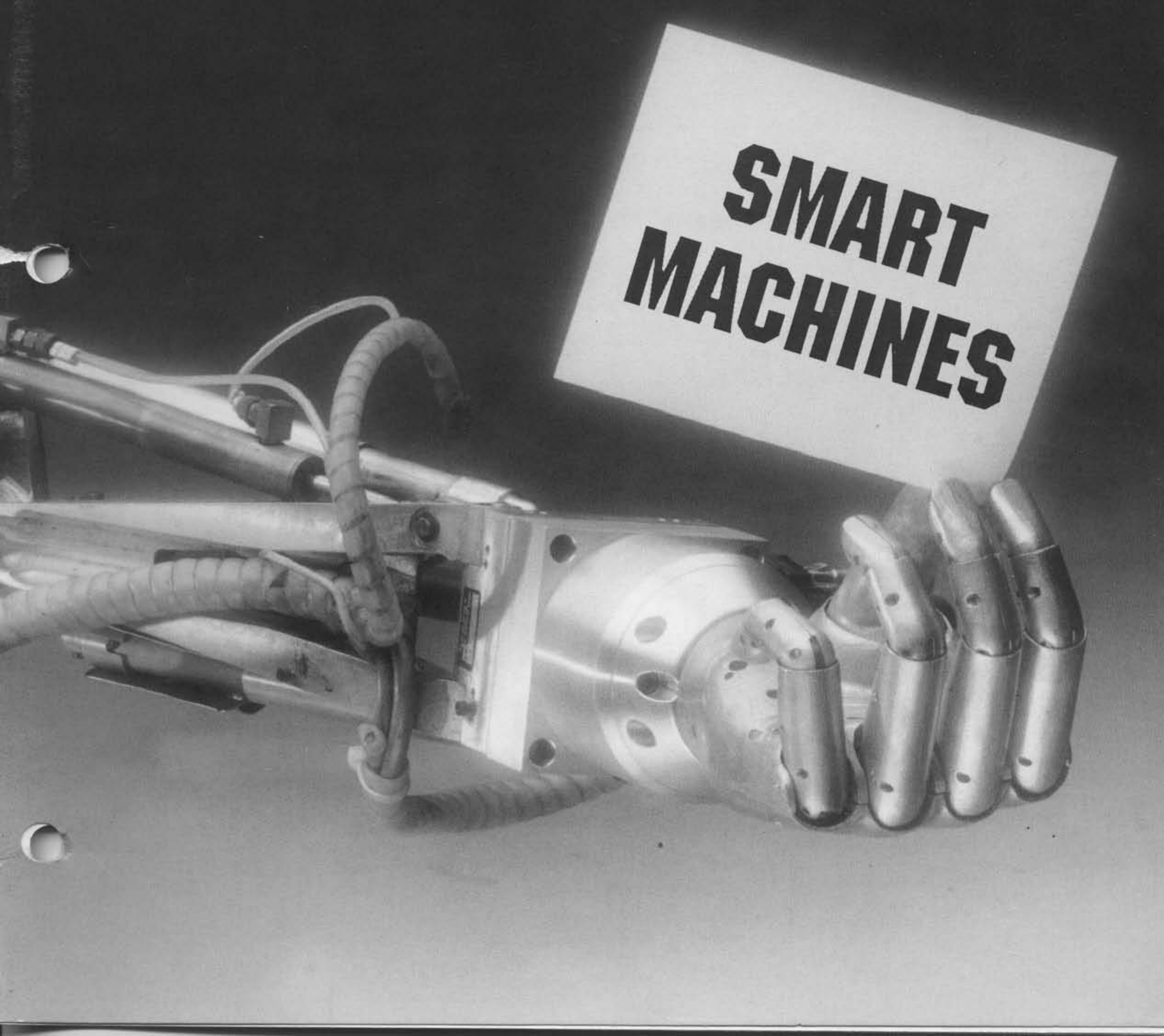
THE COMPUTER MUSEUM REPORT

VOLUME 20 SUMMER/FALL 1987



OPERATING GRANTS — CORPORATE MEMBERSHIP

Sustainer — $10,000 or more
Digital Equipment Corp.
Hewlett-Packard, Co.
International Business Machines Corp.
Institute of Museum Services
Massachusetts Council for the Arts and Humanities

Benefactor—$10,000
Aetna Life Insurance Co.
American Express Foundation
Raytheon Company
Sanders Associates
Tandy/Radio Shack Corp.
Xerox Corporation

Patron—$3,000
Amdahl Corporation
Bitstream
Boris Color Labs, Inc.
Burroughs Corporation
Coopers & Lybrand
DECUS
Dentsu, Inc.
Draper Laboratories
Gaston Snow & Ely Bartlett
Gourmet Caterers, Inc.
Honeywell
IEEE Computer Society
Lotus
Manufacturers Hanover
MASSCOMP
McGraw-Hill, Inc.
Prime Computer Corp.
Ropes & Gray
Sun Microsystems
Symbolics, Inc.
The Travelers

Contributor—$1,000
Adage, Inc.
Adelie Corp.
Analog Devices, Inc.
Analogic Corporation
Apple Computer
Arthur Andersen, Inc.
Arthur D. Little, Inc.
Bank of Boston
Bank of New England
BASF
Baybanks
Bolt Beranek & Newman
Boston Consulting Group
Boston Safe Deposit
Cincom Systems
Cognition, Inc.
Dane, Falb, Stone & Co.
Data Architects, Inc.
Data Translation
Deloitte Haskins & Sells
Eastech Management
E.M.C. Corporation
Executours, Inc.
Festive Foods Caterers
Foley Hoag & Eliot
Grafik Communications Ltd.
Goldman, Sachs & Co.
Greylock
GTE Laboratories, Inc.
Hyams Trust
Index Technology
Innova
Intel Corporation
Interface Group
MediVision, Inc.
Mentor Graphics
MICOM-Interlan, Inc.
Microcom
Micro Control Systems
NEC Corporation
NYNEX Service Company
Palmer & Dodge
Peat, Marwick, Mitchell
Pell, Rudman & Co., Inc.
Price Waterhouse
Russell Reynolds Associates
Shawmut Corporation
Scitex America
Sequent Computer Systems, Inc.
Standard Oil
Sterling Hager
Telectronics
Teradyne
Testa, Hurwitz & Thibeault
VM Software
Warner & Stackpole
XRE Corporation

Contributing Members

Donor—$500 or more

Nick De Wolf
Phil Dorn
Ray Duncan
Tom Eggers
Dan L. Eisner
Alan E. Frisbie
Branko Gerovac
Tom and Rosemarie Hall
M. Ernest Huber
Robert Kahn
Martin Kirkpatrick
Raymond Kurzweil
Andrew Lavien
Christopher Morgan
Linda J. Phillips
Paul R. Pierce
Ann Roe-Hafer
Jonathan Rotenberg
O. & K. Selfridge
Thomas F. Stephenson
Seth Stern
William Steul
Leo Yochim

Sponsor—$250

Isaac Auerbach
Jordan Baruch
Graham Beachum
G. C. Belden, Jr.
James Bell
Gordon S. Brown
Richard J. Clayton
Richard Corben
David N. Cutler
Donald R. Daykin
James B. Deaderick
Delta Management
Lucian J. Endicott
Bob O. Evans
Larry Forte
Kevin and Judith Galvin
Branko Gerovac
John Gilmore
Roberto Guatelli
W. Richard Johnson
Lawrence J. Kilgallen
Bob King
Marian Kowalski
Sheldon Lavde
Eli Lipcon
Carl Machover
Joe W. Matthews
Tron McConnell
Steven Nevins
Joseph M. Newcomer
Anthony Oettinger
James V. Patton
James A. Pitts
J. Eric Pollack
James N. Porter
Audrey Reith
C.M. Riggle
Linda & David Rodgers
Thomas S. Roy II
Michael J. Samek
John J. Shields III
Charles A. Stott
John V. Terrey
Michael Tomasic
G. Michael Uhler
Christian Walker
Allan L. Wallack
Andrew Wilson

Friend—$100

Kenneth R. Adcock
R.J. Alexander
Timothy Anderson
Rolland Arndt
Professor Arvind
Robert Z. Bachrach
Richard G. Bahr
Steve Bane
Dawn R. Banks & Robert M. Praetorius
Mario Barbacci
Steve F. Barneby
John C. Barstow
Alfred M. Bertocchi
Lois J. Bizak
Bontronics
Carol Botteron
Daniel S. Bricklin
Robert E. Briney
Fred & Nancy Brooks
D. F. Brown
John and Ann Brown
Lawrence Brown
Les Brown
Erik Bruhn
Gerald A. Bujaucius
Roger M. Buoy
W. Carlson
Maria L. Carr
George Chamberlain
George Champine
M.H. Coden
James F. Cody
Howard I. Cohen
Michael J. Coppolino
Howard E. Cox, Jr.
Ronald Creamer
Michael Cronin
Daniel Crowley
CSDP
James Cudmore
Paul Curran
Randall Davis
Joseph Dearborn
Harvey Deitel
F. Demeo
Kevin W. Dick
Lucien Dimino
Ditcargiani Family
Patrick M. Donini
Kathleen Doreau
Theodora Drapos
Dick Dunnington
R. DuVal
Esther Dyson
Joseph J. Eachus
Richard J. Eckhouse and Ruth Maulucci
William T. Elliott
Margaret Ellis
Thelma Estrin
P.J. Evans
Andrew Farber
Andrew Feit
Geoffrey Feldman and Sharon Lipp
Harold Fitch
Philip Fox
Robert France & Ruth Doan
J. Thomas Franklin
Clark Frazier
Daniel Freedman
Bruce Gee
Bruce Gilchrist
David Goodman
Edward Gordon
Roger Gould
Roger H. Goun
William Graustein
Stephen Gross
Paul C. Guglietta
Jerrier A. Haddad
J. Scott Hamilton
Keith W. Hare
James S. Harvison
Frank E. Heart
Daniel and Nancy Heff
Paulyn Heinmiller
Ted Hess
Thomas L. Hohmann
Grace M. Hopper
Nancy S. Hone
Robert Ingham
Interbase Software Corp.
Roy C. Johnson
Charles A. Jortberg
JSI, Inc.
Richard M. Karoff
John Kemeny
Bryan S. Kocher
Josh and Mabel Kopp
Mark Koretz
Neal Koss
Alan and Judith Kotok
Ralph Krans
Sieglinde Kress
Stanley Kugell
Robert Laman
Curtis Larock
Tsvi Lavi
Grace Leahy
Margaret L. Leiby
L. Lein & B Kuipers
John R. Levine
John V. Levy
Joseph L. Levy
John D.C. Little
Reed Little
George Logemann
Carl D. Lowenstein
Arthur Luehrmann
David E. Lundstrom
Joseph MacDonald
Julius Marcus
Barry Margolin
Andrew H. Mason
Melvin J. Mason
Richard O. Mason
Robert O. Mason
Sibyl Masquelier
J. Stevadson Massey
Peter Masters
Robert Mayer, Jr
Richard McCluskey
F. Warren McFarlan
Douglas McKenna
William McLean
Todd Medlock
James Meehan
Myron Mendelson
Jeanette Middour
Charles Minter
Allen Moulton
J. Craig Mudge
Rayman Mustafa
Dorothy Nash-Webber
Isaac R. Nassi
Lee Neal
Tim K. Nguyen
Landon Noll
Bernard J. Nordmann
H. Edward Nyce
Thomas P. Oberst
James N. O'Boyle, Jr.
Louise O'Donnell
Martin O'Donnell
Lawrence & Pauline Oliva
A.M. Oliver
Leon M. Padell
Joseph A. Pallone
Kenneth D. Patterson
George Peo
James H. Philip
Juan Pineda
Michael Pique
Michael Poe
John Poppen
James N. Porter
John H. Porter
David Potter
Richard Powell
John F. Pries
Robert C. Probasco
Brendan Reilly
William S. Reilly
Audrey Reith
Daniel Rose
David Rose
Thomas S. Roy II
Stephen Russell
Sabaki Corporation
Howard Salwen
Michael Samek
Robert Santy
Robert Schapp, Jr.
Phillip H. Schearer
Anne Schwartz
Bennett Schwartz
Andrew Scott
Curtis A. Scott
Ronald F. Shea
Sebell Software
Aaron Seidman
J. A. Sexauer
R. & M. Shamel
W. Lee Shevel
Charles Sholfield
W. Olin Sibert
Dan Siewiorek
Diane J. Skiba
Phil Slaughter
Allen G. Sneider
Gerald Steinback
Max J. Steinmann
Bruce G. Stewart
Hugh W. Stewart
Robert and Diane Stewart
J. Michael Stone
Paul Sullivan
Steve Swerling
Synergetic Systems
David Taraba
John Tartar
Paul Tedesco
Thomas Thackrey
Michael Thompson
William R. Thompson
Warren G. Tisdale
Michael Tomasic
H. Dean Toombs
Noah E. VanDenburgh
Thomas Vaughn
Charles Volkstorf
Christian Walker
Thomas E. Welmers
John D. Wick
Hugh Wilkinson III
James Williams
Kevin Willoughby
Roy Wilson
Richard T. Witek
Frederic G. Withington
Paul Wittman
William A. Wulf
D. L. Wyse
Hermann Zapf

Capital Campaign

64K or more

Apollo Computer, Inc.
C. Gordon Bell
Control Data Corportion
Cullinet
Data General
Gardner Hendrie
Mitchell Kapor
Carver Mead
Kenneth Olsen
John William Poduska
Wang Laboratories

32K or more

American Telephone & Telegraph
Bank of America
Henry Burkhardt
ComputerLand
Kenneth Fisher
International Data Group
Burge Jamieson
Mitre Corporation
Russell Noftsker
Robert Noyce
Robert M. Metcalfe
Fontaine K. Richardson

16K or more

American Management Systems
Anonymous
Clark Baker
The Boston Globe
Howard Cannon
David Donaldson
Doug Drane
David K. Dyer
Bruce Edwards
Index Systems
August Klein
Thomas Knight
James L. McKenney
NEC Corporation
David & Pat Nelson
Paul & Katherine Severino
Ron Smart
William Spencer
Charles E. Sporck
Ivan Sutherland
System One
Chris Terman
Minon Tonai
Stephen Watson
Daniel Weinreb

8K or more

AFIPS
Harlan E. & Lois Anderson
Erich & Renee Bloch
Winston R. Hindle, Jr.
Theodore & Ruth Johnson
John Allen Jones
Stan Olsen
Russell Planitzer
Doug Ross
Edward Schwartz
Software Results Corp.
Erwin Tomash

4K or more

Charles & Connie Bachman
Gene Brewer
Roger and Mary Cady
R. Steve Cheheyl
Robert & Eleanor Chinn
Pat Clark
Robert G. Claussen
William Congleton
Alex d'Arbeloff
Arnaud de Vitry
Robert Everett
Ford Motor Company
Jay W. Forrester
William Foster
General Systems Group
Gaston Snow & Ely Bartlett
Peter Hirshberg
Houghton Mifflin Company
ICL
Jeffrey Kalb
Allan Kent
Jack S. Kilby
Andrew C. Knowles III
David J. A. Koogler
Edward and Debbie Kramer
John W. and Edna W. Lacey
Liberty Mutual Insurance Company
Ralph and Linda Linsalata
Robert Lucky
John Norris Maguire
Richard D. Mallery
Thomas and Marian Marill
Daniel D. McCracken
Thomas and Elizabeth McWilliams
Meditech
Allen Michels
Microsoft
Robert M. Morrill
New York Air, Inc.
Nolan Norton Company
John L. Payne
Nicholas A. Pettinella
Edward G. Perkins
Robert M. Price
Regis McKenna, Inc.
Ben Robelen
Jean E. Sammet
Grant Saviers
Sequent Computer Systems Corp.
Hal Shear
Alan F. Shugart
Richard L. Sites
Stratus Computer Corp.
Del Thorndike and Steve Teicher
3Com Corporation
Jean De Valpine
Charles P. Waite
Harvey W. Wiggins, Jr.
William Wolfson

The Computer Museum
Museum Wharf
300 Congress Street
Boston, MA 02210

The Making of the Smart Machines Exhibit

Oliver Strimpel

On June 18, 1987, The Computer Museum opened a 4000 square foot exhibit entitled Smart Machines. It is the largest single exhibit the Museum has undertaken in its five year history.

Birth

The idea of a Computer Museum exhibit on artificial intelligence (A.I.) and robotics goes back to January 1985. The Museum had just re-opened in its downtown Boston site. The initial set of exhibits consisted of four galleries that were primarily historical and one gallery that dealt with a particular aspect of current technology: computer imagery. The public's positive response to the Image Gallery encouraged us to plan another thematic exhibit. After meetings with several subgroups of the Museum's Board of Directors and other interested people, the combination of artificial intelligence and robotics rose to the top of the list.

Why combine A.I. and robots? When deciding what should be included in the exhibit, we followed a definition of A.I. that was formulated by Marvin Minsky. In doing so, we opted in favor of exhibiting machines that performed tasks that, if carried out by humans, would have required some intelligence. Thus, our exhibit demonstrates the idea that A.I. encompasses the mental aspects of solving a problem or fulfilling a task while robots perform the physical motions required to carry out that task.

Of course, a major research goal is to merge A.I. and robotics, creating an intelligent autonomous agent. Shakey, one of our prize robots, epitomizes this effort. It was driven by A.I. – the problem-solving program STRIPS – but was itself a robot, complete with drive mechanisms and a range of sensors.

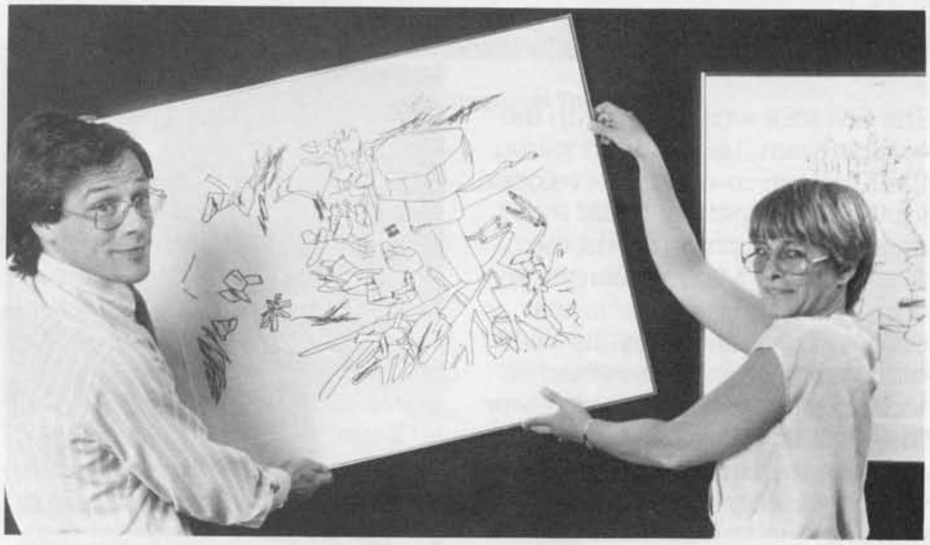


Photo: Dan McCoy/Rainbow

Oliver Strimpel and Leah Hutten hanging a drawing by Harold Cohen's program AARON.

In addition, an exhibit on A.I. and robotics serves both of the key aspects of the Museum's mission – education and preservation – while offering a unique and entertaining experience for the visitor. The educational challenge was to demonstrate and explain a rapidly evolving subject. Furthermore, we were anxious to preserve many one-of-a-kind robots that were neglected and in danger of being lost. Within the span of a few months we assembled the world's most comprehensive collection of research robots. Finally, we aimed to make the exhibit popular by selecting entertaining interactive A.I. programs, including several on music, art and games, and by exploiting the innately appealing nature of robots.

Taking Off

The exhibit went through a lengthy gestation period - from January 1985 to June 1986. Gwen Bell and I gradually built up support and interest, locating exhibit ideas, programs and artifacts, and putting some flesh on the conceptual skeleton.

In the summer of 1986, the founders of Symbolics, Inc., met

Table of Contents

at the Museum to hear a presentation given by Gwen Bell and me on the new project. They subsequently announced their intention to fund the exhibit. Gordon Bell, Museum Trustee and Associate Director for Computing and Information Science at The National Science Foundation, also made a major gift towards the exhibit. By September the project's funding was secure and a nine month countdown to the opening began.

The first task was to build up the exhibit team. Leah Hutten joined the Museum as exhibit developer for the robot section, while I concentrated primarily on the A.I. exhibits. Michael Bergman came aboard as our technical coordinator to manage the wide assortment of computers and working robots that would power the exhibits. Gwen Bell agreed to develop the historical timeline of A.I. and robots and to help catalyze the exhibit's development. Marc Leblanc, a high school student intern, became the team's resident hacker. Meanwhile, Tom Merrill readied the Museum workshop in preparation for actual construction of the exhibit.

We hired the office of Michael Sand, Inc., to design the exhibit. They transformed our ideas into a floorplan and a physical display system and also provided ideas for making the exhibit more inviting. WITCOM Associates was hired to create seven video programs from 24 different sources selected from over 70 original tapes that we had collected. The video program for the Smart Machines Theater was a particularly complex job because of the need to relate the video to the artifacts on display. DEC provided their studio for final editing where we created a master tape that was used to make a videodisk containing the video for the entire gallery. Michael Callahan was engaged to provide the audiovisual and electronic systems, Steve Cummings came on board to compose sound tracks, and Ripman Lighting Consultants took on the lighting and special effects for the Theater.

Formulating the Exhibit

The topics to be covered by the exhibit fell into six sections spanning A.I. and robotics and are described later in this *Report*.

Photo: Dan McCoy/Rainbow

Tom Merrill adjusting the "Frankenstein Set," based on a Maxell advertisement.

Since we believe that the core elements in our educational exhibits on computing are the engaging working displays, we put most of our effort into developing non-static exhibits. We were extremely fortunate in finding a very skilled group of volunteers to help script and program unique and dynamic exhibits for us. Joe Bates, on his way to a faculty position at Carnegie-Mellon University, offered to help us create an exhibit that would address the problem of knowledge representation in A.I. After discussing many fascinating but unworkable ideas, we came up with the plan to base a demonstration on a conversation with the intelligent computer HAL in the movie *2001: A Space Odyssey*. Joe wrote the script, and Marc LeBlanc programmed it onto an interactive videodisk system provided by DEC. Another successful match was made by Randy Davis of the MIT A.I. Laboratory who brought us together with Mitchel Resnick and Franklyn Turbak. Their goal was to find a way to build a rule-based expert system that would demonstrate in an entertaining way the strengths and weaknesses of rule-based techniques. They designed Haymarket, a trio of rule-based storekeepers, each of which has its own strategy for making innocent customers pay far too much money for a box of strawberries.

Still other volunteer help was provided by several of Michael Bergman's programmer friends: Tom Courtney programmed the object recognition demonstration, Sterling Barrett helped with the natural language interface demonstration and Steve Kukolich tailored a demonstration of how computers play games for Museum use. In addition, Bob Lee ruggedized the game West for us while Steve Foster, Warren Adam and Brian Sandberg, students from the Wentworth Institute, examined our historic robots and restored every possible degree of freedom. Finally, Curt Crittendon and Grinnell More built and programmed a sensing mobile robot.

To support the many working displays we planned, we sought the participation of numerous computer companies. We received full support from almost every company we approached. The matching of applications with available hardware proceeded step-by-step as each gift of equipment was confirmed. The 70 companies and 12 universities who contributed are listed on page 11.

Lastly, we put a great deal of effort and exhibit technology into the Smart Machines Theater with 25 historic robots on display. Each artifact comes to life on video with additional sound, light and motion effects that create an entertaining and instructive show.

The Final Push

The construction of the exhibit took place in the Museum's own workshop. Initially consisting of Tom Merrill and Joslin Fields, the workshop staff expanded in the final few weeks to include museum interpreters Wauter Habraken and George Kfoury and several other staff members. Indeed, almost every member of the Museum staff and Michael Sand's office joined in the construction effort. Several groups worked right through the night in preparation for the opening. Alan Symonds (Ripman Lighting), officially in charge of the exhibit's lighting, also installed the robots from the Maxell advertisement in between the cuing of the lighting and sound effects for the Theater. Together with his team from the American Repertory Theater, Alan lent his able hand to almost every aspect of fabrication. Many of the alchemical props used for the fantastic Frankenstein Set were provided by Boston University's chemistry department and Al Rifkin, the "mad scientist" owner of Able, the robot. Among the Museum staff, Michael Oleksiw, Linda Holekamp, Mark Hunt, Kathy Keough, Kurt Levitan, Greg Schroeder and Bonnie Turrentine volunteered many late hours assembling panels, painting, and helping in innumerable ways. Lynn Hall became the site manager, channelling all the available manpower into maximum productivity. Gwen Bell extended the number of available man-hours by providing abundant Chinese food every evening. Gordon Bell pioneered a new system for assembling the exhibit panels and installed the air conditioner in the machine room. Andre and Judith LeBlanc, Roger Glovsky, Patti Hillis, and Laura and Victor Gregg also joined in.

The gallery was threaded with an Ethernet local area network, connecting up the MicroVAXs, Suns, Hewlett-Packard Bobcats and the Sequent computers. With so many new machines being installed and the extension of the network, we called our friends at the MIT Media Lab for help. Their resident system wizard, Henry Holtzman, obliged and in the final 48 hours up to the opening overcame seemingly insurmountable hurdles to make all the computers work in harmony.

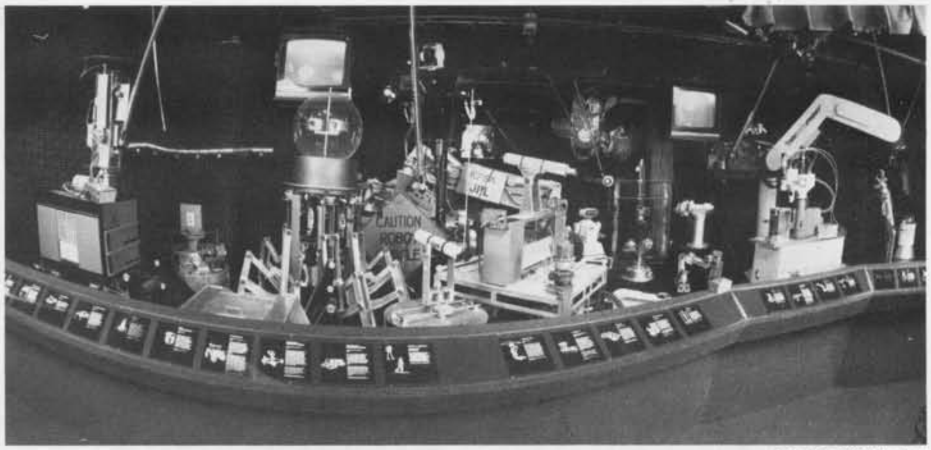


Photo: Dan McCoy/Rainbow

Twenty-five historic robots in the Smart Machines Theater.

In parallel with the concentrated effort in the gallery, our programmer friends were distributed around the building, busily adding the finishing touches: Tom Courtney (vision), Sterling Barrett (natural language front-end), Bob Lee (West), Steve Kukolich (tic-tac-toe), Jim Meehan (TALE-SPIN), Jonathan Press (grammar-checker), Mitchel Resnick and Franklyn Turbak (Haymarket), Harold Cohen (AARON), and the students from the University of Lowell (boat-builder and log-cabin builder). Marc Raibert successfully coaxed a PDP-11/40E into life to drive his one-legged hopper. Henry Holtzman, attempting to get FranzLISP (needed to run our version of ELIZA) running on the Sequent computer in the small hours of the morning, came to a standstill because of an incompatible tape format. In desperation, we called up Thinking Machines hoping someone would be around. Sure enough, Steve Strassman was there and invited Henry over to fix the problem.

To the outside eye, the days before the opening were a scene of hopeless chaos. But to those involved in the project, there was a great sense of purpose and team spirit. Hidden skills emerged among staff, contractors and volunteers, and many friendships were established.

Barely one hour before the ribbon-cutting, Shigeo Hirose's long-awaited quadruped and snake-like Oblix arrived from Tokyo. In a final burst of activity, the crate was torn open, and these unique objects took their allotted positions in the robot theater. The sounds of the vacuum cleaners had barely retreated at the far end of the gallery as the opening speeches ended, and the ribbon was cut. Six hundred contributors and museum members swarmed into the gallery. About 400,000 lines of application code, running under 4 types of LISP, C, Basic, and Pascal, 50 robots weighing 6 tons, 25 computers, and 7 video programs came to life.

Smart Machines was open!

Smart Machines

Oliver Strimpel

The unifying theme of the Smart Machines gallery is to demonstrate how machines do things that have hitherto been the province of intelligent human activity. We were determined to convey to our visitors the tremendous sophistication of the human mind and body, as well as some of the difficulties scientists face in their attempts to replicate even the simplest of human activities. The combination of A.I. and robotics was straightforward enough: we wanted to demonstrate both the mental capabilities and the physical dexterity of today's machines. This article attempts to explain how the various live exhibits selected for Smart Machines exemplify past and present trends in A.I. and robotics.

The exhibit is grouped into six sections: language understanding, knowledge-based systems, game-playing, robot sensing, mobile robots and robot arms. The historical time-line and robot theater are described in the next article.

Language Understanding

One of the major conclusions of A.I. research during the 1970s was that knowledge and language could not be clearly separated. The early attempts to understand or translate language on a word-by-word basis failed. However, research has continued along several lines, and progress has resulted in commercially successful products.

A grammar correction system from Houghton-Mifflin shows how much a computer can do without any knowledge of the meanings of words. Visitors can watch the grammar checker find mistakes and correct them automatically.

Unlike a grammar checker, parsing is just the first stage of a program that actually tries to understand the meaning of a sentence. In a natural language interface program, the knowledge resides in the database. However, the questions stated in English must be translated into a machine language query to the database. Our exhibit features Datatalker, a natural language interface from Natural Language, Inc. It asks visitors to type in information about themselves, which it stores. It then invites questions in plain English about previous visitors. The program's task is eased because it expects a question about something in its database. After parsing a visitor's question stated in English, the program tries to extract the sentence's meaning, and, if appropriate, converts it into instructions to search through its database for information that will answer the question. The result of the search is translated back into an English reply. Other parts of the program keep track of the dialog, deciding when responses are adequate.

To go beyond a simple question and answer conversation, computers need a much wider and deeper knowledge. The exhibit addresses this enormous problem by demonstrating some of complexities of building a real computer like HAL in the film *2001: A Space Odyssey*.

Photo: Dan McCoy/Rainbow

Grammar correction system. To correct a sentence such as "The student at the school beyond the bridges go home at noon," the program must parse the entire sentence and realize that neither the bridges nor the school is going home, but the student.

Using an interactive video disk system, visitors can analyze a short conversation between HAL and Dave, the astronaut. A speech synthesizer explains what HAL must know to recognize Dave's speech, how HAL might use scripts and form plans and goals. The exhibit aims to convince visitors that building a machine comparable to a person is a huge challenge, but one that is amenable to scientific research.

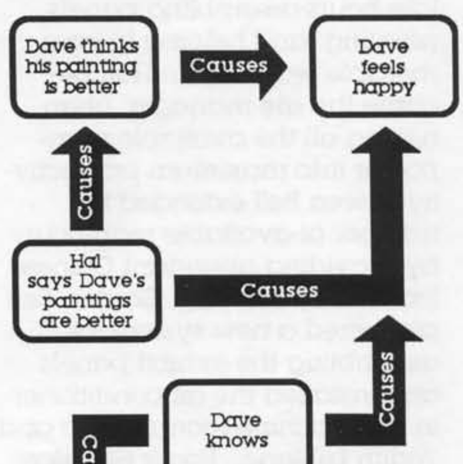


Photo: Dan McCoy/Rainbow

Haymarket - where visitors haggle with a computer. During the interaction, a tracer shows the rate at which rules are checked, and marks those whose IF parts are true, causing the THEN part to fire. The storekeepers' thoughts and speeches are spoken out loud by a speech synthesizer.

Haymarket Rules for Noah Budge

IF: the stage-of-game is greetings
SAY: "Welcome to my store. Just $6.00 for this box of strawberries."
CONCLUDE: the stage-of-game is bargaining

▪

IF: the stage-of-game is-not greetings
CONCLUDE: the number-of-interactions is-increased-by 1

▪

IF: the number-of-interactions is-greater-than 4
AND: the input-type is-not number
OR: the customer-offer is-less-than $6.00
CONCLUDE: the stage-of-game is finished
THINK: one-of "That's the last straw. This bargaining is going nowhere."
"This clown has tried my patience for too long."
SAY: one-of "You're wasting my time. Get out of my store and stay out!"
"I don't need troublemakers like you. Leave my store now!"

▪

IF: the input-type is number
AND: the customer-offer is-less-than $6.00
AND: the stage-of-game is-not finished
THINK: one-of "Is this customer hard of hearing?"
"This person's a bozo!"
"Another customer trying to take advantage of me."
SAY: one-of "No, I told you my price is $6.00."
"You don't hear too well. I said $6.00."
"Look, I'm busy. $6.00 is my price. Take it or leave it."

IF: the input-type is number
AND: the customer-offer is-equal-to $6.00
THINK: "This is a reasonable customer."
SAY: "You've got a deal!"
CONCLUDE: the stage-of-game is finished

▪

IF: the input-type is number
AND: the customer-offer is-greater-than $6.00
THINK: one-of "This customer is a sucker."
"This customer has money to burn."
SAY: "You've got a deal! Come back again!"
CONCLUDE: the stage-of-game is finished

▪

IF: the input-type is complaint
AND: the stage-of-game is-not finished
THINK: one-of "Why do I get stuck with all the complainers!"
"All I ever hear are complaints."
"Looks like I have a complainer of my hands."
SAY: one-of "Come on. I have other customers waiting. Make me an offer."
"Quit your complaining and make me an offer."

▪

IF: the input-type is compliment
AND: the stage-of-game is-not finished
THINK: one-of "This customer's trying to butter me up. That won't work."
"I'm sick of customers trying to sweet-talk me."
SAY: one-of "Enough flattery. Make me an offer."
"I'd rather have $6.00 than your compliments."

The eight rules that drive Noah Budge, a simple-minded storekeeper.

Two exhibits are conversational programs that pretend to know more than they do. ELIZA, the classic computer psychotherapist program written by Joseph Weizenbaum in 1966, takes key words from the visitor's typed-in text and uses them to trigger stock questions. It also repeats the user's words, turning statements into questions. ELIZA exploits its role as a non-directive therapist to justify its extreme passivity. In contrast, RACTER converses volubly with the visitor on many arcane topics. Like ELIZA, it has no model of the world, but responds to key words in the input text by concocting sentences based on standard forms. It attempts to skirt around its lack of understanding by making a virtue out of being zany. These programs are not presented as A.I., but as illustrations of the limitations of approaches that use words without knowledge.

Knowledge-Based Systems

The greatest number of useful applications in the field of A.I. have emerged from rule-based expert systems. Several hundred expert systems perform tasks ranging from diagnosing failures on gas turbines to suggesting which pesticides to use on a particular crop. In general, a Museum should exhibit genuine examples of its subject matter. However, expert systems are tools aimed at the technical user and would be totally incomprehensible to the majority of our visitors. As a compromise, we included one "real" expert system, somewhat modified for the Museum by its author, Randy Miller. The system is Quick Medical Reference (QMR), a medical diagnosis system that contains descriptions of nearly 600 diseases. Visitors can browse through the system, using it like an electronic textbook indexed either by disease or by symptom. Alternatively, visitors can retreive a patient's case, make QMR diagnose it, and compare QMR's hypothesis with one of their own.

We assembled several highly instructive and entertaining "non-real" rule-based systems to demonstrate the capabilities and internal workings of expert systems. In the Haymarket exhibit, visitors haggle with up to three different rule-based storekeepers to buy a large box of strawberries. The simplest, Noah Budge, has only 8 rules and never budges on his price. Eventually, he will kick you out of the store if you don't give him what he's asking for. Visitors can choose Ho Nin with 30 rules and Nora Logical, the sophisticated storekeeper with over 100 rules. Another rule-based demonstration is a wine-advisor. This proceeds via a two-way spoken conversation. Visitors are asked questions about the type of food planned for the meal and what their tastes are in general. They respond by speaking into a microphone. After up to 10 questions, the computer makes a specific recommendation.

Several rule-based systems dealing with the arts are also on display, including a musical score follower (right) and a drawing expert (below). The goal is to demonstrate the application of rule-based programming techniques in non-technical domains. A computer composition system by Charles Ames generates rock and jazz pieces, which it performs

Photo: Dan McCoy/Rainbow

An exhibit based on Roger Dannenberg's ConcertCraft program can follow a score and accompany a visitor who performs a simple tune on a keyboard. The score follower has rules that enable it to keep pace with a human performer, even if the player changes tempo and makes mistakes.

Photo: Dan McCoy/Rainbow

AARON is a computer program that draws pictures. The program's knowledge is internally represented by several thousand rules of the form:

IF: ***something is the case***
THEN: ***do the following . . .***

A picture develops as AARON threads a complicated path from rule to rule. Small variations in the picture are introduced early in the composition. Since the IF part of the rules depends on what has already been drawn, the same set of rules results in entirely different pictures each time.

Harold Cohen began work on AARON in 1972. In its early phases, the program knew how to build simple forms. It constructed drawings from these forms to produce pictures that evoked an impression of landscapes populated by creatures. In recent years, Cohen has given AARON explicit knowledge about the appearance of plants and human figures. The knowledge is in the form of hundreds of rules of the form:

IF: ***the arm is raised***
THEN: ***the palm is facing forward.***

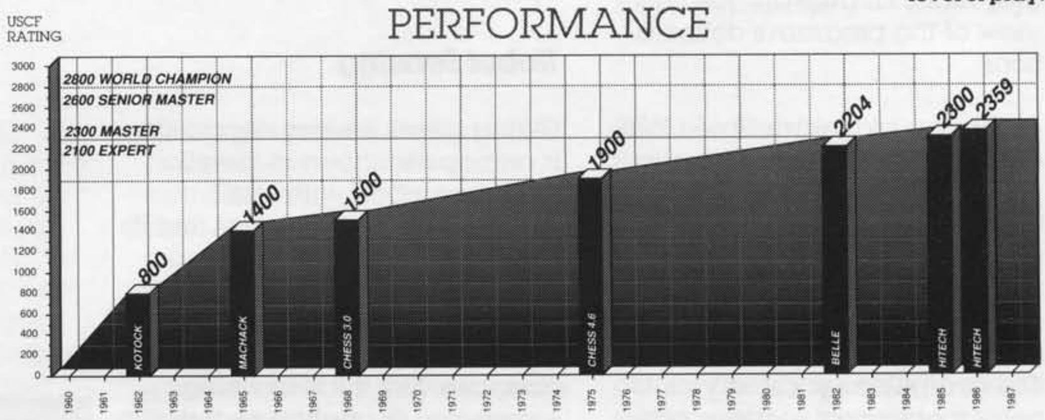
To produce figures that look like people rather than stuffed dolls, AARON has rules that describe posture and balance. Cohen's ambition is to give AARON the knowledge to color its pictures. He says, "it took me 20 years to learn to teach the machine to draw, and I expect it will take me another 20 to teach it how to color."

Once upon a time.... Joe was in the cave. Irving was in the oak tree. Lucy was in the meadow. The water was in the river. The honey was in the elm tree. The worm was in the ground. The fish was in the river. The hay was in the barn. The berries were in the meadow. Joe was sad. He wanted to become happy. He thought that Lucy liked him. He wanted to persuade her to kiss him. He trusted her. He didn't like her. He decided that if he gives her the hay then then she might kiss him. He wanted to ask her whether if he gives her the hay then she'll kiss him. He wanted to get near her. He went to the meadow. He asked her, "Will you kiss me if I give you the hay?" She knew that he didn't trust her. She decided that if he gives her the hay then she'll tell him that he was stupid. She told him, "If you give me the hay then I'll kiss you." He wanted to get the hay. He wanted to to get near the hay. He went to the barn. He took the hay. He had the hay. He wanted to get near her. He went to the meadow. He gave her the hay. She had the hay. He didn't have the hay. She was hungry. She told him, "You're stupid." He didn't like her. She wanted to satisfy her hunger. She ate the hay. She wasn't hungry. She didn't kiss him. He didn't trust her. He was afraid of her. He couldn't persuade her to kiss him. He was still sad. The End.

A tale about Joe Bird and Lucy Lamb spun by Jim Meehan's program Micro TALE-SPIN.

Visitors can challenge computer opponents in four different games. The commercially available chess-playing program SARGON III offers a strong game, boasting a rating of nearly 2200 (approaching master level play) at its highest level of play.

COMPUTER CHESS PERFORMANCE



through a Kurzweil 250 synthesizer. After selecting a musical style and a model, such as the twelve bar blues, the program selects instruments and then composes the rhythm, assigning each note a duration that depends in part on whether it is a basic, ornamental or cadence note. Finally, pitches are selected according to a set of about 20 rules. The rules make the notes conform to the harmony, create a melody and avoid repetition. The music is surprisingly convincing.

In contrast to all the systems described above, which represent knowledge as sets of rules, TALE-SPIN is based on scripts. This program came from the work of Roger Schank's group at Yale on language understanding. TALE-SPIN is a program that generates stories with a simple "point" somewhat reminiscent of the simpler Aesop's fables. The program simulates a world of characters who do things because they have problems to solve. These consist of fulfilling simple goals, such as satisfying hunger or thirst. Visitors select a main character -- Joe Bear, Irving Bird or Lucy Lamb -- and also determine the goals and character traits of the players. The program has a model of its characters and ensures that their behavior is rational. For example, if Joe Bear is thirsty and sees a river, he will try to get to the river.

In addition to rules, knowledge can be represented as frames, semantic nets and scripts. These are illustrated by panels in the exhibit.

Game-Playing

In addition to being fun, computer games are a valuable testing ground of ways to search through enormous numbers of alternative solutions to a given problem. Typically, when people play a game, they rely on knowledge of the opponent's ability and on an understanding of what it takes to win. Machines, on the other hand, rely on searching many possible moves to determine the best outcome. Research efforts have concentrated on optimizing the search for moves in chess. One approach is to perform the search in the proper order so that unpromising avenues can be eliminated early on. Another approach seeks to give the computer knowledge about chess, increasing its ability to "size-up" a given position. Hans Berliner and his colleagues at Carnegie-Mellon University used both approaches to build the world's strongest computer chess player. Their program, called Hitech, has custom hardware to generate and evaluate up to 200,000 moves a second. This enables it to search about 11 half-moves ahead while playing in a tournament. In addition, Hitech's board knowledge is equivalent to a search of a further three half-moves.

Visitors can also play tic-tac-toe and five-in-a-row and choose the computer's strategy to be one of look-ahead search, voting or random. The program offers graphics that give an "X-ray" view of the program's deliberations.

A checker player by David Slate can beat all but the most serious players. Finally, in the game "How the West Was Won," the computer plays two roles: opponent and tutor. This is a numbers game, designed to help children gain familiarity with arithmetic. The computer tutor analyzes one's moves and suggests possible improvements. It never scolds or repeats itself and lets the player discover the game for him or herself. This coach was developed as a robust, friendly and intelligent tutor that could work well in the home and classroom.

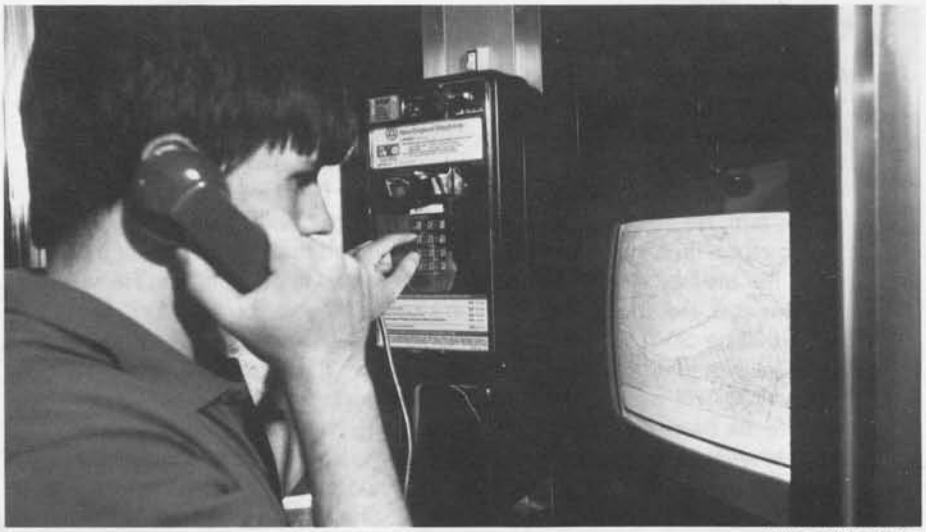


Photo: Dan McCoy/Rainbow

The computer direction assistant holds a road map of 11 square miles of Boston and Cambridge and can find the quickest route between any two points on its map. Visitors communicate directly with the computer via a touch-tone telephone. The assistant is very forgiving of mistakes and provides instructions in good, clearly-spoken English.

Robot Sensing

Giving robots sensory capabilities is an important part of the effort to endow robots with intelligence. A smart robot must find its way independently and cope with the unexpected. It can only begin to do this if it can sense the distance to any surrounding obstacles, feel if it is touching something, or analyze pictures taken with an onboard camera. Many of the historic robots acquired by the Museum and on display in the exhibit's Smart Machines Theater were built as experiments, allowing researchers to explore how a robot can gather and make good use of sensory data.

The Museum visitor can experiment with four robot senses: vision, hearing, touch and sonar. Human vision is so sophisticated that we hardly appreciate its complexity. For example, just consider how we can instantly recognize everyday objects, such as a tree or cat, even though no two examples look alike in detail. Our vision relies on a great deal of knowledge about the world and about what we expect to see. By contrast, machines rely

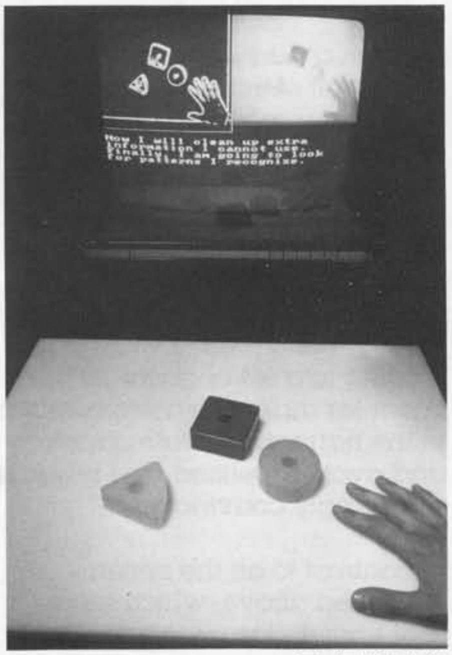


Photo: Dan McCoy/Rainbow

Visitors can experiment with a vision system by placing some simple shapes under a camera and watching how it first looks for edges and then tries to identify the shapes.

Photo: Dan McCoy/Rainbow

While wheels work well on roads, legs are needed to cross rough terrain. Perhaps the most spectacular demonstration in the exhibit is Marc Raibert's one-legged hopper. This robot balances itself on the move, rather like a person balancing a broom on a fingertip. A computer keeps track of its speed and position, adjusting the angle of the leg to keep the robot upright. An accompanying video shows one-legged, two-legged and four-legged running machines, as well as a series of legged walking robots.

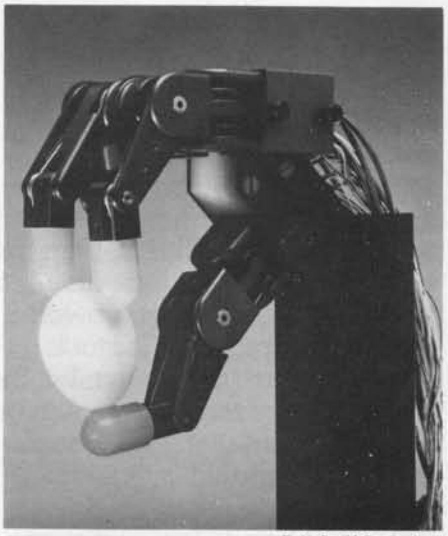


Photo: Dan McCoy/Rainbow

Ken Salisbury's three-fingered hand is featured in a video on robot hands. Built at M.I.T. in 1982, it can be instructed to hold an object with a constant force, thereby achieving a delicate but secure grasp. Feedback is obtained by means of a pressure-sensitive rubber layer that covers the fingertips.

mainly on the details of the actual image, analyzing it first to find edges, and identifying objects by their outlines. This approach makes machines better at matching complicated abstract patterns, such as fingerprints. Part of a fingerprint recognition system used by police departments all over the world is on display. Visitors try to match a fingerprint on the screen with one of several prints displayed on the wall from famous criminals. The computer then shows how it would make the match, using the points where ridges start or fork to classify the pattern accurately.

Speech recognition systems can give computers a reasonable sense of hearing, particularly if the machine has been trained by the speaker. Visitors can use several systems, including one that can be trained to respond to the visitor's voice. Even after training, computer speech recognition is limited to a few thousand words at most and generally requires the speaker to pause briefly between each word. In both speech recognition and vision, computers have yet to match the ability of a two-year old child.

A sense of touch is needed by a robot hand when it tries to grasp a delicate object. A pressure sensitive pad mounted on the robot gripper can gauge the amount of pressure being applied. Visitors see the pressure of their fingers on a pad displayed as an array of colors on a screen.

Finally, visitors can try out a sense that humans do not have - sonar. Robots use sonar to gauge the distance to surrounding walls and obstacles. The sensor emits pulses of extremely high-pitched sound, which reflect off an object and are picked up by the detector. The sound's round trip travel time indicates the distance to the object. In the exhibit, a ceiling mounted sensor measures a visitor's height by bouncing a signal off the top of the head.

Mobile Robots

In addition to its sensing ability, an intelligent, independent robot must have a suitable drive system and should be able to form and achieve goals. All the mobile robots on display in the exhibit are equipped with a drive system. Most have some form of sensing, but only Shakey seriously attempted the last and hardest requirement of forming plans and reasoning.

A mobile robot from Real World Interfaces roams around a cage, using sonar to sense and map the walls and obstacles. Visitors can try to override the robot's good sense by controlling its movement with a joystick, but it will never let itself collide with a wall. In addition, about 25 robot toys are on display and can be tried out by visitors. Most have wheels, but several can walk; some have bump sensors, or respond to claps or squeezing.

Robot Arms

Robot arms and hands attempt to replicate aspects of human manual dexterity. Arms are by far the most common type of robot. They perform a wide range of industrial tasks, from the tiny movements for assembling a wristwatch to the large powerful movements required to stack heavy cartons. In the exhibit, the real industrial arms are shown on video, and smaller, educational arms are operated by visitors.

An application mobile robots have already found is that of night watchman. The gallery's Sentry robot by Denning Mobile Robotics can carry TV cameras, infrared sensors and microphones to detect an intruder. The information it collects is radioed to a security office. Microwave beacons supplement the Sentry's onboard sonar, enabling it to patrol a path hundreds of feet long for hours on end without ever losing an exact knowledge of its position. In the exhibit, the Sentry patrols a short path, avoiding obstacles in its way. Its TV camera relays signals to another robot, the Hubot, whose onboard TV monitor displays the picture.

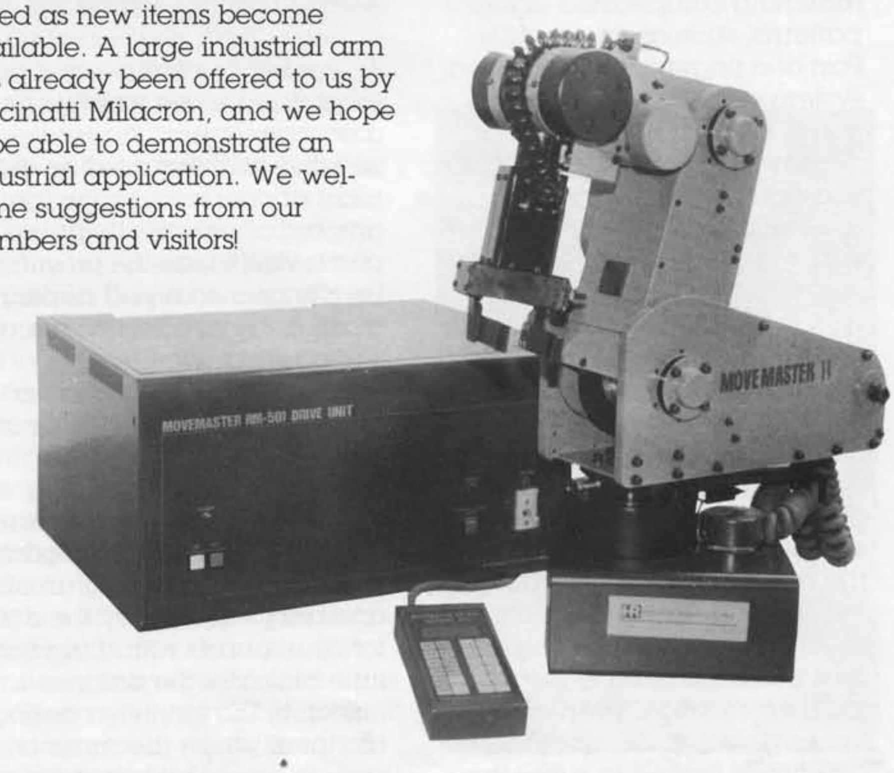
Two robot hands are on display: the five-fingered Tomovic hand attached to the tentacle arm pictured on the front cover, and a three-fingered soft gripper from Shigeo Hirose at the Tokyo Institute of Technology.

An ingenious way to achieve responsive compliance was invented at the Draper Laboratories. Their system uses an arrangement of springs that greatly eases tasks such as putting a peg into a tightly fitting hole. With a stiff wrist, a robot would jam the peg and only make it worse by pushing harder. With the compliant wrist, however, the peg finds its way into the hole smoothly. Visitors can use a compliant wrist to try this out for themselves.

A major thrust of industrial development is to tighten the link between the design and manufacture of a product. Using a computer-aided design system, an industrial designer can create a product and then send instructions for making that product directly to a numerically controlled tool or to a robot. Visitors can experiment with this process by designing a log cabin made of lincoln logs. When the design is complete, the cabin is constructed automatically by a pair of simulated robots on a screen. Real robots would need to be guided by a vision system to ensure that the logs were positioned accurately. This is demonstrated in an adjacent display in which a vision system guides a robot arm that assembles a toy boat from its parts. Both these displays were provided by the University of Lowell's Center for Productivity Enhancement.

The Future

The exhibit can be readily updated as new items become available. A large industrial arm has already been offered to us by Cincinatti Milacron, and we hope to be able to demonstrate an industrial application. We welcome suggestions from our members and visitors!



The Mitsubishi Movemaster uses its five joints and a gripper to pick up letter blocks and arrange them to spell a word typed in by the visitor. The arm is normally used for assembly or for handling chemicals.

Photo: Fay Foto

Gordon Bell and Russell Noftsker cutting the ribbon at the June 18th Smart Machines opening.

Special thanks to the Institutions and Individuals who gave time, machines, programs and other materials to make Smart Machines possible.

Funded by major grants from:

Russell Noftsker, Chairman, Symbolics, Inc.
The Founders of Symbolics, Inc.
C. Gordon Bell, National Science Foundation
The Xerox Foundation, Stamford, CT

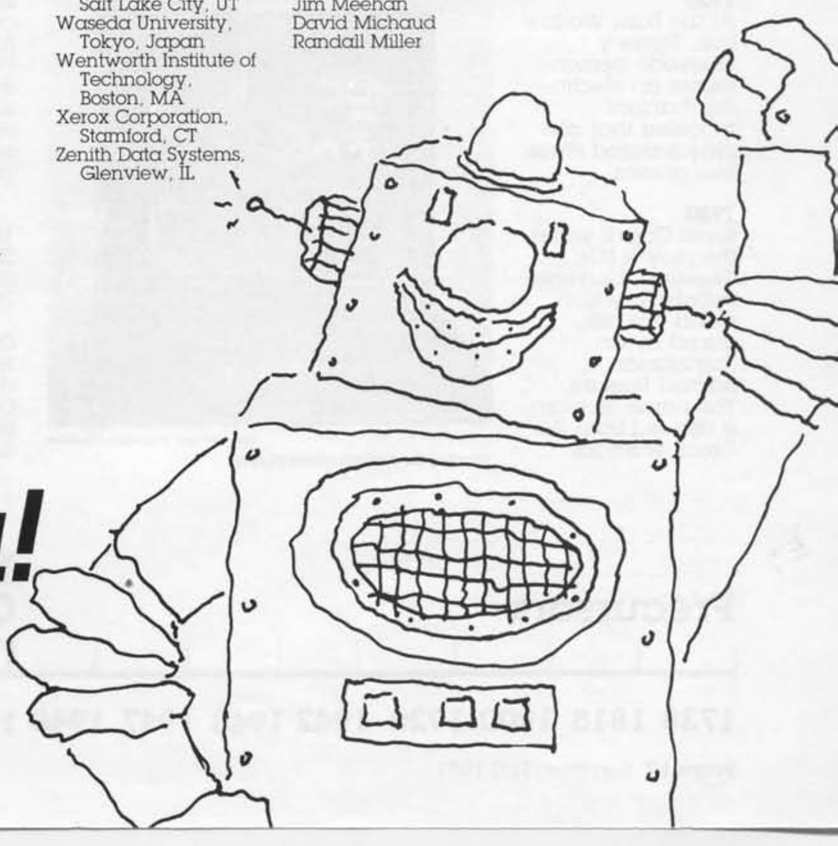
Institutions:

3COM, Santa Clara, CA
AC&R/DHB & Bess, New York, NY
Advanced Technology Systems, E. Providence, RI
Apple Computer Corporation, Cupertino, CA
Automatix, Inc., Billerica, MA
Axlon, Inc., Sunnyvale, CA
Barry Wright Corporation, Watertown, MA
Boris Color Laboratories, Boston, MA
Carnegie-Mellon University, Pittsburgh, PA
Charles Stark Draper Laboratories, Cambridge, MA
Chedd Angier Productions, Watertown, MA
Coleco Industries, West Hartford, CT
Contaq Technologies Corporation, Bristol, VT
Denning Mobile Robotics Inc., Woburn, MA
Digital Equipment Corporation, Maynard, MA
Dragon Systems, Newton, MA
Fisher America, Fairfield, NJ
Flexible Manufacturing Systems, Inc., Los Gatos, CA
FMC Corporation, Santa Clara, CA
Ford Motor Company, Dearborn, MI
General Motors Research Laboratory, Warren, MI
Gold Hill Computers, Cambridge, MA
Gulton Industries, Inc., Plano, TX
Hewlett-Packard, Cupertino, CA
Houghton Mifflin Company, Boston, MA
IBUKI, Los Altos, CA
Imaging Technology Inc., Woburn, MA
International Business Machines, Armonk, NY
Jet Propulsion Laboratory/NASA Pasadena, CA
Johns Hopkins University, Laurel, MD
Kurzweil Applied Intelligence, Inc., Waltham, MA
Kurzweil Foundation, Waltham, MA
Kurzweil Music Systems, Waltham, MA
Learning Company, Menlo Park, CA
Living Videotext Inc., Mountain View, CA
Massdata, Inc., Boston, MA
Massachusetts Institute of Technology, Cambridge, MA
Maxell Corporation of America, Moonachie, NJ
Mindscape. Inc., Northbrook, IL
Museum of Science, Boston, MA
Natural Language Inc., Berkeley, CA
Naval Systems International (Benthos/Deep Sea Systems), Falmouth, MA
NEC Home Electronics USA, Inc., Chicago, IL
NEC Information Systems, Inc., Boxborough, MA
New England Telephone Company, Boston, MA
Odesta Inc., Evanston, IL
Odetics Inc., Anaheim, CA
Ohio State University, Columbus, OH
OWI Inc., Compton, CA
Play Jour, New York, NY
Polaroid Corporation, Cambridge, MA
Raster Technologies Inc., Westford, MA
Raymond Industries, Agawam, MA
Real World Interfaces, Lyndeborough, NH
Rehabilitation Institute of Pittsburgh, Pittsburgh, PA
RobotCalc, Naperville, IL
Robotic Systems International, Sidney, BC, Canada
Scholastic Inc., New York, NY
Sequent Computer Systems, Inc., Beaverton, OR
Shape, Inc., Biddeford, ME
Smithsonian Institution, Washington, DC
Spinnaker Software, Inc., Cambridge, MA
SRI International, Menlo Park, CA
Stanford University, Stanford, CA
Sun Microsystems, Inc., Mountain View, CA
Symantec Inc., Cupertino, CA
Symbolics, Inc., Cambridge, MA
Tandy/Radio Shack, Fort Worth, TX
Technical Database Corporation, Conroe, TX
Tecnomatix, Birmingham, MI
Teknowledge, Inc., Palo Alto, CA
Tektronix, Beaverton, OR
Thermwood Corporation, Dale, IN
Thinking Machines, Inc., Cambridge, MA
Tokyo Institute of Technology, Tokyo, Japan
Tonka Toys, Minnetonka, MN
Tufts-New England Medical Center, Boston, MA
United States Robots, Carlsbad, CA
University of Lowell, Lowell, MA
University of Tokyo, Tokyo, Japan
University of Utah, Salt Lake City, UT
Waseda University, Tokyo, Japan
Wentworth Institute of Technology, Boston, MA
Xerox Corporation, Stamford, CT
Zenith Data Systems, Glenview, IL

Individuals:

Warren Adam
Al Adams
Mark Allen
Charles Ames
Charles Balmer
Sterling Barrett
Joseph Bates
Bruce Buchanan
Tom Callahan
Howard Cannon
Greg Carlson
Adam Lloyd Cohen
Harold Cohen
Raymond Cote
Tom Courtney
Curt Crittendon
Roger Dannenberg
Jim Davis
Randall Davis
Ed Demmler
Michael Domino
Ed Feigenbaum
Steve Foster
Karen Frenkel
Steve Golson
Michael Halle
Liz Haywood Sullivan
Carl Helmers
Shigeo Hirose
Henry Holtzman
Berthold Horn
Icharo Kato
Takeo Kanade
Tom Knight
Jim Kocher
Patrick Krolak
Stephen Kukolich
Bob Lee
Peter McA'Nulty
Jim Meehan
David Michaud
Randall Miller
Marvin Minsky
Hirofumi Miura
Stephen Moore
Hans Moravec
Grinnell More
Penny Nii
Stephen Pauker
George Pelyak
Jonathan Press
Marc Raibert
Mitchel Resnick
Alan Rifkin
Bernard Roth
Brian Sandberg
Penny Sander
Fern Sandhouse
Victor Scheinman
Marc Sidell
Dan Sieworek
David Silver
Isao Shimoyama
David Slate
Frank Sonnenberg
Alan Symonds
Franklyn Turbak
Leonardo Torres Quevedo
Barry Vercoe
Linda Webb
Joseph Weizenbaum
Carl West
Richard Weyhrauch
Brain Wilcox
David Zeltzer

Thank You!



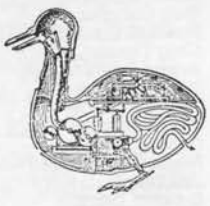
A Historical Timeline of Artificial Intelligence and Robotics

Gwen Bell and Leah Hutten

The Smart Machines exhibition has two historical components. A timeline, on display at the entrance to the exhibit, chronicles the major milestones to 1979. The Robot Theatre displays a collection of historic robots through the early 1980s. This article is intended as a synthesis of these two exhibits.

Precursors

1738
Jacques de Vaucanson builds a mechanical duck to tour and raise money for the inventor's experiments for creating life artificially. The copper duck quacks, bathes, drinks water, eats grain, digests it, and voids.



Courtesy of Bettman Archives
Drawing of de Vaucanson's duck.

1818
The book, *Frankenstein*, by Mary Shelley, includes the first description of creating a man-made being, who becomes a fearful monster.

1900
At the Paris World's Fair, Torres y Quevedo demonstrates an electro-mechanical machine that can play selected chess end games .

1920
Karel Capek writes the play *R.U.R.* (Rossum's Universal Robots) in which robots are produced by an Englishman named Rossum. The name, Rossum, is derived from the Czech word for reason, while robot is a Czech word for worker. The popularity of the play led to the widespread adoption of the word robot.

1942
Isaac Asimov publishes "Runaround" in the March issue of *Astounding*, in which he introduces the Three Laws of Robotics. This is the first known use of the term "robotics."

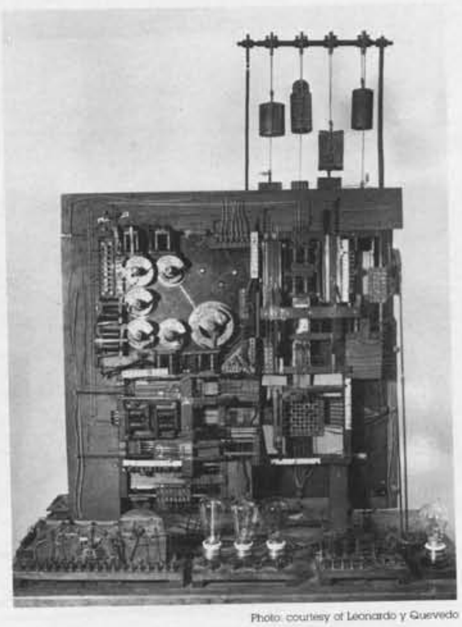


Photo: courtesy of Leonardo y Quevedo
Torres y Quevedo's chess player.

1943
Warren McCulloch and Walter Pitts propose that the behavior of the brain can be treated as a network of neurons that behave like on-off switches.

1947
Only a year after the completion of ENIAC, the first electronic computer, Arthur Samuel proposes to build a computer to play checkers.

1948
Norbert Wiener coins the term cybernetics, a philosophical perspective for describing interacting systems in terms of exchange of information.

1949
The Debate Begins: Can Machines Think?

On June 9, at Manchester University's Lister Oration, British brain surgeon Sir Geoffrey Jefferson states, "Not until a machine can write a sonnet or compose a concerto because of thoughts and emotions felt, and not by the chance fall of symbols, could we agree that machine equals brain — that is, not only write it but know that it had written it. No mechanism could feel (and not merely artificially signal, an easy contrivance) pleasure at its successes, grief when its valves fuse, be warmed by flattery, be made miserable by its mistakes, be charmed by sex, be angry or miserable when it cannot get what it wants."

On June 11, *The London Times* quotes the mathematician Alan Turing, "I do not see why it (the machine) should not enter any one of the fields normally covered by the human intellect, and eventually compete on equal terms. I do not think you can even draw the line about sonnets, though the comparison is perhaps a little bit unfair because a sonnet written by a machine will be better appreciated by another machine."

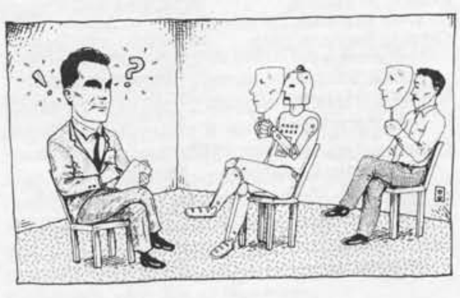


Illustration: courtesy of Joseph Deken
The Turing test.

Precursors

The Debate Begins: Can Machines Think?

1738 1818 1900 1920 1942 1943 1947 1948 1949

In New York, Claude Shannon's paper to the Institute of Radio Engineers proposes two computer chess strategies that are still in use. The first is to look at all the choices up to a fixed depth and the second is to look at a selected few to greater depth.

In the 1950s robots and artificial intelligence (A.I.) start evolving along separate tracks.

1951
Turing creates a standard test to answer: " Can machines think?" If a computer, on the basis of written replies to questions, could not be distinguished from a human respondent, then it must be "thinking."

1954
George C. Devol, Jr., applies for the first US patent for an industrial robot. He calls it "unimation" for short.

1956
John McCarthy of Dartmouth convenes the Dartmouth Summer Research Project on Artificial Intelligence, marking the birth of the field.

Herbert Simon, Allen Newell, and J.C. Shaw write "Logic Theorist," one of the earliest programs to investigate the use of heuristics in problem solving.

1957
John McCarthy and Marvin Minsky found the first artificial intelligence laboratory at M.I.T.

Simon, Newell and Shaw write the pioneering, "General Problem Solver." It is the first program that solves a problem that it hadn't been specially programmed to solve.

1958
Simon, Newell and Shaw design and use the first list processing program, IPL-V.

1959
McCarthy creates LISP. Unlike other current programming languages, LISP is designed to work with English words and phrases. A key feature is that the data and programs are simply lists in parentheses, allowing a program to treat another program — or itself — as data. This characteristic greatly eases the kind of programming that attempts to model human thought.

Frank Rosenblatt invents an ingenious evidence-weighing machine called a "Perceptron." It is supposed to recognize patterns by their parts without regard to their relationships.

In the 1960s, the Department of Defense Advanced Research Project Agency (DARPA) provides large-scale funds for artificial intelligence research at Carnegie-Mellon University, Massachusetts Institute of Technology and Stanford University.

Joe Engelberger, the entrepreneur, works tirelessly to get Joseph Devol's ideas for industrial robots into use. Engelberger eventually earns the title "Father of Robotics."

1961
James Slagle writes a Symbolic Automatic Integrator (SAINT) to solve elementary symbolic integration problems at the level of a good college freshman.

SAD-SAM (Syntactic Appraiser and Diagrammer — Semantic Analyzing Machine) is programmed by Robert Lindsay at Carnegie Institute of Technology. The program accepts English sentences about kinship relations, builds a data base and answers questions about the facts it has stored.

SAD-SAM INPUT: John is Mary's son.
SAD-SAM OUTPUT: Mary's brother is John's uncle; Mary's mother is John's grandmother, etc.

1962
Engelberger founds Unimation, the first industrial robot company. The Unimate Mark II robot welcomes visitors into the Museum's Smart Machines Gallery.

Samuel's checkers program, which has the ability to learn from its mistakes, plays at the masters level.

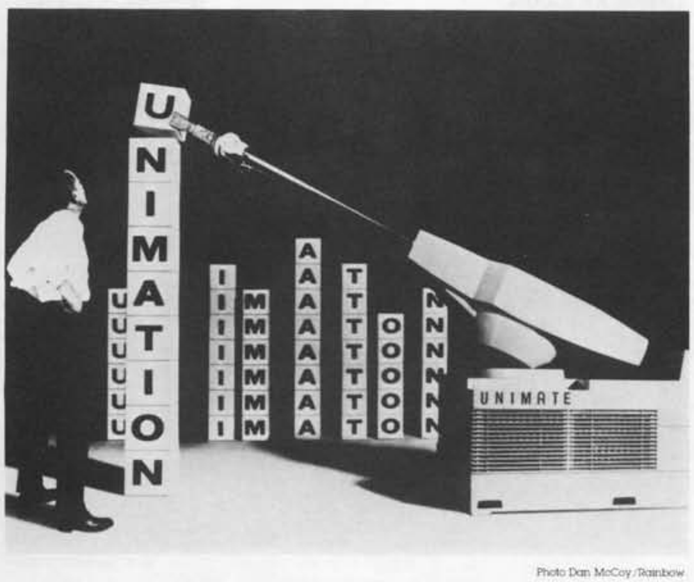


Photo Dan McCoy/Rainbow

Unimate courtesy of National Museum of American History, Smithsonian Institution.

1963
McCarthy leaves M.I.T. and founds Stanford University's artificial intelligence laboratory.

At Rancho Los Amigos Hospital an orthotic arm is designed to aid a paralyzed person.

community. The PDP-6's architecture is particularly suited for running LISP programs.

Edward Feigenbaum and Bruce Buchanan conceptualize expert systems and start the Dendral project.

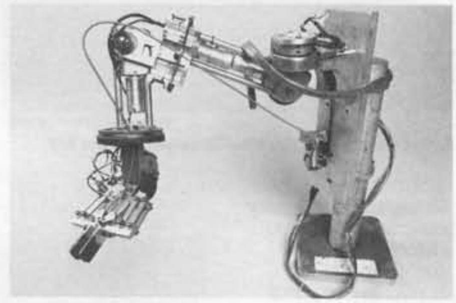


Photo Dan McCoy/Rainbow

Rancho Arm, on loan from Stanford University, Stanford, Calif.

Stanford University modifies the Rancho Arm to be controlled by a computer.

1965
A five fingered aluminum prosthetic hand is developed by Rajko Tomovic at The University of Belgrade.

The PDP-6 becomes the workhorse machine for the artificial intelligence

Hubert Dreyfus' paper "Alchemy and Artificial Intelligence," is published by The Rand Corporation. His assertion that "Even though machines can perform intelligent tasks, the evidence against their ever becoming able to be really, humanly intelligent, is overwhelming," leads to debates and research that continue into the 1980s.

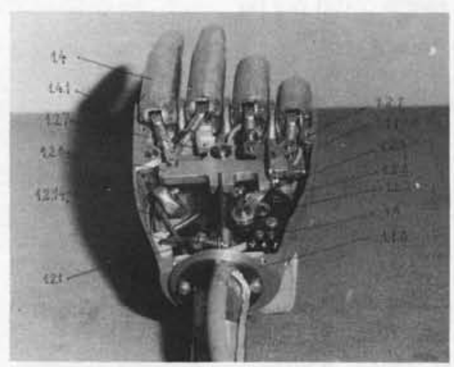


Illustration: Rajko Tomovic

Tomovic Hand, on loan from Tom Callaghan.

McCarthy Creates LISP

1951 1954 1956 1957 1958 1959 1961 1962 1963 1965

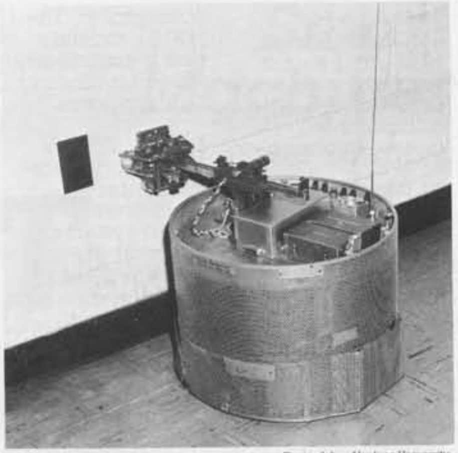


Photo: Johns Hopkins University

Beast, gift of Johns Hopkins University, Laurel, MD.

Scientists at Johns Hopkins University create the Beast (Mod II) as an experiment to replicate animal behavior in a robot. When it gets "hungry" (low batteries), it uses sonar and a photocell array to find "food" (wall power outlets). Pressure-sensitive switches perform the fine guiding of its prongs into the wall socket.

Victor Scheinman and Larry Leifer build the "Orm," Norwegian for snake. This robot arm moves by selectively inflating groups of its 28 air sacks sandwiched between seven metal disks. Its design is later abandoned because its movements could not be repeated accurately.

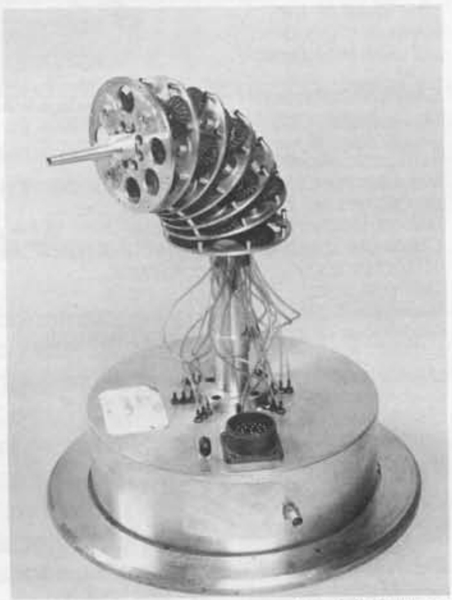


Photo: Dan McCoy/Rainbow

Orm, on loan from Stanford University, Stanford, Calif.

The Stanford Cart is built at the A.I. Lab to simulate a remotely controlled Moon rover.

1966
The program ELIZA, written by Joe Weizenbaum at M.I.T., tries to assume the role of a nondirective therapist. It turns sentences into questions and responds to key words about feelings and family.

Richard Greenblatt's MacHac is the first machine to achieve a Class C rating in the National Chess Association (approaching the level of a serious weekend amateur player).

1967
Television cameras controlled by a remote computer are added to the Stanford Cart, permitting it to follow a white line on a road.

1968
Engelberger travels to Japan and grants Kawasaki the right to build Unimates in exchange for royalties. These are the first robots built in Japan.

Bruce Buchanan and Edward Feigenbaum, working with Chemist and Nobel Laureate Joshua Lederberg, complete DENDRAL, an expert system for generating explanatory hypotheses in organic chemistry.

Marvin Minsky constructs the 12-jointed Tentacle Arm, which can reach around obstacles. A PDP-6 computer is used for control and hydraulic fluids for power.

Seymour Papert writes "The Artificial Intelligence of Hubert L. Dreyfus: A Budget of Falacies." In it, he states, "It is cowardice to ... assure us that the computer is barred by its finite number of states from encroaching further into areas of activity ... (regarded) as 'uniquely human'."

1969
Shakey, the first integrated robot system equipped with a TV camera and other sensors, slowly roams through the rooms of The Stanford Research Institute, guided by the remote radio control of an SDS-940 computer.

The Original Stanford Arm, the first successful electrically-powered computer-controlled robot arm, is constructed by Victor Scheinman. It is used to develop industrial assembly techniques for robots.

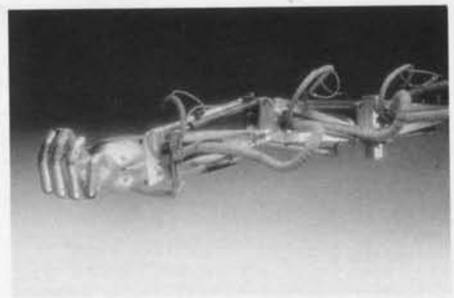


Photo: Fay Foto

12-jointed Tentacle Arm, on loan from Massachusetts Institute of Technology, Cambridge, MA.

In the 1970s, A.I. is recognized as a computer science discipline, and industrial robots are put to work in factories around the world.

1970
200 people attend the first meeting of the International Joint Conference on Artificial Intelligence (IJCAI).

Terry Winograd integrates natural language understanding and knowledge about a world of table top blocks in SHRDLU, written for his doctoral thesis at M.I.T.

1971
France installs its first industrial robot, a Unimate, at Renault's R-5 plant to build LeCar.

Stanford Research Institute gives Shakey the ability to reason about its actions. Shakey radios information from its sonar and bump sensors to a room-sized computer (DEC PDP-10 and PDP-15), which sends back commands to make Shakey move. The computer spends about half an hour to move Shakey one meter.

DARPA funds a $15 million, five-year research program to achieve a breakthrough in speech understanding.

Photo: Dan McCoy/Rainbow

Stanford Arm, on loan from Stanford University, Stanford, CA.

Industrial robots are put to work in factories around the world.

1966 | 1967 | 1968 | 1969 | 1970 | 1971

1972
At the University of Aix-Marseille, Alain Colmerauer develops the use of formal logic as a programming language, PROLOG.

LUNAR, a natural-language information retrieval system, is completed by Woods, Kaplan, and Nash-Webber at Bolt, Beranek and Newman. LUNAR helps geologists access, compare and evaluate chemical-analysis data on moon rock and soil composition from the Apollo 11 mission.

1973
Yorick Wilks writes the first acceptable language translation program, which produces respectable French from small English paragraphs.

1974
The first commercially available mini-computer controlled robot, T3, is produced by Cincinnati Milacron.

The first World Computer Chess Tournament is held.

CONS, the first computer built to optimize LISP, is completed by Tom Knight at M.I.T.'s A.I. Lab. It is the precursor of CADR and the commercial machines built at LMI and Symbolics.

1975
MARGIE (Meaning Analysis, Response Generation, and Inference in English) is developed by Roger Schank and his students at the Stanford A.I. Laboratory.

Photos: courtesy of NASA/JPL

Mars Rover Prototypes, on loan from NASA/Jet Propulsion Laboratory, Pasadena, CA.

Minsky develops the concept of frames as a convenient way to represent specific objects or concepts. Each frame consists of a name and a series of slots that describe the object's or concept's attributes.

Unimation has its first profitable year.

1976
The DARPA speech goals are met by the HEARSAY speech program developed at Carnegie-Mellon University under the direction of Raj Reddy. It beats DARPA's goal of understanding 90% of ordinary continuous speech using a vocabulary of 1000 words.

1977
Hans Moravec equips the Stanford Cart with stereo vision. A television camera that moves along a rail takes pictures of a given scene from several different angles, enabling the Cart to find the distance to obstacles in its path.

In the USA, Robert McGhee develops a hexapod walking machine controlled by a digital computer. In the USSR, scientists develop a hexapod walker controlled by a hybrid (analog and digital) computer.

EMYCIN developed by William Von Melle, Edward Shortliffe, Bruce Buchanan, and Edward Feigenbaum is the first expert system "shell." A shell is a program that provides the framework for developing an expert system. The user supplies his own rules to build an expert system in the subject of his choice.

The programs SAM (Script Applier Mechanism) and PAM (Plan Applier Mechanism) are developed by Roger Schank, Robert Abelson and their students at Yale University. SAM and PAM demonstrate the understanding of stories by using scripts and plans.

The Jet Propulsion Laboratory builds two Rover prototypes designed to explore Mars. To stay upright, the Hardware Prototype has caterpillar tracks mounted on flexible legs. The Software Prototype has both sensing ability and intelligence.

1978
The Mars Rover project is cancelled because NASA opts for a manned space program.

GM unveils its production line, which uses a programmable universal machine for assembly (PUMA) system based on the Scheinman arm.

Hans Berliner's backgammon program wins the world championship.

Consight-I, by Steven Holland, Lothar Rossol and Mitchel Ward, is able to identify and sort randomly oriented parts on a moving factory conveyor belt. When the parts move under two converging light beams, the beams are split in two. This pattern is detected by a computer connnected to a television camera. Consight-I consists of a Vicarm robot arm controlled by a PDP 11/45 computer. Commerical versions use an arm by Cincinatti Milacron.

1979
After seven years of research, Moravec's refined Stanford Cart successfully traverses, without human intervention, a room strewn with chairs.

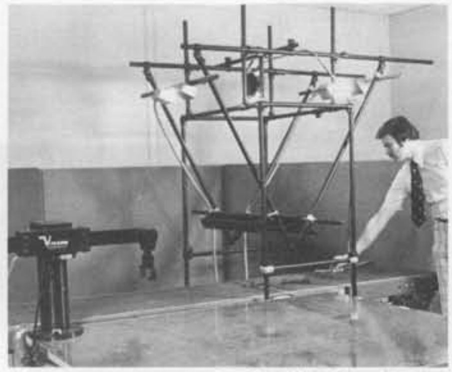


Photo: General Motors Research Laboratories

Consight, gift of General Motors Research Laboratories, Warren, Mich.

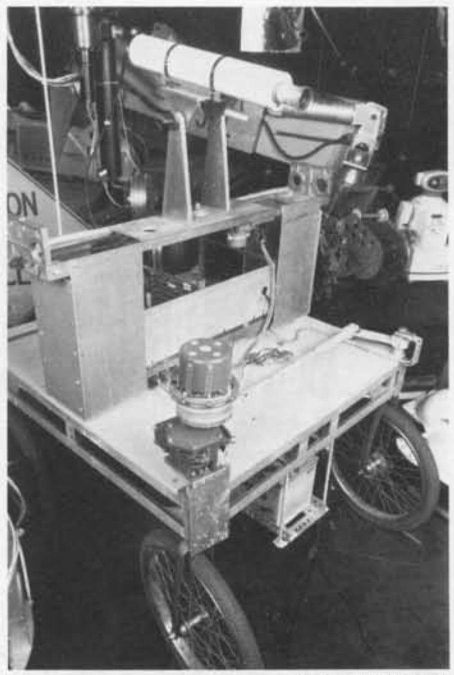


Photo: Dan McCoy/Rainbow

Stanford Cart, on loan from Stanford University, Stanford, CA.

The first World Computer Chess Tournament is held.

1972 1973 1974 1975 1976 1977 1978 1979

CONTEMPORARY ROBOTS FROM THE MUSEUM'S COLLECTION

1981
Avatar represents a breed of personal home robots that evolved following the microcomputer revolution in the early 1980s. This robot can move without bumping into things, talk, and handle objects with its arm.

1981
One of three of Shigeo Hirose's robots at the museum, the quadruped can perform a complicated task such as "feeling its way" up stairs of varying heights. It has contact sensors on the sides and bottom of its feet. When these are touched, the quadruped responds with animal-like reflexes. Each leg contains an elegant mechanical device that translates small motor movements inside the body into larger movements of the legs.

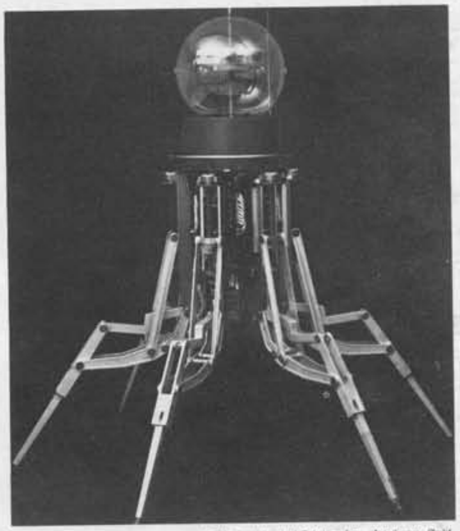


Photo courtesy of Odetics Inc., Anaheim, Calif.

Odex-1 on loan from the Smithsonian Institution, Washington, D.C.

1981
The first direct drive (DD) arm by Takeo Kanade served as the prototype for DD arms used in industry today. The electric motors housed inside the joints eliminate the need for chains or tendons used in earlier robots. DD arms are fast and accurate because they minimize friction and backlash.

Photo courtesy of Takeo Kanade

Direct Drive Arm-1, gift of Carnegie-Mellon University, Pittsburgh, Pa.

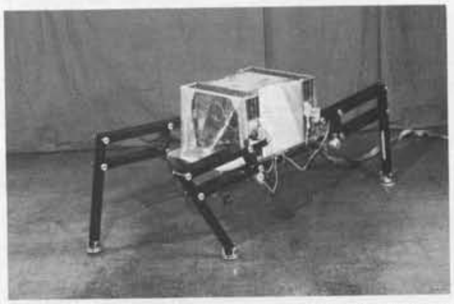


Photo courtesy of Shigeo Hirose

Titan III (Quadruped) on loan from the Tokyo Institute of Technology, Tokyo, Japan

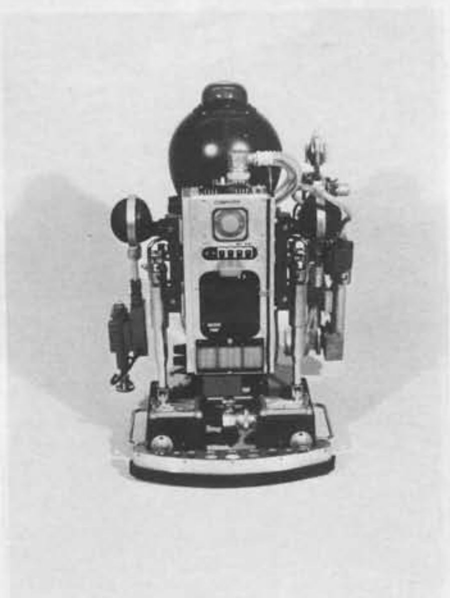


Photo courtesy of Charles Balmer Jr.

Avatar on loan from Charles Balmer, Jr., Urbana, Ohio

1983
Odex is the first commercially available walking robot. It can work in dangerous places inaccessible to vehicles with wheels. These include radioactive zones in nuclear power stations, military battlefields, and underground mines. Its legs can also serve as arms for lifting and moving objects.

1985
Underwater rovers explore the ocean depths under remote control. The famous Titanic wreck was explored by a large rover called Argo, but most underwater rovers are used for more routine inspection tasks. The Sea Rover, designed by Christopher Nicholson, can dive to depths of up to 120 meters and travel at 1.5 knots while relaying color video pictures from under the sea.

Photo courtesy of Naval Systems International A

Sea Rover, gift of Naval Systems International, a joint venture of Deep Sea Systems and Benthos, Inc., Falmouth, Mass.

Direct Drive Arm–1

Odex–1

1981 **1983** **1985**

Calendar *Fall 1987*

Oct 4
Sunday
3 PM

Britain's First Commercial Computer, The Leo 1
John M. M. Pinkerton, McLean Pinkerton Associates
The use and design of Leo 1 will be illustrated with a period film and a talk by its chief engineer.

Oct 11
Sunday
3 PM

The Society of the Mind: A Psychological Look at Artificial Intelligence
Professor Marvin Minsky, MIT

Oct 18
Sunday
2-4 PM

Whirlwind's Genesis and Descendants
A panel discussion by the pioneers that built the Whirlwind computer at MIT and subsequently carried on the research and development at the MIT Lincoln Laboratory.

Nov 1
Sunday
3 PM

Robots: A Recapitulation of Life
Professor Hans Moravec, Carnegie-Mellon University
An illustrated lecture by one of the field's innovators.

Nov 6-8

Computer Games Weekend
Classic and contemporary games will be available all weekend in the Museum galleries.

Fri night 25th Birthday Party of Interactive Computer Games

Saturday Panel Discussions: Computer Games, Past, Present and Future

Sunday Second International Core Wars Competition
MicroMouse Demonstrations

New From The Computer Museum Store

The New Computer Museum Slide Rule Tie Bar
The perfect gift for every math-minded man. This tie bar is based on the real thing, complete with A, C, and D scales and a moveable cursor. Handsomely finished in antique gold. $22.50 post-paid (Members $20.25)

☐ **YES!** I want to become a Member of The Computer Museum.

☐ **$20 Student** ☐ **$ 45 Family** ☐ **$250 Sponsor**
☐ **$30 Individual** ☐ **$100 Donor** ☐ **$500 Patron**

Members receive free admission for one full year, invitations to exhibit previews, advance notice of exhibitiions and lectures, invitations to members-only events, a subscription to our exciting quarterly magazine, The Computer Museum Report, and a 10% discount in the Museum Store.

Enclosed is my check made payable to **The Computer Museum** for $________

or charge to: ☐ VISA ☐ MasterCard ☐ American Express

Card # ________ Expiration Date ________

Signature ________

Name ________

Address ________

City ________ State ________ Zip ________

Contributions are tax-deductible to the extent provided by the law.

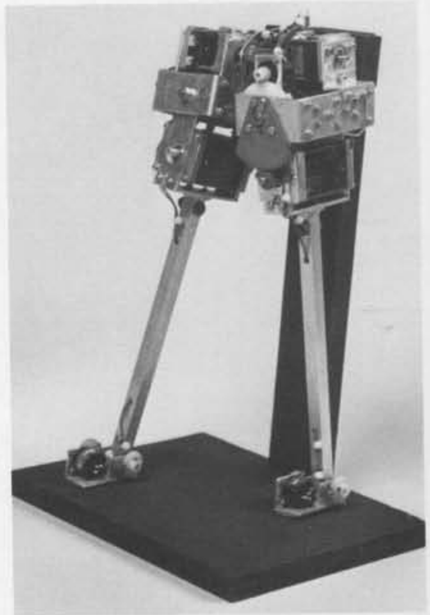
The Computer Museum

The Computer Museum is a non-profit 501(c)3 foundation that chronicles the evolution of information processing through exhibitions, archives, publications, research and programs.

Museum Hours: *Summer:* Open daily 10 – 5, Friday 10 - 9. *Winter:* Open Tuesday – Sunday 10 - 5, Friday 10 - 9. Open Mondays during Boston school vacation weeks, 10 - 5. Closed Thanksgiving, Christmas, and New Years Day. Hours are subject to change.

Membership All members receive a membership card, free subscription to The Computer Museum Report, a 10% discount on merchandise from The Computer Museum Store, free admission and invitations to Museum previews. For more information contact Membership Coordinator at The Computer Museum, 300 Congress Street, Boston, MA 02210. Telephone (617) 426-2800.

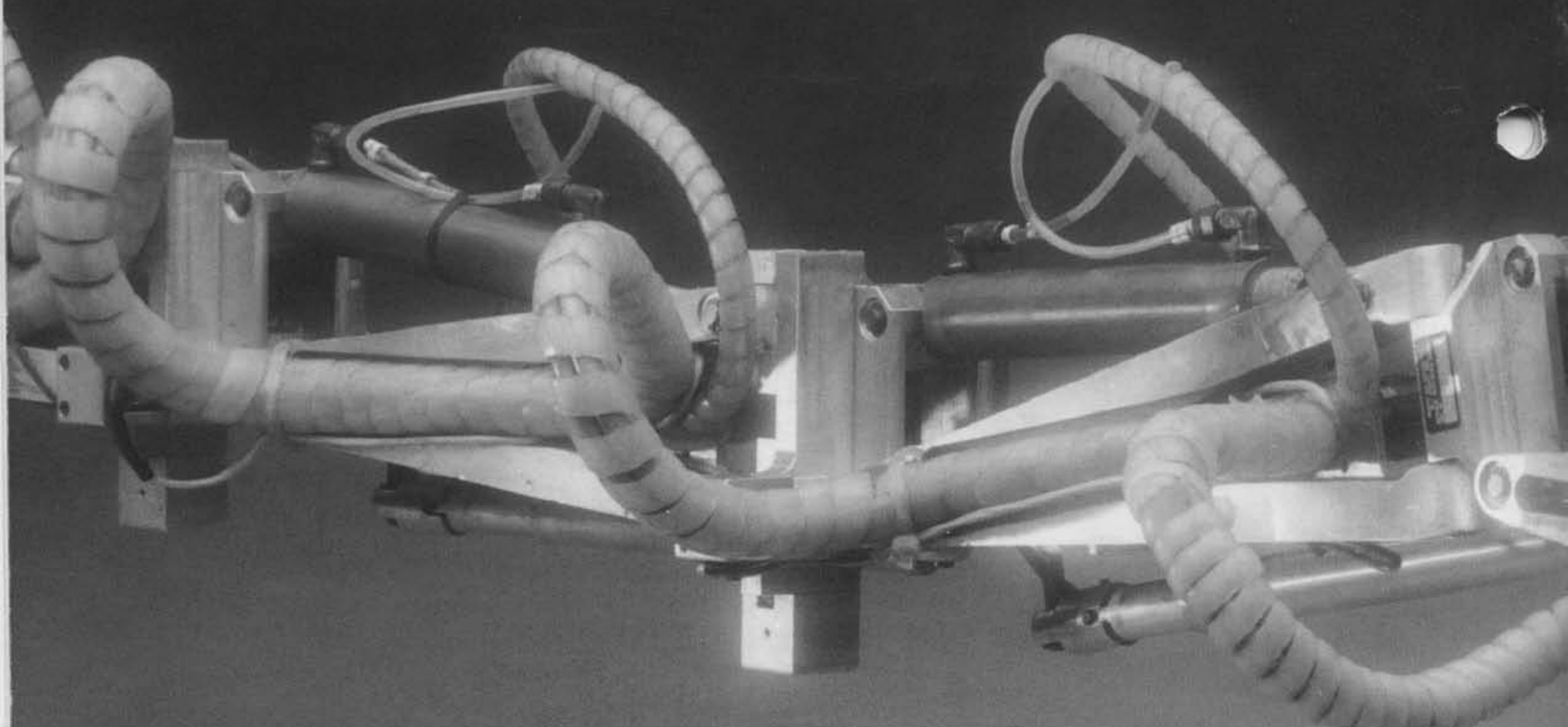
The End Bit
0000000000000001



BIPER-3, designed by Hirofumi Miura and Isao Shimoyama in 1981, was the first legged machine to balance itself dynamically. Like a person, its gait relies on its own forward momentum. It has stilt-like legs and uses its hips to pick up its feet. This gives the machine a pronounced shuffling gait like Charlie Chaplin's stiff-kneed walk.

BIPER-3 can walk forward, backward, or sideways.

On loan from the University of Tokyo, Tokyo, Japan



Address Correction Requested

Non-Profit
Organization
U.S. Postage
PAID
PERMIT NO. 110
FITCHBURG, MA.
01420

The Computer Museum 300 Congress Street, Boston, Massachusetts 02210