On intelligence

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During human evolution, our cerebral cortex increased in size in response to new environmental challenges. The cerebral cortex is the site of diverse processes, including visual perception and language acquisition. However, no accepted unitary theory of cortical function exists yet. One hypothesis is that there is an evolutionarily conserved neural circuit that implements a simple and flexible computation. This idea is known as the "canonical circuit." As Gary Marcus, Adam Marblestone, and Thomas Dean note in a perspective piece in Science, there is still no consensus about whether such a canonical circuit exists nearly four decades later. Researchers argue that there is little evidence that such a uniform structure can capture the diversity of cortical function in simple mammals.

What would it mean for the cortex to be diverse rather than uniform? Marcus and his colleagues propose that the brain may consist of an array of elementary computational units, which act in parallel as a microprocessor. To probe at questions on cortical circuitry, collaborative endeavors engaging scientists and engineers have emerged. In parallel with the Human Brain Project in Europe, the Brain Research through Advancing Imaging Neurotechnologies Initiative is developing tools to view the brain at superior spatial and temporal resolution. Researchers aim to directly study the relationship of a neuron's function to its connections. This can be accomplished by mapping neuronal connections in conjunction with acquiring functional activity data.

Top-Down vs. Bottom-Up

Researchers can scale up from the study of neurons and synapses to those of neural circuits and networks. However, this bottom-up approach may not be the best way to understand the neural basis of human cognition. Psychologist Frank van der Welde argues that this confuses the nature of understanding with the way to achieve understanding. He provides an analogy to physics. To understand the universe, a bottom-up approach would begin with an understanding of elementary particles, how these particles combine to make atoms, and how atoms to combine to make molecules. However, physics did not begin with the study of elementary particles. It began with a study of the solar system, which provided the first law of motion. In summary, understanding can proceed from top to bottom as well as bottom to top.

To understand human cognition, neuroscientists should combine top-down and bottom-up approaches. One top-down approach is generating a large-scale simulation of neural processes that generate intelligence. This project intersects neuroscience and artificial intelligence. For instance, a research team at IBM represented 8 x 106 neurons and 6400 synapses per neuron on the IBM Blue Gene Processor, and ran 1 s of model time in 10 s of real time. Large-scale simulations provide a tool to investigate the brain not limited by the experimental and ethical limitations of in vivo work. Through such virtual models alongside neuroscience studies, researchers may arrive at the neural basis of intelligence.

The Rise of Artificial Intelligence

As neuroscience details the anatomy and activity of the brain, artificial intelligence seeks to develop an independent, non-biological path to intelligence. Researchers of both fields can agree that artificial intelligence is not the equal of natural intelligence in most important tasks for human cognition such as vision, motor manipulations, and natural language understanding. However, this is not to say that artificial intelligence won't ultimately achieve principles of natural intelligence. I met with Ernest Davis, a professor of computer science at New York University, to learn more about artificial intelligence.

Advances in artificial intelligence have been incredible, from IBM Watson to Google DeepMind AlphaGo. Davis believes that AI will continue to advance and be used for positive and negative applications. For instance, AI can be used for improving the quality of medicine and building self-driving cars. "The impact of that will be largely positive though there will be a negative impact on employment. It will also be used for military purposes, and the immediate effects of that are mostly negative," Davis says. Nevertheless, artificial intelligence is far from building programs that retain human-level intelligence. The human brain has an unsurpassed ability to do complex, real-time interactions in a dynamic world.

To implement reasoning in artificial intelligence, Davis explains different techniques available by example. For instance, chess-playing program Deep Blue did reasoning by thinking through a large number of paths to the future and determining what solution works out. A second example is software verification programs. These algorithms search for bugs in programs through logical reasoning. The program provides users with a formal proof that a program doesn't have a certain kind of bug. A third example is taxonomic reasoning, which is a simple form of logical reasoning by category. This type of reasoning has been done in programs called semantic nets, which have been in use for 50 years.

A New Century of the Brain

Paul Allen, the co-founder of Microsoft, has funded two distinct research projects in neuroscience and artificial intelligence. The Washington Post aptly describes it as Allen's $500 million quest to dissect the mind and code a new one from scratch. Elon Musk has funded a rival company called NeuroLink to create human-computer hybrids. To build an artificial brain, Davis believes:

"The replica of the human brain can mean either the ability to do human-level tasks, which I think in principle is possible, or algorithms that are an imitation of the brain. We don't yet know which direction is the best way to pursue AI. There's an awful lot we don't understand about the brain so it may be pre-mature to try the latter."

Neuroscience and artificial intelligence both aim to identify architectures of intelligence and cognition. Michael Gazzaniga states that cognitive neuroscience asks: what are the algorithms that drive structural neural elements into the physiological activity that results in perception, cognition, and consciousness? Likewise, artificial intelligence asks: what are the algorithms that can generate human-like intelligence in machines to perform reasoning, planning, and learning? Both fields describe mechanisms of intelligence as "algorithms."4 To uncover human intelligence and cognition, intersections in neuroscience and artificial intelligence are necessary. Perhaps only then can we can understand what makes us human.

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