of 100,000. Clearly, this combination of inexpensive computing and communication has transformed the industrial world, leading to increased productivity and improved economies. Today, hundreds of millions of people benefit from 20th century C&C.

What we didn't realize, however, was that when you connected your PC to the Web, millions of computers around the world could now access information on your computer, whether you allowed it or not. This insecure concoction leaves us open to computer crime, and potentially even to computer-assisted terrorism or war. Just as business embraced the Web five years ago, criminals are doing so now. In 2004, 1% of U.S. households were victims of successful phishing attacks. According to a recent poll, 17% of businesses received threats of being shut down by denial-of-service (DoS) attacks [2]. Indeed, one company refusing to pay extortion spends $100,000 per year to defend against DoS attacks.

Besides neglecting security and privacy, 20th century C&C was not particularly concerned about dependability in the drive toward faster and cheaper. On the software side, the emphasis was turning the advances in performance and capacity into more features rather than improving software quality. The hardware side had similar priorities. For example, the original PC included parity memory protection, which requires extra memory. Cloners later realized they could use less memory and thus lower costs if they rewired the PC to claim the memory was perfect. As a result of the low concern for dependability of software and hardware, crashes and reboots are commonplace.

A third weakness of 20th century C&C is a result of the focus on cost of purchase versus the cost of ownership. Moore's Law, the commodity PC industry, and open source software have all shrunk the cost of purchasing hardware and software, but little has been done to make them simpler to operate. Undependability and insecurity are part of the reason for the high cost of ownership, but another is a

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general lack of concern about the difficulty of installing and operating C&C. It is estimated that businesses today spend three-to-six times as much maintaining C&C than they spent on purchasing it.

In my view, we have taken ideas from the 1970s and 1980s to their logical extreme, providing remarkably fast and cheap C&C to hundreds of millions of people. But we now are all painfully aware of the drawbacks of 20th century C&C.

Hence, I believe for our new century we need a new manifesto for C&C, and, as is my nature, I offer a four-letter acronym to help us remember it:

- **Security/Privacy:** We must protect the security and privacy of C&C users from criminals and terrorists while preventing the Orwellian vision of Big Brother. C&C in the 21st century should be as safe as 20th century banking.
- **Usability:** C&C technology must match human abilities of both the operators and the end users. The ratio of cost of ownership versus purchase of 21st century C&C should match cost ratios of 20th century radio.
- **Reliability:** We need to create C&C the world can depend upon, since some are already relying on it with technology that doesn't deserve our trust. Indeed, 21st century C&C should be as reliable as 20th century telephony.

To make genuine progress, the "SPUR" manifesto must move ahead of cost-performance in the priorities of 21st century C&C.

In addition to these SPUR challenges that must be addressed, there are many opportunities that cry for innovation. Here are just two examples:

- **Putting All Data at our Fingertips.** Search engines that have transformed first-world societies are only accessing a small fraction of the available online information, and it's still not as easy to find as it could be. The challenge is to advance the SPUR manifesto while making the expotential increase in information from your desktop, the Deep Web, video archives, and so on, searchable to all of humanity [1].

- **Massively Parallel Microprocessors.** We achieved the many orders of magnitude speedup in large part by taking advantage of implicit parallelism. Computer designers today believe we have exploited almost all the available implicit parallelism given the available power budget. Indeed, after canceling its uniprocessor projects last year, Intel said the future of high performance microprocessors was multiple processors per chip. A classic RISC processor with caches will require less than $0.1mm^2$ in near the future, so thousands could fit on a chip. Putting that into perspective, the first microprocessor in 1971 used only 2,314 transistors, yet it started a revolution that transformed our world. Hence, another bold challenge is how to advance the SPUR manifesto when the hardware building block is a computer rather than a transistor [3]. We will likely need to innovate programming languages, debuggers, operating systems, databases, and so on.

The good news is that less than 5% of humanity has lived through the weaknesses of 20th century C&C. The bad news is that if we deploy such C&C technology unchanged to the rest of humanity, I am not sure if history will judge us kindly.

If we instead rise to these challenges to address weaknesses while leveraging new opportunities—which must include research and development funding to support such efforts—then I believe the legacy of 21st century C&C will be one that we can be proud of.

Next month I'll comment on whether such funding will be available. **C**

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