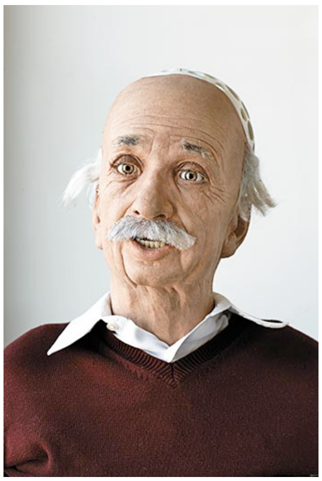
INCubator

Cognitive Robots



Wearing a shock of white hair and a familiar mustache, Albert Einstein ran through a variety of expressions. But this was not the renowned scientist, but a robot head and neck consisting of 27 motors and a bundle of wires all coordinated to display lifelike expressions. Its lips purse. Its brow furrows. Its eyes widen as though in horror, then scrunch mirthfully as it flashes a grin.

Einstein is the product of a remarkable collaboration. Hanson, a robot designer and the founder of the Dallas-based firm Hanson Robotics, has used classical sculpting techniques to animate robotic likenesses of more than a dozen people. Movellan, a psychologist and software pioneer who runs UCSD's Machine Perception Laboratory, develops technology that approximates human senses. Einstein is, at

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ARTICLES INSIDE:

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) Mobile Brain Imaging Laboratory (MoBI) at INC
http://tdlc.ucsd.edu/mocap/
Howard Poizner and Scott Makeig, Co-Directors

Corporate Relations and Industrial Partnership Program:
Shelley Marquez <smarquez@ucsd.edu>

International Exchange Scholar Program:
Tzyy-Ping Jung <jung@sccn.ucsd.edu>

Newsletter Editor:
Theodore Yu <teyu@sccn.ucsd.edu>

Webmaster and Information Technology:
Luis Palacios <lpalacio@crl.ucsd.edu>

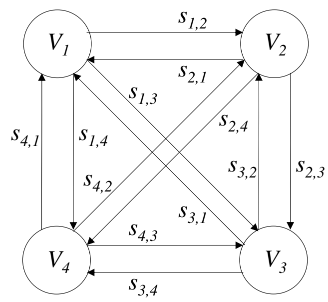
For general inquiries, contact:
Luisa Flores <m2flores@ucsd.edu>

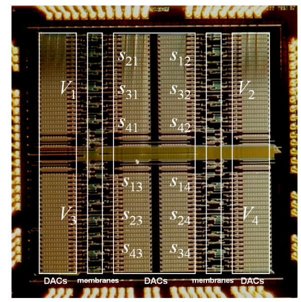
Lab profile: Gert Cauwenberghs

The Integrated Systems Neuro Laboratory (also known as the Cauwenberghs lab) is moving to Bioengineering! We are now located on the third floor of the Powell-Focht Bioengineering Hall. Research in our laboratory focuses on cross-cutting advances at the interface between in vivo and in silico neural information processing.

The aims of our research are threefold: to empower silicon integrated circuits with adaptive intelligence inspired by information processing in nervous systems; to facilitate advances in computational neuroscience by extending the size and complexity of neuronal networks emulated in silicon to the scale of the human brain; and to interface neurons with silicon--and brains with machines---to study the nervous system in vivo, remediate loss of neural and sensory/motor function, and extend the communication reach of the human mind.

Connectivity diagram (left) and chip micrograph (right) of the recently designed NeuroDyn system. The chip contains 4 Hodgkin-Huxley neurons all fully connected through 12 conductance-based synapses, where all of the parameters defining the conductances, reversal potentials, and voltage-dependence of the channel-kinetics are full programmable. (Yu and Cauwenberghs 2009)





Our approach combines analysis (neuroscience) and synthesis (neuroengineering) techniques that span bioinstrumentation, neuromorphic engineering, computational and systems neuroscience, and learning and intelligent systems. Our research activities include the design and implementation of very large scale integrated (VLSI) circuits fabricated in silicon and emerging technologies.

We pioneered the design and implementation of highly energy efficient, massively parallel microchips that emulate function and structure of adaptive neural circuits in silicon. Embedded mechanisms of synaptic plasticity in these silicon microcircuits model the adaptive intelligence of biological nervous systems interacting with variable and unpredictable environments, and assist in optimizing the

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MESSAGE FROM THE DIRECTORS

Welcome to this new edition of the INC newsletter, which in line with the fertile grounds for ideas taking root here at INC is now called the INCubator.

INC entered its 20th year of existence at UCSD, yet is vital and dynamic as ever before in its visionary approaches to neural computation in the service of knowledge and mankind that encompass computational neuroscience, neural modeling, machine intelligence, brain-machine interfaces, neuroengineering, and translational applications in biomedicine. Over the last year INC doubled its research operations to over $5 million in funds brought in by an exceptionally dynamic team of INC investigators, including over $1 million in new equipment funds for mobile brain imaging.

Recently we relocated our core operations to the entire first (B1) floor of the new San Diego Super Computer Center (SDSC) East Expansion building, housing the Swartz Center for Computational Neuroscience as well as the Temporal Dynamics of Learning Mobile Brain Imaging facilities.

We continue to forge new connections with other research groups at UCSD as well as with local industry, government labs and the clinical sector; your suggestions for ways in which we can further serve the neural computation community are welcomed.

Terrence Sejnowski and Gert Cauwenberghs
Co-Directors

Cognitive Robots (continued from page 1)

present, a research tool to explore how a machine can perceive and react to human facial expressions; that capacity could later have many practical applications in entertainment and education, alerting the robot teachers of the future, say, that their human pupils are daydreaming.

Building a robot that humans can love is pretty ambitious. But Javier Movellan (in his San Diego lab with RUBI) says he would like to develop a robot that loves human

(photo by Timothy Archibald)

Einstein is part of a larger experiment named Project One that focuses on the first year of development. This is a wildly ambitious effort to crack the secrets of human intelligence which involves, as their grant proposal says, "an integrated system...whose sensors and actuators approximate the levels of complexity of human infants."

Some scientists working on social robots, like Movellan and his team, borrow readily from developmental psychology. A machine might acquire skills as a human child does by starting with a few basic tasks and gradually constructing a more sophisticated competence —"bootstrapping," in scientific parlance. In contrast to preprogramming a robot to perform a fixed set of actions, endowing a robot computer with the capacity to acquire skills gradually in response to the environment might produce smarter, more human robots.

This is because programming in incremental fixes for various problems to interact and adapt to a fluid and changing environment becomes frustrating very quickly. "To survive in a social environment, to sustain interaction with people, you can't possibly have everything preprogrammed," Movellan says. Even from the develop-mental viewpoint, the laborious analysis of spoon-fed data—called "supervised learning"—is nothing like the way human babies actually learn. "When you're little nobody points out ten thousand faces and says 'This is happy, this is not happy, this is the left eye, this is the right eye,'" said Nicholas Butko, a PhD student in Movellan's group.

Instead, an "unsupervised learning" process is at the heart of Project One. Project One's robot will be able to move its limbs, train its cameras on "in-teresting" stimuli and receive readings from sensors through-out its body—which will enable it to borrow more behavior strategies from real infants, such as how to communicate with a caregiver. For example, Project One researchers plan to study human babies playing peekaboo and other games with their mothers in a lab. Millisecond by millisecond, the researchers will analyze the babies' movements and reactions. This data will be used to develop theories and eventually programs to engineer similar behaviors in the robot.

The robot baby will be able to touch, grab and shake objects, and the researchers hope that it will be able to "discover" as many as 100 different objects that infants might encounter, from toys to caregivers' hands, and figure out how to manipulate them.

Movellan hopes that the project will "change the way we see human development and bring a more computational bent to it, so we appreciate the problems the infant brain is solving." A more defined understanding of babies' brains might also give rise to new approaches to developmental disorders. "To change the questions that psychologists are asking—that to me is the dream," Movellan adds. "For now it is, how do you get its arm to work, the leg to work? But when we put the pieces together, things will really start to happen."

Full article available at: http://www.smithsonianmag.com/science-nature/Birth-of-a-Robot.html#

Congratulations to Ursula Bellugi and Tom Albright - inducted into NAS!

Two of our very own neuroscientists from the Salk Institute (Ursula Bellugi and Tom Albright) were inducted into the National Academy of Sciences in Washington D.C. this past April. There they experienced an unexpected delight when the President of the National Academy yielded his annual address to the President of the United States. Bellugi shares, "Obama arrived amid great deal of fanfare, with many of his science advisors alongside. His talk was absolutely thrilling, and boded extremely well for the future of science in the U.S. and was an unforgettable event for me and hundreds of others."

Here are a few quotes from President Obama's address:

"The very founding of this institution stands as a testament to the restless curiosity, the boundless hope so essential not just to the scientific enterprise, but to this experiment we call America.

..."And it is time for us to lead once again. So I'm here today to set this goal: We will devote more than 3 percent of our GDP to research and development. We will not just meet, but we will exceed the level achieved at the height of the space race, through policies that invest in basic and applied research, create new incentives for private innovation, promote breakthroughs in energy and medicine, and improve education in math and science. (Applause.)
This represents the largest commitment to scientific research and innovation in American history.

"Just think what this will allow us to accomplish: solar cells as cheap as paint; green buildings that produce all the energy they consume; learning software as effective as a personal tutor; prosthetics so advanced that you could play the piano again; an expansion of the frontiers of human knowledge about ourselves and world the around us. We can do this."

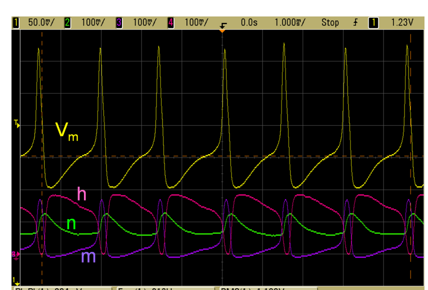
For more information check: http://www.nationalacademies.org/morenews/20090428.html

Lab profile: Gert Cauwenberghs (continued from page 2)

energy efficiency and noise robustness of nanoscale circuit components implementing the neural functions. Recently we demonstrated synaptic arrays in silicon for adaptive template-based visual pattern recognition operating at less than a femtojoule of energy per synaptic operation, exceeding the raw computational efficiency of synaptic transmission in the human brain.

A main focus of our recent work is on extending integrated sensing and actuation to dynamical interfaces to neural and brain activity. Our recent developments include implantable and wireless microelectrode arrays for distributed recording of electrical and chemical neural activity, and biopotential sensor arrays and integrated signal processing for electroencephalogram and electrocorticogram functional brain imaging. These dynamical interfaces between living and artificial nervous systems offer tremendous opportunities for transformative, integrative neuroscience and neuroengineering that are the focus of continued research in our laboratory, in collaboration with partners in academia, industry, and the clinical sector.

For more information check: http://www-biology.ucsd.edu/faculty/cauwenberghs.html



Oscilloscope trace from the NeuroDyn chip displaying the captured waveforms of the membrane voltage potential (Vm) and gating variables (m, n, and h).

Lab profile: John Reynolds

The long-range goal of Systems Neurobiology Laboratory led by John Reynolds is to understand the neural mechanisms of selective visual attention at the level of the individual neuron and the cortical circuit, and to relate these to perception and conscious awareness. For their starting point they utilize the observation that the brain is limited in the amount of visual information it can process at any moment in time. For instance, when people are asked to identify the objects in a briefly presented scene, they become less accurate as the number of objects increases.

This inability to process more than a few objects at a time reflects the limited capacity of some stage (or stages) of sensory processing, decision-making, or behavioral control. Somewhere between stimulating the retina and generating a behavioral response, objects compete with one another to pass through this computational bottleneck. The Reynolds Lab seeks to understand this selection process using a combination of visual psychophysics, neurophysiology, and computational neural modeling.

To this end they have recently published a paper in Neuron describing the spatial attention with regard to center-surround interactions and a paper in Cell investigating a model for attention.

For more information check: http://www.salk.edu/faculty/reynolds.html

Microsaccades - involuntary but certainly not random

Our eyes are in constant motion. Even when we attempt to stare straight at a stationary target, our eyes jump and jiggle imperceptibly. Although these unconscious flicks, also known as microsaccades, had long been considered mere "motor noise," researchers at the Salk Institute for Biological Studies found that they are instead actively controlled by the same brain region that instructs our eyes to scan the lines in a newspaper or follow a moving object.

"For several decades, scientists have debated the function, if any, of these fixational eye movements," says Richard Krauzlis, Ph.D., an associate professor in the Salk Institute's Systems Neurobiology Laboratory, who led the current study. "Our results show that the neural circuit for generating microsaccades is essentially the same as that for voluntary eye movements. This implies that they are caused by the minute fluctuations in how the brain represents where you want to look."

So to probe the question of whether the command center responsible for generating fixational eye movements resides within the same brain structure that is in charge of initiating and directing large voluntary eye movements, Hafed decided to measure neural activity in the superior colliculus before and during microsaccades.

He not only discovered that the superior colliculus is an integral part of the neural mechanism that controls microsaccades, but he also found that individual neurons in the superior colliculus are highly specific about which particular microsaccade directions and amplitudes they command–whether they be, say, rightward or downward or even oblique movements.

"Data from the population of neurons we analyzed shows that the superior colliculus contains a remarkably precise representation of amplitude and direction down to the tiniest of eye movements," says Krauzlis.

By showing in the current study that the superior colliculus is involved in generating microsaccades, Hafed and his colleagues could now explain why this happens. "The superior colliculus is a major determinant of what is behaviorally relevant in our visual environment, so paying attention to one location or the other alters superior colliculus activity and therefore alters these eye movements as well," says Hafed.

Full article available at: http://www.salk.edu/news/pressrelease_details.php?press_id=341

Developing Brain Imaging Methods for Studying Natural Human Behavior and Mind Monitoring via Mobile Brain-Body Imaging

The Swartz Center for Computational Neuroscience at UC San Diego will create a new imagining process to study human body/brain dynamics of subjects engaged in normal activity in ordinary room environments. The work, to be performed under a four year, $3.4 million research grant from the U.S. Navy Office of Naval Research, aims at developing a concurrent brain and body imaging modality MoBI (Mobile Brain/Body Imaging)

The principal investigator, Swartz Center Director Scott Makeig explains, "So far no imaging modality has allowed scientists to study brain dynamics of subjects performing normal activities in a 3-D environment. The MoBI modality we are developing under this project will allow such studies for the first time."

Makeig and colleagues propose to combine high-density, non-invasive electroencephalographic (EEG) or 'brainwave' recordings with full-body motion capture recording to explore the distributed brain dynamics that accompany and support natural human behavior, including interactions with objects, active agents, and other people.
Joint modeling of this data should attempt to identify individualized modes of brain/body activity and/or reactivity that appear in the operator's brain and/or behavior in distinct cognitive contexts, if successful producing, in effect, a new *mobile brain/body imaging* (MoBI) modality. Robust MoBI could allow development of new *brain/body-system interface (BBI)* designs performing multidimensional monitoring of an operator's changing cognitive state including their movement intentions and motivations and ('top- down') apprehension of sensory events.

Full articles available at:
http://sccn.ucsd.edu/MoBI_ONR_pr08.pdf

http://sccn.ucsd.edu/~scott/pdf/Makeig_MoBI_HCI09.pdf

http://discovermagazine.com/2009/jun/05-how-to-see-inside-brain-in-motion

Congratulations to Shelley Marquez - Betsy Faught Award!

Shelley Marquez, the chief administrative officer at the Center for Research in Language, the Institute for Neural Computation and the Kavli Institute for Brain and Mind, has received the 2009 Betsy Faught Award.

UCSD staff member Shelly Marquez recognized for her achievement in management.

This award is selected by a group of peers within the Academic Affairs Division to recognize excellence and outstanding achievement in the management of general campus academic units, and honors the memory of Betsy Faught. Marquez has been serving the campus for more than 25 years.

Full article available at:
http://ucsdnews.ucsd.edu/thisweek/2009/04/13_faught.asp

Congratulations! Awards, Grants, and Honors

Shelly Marquez

- 2009 Betsy Fraught award recognizing excellence and outstanding achievement in the management of general campus academic units

Howard Poizner, PI

- ONR grant award of one million dollars to expand TDLC's Motion Capture/ Brain Dynamics lab

Terrence Sejnowski

- Elected to Institute of Medicine

Ursula Bellugi and Tom Albright

- Inducted into the National Academy of Sciences

Temporal Dynamics of Learning Center

- Passed review in the spring by NSF and is assured funding for 2 more years. The review next year will be a major one that will decide on renewal for 5 more years of funding from the NSF.