INCubator

UCSD

INC completes move to new building

The INC recently completed the move into the East Expansion Building of the San Diego Supercomputer Center (SDSC). The SDSC building expansion was dedicated on October 14, 2008. The SDSC is located on the north side of the UC-San Diego campus and contains office space as well as a large machine room which houses the Center's compute and data resources.

The INC now occupies the entire B1 level floor. The South wing of B1 serves the Poizner Lab, Machine Perception Lab (MPL), Data-Intensive Computing Environments Lab (DICE), and core faculty and staff, whereas the North wing houses the Swartz Center.

The East Expansion Building of the San Diego Supercomputer Center

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MESSAGE FROM THE DIRECTORS

On the eve of its 20th anniversary, INC is continuing to embark on the exciting journey at the crossroads of computational neuroscience, translational neuroengineering, brain-machine interfaces, and computational intelligence in humans and machines.

This past year has been transformative for INC. We have completed our move in the East Annex Building of the San Diego Supercomputer Center which now serves as a home base and central focus for INC's members and a catalyst (incubator!) for cross-discipinary collaborative research. This year again, INC has experienced double digit growth in its research operations, owing to our highly dynamic team of principal INC investigators that continue to bring tremendous advances in research across all facets of neural computation.

We also teamed with the UCSD Institute of Engineering in Medicine to offer a new Neuroengineering Seminar Series, which will be the first such forum connecting the neuroscience and bioengineering communities on campus. To further catalyze the interactions between INC's core investigators and the campus-wide research community, we are also introducing a new bi-weekly Chalk Talk series featuring informal presentations and interactive brainstorming sessions on new research directions and opportunities for collaborative research. More details are on our web site, http://inc.ucsd.edu.

We hope you enjoy the samples of INC's research news in this newsletter, and consider taking advantage of the several opportunities offered by INC for you to participate and get involved. We also welcome you to join as we celebrate 20 years of INC at the INC Open House this coming Spring.

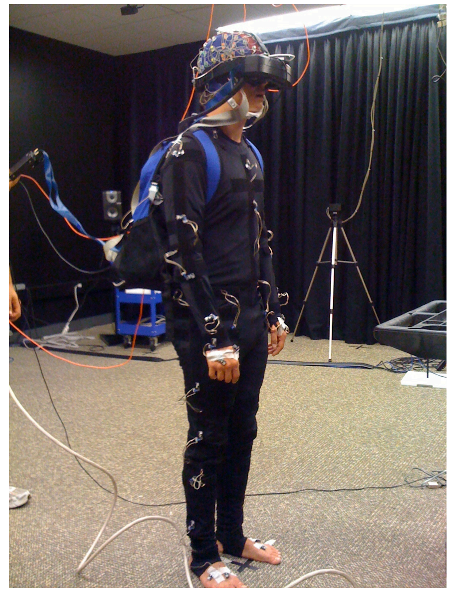
Stay tuned as we take off for a new chapter in the history of INC.

Terrence Sejnowski and Gert Cauwenberghs
Co-Directors

Lab profile: Howard Poizner

A critical need in neuroscience is to develop methods that can handle the high-dimensional world. Under a $1 million equipment grant from the Office of Naval Research, Howard Poizner and his lab are beginning to solve this problem. The Poizner Lab is in the final stages of development of an integrated system for simultaneous recording of limb, body, head and eye movements and electroencephalographic (EEG) signals, while subjects move and interact in 3D immersive, virtual environments. "This is the first facility of its type to provide these capabilities, and enables the fine-grained study of changes in motor behavior, information-seeking behavior (eye movements) and brain responses during learning that involves action," said Poizner. The subject wears a Head-Mounted Display that provides stereovision in the virtual environment, and with an embedded eye tracker, tracks the subject's eye movements in that virtual environment. The virtual environment can be programmed to change depending upon where the subject is looking. A 64 channel EEG system that the subject is wearing simultaneously records the subject's EEG. The subject can grasp robotic devices that provide touch and force

Subject wearing the EEG cap, head-mounted display and body suit with camera-tracking LEDs.



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INC at a glance

Institute for Neural Computation (INC)
http://www.inc.ucsd.edu
Terrence Sejnowski and Gert Cauwenberghs, Co-Directors
Shelley Marquez, Executive Director

Swartz Center for Computational Neuroscience at INC
http://www.sccn.ucsd.edu
Scott Makeig and Tzyy-Ping Jung, Co-Directors

Machine Perception Laboratory at INC
http://mplab.ucsd.edu/
Javier Movellan, Marian Stewart Bartlett, and Glen Littlewort, Principal Investigators

Temporal Dynamics of Learning Center (TDLC) Motion Capture/Brain Dynamics Facility at INC
http://tdlc.ucsd.edu/mocap/
Howard Poizner and Scott Makeig, Co-Directors

Mobile Brain Imaging Laboratory (MoBI) at INC
Scott Makeig, Principal Investigator

Poizner Laboratry at INC
http://inc2.ucsd.edu/poizner/
Howard Poizner, Principal Investigator

Dynamics of Motor Behavior Laboratory at INC
http://pelican.ucsd.edu/~peter/
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'Reach for Tomorrow' at CALIT2's Machine Perception Lab

The students were participants in the nationwide Reach for Tomorrow (RFT) program, a non-profit organization that motivates teens and pre-teens in grades 7 through 10 in selected public and charter schools to perform to their highest potential. RFT's strategy stems from the notion that pre-high school years are critical years in a young person's life and frequently determine their subsequent academic and career opportunities. Chairman and founder Peter K. Underwood describes the typical RFT student as a "middle of the bell curve, average student who has the capacity to do better."

Since its inception in 1993, RFT has partnered with numerous foundations, corporations, universities and other institutions to sponsor its Summer Program, a week-long excursion (this year, to UC San Diego) that exposes students to state-of-the-art technology and scientific innovation at no cost to the student. The RFT program at UCSD is sponsored by the Temporal Dynamics of Learning Center, which is funded by the National Science Foundation's Science of Learning Centers.

It doesn't get much more state-of-the-art than the Einstein Robot, a head-and-shoulders automaton complete with a bushy mustache. As part of their tour of the lab, the RFT students were able to interact with the robot and even touch a piece of its skin — a material called "Frubber" that is specially designed to resemble human flesh. A product of the MP Lab, the robot recognizes a number of human facial expressions and can respond accordingly. Scientists consider it an unparalleled tool for understanding how both robots and humans perceive emotion, as well as a potential platform for teaching, entertainment, fine arts and even cognitive therapy.

Students in the Reach for Tomorrow program interact with the Machine Perception Lab's "facial remote control," while assisted by Principal Investigator Marian Bartlett.

The Einstein Robot was a big hit during the Reach for Tomorrow tour of the Machine Perception Lab at Calit2.

Students also got a look at RUBI, a robot tutor equipped with an Intelligent Tutoring System that teaches pre-school children colors, shapes, and even vocabulary words. The general consensus was that RUBI (which required only $200 to make, plus the cost of a laptop) seemed "more like a toy" and thus, friendlier than hyper-realistic Einstein (who snarled and made a face when one student got too close).

The students were also invited to interact with a suite of computer games developed in the MP Lab, including a custom-designed memory game designed for people with autism to help them recognize and understand facial expressions.

Full article available at:

http://ucsdnews.ucsd.edu/newsrel/general/07-09RFT.asp

Lab Profile: Howard Poizner (continued)

The virtual environment for the subject to interact with.

feedback so that the subject "feels" virtual objects; 20 speakers provide 3D auditory stimulation; and while the subject is moving, 24 optoelectronic cameras are tracking his 3D limb and body movements from every angle and representing his movements in real time as those of a computer avatar moving in the virtual environment. The figure above (inset) shows a subject wearing an EEG cap, a Head-Mounted Display, and a body suit with LEDs that the cameras are tracking. The main portion of the figure shows a birds-eye view of the subject represented as a computer avatar standing in a virtual town. The subject is mobile and free to explore the virtual town. Virtual environments allow powerful experimental control over the environment: Buildings can be altered or removed to examine brain responses to novel situations after spatial learning, or the feedback of a subject's own movements can be altered to study how the subject adapts behaviorally and neurally to novel sensorimotor environments.

Working with Dr. Tom Liu, Director of UCSD's Functional Magnetic Imaging Resonance (FMRI) Center, Dr. Poizner will be adding capabilities for presentation of virtual environments, motion capture, and simultaneous recording of EEG during fMRI experiments. Such capabilities will allow us to gain a detailed view of the temporal dynamics of neural activity within brain regions that have been identified as active by fMRI, and to associate this neural activity with detailed characteristics of the subject's behavior.

Dr. Poizner has recently been informed that he will receive a $4.5 million multidisciplinary grant from the Office of Naval Research to use the system he has developed to study the rich representations the cortex creates during learning that is self-supervised and without explicit feedback or reinforcement. The grant involves a collaboration of researchers from UCSD, the Salk Institute and UC Irvine to study unsupervised learning from the neurobiological to the behavioral levels. These studies, using the one-of-a-kind facilities developed under the ONR equipment grant, should refine our understanding of the neural and behavioral mechanisms underlying action in our high dimensional world.

Excerpts from an Interview between Terrence Sejnowski and the DANA Foundation

Q&A with TERRENCE J. SEJNOWSKI, Ph.D.
Institute of Neural Computation, University of California, San Diego
Computational Neurobiology Laboratory and Howard Hughes Medical Institute, Salk Institute for Biological Sciences
Member, Dana Alliance for Brain Initiatives

Q: You recently co-authored a review paper for Science entitled "Foundations for a New Science of Learning." What do you mean by "new science of learning?"

A: The new science of learning describes an emerging discipline that is applying sophisticated computational models to more traditional approaches to understanding learning, with the ultimate goal of improving educational practice.

There has been a real convergence of a very powerful body of mathematics and theories inspired by psychology. Initially developed to solve engineering problems, the convergence of the two fields was then applied to understanding biological mechanisms in human brain. That's what we mean by the new science of learning. I think this is one of the great success stories in all of neuroscience and engineering over the last decade.

Q: When we talk about "machine learning," it's easy to envision how engineering advances have contributed, but what role is neuroscience playing?

A: Neuroscience has inspired some of the most effective learning algorithms in machine learning. One of the most exciting of these approaches is reinforcement learning, a thriving field that emerged from developing computational models of classical conditioning. It describes the process by which an individual learns to predict which actions it must take to maximize reward in a given environmental situation. This field has flourished both as an engineering discipline and as a way to interpret biological data.

One of the milestones in the convergence of these fields occurred about 15 years ago, when two post-doctoral students in my lab, Peter Dayan, Ph.D., and Read Montague, Ph.D., used an algorithm called temporal differences – a mathematical method for predicting future rewards in reinforcement learning – to try to understand how honeybees learn to forage. They were specifically interested in the roles played by a type of neuron in the bee brain that links odor processing to reward. Using this algorithm, they were able to very accurately model honeybee foraging and explained risk aversion in bees, a behavioral phenomenon in which uncertain food sources are avoided in favor of a lower amount of payoff that is steady and predictable. That was the first model of a neurobiological system based on temporal difference learning.

We then realized that we could also apply this method to dopamine neurons in mammals in order to understand the reward-learning system, which is the system that guides behavior in all vertebrates and is hijacked by drugs of addiction like cocaine or alcohol. The very same algorithm for temporal differences turned out to be the key to understanding the properties of dopamine neurons, which were discovered by Wolfram Schultz, M.D., Ph.D., and how they contribute to behavior. This is an example of how understanding something about a biological system that is a fundamental driver of

Excepts from an Interview with Terrence Sejnowski (cont.)

human behavior was aided by a theory from engineering.

Q: In what ways has the study of how children learn been used to solve engineering problems?

A: Children's brains are still developing and we need to understand how that helps them to learn. Engineers, having seen that imitation is highly effective in humans, combined imitation learning with reinforcement learning to boost the performance of control systems. In apprenticeship learning, for example, a powerful computer tracks the actions of an expert human controlling a complex system, and then programs the reinforcement system to imitate and learn the very complex motor commands that the human makes. Engineers are now able to reproduce human skills that were previously thought beyond the reach of machines. For example, Andrew Ng, Ph.D., at Stanford has used apprenticeship learning with reinforcement to automatically control helicopters that do stunts like flying upside down.

Q: How is this kind of reinforcement learning in machines being applied to childhood education?

A: What is emerging out of this is a new generation of robots that interact with humans on their own terms. We call them social robots. Javier Movellan, Ph.D., at the University of California, San Diego's Institute for Neural Computation is building social robots that interact with 18-month-old toddlers in the Early Child Education Center on campus. The current prototype is called "Rubi."

The goal of this research program is to try to understand what gets the attention of toddlers. At that age, they are extremely distractible and it's hard to hold their attention, so a lot of the teachers' time is spent just keeping track of the children, making sure they don't do any harm as they run around and interact with each other. The social robots are an experiment to see what it would take for a child that age to be able to interact with the robots and whether or not they would learn from them.

Q: What are the next steps in this research?

A: What has been shown to date is a proof of the principle that it is possible to create robots that engage in social interactions with human beings, at least at the preschool age. Now the really important work begins, which is how to use that rapport to help the child learn and understand new concepts – in short, to perform individualized educational instruction. Social interactions will be absolutely critical to achieving that goal.

The possibilities are staggering. Using machine learning, this robot will be able to record every answer that the child gives and track it over time to determine what the child has mastered and what he or she is having trouble with. It will then be able to craft a teaching schedule that is optimal for that child. In this way, the robot is essentially creating an individualized curriculum based on all the information about that child that is being fed into the robot's internal model of the child.

Q: Is there resistance to the idea of children being taught by robots?

A: In our experience, the children who have interacted with Rubi love her. The teachers find Rubi to be a helpful assistant. It may be that not every child will work well with a social robot, or you may need to individualize the form of the robot to the child. But these three fundamental principles that have been identified so far – shared attention, social imitation, and empathy – seem to be critical for getting young children to respond and be open to learning. As the child matures, there will likely be additional things that will be needed, such as attention to motivational issues. The task is likely to get considerably more complicated as we start developing these kinds of applications for older children, but based on the popularity of computer games among

Excepts from an Interview with Terrence Sejnowski (cont.)

children, we think the possibilities for such applications are enormous.

Q: Why are the social aspects of these robots seemingly so critical to their success?

A: Learning is gated by social interaction. It's clear, for example, from work by a group at the University of Washington at Seattle lead by Patricia Kuhl, Ph.D., that learning languages is gated by the interaction between the mother (or nanny) and child. She has shown that a Chinese-speaking nanny is able to teach a child some sounds in Chinese, but if you play a video of that same nanny to another child, the child doesn't learn the sounds. So unless you have a human being actually there interacting with the child, the learning does not take place. Yet, so long as a robot passes these tests of interaction and the child's brain is socially engaged – which involves a lot of things, including facial expressions that one might not be consciously aware of – then magic happens and learning occurs. When these social cues are missing, everything falls flat.

This is true for the teacher as well as for the student. I once taped a lecture for a class. I thought it would be easy, but it turned out to be one of the most difficult teaching experiences I ever had. I knew how bad it was going to be when I told my first joke and no one laughed. As humans we need that social feedback. If you don't get it, you have no idea what is getting through. Teaching is all about getting that feedback and adjusting things accordingly. It's a two-way street; it's just as essential that the teacher gets feedback from the child as it is that the child gets feedback from the teacher.

Read more: Meltzoff AN, Kuhl PK, Movellan J, Sejnowski TJ. Foundations for a new science of learning. *Science* 2009 July 19; 325(5938):284-288.

Full article available at: http://www.dana.org/media/detail.aspx?id=23284

Seminars and Upcoming Events and Announcements

INC Chalk Talk Series

- Biweekly meetings starting February 4 on Thursdays, noon-1pm at the INC headquarters in SDSC.
- Each meeting will feature one of the core of affiliated labs/groups, with informal presentation of late-breaking research and new research directions.

Joint INC/IEM Neuroengineering Seminar Series

- Jan. 15, 2010, Bin He, University of Minnesota, *"Spatio-temporal Functional Neuroimaging of Brain Activity"*
- Feb. 5, 2010, Irina Rish, IBM, *"Mind Reading: Interpretable Predictive Modeling of Mental States from fMRI Data"*

TDLC All-Hands Meeting -- January 22, 2010

Swartz Center and INC Open House Demonstrations -- Save the date! March 4, 2010

Congratulations! Awards, Grants, and Honors

Matthew Leonard, Graduate Student

- completed Master's research including training in neuroimaging and theories on language acquisition

Michael A. Pitts, Post-Doc

- received training in EEG/ERP methods through work with Dr. Steven Hillyard and in fMRI methods through work with Dr. James Brewer