SYSTEM DEVELOPMENT FOUNDATION

ANNUAL REPORT JUNE 30, 1986

One Maritime Plaza, Suite 1770
San Francisco, CA 94111
(415) 362-0480

SYSTEM DEVELOPMENT FOUNDATION
ANNUAL REPORT

CONTENTS

REPORT OF THE DIRECTOR OF PROGRAM ADMINISTRATION

EVOLUTION OF THE FOUNDATION'S PROGRAM

The System Development Foundation has developed a program to support basic research in the information sciences. This program evolved under two constraints. One was a decision that the Foundation should focus primarily on those areas of research that the System Development Corporation initially was created to address: "the information sciences, information processing and the man-machine interface." The other constraint was a decision that the Foundation would operate for a finite term, rather than in perpetuity.

By June 30, 1986, the Foundation had approved more than $80 million in grants to implement its program. Table 1 shows the distribution across eight research areas of all grants made from December 1981 through June 1986.

ACTIVITIES IN FISCAL YEAR 1986

The grants made between July 1, 1985 and June 30, 1986 are summarized by program area in Table 2. During this period, the Foundation concentrated its funding on projects that already have been funded but need continued support in order to bring their research to fruition.

THE RESEARCH PROGRAM

The Foundation's program as a whole can be described as a fundamental investigation into representation, meaning, and cognition. However, for administrative reasons, the overall program has been divided into eight areas of research. The category *Principles of Information Science* includes investigations that address the basic issues of the Foundation's research program. Projects in this area range from database construction to the design of integrated circuits.

Much of the research supported by the Foundation in the area of *Computational Linguistics and Speech* operates on the two-pronged hypothesis a) that the generation, interpretation, and acquisition of language is a computational process, and b) that, conversely, computation is a linguistic process. From this point of departure, groups of linguists, philosophers, logicians, psychologists, computer scientists, and artificial

TABLE 1 *Distribution of Funding by Program Area December 1981 to June 1986*

Program Area	Amount	Percent of Total
1. Principles of information science	$ 9,256,000	11
2. Computational linguistics and speech	27,167,000	33
3. Symbolic mathematics	1,305,000	2
4. Robotics	11,184,000	13
5. Non-von Neumann computation	3,066,000	4
6. Neuroscience	8,436,000	10
7. The man-machine interface	4,308,000	5
8. Computer music	8,371,000	10
9. Unrestricted (Rand)	10,000,000	12
Total	$83,093,000	100

TABLE 2 *Grants Made from July 1, 1985 to June 30, 1986 by Program Area*

Program Area	Amount	Percent of Total
1. Principles of information science	$ 877,000	32
2. Computational linguistics and speech	317,000	11
3. Symbolic mathematics	20,000	1
4. Robotics	393,000	14
5. Non-von Neumann computation	0	0
6. Neuroscience	871,000	31
7. The man-machine interface	25,000	1
8. Computer music	278,000	10
Total	$2,781,000	100

intelligence researchers have been working together and are creating a new field of inquiry tentatively called "Information, Computation and Cognition." Researchers in this new field hope to provide answers to questions such as "What is the nature of information?," "How is information acquired and used by minds and machines?," and "What types of structures can be used to represent information in minds and machines?"

Research in *Symbolic Mathematics* seeks to represent mathematics, an already highly formalized body of knowledge, in such a way that computers can efficiently use that knowledge in solving real problems. Advances in software practice, such as object-oriented programming, now make it possible for researchers to identify the underlying problems of representing and applying mathematics in a computer environment.

In *Robotics*, the Foundation is supporting studies of the principles of locomotion, manipulation, and perception. In all three areas, many of the same principles appear to apply to animals as well as to artificial devices, such as robots. The investigations in this program area explore these common principles.

Until recently, computer science has lacked the concepts and the formal notation to treat computation that is not of a linear, serial nature. The principles underlying parallel and distributed computing, i.e., *Non-von Neumann Computation*, need to be much better understood. Several of the projects supported by the Foundation in this area of research have resulted in the creation of generalized software management schemes that simultaneously oversee and control a number of specialized parallel processors.

In *Neuroscience*, the study of representation and meaning is the investigation of how the process of signal detection and cognition takes place on a neural substrate. Machine computation has provided the field of neuroscience with new theoretical methods and, more importantly, with a new ability to test theory. With computer models, researchers can now explore the predictions of theories of neural activity based on interactions within complex systems of neurons. Research of this type also tests the generality and applicability of theories of information processing that can be simulated with digital computers.

The *Man-Machine Interface* has several dimensions. Innovative research on the basic physiology of human interaction with computers has been accomplished. There also has been an increasing number of sound psychological studies of one-to-one interaction between human beings and computers. The Foundation has encouraged the search for basic principles governing this interaction to guide and supplement the large existing efforts to engineer specific solutions. Another area of supported study is the complex and somewhat diffuse interaction of computer systems with human organizations.

Computer Music is a field in which art and science meet. The Foundation has awarded grants to permit computer musicians not only to continue their artistic explorations, but also to direct their research toward expressive, inexpensive computer musical instruments. The problems of computer music tie directly to the other program areas of the Foundation. For example, a central problem for computer musicians is linguistic: to understand enough about the formal structure of musical ideas to represent them expressively and easily to both humans and machines. In addition, dimensional analysis suggests that a computational architecture for computer music may best be based on a non-von Neumann concept.

SELECTED EXAMPLES OF RESEARCH ACHIEVEMENTS

In this section, a few examples of research results of the past year are described. Not all of the eight program areas are represented here. Instead, these new findings are presented in order to illustrate the kinds of research that the Foundation has funded.

Principles of Information Science: *Underlying Relationships between Computation and the Physical World*

David Feinstein, one of Carver Mead's graduate students at the California Institute of Technology, has written his Ph.D. thesis on a reexamination of the connection between information theory and thermodynamics. Feinstein has discovered a new relation that links these two fields in a simple way. He finds that the *free energy* of thermodynamics and the *mutual information* of information theory, when appropriately transformed, become identical operators in the asymptotic limit of long time periods.

In this thesis, time has been viewed as a channel and the state of the system as a message. As the system's state evolves with time, the information content of the message is degraded. Thermodynamics quantifies the advance of a system toward equilibrium by measuring its free energy, while information theory quantifies the loss of memory of the initial state by measuring the mutual information. The free energy depends on the internal energy of the thermodynamic system, and the mutual information depends on the conditional entropy of the information system. The internal energy is a linear operator that maps the state vector at time t onto a scalar with the dimensions of energy, and the conditional entropy is a linear operator that maps the state vector at time zero onto a dimensionless scalar. *Rescaling* the internal energy makes it dimensionless. *Rereferencing* the conditional entropy makes it refer to the state vector at time t, rather than the state vector at time zero. Feinstein has proved that the rescaled internal energy and the rereferenced conditional entropy become identical operators in the asymptotic limit of long time periods. This identity holds for the class of systems where the time constants of different modes differ by less than a factor of two.

There are three new results in this work. The first is the calculation of the long time limit of the rereferenced conditional entropy in information theory; the second is the statement of the relation between the internal energy of a thermodynamic system and the conditional entropy of information theory, mentioned above; and the third is the statement of the relation between the free energy and mutual information. This formulation of the relationship between thermodynamics and information theory will provide the basis for exploring new applications of conditional entropy, which was introduced in information theory by Shannon in 1948. One such application would be to examine the role of conditional entropy in the classical problems in non-equilibrium thermodynamics. There may also be a role for conditional entropy in connecting fluctuation phenomena with energy dissipation in thermodynamic systems.

Principles of Information Science: *Manipulable Computer Architectures*

Zamir Bavel and his group at the University of Kansas have been using the *tier automaton model* to study the dynamic operation of an entire computing system. They have achieved two significant results in this work.

The first came in modeling communication networks and their protocols with a theoretical tier automaton model. Previous attempts to model entire communication systems had failed to incorporate the transmission medium. They also failed to include direct causal linkage between transmitter and receiver. The result was a static model that required an observer to intervene in order to make the system function. The new tier automaton model provides the dynamic operation of an entire computing system by introducing the activation power of the trunks of the tier automaton within a single monolithic structure. This model can run autonomously in either a synchronous or asynchronous mode and needs external interruption by the operator only when such interruptions are required by the overall system design.

The tier automaton model has been successfully applied to a number of communication protocols. The representation models the entire operation without interruption, includes a representation of the transmission medium, and is easily simulated by a computer program. The result is a facile tool with which reliability, safeness, liveness, and other desirable properties of network protocols may be studied advantageously. Work with this model also showed how to manipulate communication protocols by means of homomorphisms on their tier automaton representations. When two different protocols were represented, their homomorphisms not only improved their performance, but in both cases yielded the *alternating bit protocol*--a superior protocol for a network which is different from the networks of the original protocols. This is significant because it introduced the new concept of being able to improve on network architectures and protocols. More importantly, it also demonstrated for the first time that the tier automaton can dynamically manipulate computer architectures. The definition of the tier automaton, a general scheme for its application to communication protocols, the means with which to manipulate such protocols, as well as the representation and manipulation of some well-known protocols, have been published.

The second significant result achieved by this project demonstrated that Petri net representations of computer architectures can be represented by tier automata. The large number of problems in the literature that have been solved using Petri net representations of various computer architectures can now be manipulated by the tier automaton model. One very important feature is that these manipulations do not require one to produce a tier automaton model of a given architecture from the specifications of that architecture, but permit one to work directly with the tier automaton translation of the Petri net representation of the architecture.

This investigation of the tier automaton representation of Petri nets has led to a considerably more powerful version of the tier automaton called the *power tier automaton*. Since marked Petri nets are capable of unbounded action, it was necessary to increase the distinction between an active state-tag pair and one that is not active. This was accomplished by introducing an "index of activeness" for such a pair, where the index ranges over the set of nonnegative integers. These needed enhancements of the original tier automaton model resulted in the power tier automaton.

The computing capacity of the power tier automaton has been shown to be at least as large as that of Petri nets. (The complexity problem is under study.) This model proves to be a much more compact representation of finite architectures, both in detailed specifications and pictorially, than the tier automaton is. This is a major advantage in those cases where "state explosion" is a constant concern.

Another result of representing Petri nets as tier automata is the *activation net*. This is a model that combines features of the tier automaton and of Petri nets and adds new properties to both. The activation net is proving to be a very interesting and valuable tool for the study of problems of concurrency, which are at the heart of parallel computation. The definition and an intuitive illustration of the activation net, together with the activation net representations of some well-known concurrency problems, have been published. The power of the activation net has been shown to equal that of a marked Petri net.

Computational Linguistics and Speech: *Investigation of Computerized Comparative Lexicography*

The Lexicon Project of the Center for Cognitive Science at MIT is under the direction of Kenneth Hale and Jay Keyser. The Center is engaged in a cross-linguistic study that focuses on four languages: English, Berber, Warlpiri, and Winnebago. English is the only one of the four languages that has a strong written tradition. For all of these languages, the central purpose is the scientific study of human lexical competence.

When we say, "Plato greeted Socrates," we understand Plato to be the greeter and Socrates to be the recipient of the greeting, and not vice versa. Why this should be the case is by no means obvious, and explaining this aspect of human lexical knowledge is a fundamental problem of scientific lexicology. This is just one instance of the general problem of the relationship between verbal meaning and grammatical form.

The investigators take the study of the lexicon, or scientific lexicology, to be an integral part of the general research program of linguistics, the goal of which is the development of an adequate explanatory theory of the human capacity for language. The research studies the meanings of lexical items and elaborates a theory of the representations of lexical entries in which the meaning, or *Lexical Conceptual Structure*, is properly associated with the syntactic projection of an item--i.e., a theory of the relation between thematic roles and grammatical functions.

An on-going project connected with this research in scientific lexicology is the implementation of a framework that will allow the researchers to build a computer-based database for English verbs. This database will contain information about the properties of verbs considered relevant to the realization of ideal lexical entries.

Continuing research on Tamazight Berber (spoken in Morocco) involves two essential activities: First, the construction of actual dictionary entries, each displaying linguistically crucial information in a format that reflects general principles of lexical organization, and second, the investigation of Berber grammar, with a view to discovering the general principles of lexical grammar that must form a part of a usable dictionary of Berber verbs.

During the past year, Berber has contributed as much as, and perhaps more than, English to the understanding of verbal transitivity alternations. Mohammed Guerssel has investigated the pervasive contrast between Berber verbs that form a transitive by means of the prefix *ss-* 'causative' and verbs that, like the English verb, *break*, show no overt transitivizing morphology. He has been able to relate this division to a semantic opposition--which he labels *intrinsic/extrinsic*--according to whether the process or action denoted by a verb is intrinsic to the "central participant" (e.g., to *John* in *John laughed*) or not intrinsic to it (e.g., as it is not in the case of *the pot* in *the pot broke*). This amounts to recognition of a primitive human theory of processes according to which certain processes are always "caused."

With this view of the lexical semantics of Berber verbs, Guerssel has succeeded in expressing a wide range of generalizations in the lexicon of that language. But his work goes well beyond Berber in its significance, since the semantic opposition he has identified is relevant in all four languages of the project. This work may point the way to a truly explanatory theory of verbal diathesis, one according to which the lexical commitment of thematic roles to grammatical functions in syntax follows automatically from Lexical Conceptual Structure.

Warlpiri is an Australian aboriginal language. In addition to perfecting sections of the dictionary, investigators are currently engaged in the systematic lexicographic study of the Warlpiri *preverb*, the element that is responsible for the rather large verbal lexicon of the language. Most verbs in Warlpiri are morphologically complex, involving combinations of preverb and verbal root, and the syntactic and semantic regularities inherent in these combinations comprise an important topic of research in the language.

Winnebago is an American Indian language of the Siouan family. The formulation of dictionary entries for Winnebago verbs continued to be the primary focus of Josephine White Eagle's work during the past year. Work continued on the internal make-up of the Winnebago verb word, the most complex of the lexical categories in the language. This year a study of Winnebago syntax was initiated, beginning with an examination of the syntactic and semantic form of content questions, the syntax of relative clauses, and the grammar of sentential complements. This research on grammar is essential not only for the companion volume on grammar, but also for the grammatical notes that constitute a necessary part of each lexical entry in the dictionary.

Computational Linguistics and Speech: *An X-Ray Microbeam System for Studying Speech Production*

The X-ray microbeam facility and its research program at the University of Wisconsin are under the direction of James Abbs and have been largely supported by the National Institutes of Health; however, the System Development Foundation has been able to contribute several key elements to the facility. The overall goal of the program is to understand the physiology of normal speech patterns in human subjects.

Because more than one hundred muscles in the mouth and throat are used to form a simple one-syllable word, normal speech is an extremely complex act. If any of these muscles fail to function properly, the person will have impaired speech, which is a common problem throughout the world. Because speech is unique to humans, animals cannot be used as surrogates for in-depth physiological studies. The essential feature of the X-ray microbeam design is that it minimizes the radiation dosages to the people whose speech is to be studied. During a 20-minute exposure by the new X-ray microbeam, a subject will receive about as much radiation exposure as during a routine dental X-ray.

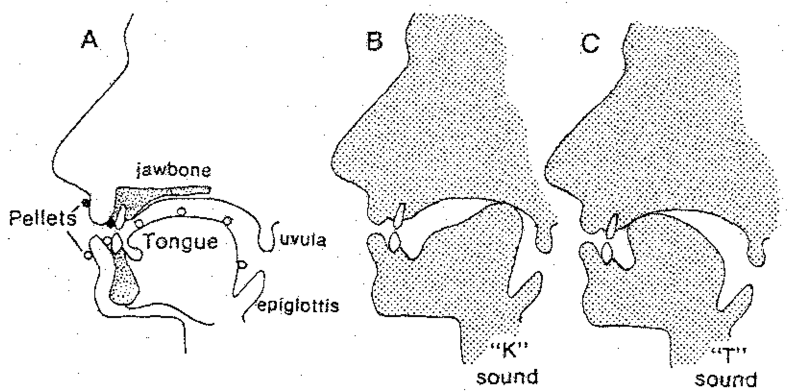

Figure 1.
A) Pellets located on the tongue and lips.
B) Position of the tongue and lips for the sound "k."
C) The sound "t."

A prototype of the microbeam apparatus was built at the University of Tokyo by Osamu Fujimura, who is now at the AT&T Bell Laboratories and is a collaborator with Abbs on this project. The X-ray microbeam works by focusing a narrow but powerful beam of X-rays on small regions of the mouth. The beam is steered by a computer and tracks speech muscles by homing in on small gold pellets strategically glued to different parts of the mouth. The computer, told roughly where the pellets are, orders the microbeam to make a general sweep to find them and then to track them individually as they move during speech. The computer can locate and record eight or nine pellets in less than a millisecond. As seen in Figure 1, a number of pellets can be observed in sequence in order to track the motion of the structures, such as the lips and tongue, to which they are attached.

To produce the X-ray beam, an electron beam is focused on a thin sheet of tungsten. As electrons strike the tungsten, photons or X-rays are produced. A fine beam of those X-rays is picked off by a pinhole-sized aperture which then focuses the X-ray beam on a target--in this case, the human head. This arrangement is indicated in Figure 2. The X-ray beam emitted by the Wisconsin-built device uses much higher energy X-rays than the older Japanese machine and is better able to penetrate the teeth, bone and tooth fillings that surround the tongue. The other major improvement over the earlier Japanese device is the use of advanced computer technology. A set of very fast, specialized computers drives the beam, retrieves and stores the data, and allows researchers to quickly and efficiently manipulate selected information. As mentioned above, the computer steers the beam around regions of the mouth and each pellet's position. It also samples the transmitted X-rays to detect "shadows" and then compensates the beam exposure before moving on to the next pellet. The computer-controlled X-ray machine was built by Murray Thompson and his engineers at the Physical Sciences Lab of the University of Wisconsin.

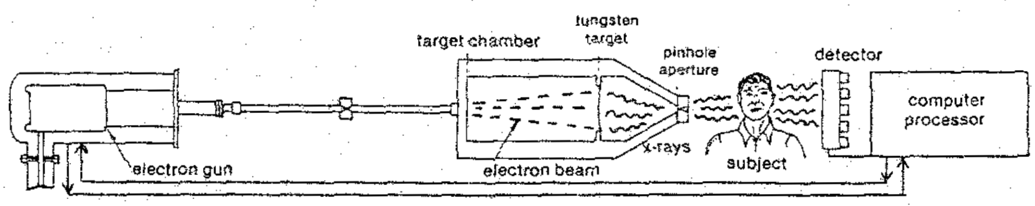

Figure 2.
The X-ray microbeam apparatus.

When the motions of parts of the tongue have been recorded, quantitative techniques can be used to determine how much and how fast the part holding a pellet has moved. They also can show how those movements in people with normal speech differ from those in people with speech problems such as those caused by Parkinson's disease, cerebellar dysfunction, or stuttering. This unique microbeam facility is available to researchers from all over the world and should provide new insights into the field of speech physiology research in the years ahead.

Computational Linguistics and Speech: *The Computational Feasibility of Natural Language Inferences when Information Is Limited*

During the past year, in collaboration with Daniel Osherson of MIT and Michael Stob of Calvin College, Scott Weinstein of the University of Pennsylvania has extended his research on the theory of machine inductive inference in a number of new directions. This work is reported in four papers. The first introduces a new perspective in the study of machine inductive inference. It considers how inference problems might be factored into the action of multiple "expert advisors" whose advice is aggregated by a general purpose inference mechanism. This theoretical perspective may spawn more concrete research on "distributed expert systems."

The second paper demonstrates a novel feature of one of the most closely investigated models of scientific inference. It shows that a Bayesian strategy dramatically restricts the class of inference problems that can be solved by computable inference methods. This result will have considerable effect on several approaches to the study and application of machine inductive inference and will bear directly on important issues in epistemology.

The third paper addresses the problem of generating inductive inference machines from descriptions of the problem domains in which they are intended to succeed. The result provides the theoretical underpinnings for the construction of interactive inference mechanisms that could accept the advice of a user in generating a successful method by which given collections of languages and functions could be inferred automatically. The proposed theoretical framework promises to be of significance both from the point of view of ongoing research in cognitive science dealing with problems of inductive inference, as well as technological developments in automated inference systems.

The final paper deals with the use of parallel distributed processors for inductive inference. It provides two models for the use of such architectures in constructing inference mechanisms and compares the inferring power of such systems with that of arbitrary inductive inference machines. The results lay the groundwork for a theoretically sound approach to questions about the usefulness of parallel distributed processors as models of cognitive processes.

Robotics: *Dynamic Legged Locomotion*

Marc Raibert and his group at Carnegie-Mellon University have achieved some new results in their work on the dynamics of legged locomotion.

They have found that a simple set of principles can provide balance and control for a variety of dynamic legged systems. The machines that have been studied so far include a planar one-legged hopping machine, a three-dimensional one-legged hopping machine, a planar biped running machine, a quadruped, and a monopod with rotary leg joints. The techniques used to control each of these machines derive from a single set of control algorithms, modified in various ways in each case. The overall approach decomposes locomotion control in order to regulate separately three aspects of the body's behavior--its hopping height, forward running speed, and posture.

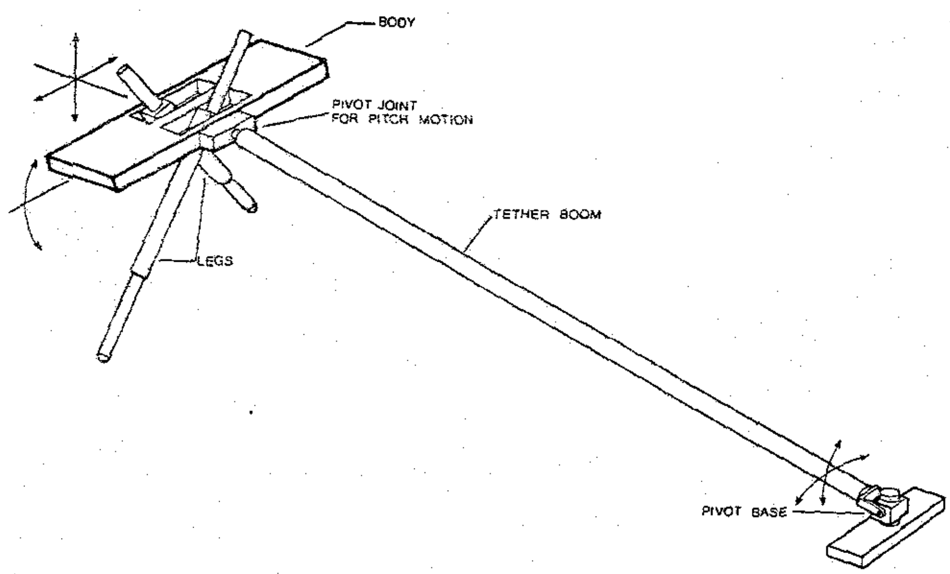

Figure 3.
Planar biped with tether.

Two new running machines have dominated their recent work. One machine, the planar biped shown in Figure 3, was built to study dynamically stable locomotion on rough terrain and high speed locomotion. It also has been used to perform gymnastic maneuvers, as shown in Figure 4. The other machine, the planar monopod shown in Figure 5, was built to study additional mechanical aspects of leg design.

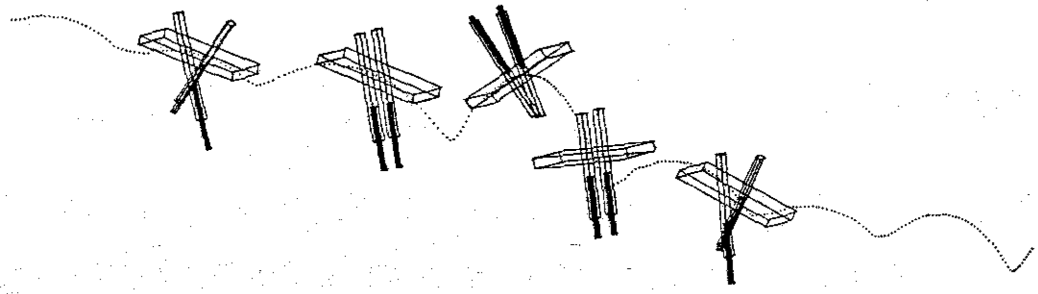

Figure 4.
Cartoon of a planar biped doing a forward flip.

The basic factors that limit speed in legged locomotion are energy, control, mechanical design, and computing. Raibert's group is working to identify physical and control constraints that limit the running speed of the biped. Identifying the factors that limit running performance is part of an effort to increase the top running speed of the planar biped, which can now run at 5.3 meters/second (11.5 mph), more than twice as fast as the previous machines.

The promise of travel on rough terrain is the key to Raibert's expectations that legged vehicles may someday be useful. A project is under way to study locomotion on rough terrain. It addresses the problem of controlling the length of each stride in order to position the foot on a particular spot on the ground. Three approaches to manipulating stride are being explored. One approach adjusts the duration of the flight phase, holding the duration of stance and the forward speed constant. A second approach adjusts the stiffness of the leg to change the duration of the stance phase, holding the duration of flight and forward speed constant. The third approach adjusts forward running speed, holding cadence constant. A practical system, running on rough terrain, may eventually combine these and other techniques for manipulating stride. They are being studied now in isolation in order to gain a better understanding of each one.

One way to build legs that are stronger, lighter, faster, and more reliable may be to use rotary joints rather than linear telescopic joints. Previous work produced four machines that ran successfully on telescopic legs. However, the moment of inertia and weight of these legs is high, their reliability is low, and they are difficult to build. Articulated legs, those that use rotary joints, can be designed to solve some of these problems. One hurdle will be to incorporate the elastic storage elements vital to good dynamic behavior, without overcomplicating the control. A first design is pictured in Figure 5. Tests show that it performs quite well as part of a planar hopping machine, though its asymmetry and high natural frequency pose new locomotion control problems. This work is aimed at designing an articulated leg for a quadruped.

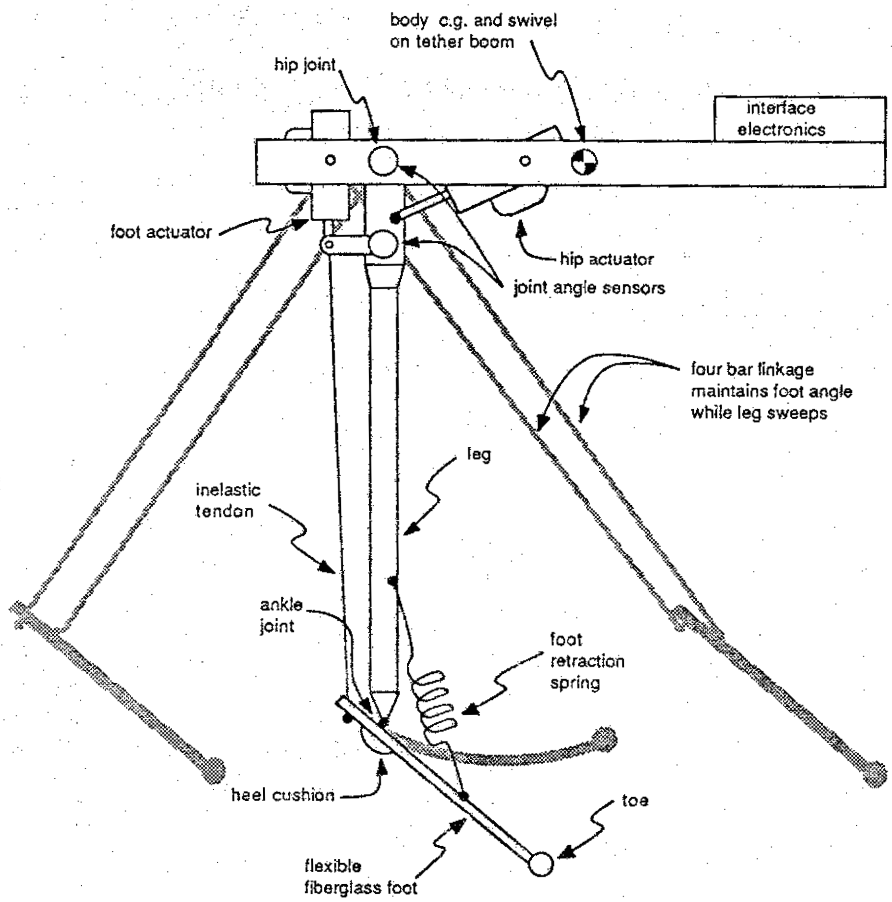

Figure 5.
A one-legged hopping machine using
an articulated leg.

Robotics: *Micro Electromechanical Systems Project*

Steve Jacobsen and John Wood have been studying very small electromechanical systems at the University of Utah. These *micro electro mechanical systems* (MEMS) are of interest because their very small scale significantly changes the ratios of surface areas, volumes, and interaction lengths. These scaling effects can be used to design machines with extraordinary performance characteristics and their study was inspired by examples of biological systems such as muscle, in which large numbers of small components are combined to produce actuators and sensors with impressive performance, efficiency, and control.

The design and fabrication of these small systems is very difficult. Intuition, based on experience with larger sized machines, provides little help when designing very small systems. The MEMS Project has been devoted to understanding how to fabricate, apply forces to, and sense the movement of small mechanical elements. Movable mechanical elements with as many as six degrees-of-freedom are manipulated by forces applied by locally generated electric or magnetic fields. These fields can be static, when they are generated by polarized or electrostatically charged materials, or dynamic, when produced by conductors whose potentials are appropriately varied in time. Methods for sensing the position of small mechanical elements are being explored and a number of experimental systems, using field intensity measurements and optical techniques, have been tested.

A small cantilevered, optical fiber servo system has been used to guide the study of various actuating and sensing modalities and also to study methods for fabricating components such as integrated circuits and electrets. Scaling arguments suggest that electrostatic forces are most interesting when electric forces dominate inertial forces. This situation obtains for objects of microchip size (i.e., when dimensions are less than 50 microns). However, such small dimensions were considered to be too difficult to work with at the beginning of the project. Instead, preliminary experimental studies were performed on small but "laboratory size" apparatus that is suitable for studying small scale fields and could be rapidly fabricated and manually modified and/or adjusted. The first experimental system is shown in Figure 6.

This miniature servo system consists of a stator, or base, composed of a series of strip drivers. The ten adjacent planar insulated conducting strips, each 200 microns wide and 2 cm. long, are attached to amplifiers that set, or sense, the voltages on each strip. A long, thin quartz fiber is mounted above the strips to act as an armature, as shown in Figure 6. Due to the 100-to-1 aspect ratio of the strips and the armature, the system may be approximated by a two-dimensional system with two degrees-of-freedom.

The basic strip driver and quartz fiber system can be arranged to include almost all of the elements of a total microsystem including an armature, a stator, electrets, dynamic field generators, field sensors, and position sensors of several types. The system was first used to determine experimentally the electric field shape and strength by mounting a thin wire as a probe (armature) which was connected to a very high input impedance, intermittent sensing voltmeter. In this way, the field generated by strip drivers, in a number of voltage configurations, could be measured and compared to theoretical models.

A number of experiments were performed with a cantilevered armature consisting of a 140-micron diameter quartz optical fiber as shown in Figure 6. The optical fiber was coated or wrapped with electret material consisting of a 20-micron, Teflon® layer. The Teflon was then electrically charged.

Under the action of fields produced by the driver strips, the quartz fiber could be moved about and its deflection measured. A lateral effect photo diode (LEPD) monitored a laser beam passing through the fiber to determine the displacement of the fiber by the driver field. This basic configuration has been used for several related studies. First, static deflection of a fiber was measured for various strip driver voltages, and the results were used to confirm measurements of linear charge density and field strength. Second, the apparatus was used to test an active feedback system for controlling fiber motion and stabilizing it in otherwise unstable positions (i.e., positions close to the drivers where image forces

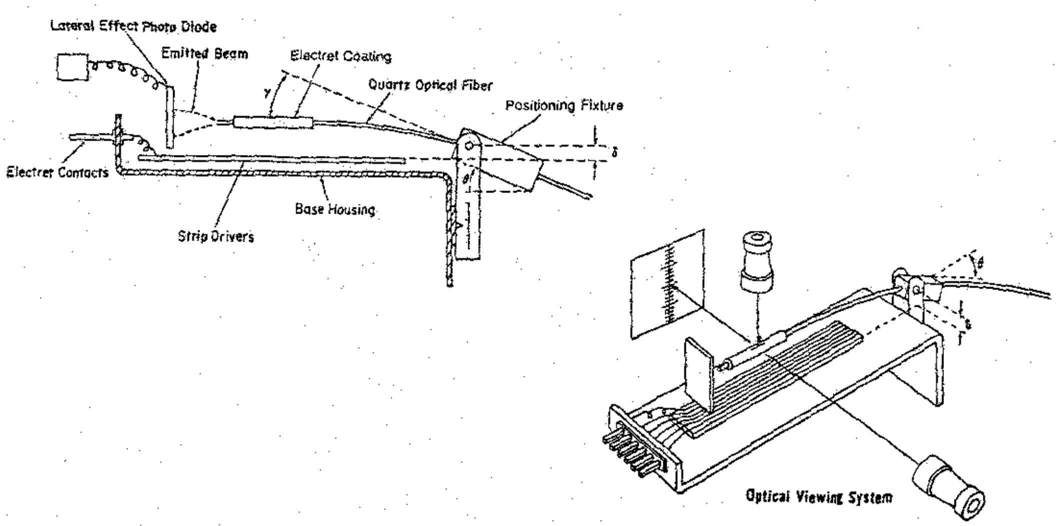

Figure 6.
A realistic sketch of a "laboratory size" apparatus suitable to study small scale fields that allow rapid fabrication and manual adjustment.

dominate). And third, the apparatus was used to test various concepts in AC stabilization. The trajectory of a cantilevered fiber in an AC field for stable and unstable cases has been studied.

These results indicate the feasibility of a whole new class of sensors, optical devices, chemical processors, and actuators with extraordinary performance.

Man-Machine Interface: *Social Aspects of Computing*

Lee S. Sproull and her group at Carnegie-Mellon University have completed a book-length manuscript on the social aspects of computing. The report presents a collection of systematic studies conducted during a four-year period across the entire CMU campus--a "computer intensive" community. The book is titled *Chalkboards and BBoards: Computing and Organizational Change* on Campus and will be published in 1987 by the Cambridge University Press.

One of Sproull's studies concentrated on the experiences of CMU freshmen as they were introduced to computing. The investigators found that, when freshmen encounter computing, they do more than acquire a new set of skills for dealing with machinery. They also encounter a new culture. The machine and the software are cultural artifacts surrounded by norms, values, a status hierarchy, rights, rituals, language, heroes, fools and all the other trappings of an ongoing culture.

Every spring for the past four years, Sproull's group asked all liberal arts CMU freshmen to describe their reactions to each of their classes. Each year, the data shows that the computing experience is different from other courses. However, the differences between computing and other courses are decreasing over time. Computing is coming to look more like other freshman courses because of changes at CMU. These changes include new teaching approaches, improved computer facilities, and more students who now come to CMU with prior computing experience.

The Sproull study also shows that not everyone is equally enthusiastic about computing. CMU students who studied computing in high school find it less alienating than others do, and more women than men report that computer science is "different" from their other courses.

This study of the impact of widespread computer usage, which has been conducted in both university and corporate environments, will provide an important historical reference for the future.

GRANTS MADE BY SDF

from December 1981 through June 1986

PRINCIPLES OF INFORMATION SCIENCE

University of Southern California

Award date: June 15, 1982	*$808,600*	*3 years*
Award date: February 11, 1985	*$ 76,024*	*6 months*
Award date: February 9, 1986	*$525,448*	*15 months*

To study pattern analysis with principal application to molecular biology. (SDF 15)

Michael Waterman, principal investigator

Rand Corporation

Award date: September 14, 1982	*$84,000*	*9 months*
Award date: November 9, 1983	*$15,000*	

To study a specification-based language translation system. (SDF 58)

Henry Sowizral, principal investigator

California Institute of Technology

Award date: December 15, 1981	*$1,489,764*	*3 years*
Award date: August 12, 1984	*$1,623,536*	*33 months*

To investigate the underlying relationship between computation and the physical world. (SDF 237)

Carver Mead, principal investigator

Northwestern University

Award date: June 15, 1982	*$ 12,500*	*3 months*
Award date: September 14, 1982	*$326,664*	*3 years*

To study the relationship between modes of representation and what is represented, with attention to graphic presentation. (SDF 248)

Howard Becker, principal investigator

Association for Computing Machinery

Award date: November 5, 1982	*$8,920*	

To facilitate the participation of distinguished non-U.S. researchers in the Sixth Annual International Information Retrieval Conference. (SDF 257)

Michael McGill, principal investigator

University of Michigan

Award date: April 18, 1983	*$24,682*	*3 months*

To define the problems of research on induction in adaptive systems. (SDF 314)

Richard Nisbett, principal investigator

San Jose State University

Award date: December 15, 1981	*$ 167,800*	*1 year*
Award date: September 14, 1982	*$ 10,000*	*4 months*
Award date: December 7, 1982	*$2,211,000*	*3 years*
Award date: August 12, 1984	*$ 20,000*	
Award date: February 9, 1986	*$ 265,990*	*9 months*

To investigate the structure of statistical data and its implications for the derivation of information, database organization, and tabular and graphic presentation. (SDF 327)

James L. Dolby, principal investigator
(succeeded by Martin Billik, principal investigator)

Stanford University

Award date: June 15, 1982	*$20,000*	4 months

To facilitate the visit to Stanford University of Professor Eliahu Shamir of Hebrew University, to work on parallel probabilistic algorithms. (SDF 349)

Jeffrey Ullman, principal investigator

University of Chicago

Award date: June 15, 1982	*$38,500*	1 year

To study the role of functional multiplexing and developmental constraints in the conceptualization and design of non-von Neumann computer architecture. (SDF 357)

William Wimsatt, principal investigator

National Research Council (U.S.)
Award date: March 15, 1983 *$25,000* *3 months*

To support technical review and editing of the Committee on the National Statistics draft report, "Sharing Research Data." (SDF 362)

Miron Straff, principal investigator

University of Utah
Award date: September 13, 1983 *$7,000* *3 months*

To study questions and approaches in sensory information processing via digital signal processing. (SDF 456)

Thomas Stockham, principal investigator

University of Manchester (England)
Award date: May 8, 1984 *$21,000* *1 year*

To explore issues relating to the portability of network systems software. (SDF 458)

Derrick Morris, principal investigator

Oxford University
Award date: September 13, 1983 *$40,000* *1 year*

To study the computational modeling of vision. (SDF 461)

Andrew Parker and Colin Blakemore, principal investigators

Princeton University
Award date: September 13, 1983 *$20,000* *8 months*

To publish a collection of John Tukey's works and writings. (SDF 508)

John Tukey, principal investigator

University of Michigan
Award date: June 14, 1983 *$119,000* *1 year*

To complete a book on inference and the growth of knowledge based on interdisciplinary research on perceptual-motor adaptation and conceptual aspects of induction in organisms. (SDF 524a)

Richard Nisbett, John Holland, Keith Holyoak, and Paul Thagard, principal investigators

University of Michigan
Award date: February 13, 1984 *$9,500*

To convene a conference on induction. (SDF 524b)

Richard Nisbett and Gary Olson, principal investigators

George Washington University
Award date: September 13, 1983 *$12,000*

To convene a special research symposium in honor of Marvin Denicoff of the Office of Naval Research. (SDF 554)

W. H. Marlow, principal investigator

University of Kansas
Award date: May 15, 1984 *$785,168* *30 months*

To study manipulable computer architectures. (SDF 565)

Zamir Bavel, principal investigator

San Jose State University

Award date: December 13, 1983	*$235,000*	*1 year*
Award date: December 3, 1984	*$135,000*	*9 months*
Award date: July 31, 1985	*$ 8,625*	

To study knowledge representation and computational formalisms. (SDF 575)

Henson Graves, principal investigator

The Computer Museum
Award date: December 13, 1983 *$10,000*

To relocate and exhibit the SAGE ANFS/Q7 computer at the Computer Museum. (SDF 576)

Gwen Bell, principal investigator

University of Detroit
Award date: August 12, 1984 *$23,675*

To conduct oral history interviews relating to the System Development Foundation. (SDF 677)

John Staudenmaier, principal investigator

National Academy of Science
Award date: February 9, 1986 — *$69,515* — *6 months*

To assist in the completion of a report entitled "Ten-Year Outlook on Research Opportunities in the Behavioral and Social Sciences." (SDF 850)

David Goslin, prinicipal investigator

University of California, Berkeley
Award date: May 5, 1986 — *$7,591*

To assist in the completion of the Ralph W. Tyler Oral History Project. (SDF 862)

Willa Baum, principal investigator

Total Principles of Information Science ***$9,256,502***

COMPUTATIONAL LINGUISTICS AND SPEECH

Center for Advanced Study in the Behavioral Sciences
Award date: February 2, 1982 — *$108,498* — *3 months*

To explore issues in structural semantics and to complete the manuscript, "Situations in Discourse," with six co-investigators. (SDF 240)

Hans Kamp and Stanley Peters, principal investigators

Massachusetts Institute of Technology
Award date: June 15, 1982 — *$435,569* — *2 years*
Award date: June 14, 1983 — *$227,320* — *1 year*

To study the formalization and quantification of acoustic-phonetic knowledge with application to phonetically based continuous speech recognition. (SDF 243)

Victor Zue, principal investigator

Yale University
Award date: December 15, 1981 — *$772,948* — *30 months*

To study text comprehension and language processing, with an emphasis on knowledge representation. (SDF 344)

Robert Abelson and Roger Schank, principal investigators

Stanford University			
	Award date: June 15, 1982	*$125,000*	*15 months*

To complete a manuscript on the hermeneutics of computer science and to investigate temporal aspects of computer linguistics. (SDF 358)

Terry Winograd, principal investigator

Massachusetts Institute of Technology			
	Award date: June 14, 1983	*$776,880*	*3 years*
	Award date: May 20, 1985	*$ 50,000*	*1 year*

To investigate computerized comparative lexicography for creating dictionaries of spoken languages that have no written form. (SDF 389)

Kenneth Hale and S. Jay Keyser, principal investigators

Stanford University			
	Award date: March 15, 1983	*$725,826*	*30 months*

To study the development of semantic theory of natural and computer languages in terms of situation semantics. (SDF 402)

John Perry, Jon Barwise, and Stanley Peters, principal investigators

University of Delaware			
	Award date: March 15, 1983	*$410,720*	*3 years*

To conduct an analytic study of the research on computer language. (SDF 403)

A. Toni Cohen, principal investigator

Massachusetts Institute of Technology			
	Award date: April 21, 1983	*$5,650*	

To convene a conference on types and polymorphism in programming languages. (SDF 444)

Albert Meyer, principal investigator

Stanford University

Award date: July 14, 1983	*$13,641,000*	*4 years*
Award date: September 13, 1983	*$ 3,573,000*	*4 years*
Award date: August 15, 1984	*$ 1,257,842*	*3 years*
Award date: August 13, 1984	*$ 684,441*	*3 years*
Award date: December 3, 1984	*$ 25,000*	*1 year*

To investigate language as a computational process, computation as a linguistic activity, and the semantic foundations for both, and to establish a Center for the Study of Language and Information (CSLI) at Stanford University. (SDF 460)

Jon Barwise, Barbara Grosz, and John Perry, principal investigators

SRI International

Award date: July 14, 1983	*$2,387,000*	*4 years*
Award date: August 13, 1984	*$ 866,722*	*3 years*

To investigate language as a computational process, computation as a linguistic activity, and the semantic foundations for both, and to provide for SRI International's participation in the Center for the Study of Language and Information at Stanford University. (SDF 460)

Barbara Grosz, principal investigator

Stanford University

Award date: May 9, 1985	*$13,340*	*6 months*

To conduct a workshop on Japanese linguistics. (SDF 460i)

Joan Bresnan and Barbara Grosz, principal investigators

University of Rochester

Award date: May 17, 1983	*$12,540*	*3 months*

To collaborate on a linguistic research project with Bolt, Beranek, and Newman. (SDF 481)

James Allen and Patrick Hayes, principal investigators

University of Wisconsin		
Award date: June 14, 1983	*$ 95,729*	*7 months*
Award date: May 15, 1984	*$183,708*	*19 months*
Award date: June 5, 1986	*$ 19,932*	*1 year*

To complete an X-ray microbeam system for studying speech production. (SDF 492)

James Abbs, principal investigator

Northeastern University		
Award date: October 29, 1984	*$10,000*	

To study continuous speech recognition. (SDF 566)

Jean-Francois Mari, principal investigator

University of Pennsylvania		
Award date: May 15, 1984	*$55,023*	*1 year*
Award date: May 18, 1986	*$19,500*	*3 months*

To study the computational feasibility of natural language inferences under conditions of limited information. (SDF 590)

Scott Weinstein, principal investigator

Massachusetts Institute of Technology		
Award date: August 11, 1985	*$48,179*	*1 year*

To study the computational feasibility of natural language inferences under conditions of limited information. (SDF 590)

Scott Weinstein, principal investigator

Stanford University		
Award date: August 12, 1984	*$10,500*	

To convene a conference on perceptual organization. (SDF 622)

Jon Barwise, principal investigator

University of Texas, Austin		
Award date: May 15, 1984	*$55,886*	*1 year*
Award date: May 20, 1985	*$36,763*	*1 year*

To study the computational analysis of non-concatenative morphological systems. (SDF 626)

John McCarthy, principal investigator

University of Massachusetts, Amherst		
Award date: May 18, 1986	*$44,081*	*1 year*

To study the computational analysis of non-concatenative morphological systems. (SDF 626)

John McCarthy, principal investigator

University of Massachusetts, Amherst		
Award date: May 15, 1984	*$ 3,349*	*3 months*
Award date: May 15, 1984	*$13,100*	*1 year*
Award date: September 28, 1984	*$ 2,500*	

To prepare for publication a manuscript on property theory. (SDF 633)

Michael Jubien, principal investigator

University of Massachusetts, Amherst		
Award date: May 15, 1984	*$263,300*	*3 years*

To investigate the formal foundations of semantics. (SDF 650)

Barbara Partee, principal investigator

Carnegie-Mellon University	
Award date: May 15, 1984	*$1,500*

To explore the establishment of a Center for Applied Logic. (SDF 651)

Dana Scott, principal investigator

University of California, San Diego	
Award date: October 10, 1984	*$13,500*

To conduct a workshop on Japanese linguistics. (SDF 675a)

S.-Y. Kuroda, principal investigator