COGNITIVE SCIENCE **11**, 159–161 (1987)

Reply to Krellenstein on Parallel Computation

PAUL THAGARD
Princeton University

I recently argued that the position in the philosophy of mind called *functionalism* is undermined by the importance of recent work on parallel computation (Thagard, 1986). In reply, Krellenstein (1987) contends that parallelism does not have the philosophical significance I claimed for it. Although his contentions are plausible if one focuses on what is in principle computationally possible, they fail if one looks at real problems.

(1) SERIAL VERSUS PARALLEL

In replying to my argument that the speed furnished by parallel processing is highly relevant to the understanding of intelligence and mind, Krellenstein says that "the serial simulation of parallel processes and the portability of software are computational principles and everyday empirical realities." While it is true that *in principle* parallel processes can be simulated on serial machines, the practical reality is that such simulations can be painfully slow. Ten years ago graduate students in artificial intelligence could be told not to worry about parallel computation because you could always simulate it on a serial machine. But now that speed-ups achieved in serial processes are running up against physical constraints such as the speed of light, increasing amounts of research in computer science in general and also in AI are concerned with parallel computation. According to Denning (1986), current supercomputers are within a factor of 10 of the processor speed limit determined by the speed of light in a chip. Once this limit is reached, the in-principle serial simulation of parallel processes will be no more of an "empirical" reality than the in-principle simulation of any computer by a Turing machine. The developers of connection machines and other parallel architectures (see references in Thagard, 1986) have important practical reasons for seeking the speed afforded by parallel processing that should not be ignored for abstract philosophical reasons. As for portability, at the practical level it is noteworthy that a great deal of non-trivial work is required to port programs between such simple machines as the IBM PC and the Apple Macintosh, let alone between more complex machines.

I am grateful for conversations with Stephen Hanson, Charles Rosenberg, and David Waltz.

Correspondence and requests for reprints should be sent to the author at the Cognitive Science Laboratory, Princeton University, 221 Nassau Street, Princeton, NJ 08542.

(2) VIRTUAL MACHINES

Krellenstein states that any given system may be viewed as consisting of multiple virtual machines. Application of the idea of a virtual machine is appealing in principle, but again runs up against practical realities. I am writing this reply on a Sun 3 workstation running UNIX, which is indistinguishable for practical purposes from the Pyramid 90x, also running UNIX, on which I also sometimes work. Thus, as Krellenstein would argue, their hardware differences are irrelevant and they are indeed the same virtual machine. But this argument is only plausible for machines sufficiently close to each other. Once one starts to deal with parallel architectures that differ radically from each other and from the familiar serial architectures, it becomes much more difficult to talk of a system instantiating any virtual machine.

Consider the Connection Machine of Hillis (1985), a highly parallel device that uses more than 65,000 small processors. There is a simulator for the Connection Machine that runs on a serial Symbolics Lisp Machine, which thus runs the same virtual machine as the Connection Machine. So why do people want a parallel machine? Because on some complex problems the Connection Machine is 2,000 times faster. Thus a problem that might take 1 day to run on a Connection Machine could take longer than 5 years on the simulator! Given current technology, there is no immediate prospect of making a Symbolics that is 2,000 times faster than current ones. From a purely theoretical level parallelism may not seem to matter, but the empirical realities are otherwise.

(3) MULTIPLE HYPOTHESES

I argued that parallel computation is important, not just for sheer speed, but because of qualitative advantages as well. One of these is flexibility, which I illustrated using the example of multiple hypotheses. A parallel system can be more audacious in its consideration of hypotheses, since parallelism will permit it easily to look at many at once. Krellenstein argues this is just a matter of speed, since a serial machine with enough resources could just as easily pursue many paths. He is of course right that in principle a serial machine could be built that entertains multiple hypotheses as well as a given parallel machine, but the difficulty of doing so must not be underestimated. Consider a scientific community as a kind of parallel processing system, with each scientist a processor, and with different scientists pursuing different hypotheses. If there were a hundred scientists and we could build a processor a hundred times more powerful than any scientist, it might seem that simulation of the whole community would fall into place. We could just simulate one scientist, then another, and so on until all hundred had been simulated and the results could be assessed.

This simulation, however, would fail to capture some important qualitative aspects of the scientific community, such as asynchronous activity and communication. The work of scientist #23 may well be influenced by regular communication of what scientist #61 is doing. A parallel implementation with communication links between scientists not dependent on any overall synchronization would be much harder to simulate using a serial machine than the mere hundred times would suggest. Simulating the asynchronous communication may well slow the computer down so much that a useful serial simulation will not be empirically possible. There is also the issue that I discussed in my paper under the heading of *producibility*, of whether anyone could ever build such a complicated serial machine. The development of software and hardware interact in important ways that belie the in-principle independence of software.

Thus Krellenstein's replies do not undermine my arguments concerning the relevance of parallel computation to the mind-body problem.

REFERENCES

Denning, P. (1986). Parallel computing and its evolution. *Communications of the ACM, 29* 1163–1167.

Hillis, W.D. (1985). *The connection machine.* Cambridge, MA: MIT Press.

Krellenstein, M. (1987). A reply to "Parallel Computation and the Mind-Body Problem". *Cognitive Science, 11,* 155–157.

Thagard, P. (1986). Parallel computation and the mind-body problem. *Cognitive Science, 10,* 301–318.