Building A Better Brain

Rensselaer's Cognitive Science Department conducts research aimed at understanding how humans think. Ultimately, that knowledge will be used to build better artificial intelligence systems and to engineer improved interfaces between artificial and natural cognitive systems.

By Sheila Nason

Robots aren't very smart, according to Selmer Bringsjord, Rensselaer professor of cognitive science. A clever toddler can conduct a more understandable conversation than the best of today's artificial intelligence (AI) devices. A computer may be able to win at chess by quickly testing vast numbers of possible moves, but if someone changes the rules of the game, the computer will be stymied, and the human will win.

"We are still the most intelligent entities in the known universe," says Bringsjord, who chairs Rensselaer's Department of Cognitive Science.

But humans want smarter AI systems to do everything from entertaining us in the newest interactive game to simulating battlefield scenarios as an aid to combat planning.

Rensselaer's cognitive science researchers are working on the problem. They conduct research aimed at understanding how humans think and then make use of that knowledge to build better artificial intelligence systems and to engineer improved interfaces between artificial and natural cognitive systems.

Intelligence-Tested: Bettina Schimanski and Selmer Bringsjord with PERI. Photo by Mark McCarty.

An Irresistible Subject

Cognitive science — understanding why we're so smart — is an irresistible subject to humans, says Bringsjord. Studies go back, arguably, to Aristotle and certainly to Hobbes, who speculated that all human intelligence consists of mechanical computations.

On a more practical level, cognitive science occupies a central place in an interactive entertainment industry that brings in billions of dollars. From movies without human characters to video games to displays at the Universal Studios theme park, there is a demand for more realistic synthetic characters and better interfaces. Cognitive science is also of great interest to national defense agencies for, among other things, improved intelligence analysis and more effective personnel training.

Rensselaer's Cognitive Science Department was formed in 2001 from the former Philosophy, Psychology, and Cognitive Sciences Departments. The highly interdisciplinary program brings together computer engineering and such social sciences as psychology, a combination that is increasingly necessary in a world in which humans must constantly interact with ever-more-complex thinking machines. Today the department consists of 12 tenured faculty members, two research professors, four clinical faculty members, one adjunct professor, and two post-docs.

Yingrui Yang, an assistant professor who specializes in human reasoning and decision-making, was the first faculty hire. He collaborates with Bringsjord on war-gaming work. Assistant Professor Brett Fajen also joined the faculty in 2001. His expertise is in perception and action, dynamical systems modeling, and virtual environments.

Professors Wayne Gray and Ron Sun brought their expertise in computational cognitive modeling to the department. The newest faculty addition is Assistant Professor Nick Cassimatis, who had been working at the Naval Research Laboratory's AI Center to improve the conversational abilities of robots.

Members of Rensselaer's Cognitive Science Department conduct research in next-generation AI, next-generation computational cognitive modeling, and cognitive engineering.

Many projects involve aspects of all three research areas.

AI Systems That Can Pass IQ Tests

A cognitive system — human or artificial — can perceive information in the environment, analyze that information, and act upon it, according to Bringsjord, who directs the Rensselaer Artificial Intelligence and Reasoning (RAIR) Laboratory. Bringsjord argues in favor of the term "Psychometric Artificial Intelligence," which is taken from psychometrics, the science of measuring and testing psychological properties. Under this definition, an artificial agent is intelligent only if it excels at all established, validated tests of intelligence.

Bringsjord led the team that developed PERI (Psychometric Experimental Robotic Intelligence), a 3-foot tall robot with a vision system and a dexterous manipulator. The AI used in PERI is based on logic instead of on patterns, mathematics, and numerical computing. Using these talents, PERI became the first robot to pass part of an IQ test. The robot achieved a perfect score on a section of the Wechsler Adult Intelligence Scale-Revised, a timed test in which colored blocks are arranged to match card designs.

At present, Bringsjord's team is working to help PERI pass two harder sections of the IQ test. In one, examinees are given pieces of an object. They must figure out what it is and put the pieces together. In the other, examinees are given a group of snapshots of people, and they must assemble the pieces to make a coherent story.

Bringsjord, who is a consultant to gaming, multimedia, and e-learning companies, has also built Brutus, a creative AI system that can write short stories of up to 500 words based on the concepts of betrayal, deception, and evil.

RAIR lab researchers are interested in the entire concept of advanced synthetic characters, whether they appear as robots or as characters in the advanced computer games developed in the RAIR lab. At present, the group is working on "E," an evil character who is very good at lying.

Bringsjord and Research Professor Konstantine Arkoudas are funded by the Defense Advanced Research Projects Agency (DARPA) to build an intelligent system that can learn by reading. The system will be based on MARMML (Multi-Agent Reasoning and Mental Metalogic), which was developed by Bringsjord and others in earlier work.

Unlike current systems, the intelligent machine envisioned by Bringsjord and Arkoudas would be able to read about a new topic and create mental models of the material, to weave the new knowledge with what it already knows, and to understand context issues such as who wrote the article and why. It would also be able to make inferences from the material and to communicate about the topic in English. Finally, it would be able to work cooperatively as part of a team of machines.

Cassimatis, who works on integrated models of language and physical reasoning, says most people don't realize how many aspects there are to human conversation. The ear records sound waves, and the brain knows what syllables they represent. The mind understands how the words fit together linguistically. The listener fits the new information into what is already known and, at the same time, gets into the speaker's mind, reaching conclusions about what the speaker is trying to say. All of these processes are currently modeled using different computational techniques. He is working to integrate those processes to simulate the process humans perform naturally and instantaneously.

Cognitive Engineering: "Milliseconds Matter"

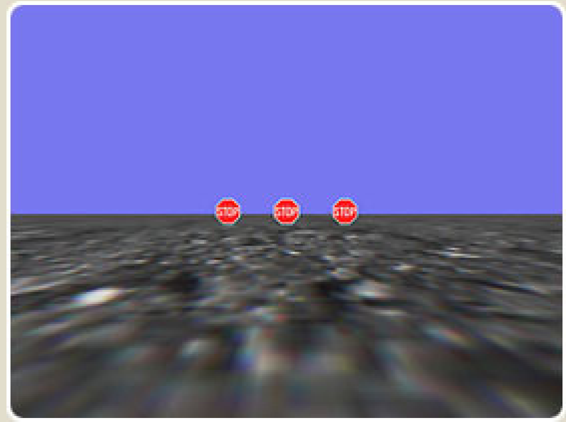
The Cognitive Science Department is positioned directly between theoretical work and applied problems. Knowledge of cognitive systems contributes to solving real problems, while knowledge gained from solving the problems constantly tests and improves the theories. Many of the research programs in the department involve cognitive engineering, designing smooth interfaces between humans and machines.

Gray, for example, has put his models to work in a number of practical studies, including attempting to locate enemy submarines hiding in deep water and developing intelligent tutors. In a contract with the Air Force Office of Scientific Research, he is studying how radar operators decide which blips on the screen pose the most serious threats.

One side of a computer screen displays the numbered blips. On the other side, the test subjects can call up boxes with information on specific blips. Creating and reading the boxes takes time, and operators subconsciously make least-effort tradeoffs.

With the motto "milliseconds matter," Gray has shown that knowledge acquisition costs measured in 100s of milliseconds may lead people to rely on error-prone memory rather than shift attention and eyes to a nearby position.

To combat terrorism, intelligence agencies must come up with newer, faster, and more efficient ways of extracting vital information from the vast amount of digital data that is available on the Web and in specialized networks. Gray and Bringsjord are part of a federally funded team that is working on this problem.



Screenshot from one of the simulated environments used in the driving lab.

Much of Rensselaer's role is to create cognitive models, or "simulated cyborgs," to rapidly evaluate different combinations of next-generation technological tools. The cyborgs will show what types of technology work best for a given assignment.

Gray and Qiang Ji, assistant professor of electrical, computer, and systems engineering, are funded by the ONR to develop a system that can offer extra help to humans when they need it. Ji engineers highly sophisticated computer-imaging systems that can study a human face and analyze the size and shape of such features as the eyes and the mouth to warn, for example, that the human is too tired to continue driving.

Image from the virtual reality lab shows one of the virtual environments that Rensselaer cognitive science researchers are using to study interceptive action.

In this project, Ji is developing methods to warn when the human at the computer is confused, and Gray will determine at what point in the reasoning process the problem has occurred. They will then develop AI tools to intervene by such actions as changing the software environment or highlighting pertinent data on the screen.

Fajen has support from the National Science Foundation to study visual perception and the control of braking. As part of this work, he places human subjects in front of a projection screen and monitors their use of a joystick as they react to images such as stop signs. His goals are both to find methods to improve traffic safety and to better understand how people learn to improve their performance.

Michael Kalsher, associate professor of cognitive science, looks at issues that impact the effectiveness of warning labels. A member of the American Natural Standards Institute committee that sets the rules for these warnings, he says warnings must be understandable to the target audience, and they have to communicate a strong message that people will remember and be motivated to obey.

Kalsher also collaborates with scientists at the Aberdeen Army Research Lab on the use of laptops and other technology to improve communication in noisy environments like tanks and helicopters, where seconds can make a difference between life and death.

A Long, Long Road

Bringsjord says that despite all the work being done, researchers are still a long, long way from building artificial systems that can think, converse, and act like humans.

There are currently some robots that might be compared to lower-level animals such as insects or rodents, he says. Some versions, for example, can move well through an environment, replicating the motions of grasshoppers. If there is a sudden, unexpected change in the environment, however, the grasshopper will adapt and outperform the robot.

But such physical maneuvers are not what distinguishes humans, he adds. Humans can use cognitive models to achieve the results they want. If a man wants to jump farther, he can figure out how to train to improve his performance. That is far beyond what a grasshopper can do, let alone a robot. As for conversation, that is a very difficult application, he says.

Cassimatis compares the development of robots that can converse naturally to a 100-mile foot race. “We’re a lot farther along than we were 10 or 20 years ago,” he says. “We’ve covered 15 miles, which was hard, but we still have 85 to go.”

Every day in their laboratories, Rensselaer researchers are making strides down that long, long road.