INFUSION

Innovations from the NASA CICT Program

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Computing, Information, and Communications Technology Program

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If I Only Had a Brain—Modeling AI for Robots

- **The KIV (K-4) brain model enables computers to simulate how the brain orients the body in space and navigates toward a destination**
- **May enable robots to adapt to changing environments**

Many neurobiologists today think that brain activity is chaotic wave energy, governed by nonlinear dynamics. CICT-funded researchers are using this nonlinear dynamics approach to model how the brain orients the body in space and uses positive and negative reinforcement from the environment to autonomously navigate to a destination. The goal is to enable robots to do the same on future NASA missions.

This research is being funded by CICT's Information Technology Strategic Research (ITSR) Project, and supervised by Benny Toomarian, manager of ITSR's Revolutionary Computing Algorithms (RCA) subproject. The principal investigator is Robert Kozma, professor of computer science at Memphis University, who is collaborating with Walter J. Freeman, professor of neurobiology at UC Berkeley, and their respective colleagues.

Revolutionary computing for space
"The RCA subproject," says Toomarian, "is developing new computing methodologies and models to advance the capabilities of future spacecraft, while meeting NASA's requirements for high speed, low mass, and low power consumption. Our Bio-inspired Computing element, which includes Robert Kozma's research, is investigating neural networks, genetic algorithms, and cognitive science to discover biologically inspired methods of storing information and performing computations."

Modeling self-organizing behavior
Robert Kozma says, "We're exploring and developing models of self-organizing behavior in biological and artificial organisms. To do so, we're combining insights from artificial intelligence, cognitive science, and neuroethology, which is the study of the brain's behavior patterns. We're specifically exploring the role that chaotic dynamics may play in self-organizing behavior."

Kozma's colleague, Walter Freeman, first observed chaotic dynamics while researching how rabbits perceive their environment through the olfactory, or smelling, sense. He and his colleague in that study, Christine Skarda, concluded that the normal background activity of neural systems is chaotic.

Making sense from chaos
Kozma and Freeman believe that the vertebrate brain uses chaotic, or aperiodic, dynamics to self-organize patterns of

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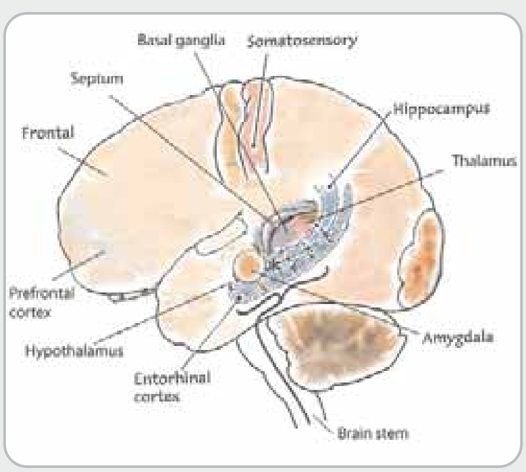

CICT researchers have developed the KIV architecture to model the brain's limbic system (left), the simplest neurological structure capable of acting intentionally. The model could help future NASA robots do the same.
Above: Mars Exploration Rover 2004

Technology Spotlight

Technology
KIV (K-4) brain model for self-organizing dynamically adaptable systems (SODAS)

Function
Can be used to design software agents that enable robots to intentionally adapt to a changing environment in order to accomplish science goals

Relevant Missions
- Exploration Systems Mission Directorate robotic missions

Features
- Integrates multiple sensory inputs for decision-making and action by the model's "amygdala"
- Produces aperiodic dynamics for use in perceptual, memory and behavior-producing systems
- Operates through continual sequences of phase transitions of 4-5 per second

Benefits
- Enables researchers to develop intentional software agents for robots
- Integrates the what, where, why, and how required for decision making
- Operates robustly in remote and/or hazardous environments

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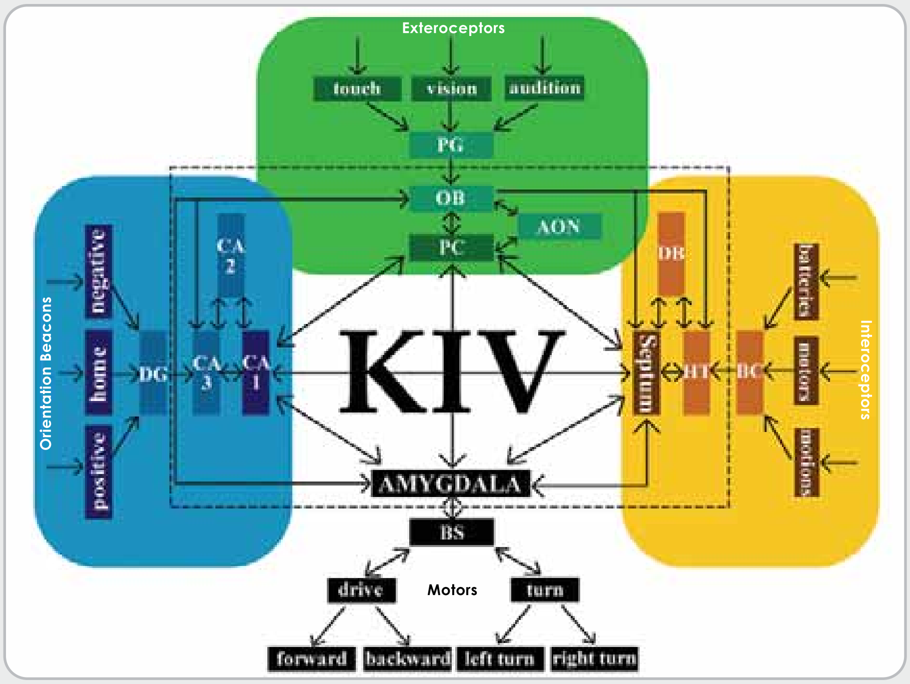
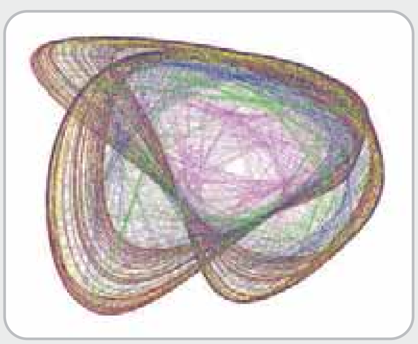


The KIV architecture (above) models the brain's limbic system. PG=periglomerular; OB=olfactory bulb; AON=anterior olfactory nucleus; PC=prepyriform cortex; HF=hippocampal formation; DG=dentate gyrus; CA1, CA2, CA3=curnu ammonis sections of the hippocampus; BG=basal ganglia; BS=brain stem; HT=hypothalamus; DB=diagonal band.

meaning and memory. The brain is usually in a high-dimensional, disorderly "basal" state, and then, four or five times a second, it instantly organizes itself to recognize something familiar, or to make a decision. These are the brain's phase transitions from a chaotic state to an attractor. An attractor is an area in which a chaotic system's seemingly random "trajectories" cluster together—for example, the hippocampus or cortex in the brain (see illustration below). Phase transitions and attractors in one area



This KIV-generated graphic shows how the brain transitions between chaotic states and the attractor 'wings' or lobes seen here.

of the brain affect attractors in other areas to produce intentional behavior. Kozma and Freeman have emulated these dynamics in their model of the vertebrate brain, "KIV."

KIV models the brain's limbic system

KIV models the brain's limbic system (see illustration, page one), which neurobiologists consider the simplest neurological structure capable of intentional behavior. KIV models the "what" (perception), "where" (memory/mapping), "why" (goals/values), and "how" (motor skills) that are needed to act intentionally. KIV has been shown to successfully exhibit the same properties as human brain signals displayed on electroencephalographs.

Designing intentional software agents

Freeman has defined intentional behavior as "an act of observation through time and space, by which information is sought for the guidance of future action." Intentionality consists of the neurodynamics that make this possible. By simulating these neurodynamics, KIV enables researchers to design software agents that act intentionally in an inherently self-consistent manner—even in a continuously changing environment that contains some noise and anomalous behavior.

Robots with KIV learn to navigate

Kozma says, "At NASA Jet Propulsion Lab, we collaborated with robot experts to successfully run our KIV Amygdala model in a 2-D computer simulation of a rocky Martian landscape. We've also successfully tested KIV on an actual mobile robot called EMMA."

EMMA uses the body and sensory signals of SONY's robot dog AIBO, but its control system has been replaced by KIV. EMMA uses a video camera and infrared distance sensors to detect obstacles in its environment.

In published articles, Kozma and Freeman explain how EMMA with KIV used positive and negative reinforcement to learn the most effective path to a goal, and used habituation to reduce the distraction of ambient noise and other irrelevant sensory inputs.

What's next?

"We have shown that KIV can autonomously navigate in a changing environment," says Kozma. "We will continue to define KIV's operational parameters for different tasks and platforms, with the goal of implementing it on a NASA robot, such as a Mars rover."

–Larry Laufenberg

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