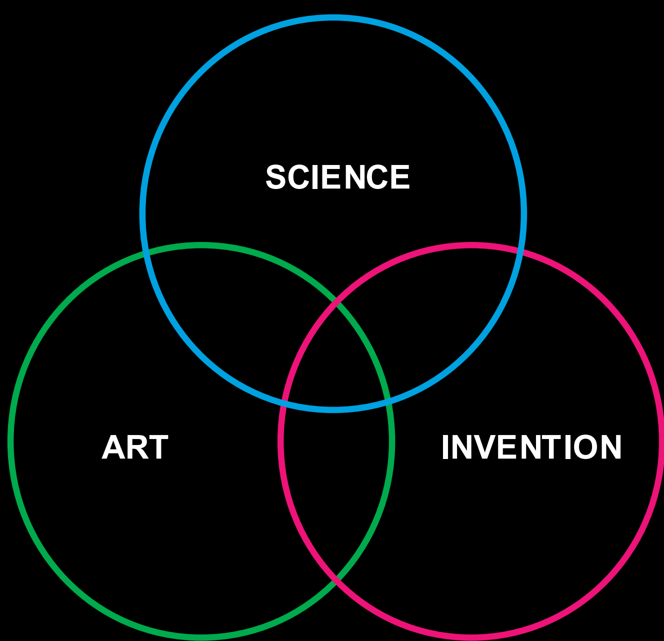
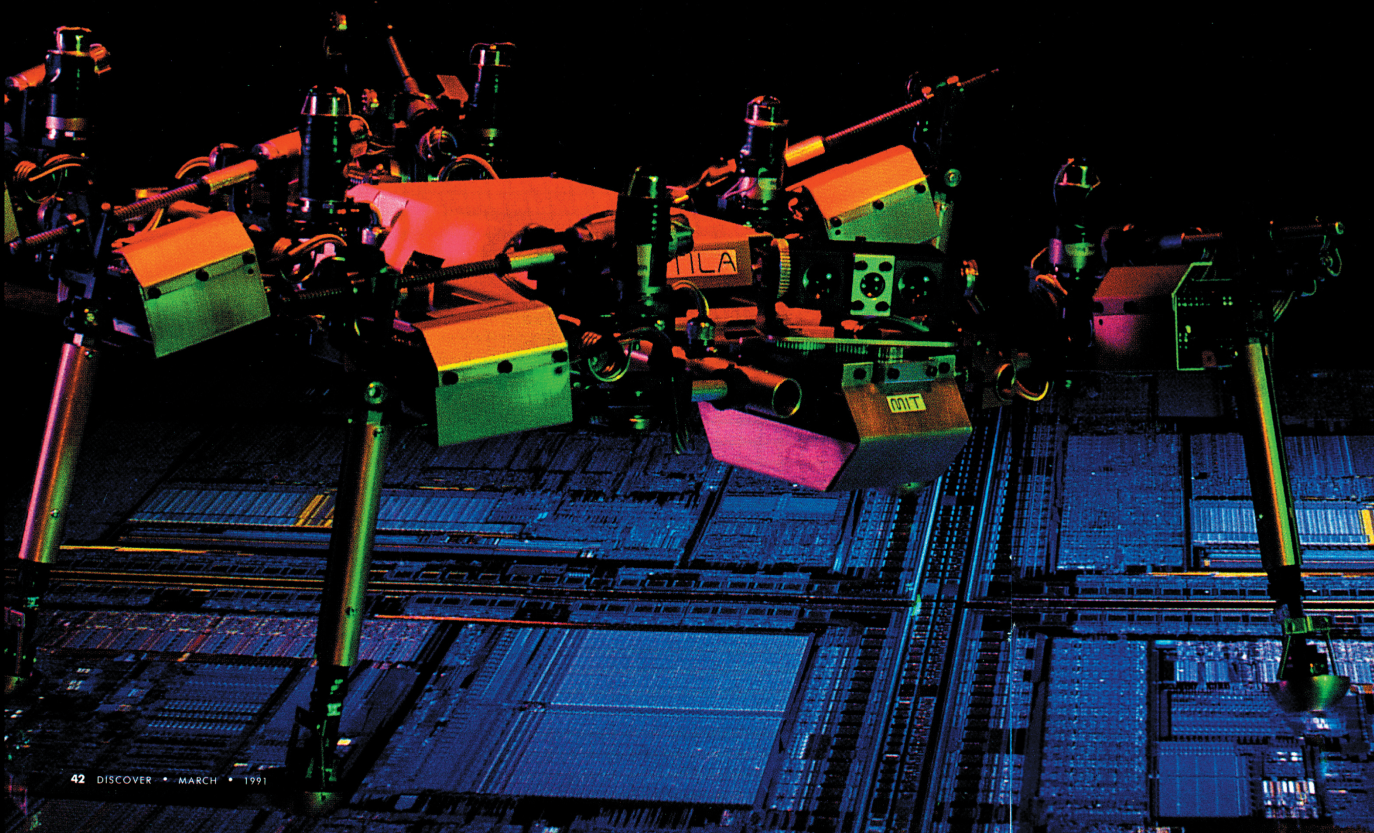
Interpersonal communication is a dance where participants mutually respond to each other in fluid harmony. We communicate with our entire body. We touch, vocalize, gesture, change posture, express with our faces, and make use of shared physical space. Communication with modern technologies, however, is impoverished in comparison. Typical devices abstract away our body and reduce our dimensionality to support only a few communication modalities. Talking with computers is effectively pushing voice-activated buttons. The interaction is flat and lifeless.

In contrast, I see robots as a promising new communication medium that can interact with us in a more richly embodied and dynamically vibrant way. To realize this vision, I design robotic creatures that communicate with us and mutually engage us as living creatures do, through the fundamental constituents of expression, movement, melody of voice, and touch. They convey an animate presence and engage us in the human dance of communication that touches us on a social and emotional level.

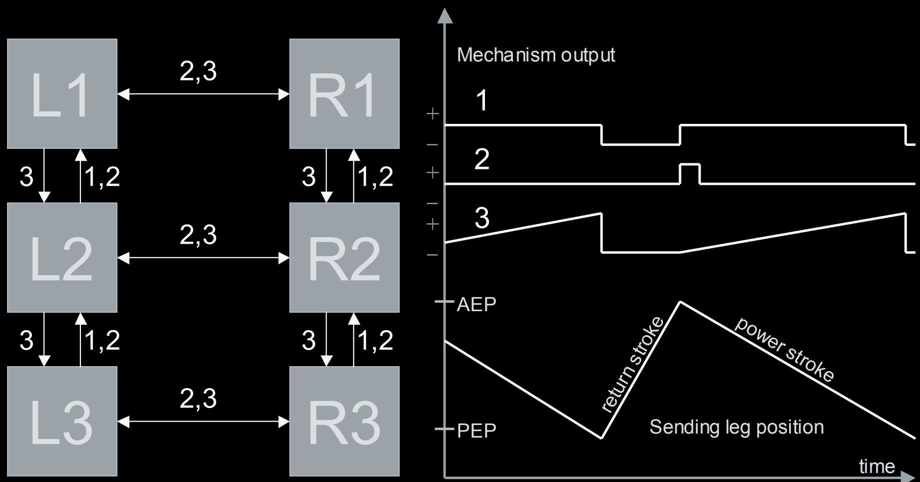


My approach to design integrates a deep scientific understanding of human behavior, artistic insights for communicative expression, and methods from robotics and artificial intelligence to invent technological creatures that intrigue us intellectually and touch us emotionally.



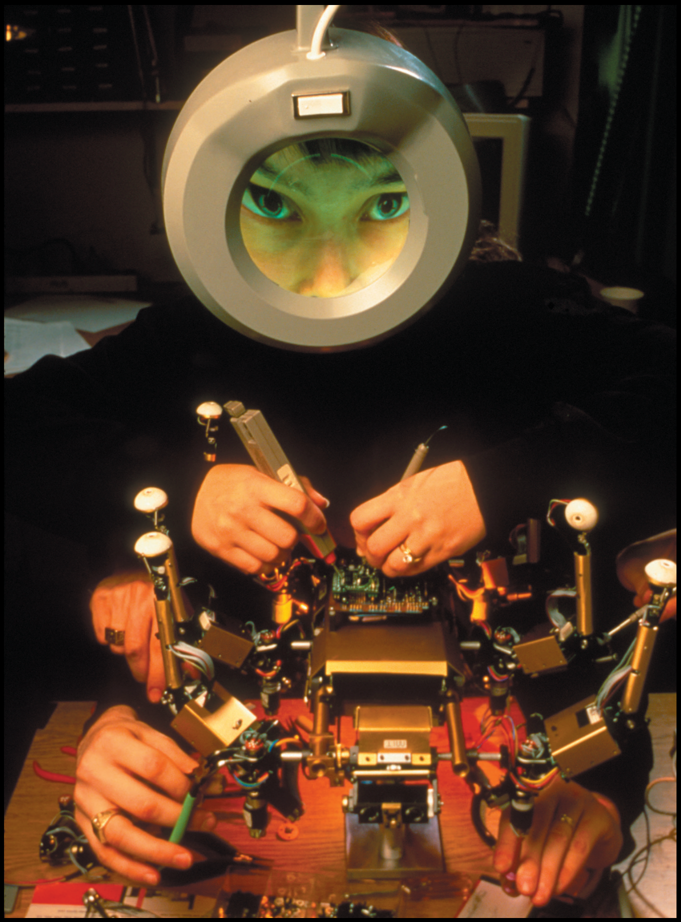
	HANNIBAL, 1993
	Planetary Micro-rover
DESIGNER	Cynthia Breazeal
	M.S. thesis project
	MIT A.I. Lab, Cambridge
PHOTOGRAPHY	Rick Friedman
EXHIBITED	MIT Museum, Cambridge

Principles of insect locomotion inspire the design of Hannibal, a small planetary rover prototype. The vast majority of natural terrain is inaccessible by wheeled vehicles but easily roamed by animals on foot. A six-legged gait is stable over rugged terrain, even with the loss of a leg. This pioneering work helped to convince NASA's Jet Propulsion Laboratory to adopt the use of small autonomous robots as planetary rovers. The Sojourner micro-rover merges the idea of six legs with wheels to traverse the surface of Mars.



INSECT LOCOMOTION

Scientific models of walking stick insect locomotion proposed by entomologist Holk Cruse served as the algorithmic basis of Hannibal's adaptive locomotion controller.



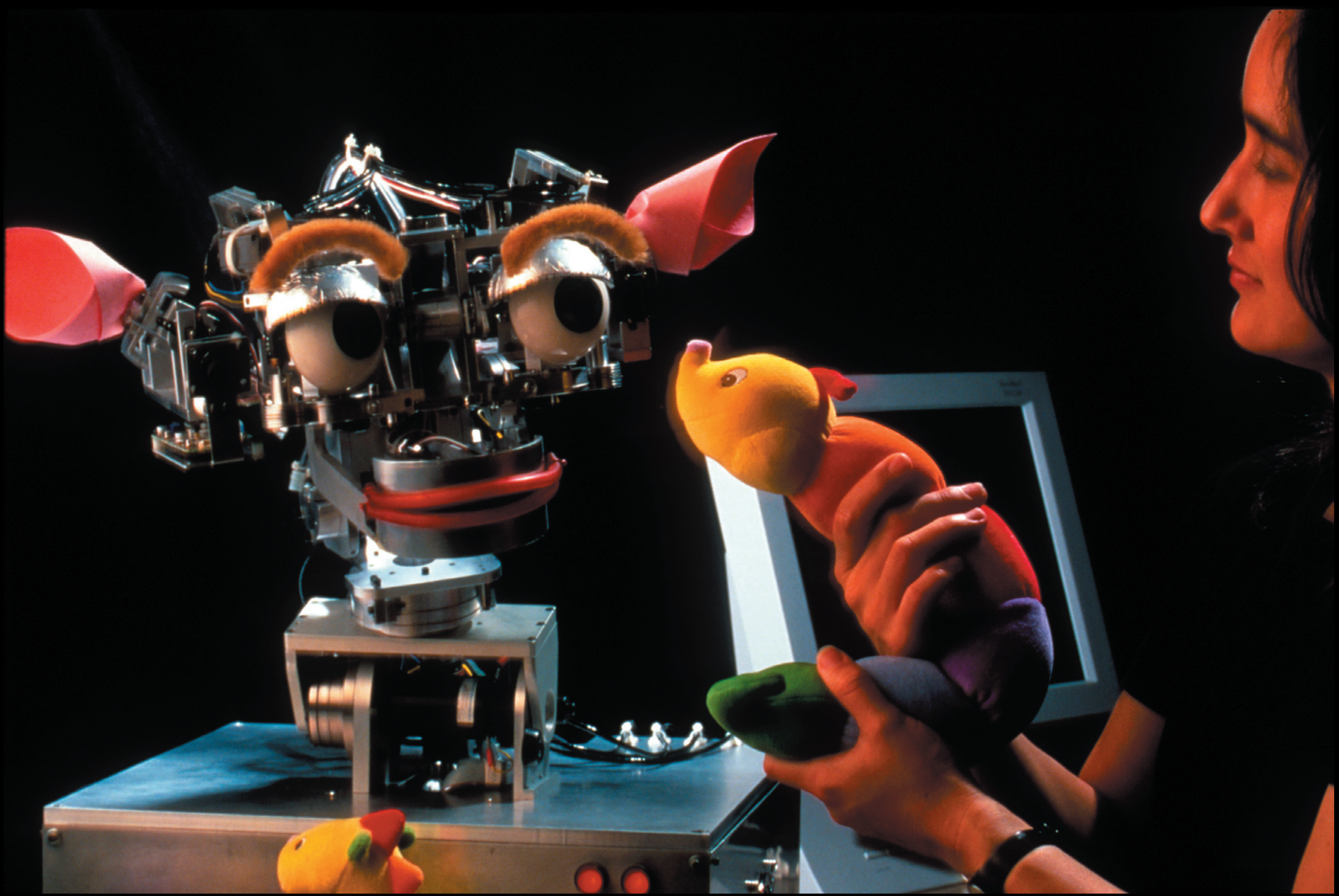
BUILDING HANNIBAL

PHOTOGRAPHY Peter Menzel

When created, Hannibal was the most sophisticated robot for its diminutive size. About one foot in length and weighing only 6 pounds, it packed 18 motors, over 60 sensors, and 8 micro-processors.

	KISMET, 2000
	Sociable Robot
DESIGNER	Cynthia Breazeal
	Ph.D. thesis project
	MIT A.I. Lab, Cambridge
PHOTOGRAPHY	Peter Menzel
EXHIBITED	MIT Museum, Cambridge

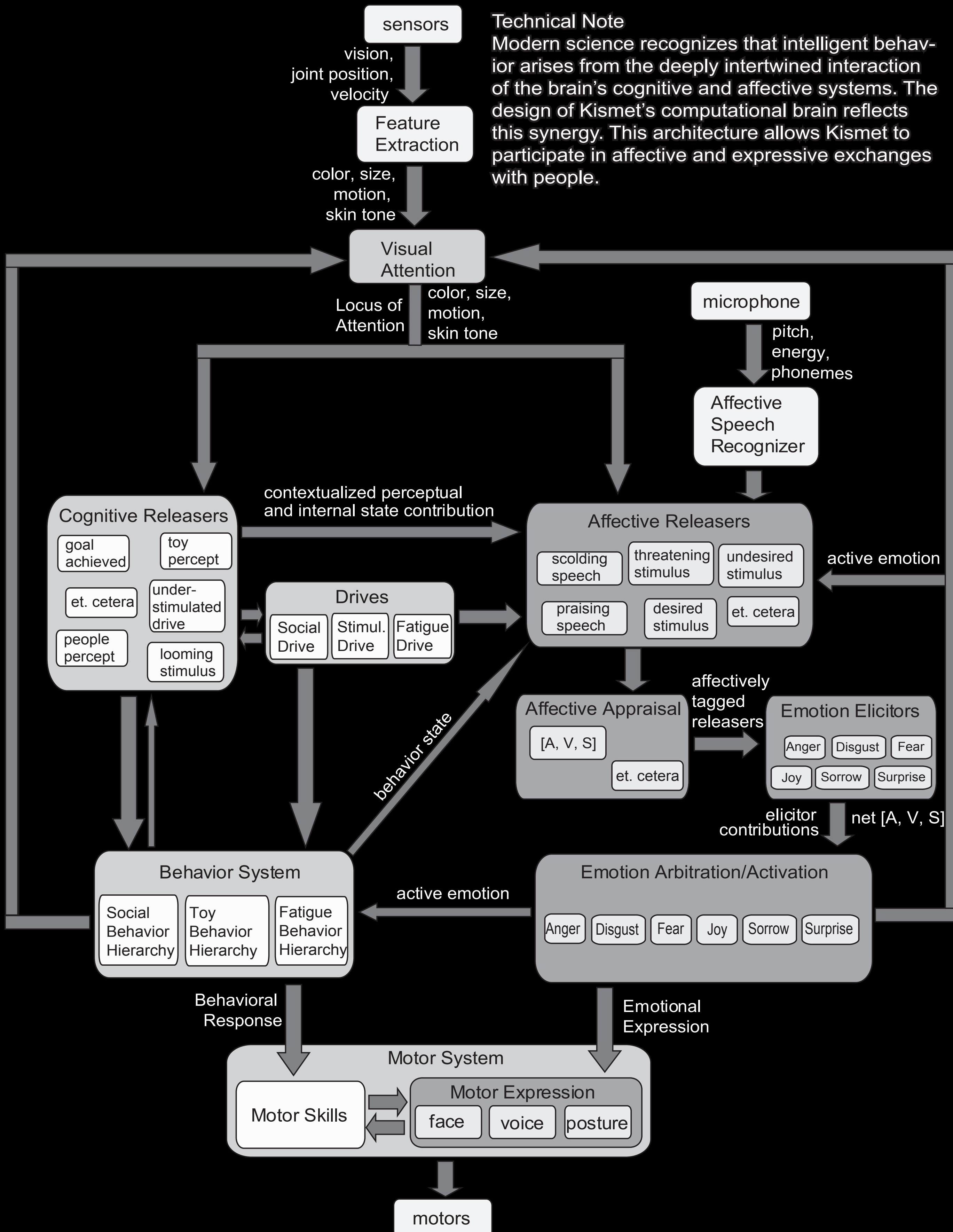
Kismet's implementation is inspired by the social development of human infants and their earliest communications with adults.
These exchanges are often described as an expressive dance where para-linguistic cues are mutually adapted and exchanged between infant and caregiver. The timing and rhythm of these cues are mastered long before the child's first spoken words. These insights helped me to explore the fundamental elements of human communication and how they could be adapted to a robotic form.

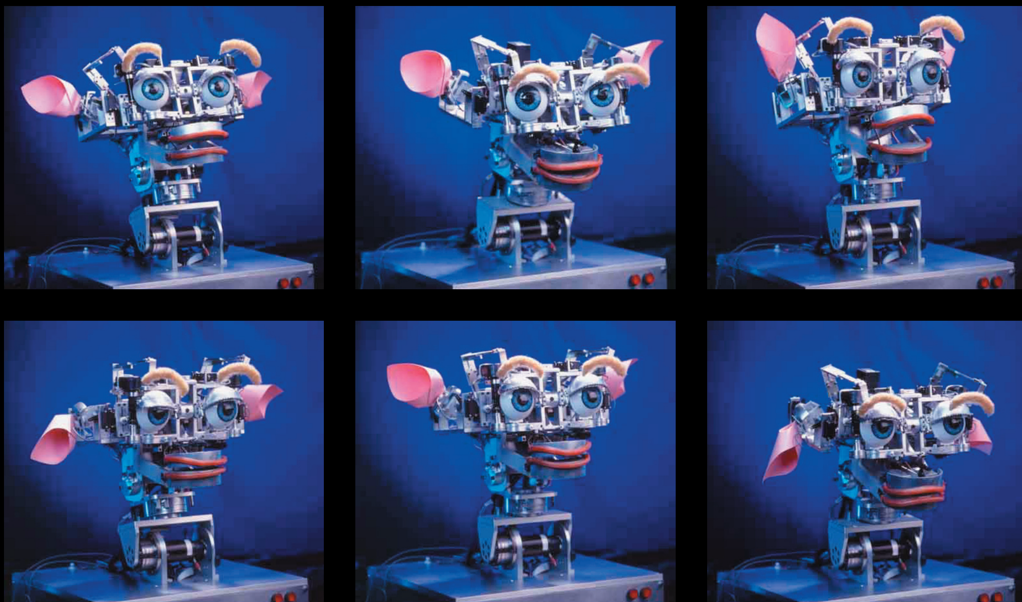


Kismet was designed to convey a sweet curiosity and eagerness to interact with people.

Technical Note

Modern science recognizes that intelligent behavior arises from the deeply intertwined interaction of the brain's cognitive and affective systems. The design of Kismet's computational brain reflects this synergy. This architecture allows Kismet to participate in affective and expressive exchanges with people.



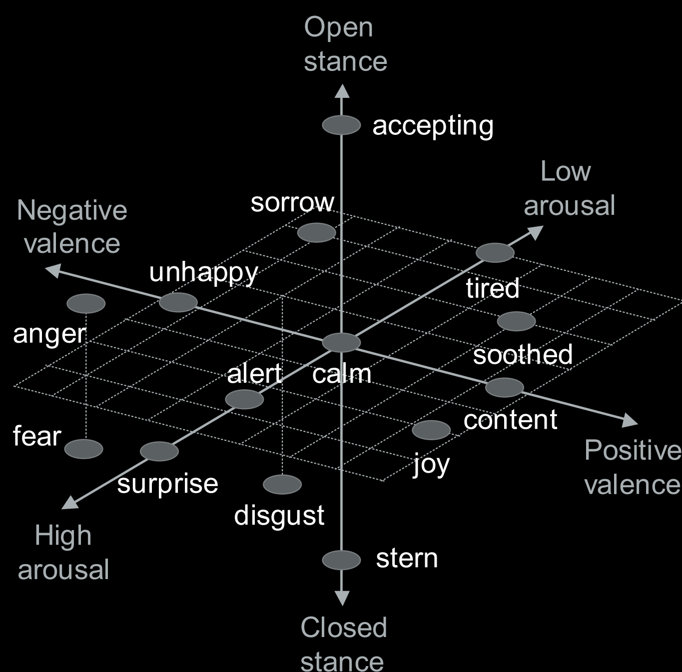


EXPRESSIONS	
PHOTOGRAPHY	Sam Ogden

A sample of 6 emotive expressions.

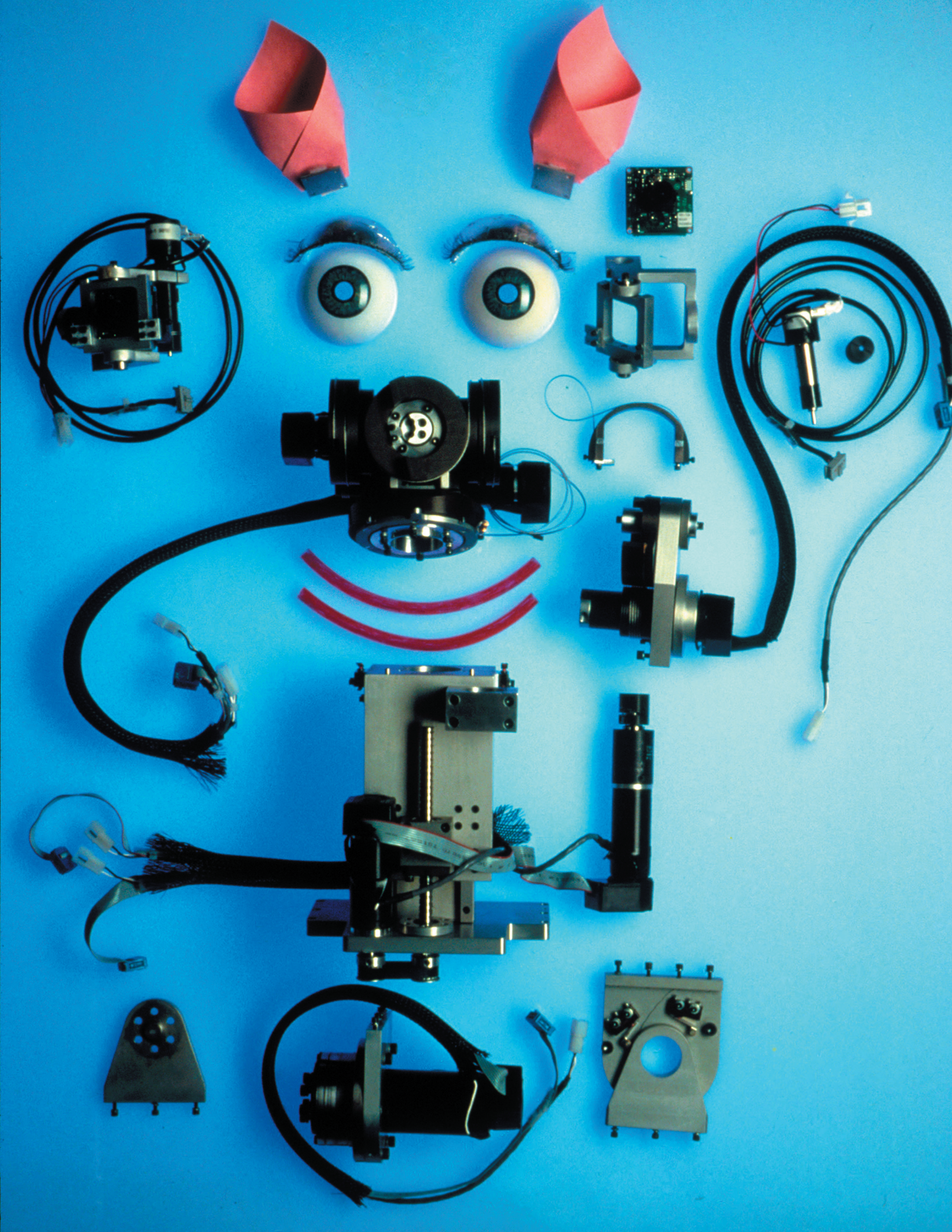
AFFECT SPACE

Emotion categories are decomposed into fundamental affective dimensions. The current emotive state of the robot represents a moving point within this space. Each point maps to a characteristic facial expression where 6 examples are shown above. Kismet's face serves as a window into its computational brain, transparently communicating its affective state to others.



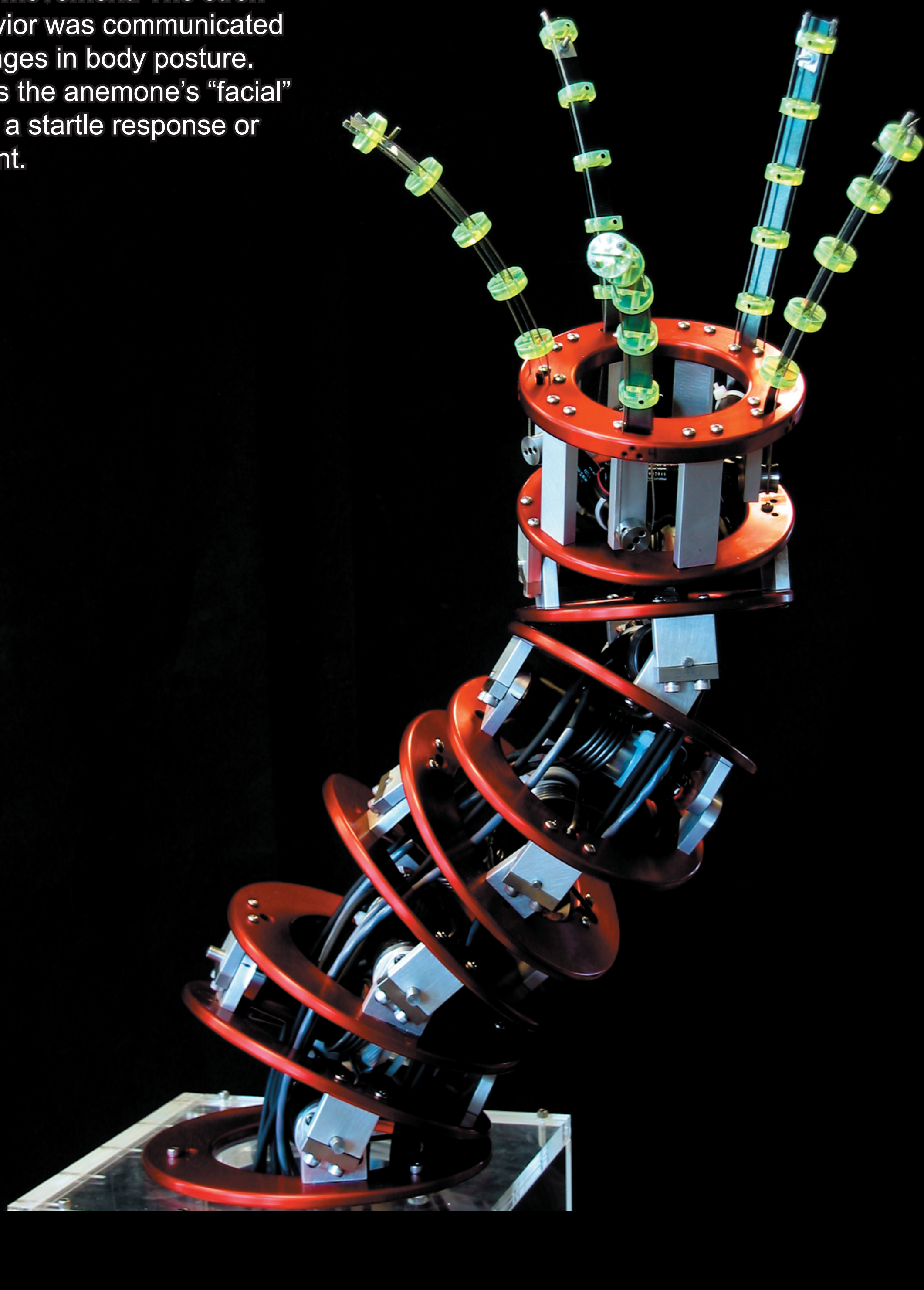
	DISASSEMBLY
PHOTOGRAPHY	Peter Menzel

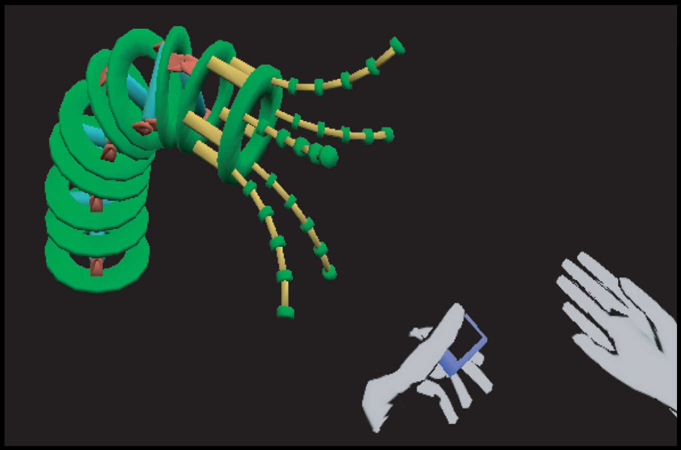
Exploded view of Kismet.



	ANEMONE, 2001
	Serpentine Robot
DESIGNERS	Cynthia Breazeal
	Robotic Life Group
	MIT Media Lab, Cambridge
PHOTOGRAPHY	Jeff Lieberman

The anemone robot was developed to explore human interaction with a non-anthropomorphic robot. The multiple body segments and crown of tentacles give the robot a serpentine and organic quality of movement. The strongest expressive behavior was communicated through dynamic changes in body posture. The tentacles serve as the anemone's "facial" features, flaring out in a startle response or rippling with excitement.



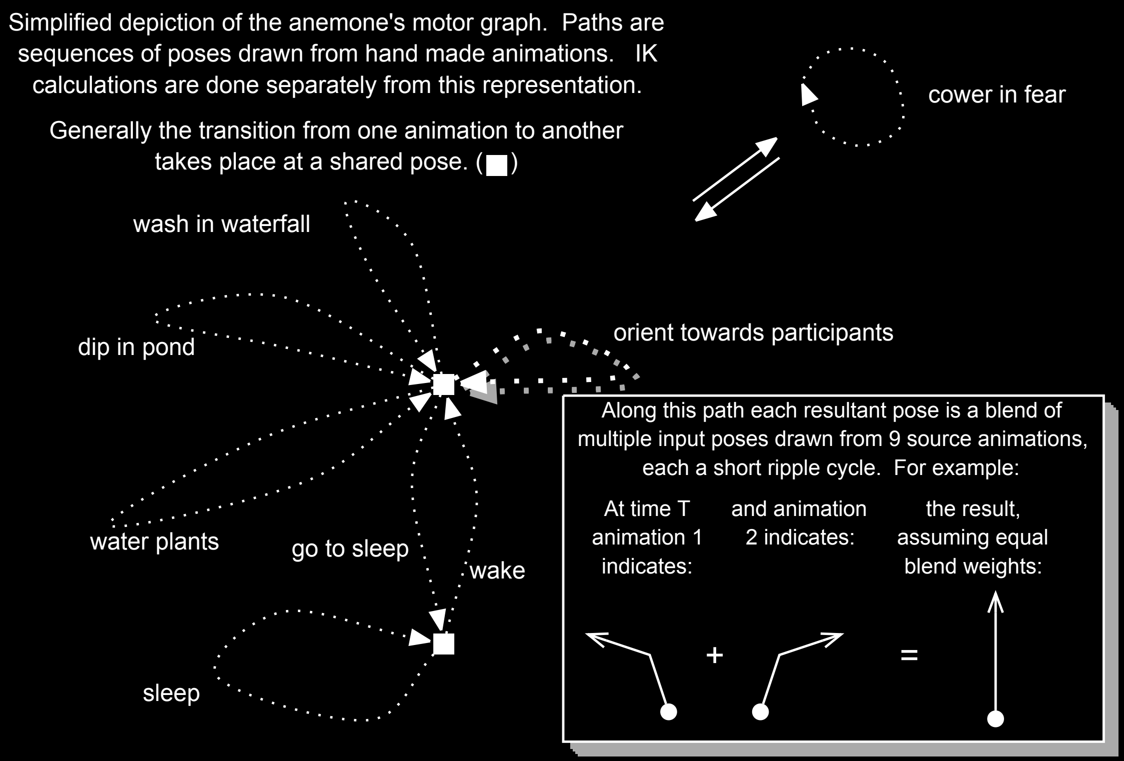


ORIENTATION 1	
RENDERING	Jesse Gray

The anemone orients toward and visually tracks hands. This behavior was first developed in simulation...

ORIENTATION 2	
PHOTOGRAPHY	Jeff Lieberman

...and then demonstrated in physical interaction. The waving hand attracts the attention of the robot.

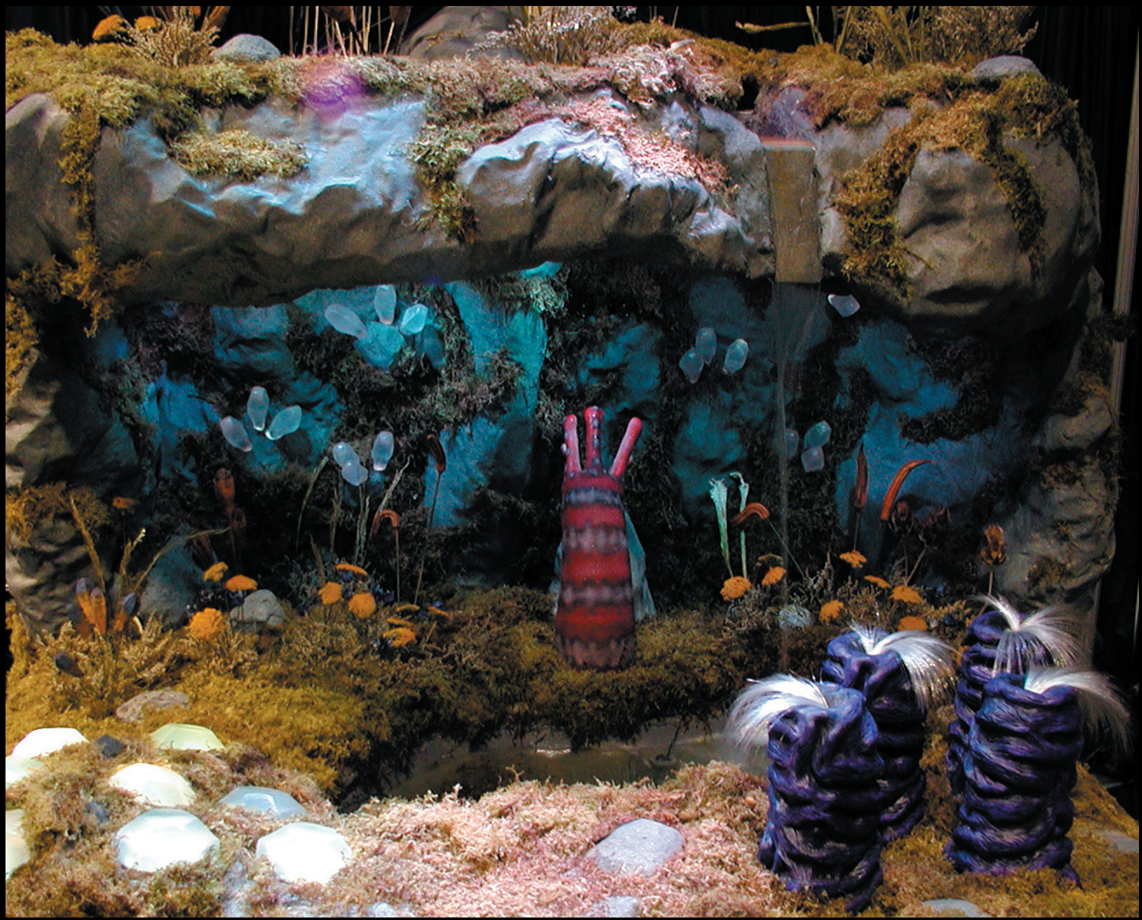


POSEGRAPH

Hand crafted animations are used as data that are subsequently blended, layered, or sequenced to generate the full movement repertoire of the robot. This posegraph illustrates the transitions between various behaviors.

	# TERRARIUM, 2002
	Interactive Robot Theatre
DESIGNERS	Cynthia Breazeal
	Robotic Life Group
	MIT Media Lab, Cambridge
PHOTOGRAPHY	Jeff Lieberman
EXHIBITED	SIGGRAPH Emerging
	Technologies Exhibit
	San Antonio

Audience participants interact with the creatures of this fanciful robotic terrarium as it transitions from day to night. By day, an anemone-like creature is awake and interacts with people. If someone gets too close, however, it becomes frightened and recoils defensively. At night, a variety of nocturnal creatures emerge that the audience interacts with through touch, eliciting light and musical responses. Together, these elements create a physically interactive, ever changing, multi-sensory experience.



Technical Note

The interactive terrarium is an intelligent stage with embedded sensing, computation, and communication infrastructure. It is approximately 7 ft wide by 7 ft deep by 10 ft high and integrates 8 channels of digital audio and music, 40 color controlled lights, 6 ultrasonic foggers, 1 waterfall pump, 4 capacitive sensors, 2 servo controllers, and 8 drum triggers.

FIBER-OPTIC NEMATODE

PHOTOGRAPHY Jeff Lieberman

These nematode-inspired robots sparkle at the tips of their soft fiber-optic filaments. They respond to touch by detecting the proximity of people through capacitive sensing, causing them to react musically, change color, and gracefully withdraw into their shells. This produced a relaxing interaction that was widely popular with audience participants.

DRUM CRYSTALS

PHOTOGRAPHY Jeff Lieberman

The drum crystals allow participants to create rhythm sequences based on how hard the crystals are tapped.

	CYBERFLORA, 2003
	Robotic Flower Garden
DESIGNERS	Cynthia Breazeal
	Robotic Life Group
	MIT Media Lab, Cambridge
PHOTOGRAPHY	Jeff Lieberman
EXHIBITED	Cooper-Hewitt National
	Design Triennial, New York

This robotic flower garden is comprised of 4 species of cyberflora. Each combines animal-like behavior and flower-like characteristics into a robotic instantiation that senses and responds to people in a distinct manner. A soft melody serves as the garden's musical aroma that subtly changes as people interact with the flowers. Delicate, graceful, and intriguing, Cyberflora communicates a future vision of robots that will be sensual and life-like in their responsiveness to us, while remaining true to their technological heritage.

One point the Triennial makes well is that designers are working anywhere a vivid imagination can be beneficial. These days, design is as near as a pair of updated Birkenstocks by Fuseproject. It can be as routine as a printout of digital bits and a map of the human genome. Or, one day, it may even be as humane as Breazeal's garden of robotic lilies and orchids, dipping and swaying at the nearness of you.

The Washington Post
Sunday, April 27, 2003

CHROMAFANT BLOSSOM

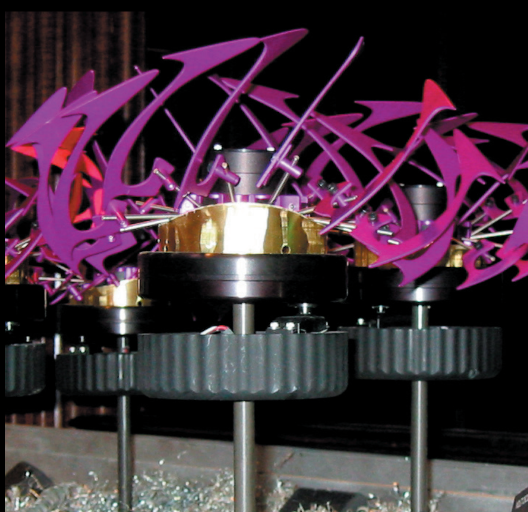
PHOTOGRAPHY Jeff Lieberman

Silicone and aluminum blossoms use capacitive sensing to detect a nearby hand, causing them to gracefully sway and glow bright colors.

COBRA ORCHID

PHOTOGRAPHY Jeff Lieberman

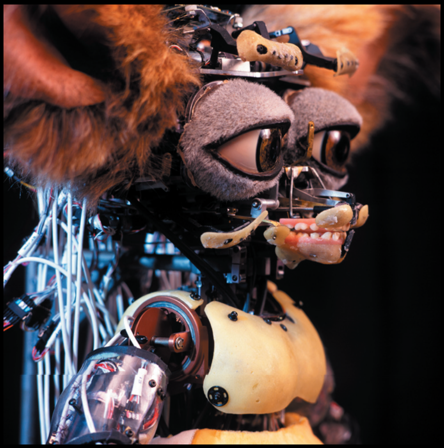
Translucent acrylic segments give this orchid-like flower its serpentine quality of movement as it orients to the warmth of a human body.



VIOLET OSCILILIES

PHOTOGRAPHY Jeff Lieberman

Inspired by the movement of tall grass to a sweeping breeze, aluminum tines bob and ripple with excitement as a hand passes over them.



Technical Note
With 61 motors and standing 2.5 ft tall, Leonardo is the Stradivarius of robots; it is the most expressive robot in the world today.

	LEONARDO, 2003
	Sociable Robot v2.0
DESIGNERS	Cynthia Breazeal
	Robotic Life Group
	MIT Media Lab, Cambridge
	Stan Winston Studios,
	Van Nuys
PHOTOGRAPHY	Sam Ogden

Leonardo explores an organic aesthetic in human-robot communication and cooperation. Inspired by its predecessor, Kismet, and the character of Teddy in the movie A.I., Stan Winston Studio designed the physical (top) and cosmetic (bottom) aspects of the robot. We are developing a computational brain for Leonardo that will be worthy of its wonderfully expressive body, allowing it to explore the world and learn from playful exchanges with people. This is a work in progress.

Robots are special. They are a rich medium for interaction and communication. They are also a technology that is uniquely positioned to interact with us in our physical and social world.

My pioneering work explores a quality of human-robot interaction that captures what is special about our interactions with living creatures. All aspects of their design are inspired by life, from their physical bodies to their computational brains. Nonetheless, they are different from plants, animals, and people. For this reason, I give them a unique form that is true to their technological heritage. I work to find their own voice so that they can communicate with us and share our lives in beneficial and deeply rewarding ways.

Dr. CYNTHIA BREAZEAL

PHOTOGRAPHY Rick Friedman

Cynthia Breazeal is an Assistant Professor of Media Arts and Sciences at the MIT Media Lab in Cambridge, MA where she directs the Robotic Life Group.