The Course of the Mind

By Steven Ashley

One of the greatest mysteries of nature is the human mind. Understanding how the brain produces intelligent behavior, and how that might be replicated by machines, are among the greatest problems facing science and technology. Even on a solely personal level, consider: What's more interesting to you than *you* and how you work? Nothing, except perhaps the prospect of a "robot-you" to help you live and work better.

Yet despite decades of study, the three-pound bundle of moist gray matter inside your skull has remained a black box, for the most part a padlocked one. Although the early computer scientists were optimistic in the mid-1950s when "artificial intelligence" began growing into an academic field, succeeding years taught them that emulating the operations of 100 billion highly evolved, networking neurons is much harder than it first seemed. Harder than winning championship chess matches, it turned out, or teaching machines to recognize voices and translate texts by analyzing huge numbers of labeled training examples, as do Apple's Siri and IBM's Watson.

"These recent achievements only underscore the limitations of computer science and artificial intelligence," says Tomaso Poggio, professor of brain sciences and human behavior at MIT and co-founder of the Brains, Minds and Machines course at MBL, which launched in the summer of 2014. "We do not yet understand how the brain gives rise to intelligence, nor do we know how to build machines that are as broadly intelligent as we are," he says.

Poggio, who heads up the Center for Brains, Minds and Machines (CBMM) at MIT, thinks it's high time to renew the quest to achieve the field's grand goal to explain the brain. Success in this endeavor should bring not only improved therapies for neurological diseases but computers with robust and sophisticated algorithms that exhibit human-like intuition and understanding of social nuance.

"We know much more today than we did before about biological brains and how they produce intelligent behavior," he states. "We're now at the point where we can start applying that understanding from neuroscience, cognitive science, and computer science to the design of intelligent machines."

Poggio and two dozen other researchers from MIT, Harvard University and elsewhere are collaborating to do just that at CBMM, which was founded on the premise that faster progress toward understanding human intelligence will come if computational, biological, and psychological approaches are combined. As part of the Obama Administration's BRAIN Initiative, the National Science Foundation funded the center with a $25 million grant in 2013.

Not long thereafter, Poggio, neurobiologist Gabriel Kreiman of Harvard Medical School, and several other center principals began to consider where to conduct CBMM's first summer-school course. “Given the MBL’s strong outreach efforts, its broad-umbrella approach to science, and its long history in fundamental neuroscience research, it was the obvious choice,” says L. Mahadevan, an applied mathematician, biologist, and physicist at Harvard University and a lead investigator at CBMM.

“We approached MBL Education Director Bill Reznikoff, who was very enthusiastic, particularly because our course would complement MBL’s popular Methods in Computational Neuroscience course, which approaches the subject from the cellular scale,” Mahadevan says.

The group scheduled Brains, Minds and Machines to overlap with other MBL special topics courses to take advantage of the spectacular gathering of neuroscientists and other experts that the courses draw to Woods Hole. “We hoped that we would get good synergy because of the courses’ complementary nature and all the good people from many fields that would be there to cross-lecture,” Kreiman says.

Brains, Minds and Machines attracted immediate attention in the academic community and admission proved highly competitive. “From about 200 high-level applicants, we selected 25 graduate students from a variety of fields including biology, neuroscience, cognitive sciences, technology, mathematics, machine learning, and software,” Mahadevan says. The course lecturers were “top people from five or six institutions … whose expertise spanned the broad range of areas under this topic,” he says.

The “hugely integrative” talks focused on the theoretical mathematical foundations of the biology of vision at the same time as the social aspects of cognition. The first part of the two-week class provided instruction on theoretical foundations and computational methods used in intelligence research, and introduced students to empirical methods used in neuroscience and cognitive science to probe the function of neural circuits and emergent behavior. The latter part of the course examined research topics now under investigation at CBMM.

“Our post-docs also [worked with the students on independent projects], covering areas that ranged from intuitive physics to understanding aspects of image recognition,” Mahadevan says.

Some students worked on “building computational models to visually recognize objects and faces with the goal of achieving human performance levels in complex recognition tasks (asking questions such as ‘What is there?’ ‘Who is there?’)” Kreiman says. These projects “took inspiration from studies of the underlying neurobiological circuitry in the brain.” Other students investigated the roots of social interactions by studying situations in which social inferences—guessing what other people are thinking based on sparse data—are key, and attempted to emulate that process using probabilistic programming techniques. Another team “examined at the behavioral level how infants learn fundamental physical concepts, such as mass and momentum, from experience, and tried to embed those ideas into computer algorithms,” he says.

This summer, in addition to continuing with last year's projects, "cognitive robotics projects" will be introduced in the course, Kreiman says. Some will use the iCub robot, a meter-tall, humanoid robotic test-bed developed by several European universities for research on how human-like manipulation of objects and the environment play a major role in human cognition.

The MBL classroom for the oversubscribed course last year was jam-packed with students, faculty, and a few fortunate onlookers. "I think it was a little unusual how many faculty members from partner institutions ended up auditing the course," Mahadevan notes. "It seemed that after everybody sat through the day lectures, many attended the traditional *ad hoc* evening lecture sessions, some of which went on late into the night," he says, laughing. "That's always a good sign."

Did the researchers make any advances in demystifying how intelligence is created? "It was only the first year, of course, so there's been precious little chance for any 'Ah, ha!' moments just yet," Mahadevan observes. "But the course is a fantastic opportunity to get the views of one's colleagues—from physics, biology, cognitive neuroscience—about what, to be honest, is a terribly hard question."

Brains, Minds and Machines
August 13 - September 3, 2015
Directors: Gabriel Kreiman, Harvard University and Tomaso Poggio, Massachusetts Institute of Technology (L. Mahadevan, honorary director)
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