Engineering Intelligent Systems

What is intelligence? Where did it come from?   What is its fundamental nature? What are its elemental constituents? Can it be created artificially? If so, how?

The answers to these questions are beginning to emerge.   As the second millennium draws to a close, we are beginning to see real answers to questions that have occupied the attention of philosophers and scientists for many centuries. Since the time of Plato and Aristotle, the nature of knowledge and the role of human reason have been the subject of serious intellectual inquiry. Great minds such as Bacon, Decartes, Hume, Kant, Pascal, Helmholtz, Darwin, James, Freud, Russell, Mach, Pierce, Piaget, and many others have provided fundamental insights into the mysteries of the mind.   Today, both biological and artificial forms of intelligence are the subject of intense study. There is good evidence that we have entered a period in which the ancient mysteries of the mind are yielding to scientific inquiry.

For example, the neurosciences have provided deep insights into the anatomical, physiological, chemical, and computational basis of cognition. Neuroanatomy has produced extensive maps of the computational modules and interconnecting data flow pathways making up the structure of the brain. Neurophysiology has demonstrated how neurons compute a rich library of mathematical and logical functions, and how they store, retrieve, and communicate information. Neuropharmacology is discovering many of the transmitter substances that control the emotions, compute value judgments, assign priorities, generate reward and punishment, activate behavior, and produce learning. Psychophysics provides many clues about how the brain operates to perceive objects, events, time, and space, and how it reasons about relationships between the self and the external world. Cognitive psychology is exploring how the brain represents knowledge; how it perceives objects, events, situations, and relationships; how it analyzes the past and plans for the future; and how it selects and controls behavior that achieves goals and satisfies desires. Behavioral psychology adds information about mental development, emotions, and behavior.

Over the past five decades, the invention of the computer and rapid advances in computational power have made it feasible to launch serious attempts at building intelligent systems. Artificial intelligence and robotics have produced significant results in planning, problem solving, rule-based reasoning, and understanding of images and speech. Research in computer-integrated manufacturing has achieved major advances in the representation of knowledge about products and processes and in controlling intelligent machines in a wide variety of manufacturing operations. Intelligent vehicles and weapons systems can perform military tasks of great complexity with precision and reliability. Research in learning automata, neural nets, fuzzy systems, and brain models provides insight into adaptation and learning, and the similarities and differences between neuronal and electronic computing processes. Game theory and operations research have developed methods for decision making in the face of uncertainty. Autonomous vehicle research has produced advances in real-time sensory processing, world modeling, navigation, trajectory generation, and obstacle avoidance. Research in industrial automation and process control has produced hierarchical control systems, distributed databases, representations of object geometry and material properties, data-driven task sequencing, network communications, and multiprocessor operating systems. Modern control theory has developed precise understanding of stability, adaptability, and controllability under various conditions of feedback and noise. Research in sonar, radar, and optical signal processing has developed methods to fuse sensory input from multiple sources, and assess the believability of noisy data. Progress is rapid, and there exists an enormous and rapidly growing literature in each of the above fields.

Perhaps most important, there is emerging at least the broad outlines of a general theoretical framework that promises to transform the study of intelligent systems from a philosophical debate based on psychological observations into a true experimental science based on attempts to build intelligent systems and measure their performance. The study of intelligent systems is beginning to coalesce around what might best be termed a "computational theory of mind." The fundamental concept on which this theory is grounded is that the brain is a machine and the mind is a process that runs in the brain. In short, the mind is what the brain does.

What still eludes us is an understanding of the science of mind and brain at a level that would enable engineers to design and build intelligent systems with significant capabilities. The level of performance of current artificial intelligence and robotic systems is extremely limited in comparison with biological systems in many important ways. Early successes with toy problems in the laboratory have not scaled up to solve real problems in the natural world. Current laboratory robots are disappointingly incapable of performance that rivals any natural intelligence beyond that of some insects -- and even in this domain, robots have a long way to go to duplicate the performance of dragon flies or spiders. Perhaps the biggest barrier to future progress is the lack of a theory with sufficient specificity to support the engineering design and construction of intelligent systems. Although we know how to build computers that can perform billions of computations per second, and we can write software programs that can defeat the world champion in chess, we still cannot duplicate the capability of a six year old human in understanding natural language, or even in tying a shoe. We have only a vague understanding of how the brain represents knowledge about the natural world, and we have not been able to endow computers with common sense. We do not know how to build sensory systems that can perform as well as cats or squirrels in recognizing and tracking objects of interest by sight and sound. We are not able to build actuator systems that duplicate the motor performance of a deer or a butterfly. And we are unable to mimic the spatial and temporal reasoning abilities of a bird in controlling flight through the branches of a tree, or even that of a housefly in performing intricate maneuvers such as evading being swatted and landing upside down on the ceiling.

In this joint conference, we approach the phenomenon of intelligence from a systems engineering viewpoint. How can we bring together results from a wide variety of disciplines – from intelligent control, computational theory, automation, robotics, intelligent systems, and semiotics – to address the problem of engineering intelligent systems? Our goal is to integrate many different approaches and bring together diverse communities of researchers in pursuit of the science and technology of intelligence. Our hope is that the mixture of ideas that will emerge during this conference will advance us toward our goal of engineering intelligent systems.

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