

A Comparison of Human and Computer Information Processing

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INTRODUCTION

Over 30 years ago, TV shows from *The Jetsons* to *Star Trek* suggested that by the millennium's end computers would read, talk, recognize, walk, converse, think, and maybe even feel. People do these things easily, so how hard could it be? However, in general we still don't talk to our computers, cars, or houses, and they still don't talk to us. The Roomba, a successful household robot, is a functional flat round machine that neither talks to nor recognizes its owner. Its "smart" programming tries mainly to stop it getting "stuck," which it still frequently does, either by getting jammed somewhere or tangling in things like carpet tassels. The idea that computers are incredibly clever is changing, as when computers enter human specialties like conversation, many people find them more stupid than smart, as any "conversation" with a computer help can illustrate.

Computers do easily do calculation tasks that people find hard, but the opposite also applies, for example, people quickly recognize familiar faces but computers still cannot recognize known terrorist faces at airport

check-ins. Apparently minor variations, like lighting, facial angle, or expression, accessories like glasses or hat, upset them. Figure 1 shows a Letraset page, which any small child would easily recognize as letter "As" but computers find this extremely difficult. People find such visual tasks easy, so few in artificial intelligence (AI) appreciated the difficulties of computer-vision at first. Initial advances were rapid, but AI has struck a 99% barrier, for example, computer voice recognition is 99% accurate but one error per 100 words is unacceptable. There are no computer controlled "auto-drive" cars because 99% accuracy means an accident every month or so, which is also unacceptable. In contrast, the "mean time between accidents" of competent human drivers is years not months, and good drivers go 10+ years without accidents. Other problems easy for most people but hard for computers are language translation, speech recognition, problem solving, social interaction, and spatial coordination.

Advanced computers struggle with skills most 5 year olds have already mastered, like speaking, reading, conversing, and running:

Figure 1. Letraset page for letter "A"



As yet, no computer-controlled robot could begin to compete with even a young child in performing some of the simplest of everyday activities: such as recognizing that a colored crayon lying on the floor at the other end of the room is what is needed to complete a drawing, walking across to collect that crayon, and then putting it to use. For that matter, even the capabilities of an ant, in performing its everyday activities, would far surpass what can be achieved by the most sophisticated of today's computer control systems. (Penrose, 1994, p. 45)

That computers cannot even today compete with an ant, with its minute sliver of a brain, is surprising. We suggest this is from processing design, not processing incapacity. Computer pixel-by-pixel processing has not lead to face recognition because, as David Marr (1982) observed, trying to understand perception by studying neuronal (pixel level) choices is “*like trying to understand bird flight by studying only feathers. It just cannot be done.*” Processing power alone is insufficient for real world problems (Copeland, 1993), for example, processing power alone cannot deduce a three-dimensional world from two-dimensional retina data, as the brain does.

Enthusiastic claims that computers are overtaking people in processing power (Kurzweil, 1999) repeat the mistake AI made 40 years ago, of underestimating life's complexity. If computers still struggle with 5 year old skills, what about what children learn after five, while “growing up?” The Robot World Cup aims to transform current clumsy robot shuffles into soccer brilliance by 2050 (<http://www.robocup.org>). If computing is going in the wrong direction the question is not whether 50 years will suffice, but whether a 1,000 years will. In contrast, we suggest that:

1. For computers to do what people do requires a different type processing.
2. Computers that work with people can combine the strengths of both.

BACKGROUND

Brains can be compared to computers as information processors, because:

1. Neurons are on/off devices that can represent digital information.
2. The neuron threshold effect allows logic gates (McCulloch & Pitts, 1943)
3. The brain has input/output channels (the senses) as a computer does.
4. The brain works by electricity as computers do.
5. As a computer has many transistors so the brain has many neurons (about 10^{10} , more than there are people in the world).

We contrast how computers process with how the brain processes the senses to combine their strengths, not to decide which is “better.” This has implications for:

1. **Computer design:** To improve computer design. While computer systems evolved over about 60 years, the brain has evolved over millions of years, and was rigorously beta tested over many lives. It probably embodies useful design principles.
2. **Computer human interaction (CHI) Design:** To improve CHI design. Computer success often depends on human interaction, and knowing how people process information can improve this.

COMPUTER VS. HUMAN INFORMATION PROCESSING

We use a systems theory approach (Bertalanffy, 1968) to contrast computer and human information processing. A processing system, whether computer or brain, is presumed composed of processors, whether computer or cognitive, that receive input from sensors or ports, and send output to effectors or peripherals. The following discussion applies whether the system is physical (hardware) or informational (software).

Von Neumann Computers

While the brain's design is relatively consistent between people due to genetics, a computer's design is whatever its designers choose it to be. In the following, “the computer” refers to computers whose design derives directly from Von Neumann's original architecture, which encompasses the vast majority of computers in use today. In his original design, Von Neumann made certain assumptions to ensure valid processing:

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