Doctoral student studies how to evolve artificial brains

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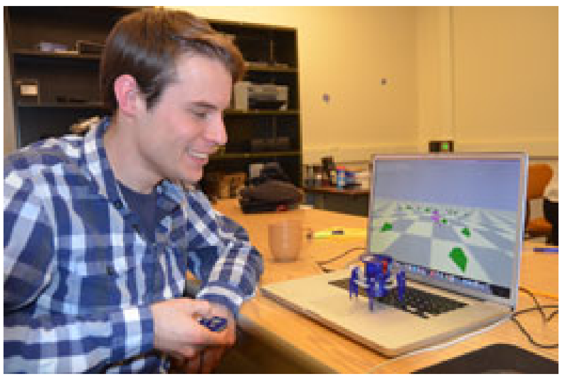

Joost Huizinga, a doctoral student from VU University Amsterdam in the Netherlands, observes a robot spider near his keyboard while his "spider bot" creation moves on his computer screen. Huizinga is working to create a model in which an artificial computer brain can think and act more like an animal or human. Credit: UW Photo

Joost Huizinga watches the six-legged "spider bot" he created scuttle across his computer screen.

At first, it wobbles and walks unsteadily as it attempts to gobble up green-shaped pyramids that denote food. The artificial arachnid makes a few successful attempts, enveloping a few pyramids and making them disappear. But, after a short time in its pursuit of food, the spider loses its balance, ends up on its back and flails about.

"It's an unevolved spider," says Huizinga, with a shake of his head. "It falls on its back and is helpless as a turtle. It definitely has to (learn to) walk first."

Huizinga, a doctoral student from VU University Amsterdam in the Netherlands, came to the University of Wyoming in January to conduct research with Jeff Clune, a UW associate professor in the Department of Computer Science. Huizinga is researching how to evolve computer brains in ways that are more similar to how animal brains are organized. Specifically, he is working to figure out how evolution produced key properties in the wiring of animal brains – namely, why animals (including humans) evolved to have brains that are regular, hierarchically and modularly organized.

"The goal of my research is to look at modularity and regularity," says Huizinga in the UW Engineering Building's Evolving Artificial Intelligence Laboratory. "Both have been researched separately. My goal is to combine them."

Modularity means that the brain is composed of innate, neural structures or modules that have distinct, established evolutionarily developed functions. Regularity refers to patterns in the brain that are repeated. Huizinga wants his model to mimic both.

Improving Intuitiveness

In most research using computer or artificial brains, the neural network is created to accomplish one task and solves it in "a very entangled way," Huizinga says.

"Everything (in the computer brain) is associated at the same time," he explains. "If you want it to recognize a striped cube, it processes 'striped' and 'cube.' It cannot distinguish 'cube.' If you give it a speckled cube, it doesn't recognize that it's a cube."

To correct that jumbled thought process, Huizinga continues to work on a model in which the artificial brain has modules, meaning the brain is divided more closely in a way that resembles how the brain of a human or animal functions. So, in the example of the striped cube, there will be separate modules to recognize both the pattern and the cube, respectively.

"That way, when the model has a speckled cube, it already knows what a cube is and then can distinguish the color pattern," Huizinga says. "Having a module allows you to have a function at a certain position or place in the brain."

To create that modularity, Huizinga applies "connection costs" to the artificial brain. In short, the artificial brain is penalized for very long connections that string from the far left side of the brain to the far right. Keeping connections shorter makes it easier to create more modules in an artificial brain and, as a result, allows for more functions, he says.

"When we select those who will survive and who will not make it to the next generation, we will look at those connection costs and their performance on the actual tasks," he says.

Regularity in the model will develop through the artificial DNA used in the program. To produce this regularity, he uses DNA that has far fewer genes than there are connections and neurons in the brain. As a result, information has to be reused, creating regular patterns.

"What we define as DNA, in this case, is basically a code on how to construct a human or animal brain," Huizinga says.

Huizinga sees robots playing a bigger role in the future. At the most basic level, he envisions robots designed to collect trash over all kinds of terrain. At a more advanced level, robots could be used for search-and-rescue missions of stranded hikers in the Laramie Range, he says.

"Because we have this modularity, we can build upon those modules and evolve this singular (artificial) brain, and evolve it to be more complex over time," he says. "Eventually, the robot would have more autonomy."

He surmised such autonomy would be essential in future space exploration of the moon or on Mars, for example. Huizinga points out the small exploration rovers NASA used on Mars, beginning in 2003, had, at times, difficulty navigating uneven terrain. In one instance, the rover called "Spirit" became stuck in a soft, sandy area. In other incidents, both "Spirit" and "Opportunity" experienced limited solar power, rendering them both nearly inoperative, during raging dust storms.

"They (rovers) often fail because they are missing the awareness we do find in higher-level animals," Huizinga says.

"Compare where animals can tread versus where out robots can go," Clune says. "Animals soar in the skies, climb through dense forest canopies, scale mountains, run over rugged terrain, burrow through the earth and swim in turbulent water. Our robots can barely walk around on a perfectly flat floor."

He continues, "Also, consider the range of behaviors that animals can perform (finding food, making nests, chasing and avoiding being chased, etc.) If we want robots that can put out forest fires, find survivors after a natural disaster, or just to clean our houses, we need them to exhibit the agility and amazing learning capabilities of natural animals."

Parallel Performance

To improve the functionality of his model, and ultimately his spider bot, Huizinga runs his program through Mount Moran, UW's high-performance computing cluster nicknamed after a mountain peak in western Wyoming's Tetons.

Mount Moran enables atmospheric and earth sciences faculty—who will be able to use the NCAR-Wyoming Supercomputing Center (NWSC)—to learn what to expect with their software. The cluster provides the opportunity for that group of faculty to work out issues caused by scaling up parallel algorithms from tens or hundreds of processors to thousands of processors, before moving up to tens of thousands of processors on the NWSC.

The cluster also provides a research resource for any UW research faculty member—such as bioinformaticists, social scientists, pure mathematicians and theoretical physicists—who have a complex problem or whose research doesn't fall within the scope of the NWSC.

Additionally, UW students are welcome to use the high-performance computing center for their work, which is often in concert with UW faculty.

"Joost, himself, has likely already used thousands of hours of computing on Mount Moran," Clune says. "My guess is that he is probably one of the top users of Mount Moran since its inception."

Initially, Huizinga explored whether there were any doctoral positions in his field at VU University of Amsterdam. A few months later, Huizinga says his faculty adviser, Everet Haasdijk, who is friends with Clune, wrote Huizinga a letter of recommendation.

"I actually applied to work with Dr. Clune first, and then applied to UW," Huizinga says.

Working with Clune, Huizinga says he has learned to present his research in a more forward manner than he experienced with his professors in the Netherlands.

"He has a mastery of both his conceptual issues in our field and he is technically gifted, allowing him to quickly code up any experimental idea we have in order to test it," Clune says of Huizinga. "He is passionate about the ideas we are investigating and, in less than a year, has produced interesting results that we are currently writing up for publication."

"I do know that I want to stay in academia, so I want to go into research or go for a post-doctoral degree," Huizinga says. "I haven't decided whether to stay in the U.S. or go to the Netherlands."

Huizinga glances briefly at his spider bot on the computer screen and mentions it not only has to learn to obtain food, but learn how to avoid predators, too. Of course, after it learns to walk.

"Humans' (brains) are the end goal," Huizinga says of his research. "At this moment, if we could have (artificial) cheetah brains, we'd be very happy. Right now, we're slightly above a fly."

Provided by University of Wyoming