RB FORUM

January, 1983 Published monthly by RB Robot Corp. • Golden, Colorado Volume 1, Number 1

OUR PREMIERE ISSUE

You see before you the first issue of the *RB Forum* — a monthly newsletter compiled by and for owners, users, and "friends" of the RB5X Intelligent Robot.

The *Forum*, as its name implies, is a place where RB enthusiasts can exchange ideas and discoveries, discuss, analyze, and even argue in print about the many aspects of experimental robotics.

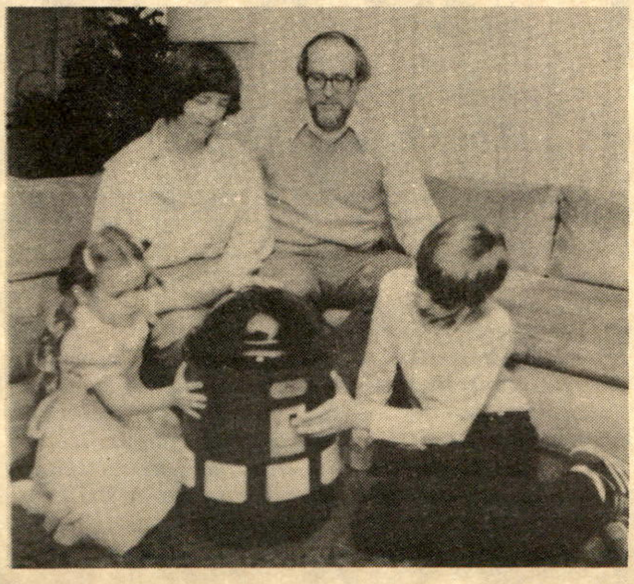
We are eager to hear from you.

What have you taught your RB? Have you added an incredible capability you'd like to share with the RB world? Is there something you'd like to do with your RB, but just can't quite work out?

Have you accomplished an "impossible" feat of engineering? Or does your RB have a special relationship with your German Shepherd? Let us know!

In addition to publishing the experiences and questions of RB users, the *Forum* will present a variety of materials on the subject of robotics. These will include original pieces by experienced roboticists, reprints and excerpts from pertinent articles, background information, technical updates, and features. Each issue will also contain a "Books" section, in which current robotics literature — everything from science fiction to artificial intelligence research — will be abstracted and made available for you to order.

We believe that the young science of robotics has a glorious future, and that some of its most exciting developments will come from private citizens, working to discover what is now just out of reach. We also believe that such discovery is stimulated by the free exchange of ideas. It is to these beliefs that the *RB Forum* — and indeed the RB itself — is dedicated. We look forward to sharing the process with you.



THERE ARE 3 KINDS OF ROBOTS IN THIS WORLD ...

Suddenly, robots are everywhere.

The new breed of robots is not just the science fiction kind we've all grown up with, the futuristic creatures of novels and cartoons, actors in dream-like costumes. Real robots, some with characteristics that have always been considered distinctly human, are beginning to emerge from the isolation of high-tech laboratories to reach the attention of the general public. For example:

- Thousands of robots are already in use in factories across the country.
- In just the last year, periodicals as diverse as *The New Yorker, Business Week, National Geographic, Scientific American, Barron's,* and the *Wall Street Journal* have published articles relating to the growing field of robotics.
- One TV soap opera includes a robot in its regular cast.
- A recent Associated Press story described an incident in which a $9500 robot was abducted —"robot-napped"— in Texas, and recovered a month later: "none the worse for wear, except that his derby hat was missing."

Robots are becoming not only technological realities; they are becoming familiar in some context to almost everyone.

Nevertheless, the term "robot" covers a tremendous variety of devices: the soap opera character and the machine painting cars for General Motors have little in common beyond their name; they are different in structure, in appearance, and in function.

In general, robots can be divided into three categories according to their purpose: the show robot, the industrial robot, and the educational robot.

Hooray for Hollywood

Show robots, like the TV star and the "robot-napping" victim, are used primarily for promotional purposes. They have a more or less human appearance. Many of them have faces, heads that turn, blinking eyes, and "voices" — often provided by a behind-the-scenes human with a microphone. Most show robots do carry a microcomputer in their chests, programmed for movement and sometimes for games and graphics. They are entertaining, often ingeniously so, and in the course of their development, they have provided researchers with a considerable amount of technical knowledge.

The Working Stiff

At the other end of the spectrum, industrial robots rarely have even the slightest resemblance to a human being in terms of appearance, but they are designed to do work that traditionally has been done by humans. Many of the tasks performed by robots in industry are either too tedious or too dangerous to be done efficiently by human workers. A robot can be oblivious to noise and to scorching heat; it may be designed to lift very heavy weights, to weld auto bodies in 8 places at once, or to assemble parts with extreme speed and precision. And, of course, a robot never gets bored.

In many countries, industrial robotics is more widespread than in the United States, but its practical use is growing rapidly here, and American robotics technology is among the best developed in the world.

An Apple for the Teacher and Then Some

The third category of robots is educational. An educational robot may have some qualities in common with the other two kinds; for example, it may look more appealing than a typical factory robot, and may show a greater degree of autonomy than a typical promotional robot, but its primary purpose is different from either of these, because it is designed to teach.

There are many ways in which a robot can be an educational tool. Some grade schools have begun to use small robots to demonstrate principles of mathematics and science which previously were studied only in abstract terms. Since computers have become so successful among the young, robots capable of interfacing with a personal computer literally bring another dimension to a student's programming ability. It has even been reported that autistic children respond well to robots, because they seem to unlock an interest and an involvement these children are unable to achieve in more traditional ways.

Educational robots are also becoming more common as part of the curriculum in colleges and universities. Engineering departments and computer science departments, for example, use them to familiarize their students with mechanical design, electronic design, sensor systems, and computer software, and to carry on advanced research in robotics technology.

Do You Think They Think?

One of the most interesting areas of current robotics research is in the field of "artificial intelligence" — that is, the ability of machines to learn from experience, to determine priorities, and to generalize. The search for artificial intelligence has been based on two separate but related pursuits: one is the attempt to make computers and robots even more useful in industry and education; the other is to increase our understanding of the mechanism of the human brain. Whether or not a machine can think depends to some extent on your definition of the word "think", and to some extent on your philosophy; but one thing is certain: the question will continue to be asked with increased sophistication as computers and robots acquire greater capabilities.

Designers of the RB5X are following a quite different tact in the pursuit of artificial intelligence — an approach that stresses the evolution of machine thinking which is quite independent of how humans execute the same process. (See Evolutionary Adaptive Machine Intelligence in the next issue of the RB Forum.)

The Future

Although it may sometimes sound as if robotics is a highly advanced science, it is still in its infancy, and this is equally true for entertainment purposes, industry, and education. Everyone who works with robots still has a great deal to learn. It is often said that the field of robotics is proceeding in much the same way that the microcomputer industry developed only a few years ago. The basic technology exists for an astounding change in our lives, based on the development of robots, and the greatest advances are likely to come in a very short time from those with enough determination and imagination to fulfill that potential.

AN INTRODUCTION TO RB SELF-LEARNING

The RB5X is a starter system robot, designed for individuals interested in learning about robotics and in experimenting with a basic, preassembled device. Engineers, technicians, computer programmers, hobbyists, and educators all find the RB an excellent way of approaching the study of robotics.

Perhaps the most intriguing aspect of the RB for all of its users is its ability to learn from its own experience. Its self-learning ability, based on the work of hobby robotics author David L. Heiserman, can be described in a simplified way as follows:

Learning to Learn

The RB functions on three levels of intelligence. First is the so-called "Alpha" level — actually pure reflex. When an RB operating on Alpha level touches an object in its path, it responds randomly; that is, it will turn left, turn right, back up, go forward, or stop briefly. Its reactions are completely unpredictable, and essentially without meaning. Since the basic motivation built into the RB is to keep moving, it continues to try these responses until it finds one that does not interfere with its progress.

The Ranking Process

At that point, it begins to function on the second level — the Beta level. Its memory stores away that first experience and the successful response, and "ranks" that response as superior to the others.

For example, let's say that the RB's #2 sensor bumps a wall. After trying a few of its alternatives, it finds that backing up is a successful solution to the problem. When it backs up, it can, in fact, keep moving. The RB stores away that information, and, in the process, ranks "backing up" as an appropriate response to an obstacle at the #2 sensor. Because of that experience, it will have a higher confidence level in "backing up" than in its other possible actions. It has learned something.

Now let's say that the RB moves to a position in which it cannot back up; its #6 sensor is obstructed when it tries.

However, turning left works fine. The action of turning left will begin to have a high confidence level associated with bumper #6. You can see that it will take a great many such occurrences of trial-and-error experiences before the RB begins to develop its own truly recognizable pattern of responses to its particular environment. The study of these patterns and the RB owner's ability to alter its Beta programs to achieve alternate behaviors is one of the great appeals of the RB.

Generalization

The memory of the RB has enough capacity to store away and rank a great many experiences. As it continues to learn in this manner, it develops a considerable amount of information, in the sense that it knows not only which responses are successful in a specific situation, but also which are most likely to be successful in general.

It is at this point that the highest level of RB's current intelligence — the Gamma level — is employed. An RB that has experienced its environment fully has developed what might be called "theories" about how to deal with obstacles. For example, a given RB in a given room may have learned that backing up solves its problem more often than any other response, but that turning left is nearly as successful, and that turning right almost always yields poor results. It has learned to generalize.

If you clear the RB's memory and then allow it to start again, even in the same environment, it may very well work out a new set of generalizations, equally effective, since the sequence of experiences and successful responses — and therefore the rankings — will be different.

Self-Learning and Adaptation

An RB equipped with a sonar sensor — like a bat — has more to work with: another basis, ultimately, for forming "theories." Now it learns not only from touch; instead, it senses an object in front of it and learns at what distance it must change direction in order to avoid that object. Obviously, this makes it more autonomous; the environment may change, but the RB is more capable of recognizing change, and of knowing what to do about it before a physical encounter occurs.

Two or more RBs equipped with data telemetry options can actually share their knowledge, pooling resources and training one another.

How would an RB equipped with a light sensor respond? It depends on the RB in question, the sensor itself, and, of course, any programming the owner might care to add. An RB with the kind of experience described above might decide spontaneously to back away from a light at a distance of its own discretion. The truth is, no one knows, until you, we, or someone else attaches a light sensor to the RB and writes programs for it.

By now, you are no doubt beginning to see the possibilities. Working with an RB5X, an owner can provide the device with any number of capabilities and learning experiences. Since the RB's memory may be transferred easily to a personal computer for study, the operator can expand personal knowledge of software, robotics, and even learning itself.

The RB is an educational robot in the broadest sense of the term, in that it allows its owner to explore, and in the quickly expanding field of robotics, exploration is the key to new technology.

ROBOTICS IN THE NEWS

"Most mechanized creatures wandering around at conventions, puttering in the department stores at Christmastime and serving drinks to guests in posh apartments are not robots but are remote-controlled vehicles."

"RB Robot Corporation has taken a major step forward in the development of home robots: It has created the RB5X, which the company claims to be 'the first manufactured intelligent robot for the home experimenter.' "

"Unlike radio-controlled units, the RB5X learns from experience. It is equipped with microprocessor, memory, programs and tactile sensors. It detects and responds to objects in its path."

—Jim Strothman
"High Tech"
Register and Tribune Syndicate,
Oct. 15, 1982

"A number of features of the RB5X make it appropriate for the hobbyist."

"The machine has a standard RS-232 serial interface to allow experimenters to connect it to microcomputers. Users can develop programs on a minicomputer and transfer them to the robot via the interface, or they can use a computer to monitor the robot's memory."

—"In Focus"
***InfoWorld*, November 8, 1982**

"New software market. The home robot makers believe that the robots' capabilities will be developed quickly by initial buyers who, because they will tend to be more technically sophisticated, will create software programs to make the hardware more useful... Most manufacturers will also offer add-on accessories. RB5X, which is 21 in. tall and costs $1,195... has a $300 package that adds ultrasonic sensors and triples the computer memory."

"Such capabilities will make the robots particularly appealing to the educational market, Heath's Bonham believes."

—New Products: "Home Robots are Coming"
***Business Week*, December 13, 1982**

"Though it does not presently have an arm (its Master says that next year there'll be one), RB indeed has an on-board computer, can be programmed, is mobile, and is powered by batteries..."

"...the robot's base has eight protruding bumper-switch sensors around its perimeter, mounted fairly close to floor level. They might be considered as elbow 'funny bones' since reflex action occurs whenever a bumper sensor's microswitch is activated. The random reflex response is limited to five courses of action: turn left, turn right, back up, go forward, and stop for a short period of time. In other words, RB can simulate an inebriated person's walk around a room without falling down even once."

"Using its memory, RB can be programmed with a form of AI (artificial intelligence) so that it learns something from its bumping experiences. Its reaction to each contact event is scored again and again as RB wanders about. After many learning experiences, RB's event memory will know which reactions work with what collision and react accordingly instead of unpredictably. The memory can be cleared and, when

RB is placed back in the same room, it will most likely develop a different 'learned' response..."

—"The New Wave of Personal Robots"
Computers & Electronics
(formerly *Popular Electronics*),
January, 1983

"Joe Bosworth would like to introduce you to a new pet. It's housebroken. It doesn't eat, doesn't drink, and doesn't shed. Once taught a trick, it never forgets and potentially, it's as smart as you are."

"It's RB5X, the intelligent robot."

"Bosworth is the president of RB Robot Corporation..."

"Robots are the next frontier for computers, he says. 'They're computers that can operate in the world.' "

"RB5X — the X is for experimental — is to the field of robotics what the Apple is to computers, he continues. It allows people to get into robotics without the $70,000 to $80,000 cost..."

"Coming up on the list of options will be a robotic arm capable of picking up, carrying and releasing small, light objects, and data telemetry which will allow one RB5X to teach another RB5X what it has learned.

"That's right. The RB5X isn't only capable of accepting instructions from its owner. It can learn by itself..."

"They have potential as pets, he says, but pets who will turn on the television set, dial the phone, even be the phone."

"Speculation about the possibilities is 'absolutely catching,' Bosworth says."

—Don Lyle
Rocky Mountain News,
Nov. 28, 1982

WHERE YOU CAN SEE THE RB

The following dealers carry the RB5X:

ALASKA:
Juneau Electronics
1000 Harbor Way
Juneau, AK 99801
(907) 586-2260

CALIFORNIA:
Advanced Computer Products
1310 'B' East Edinger
Santa Ana, CA 90638
(714) 558-8813

PENNSYLVANIA:
Computerland of Pittsburgh
5499 Route 8
Gibsonia, PA 15044
(412) 443-1560

TEXAS:
Computerland of McAllen
3000 North 10th
McAllen, TX 78501
(512) 686-3743

RB Forum is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303) 279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot. Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptions Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB FORUM

February, 1983 | Published monthly by RB Robot Corp. • Golden, Colorado | Volume 1, Number 2

THE RENAISSANCE ROBOT MASTER

Building a robot — or adapting one to match your vision of what a robot should be — is a challenging task. So challenging, in fact, that it sometimes seems to demand the talents of a 20th century renaissance man or woman, as the case may be.

You need at least a smattering of knowledge about a great variety of things: mechanical systems, sensor systems, electronics, computer programming, and more.

It also helps to have some admirable personality traits: patience, determination, curiosity, creativity, and even the ability to dream a little.

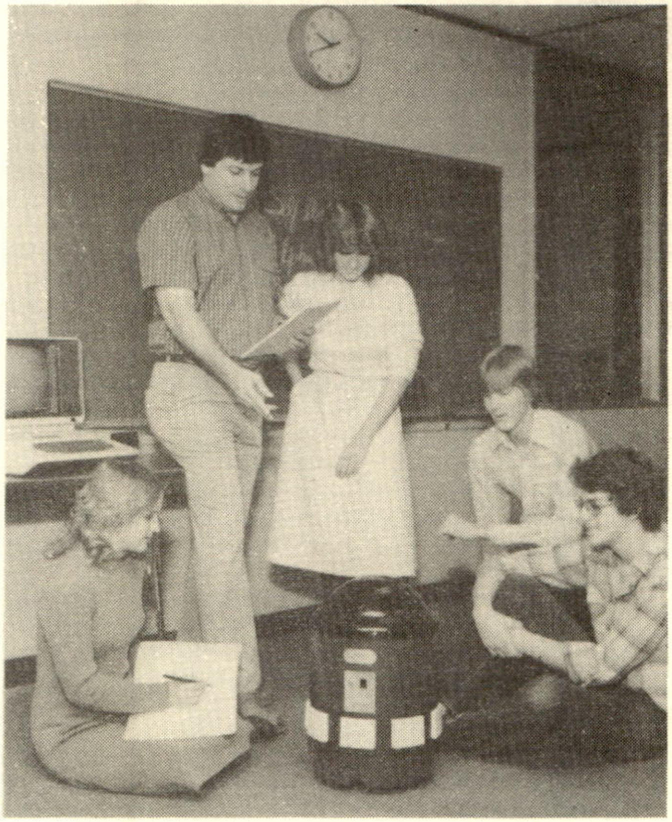
And to add to all this, one would be wise to develop a philosophy that takes the robot into account.

RB Forum is here to help.

While we can't cover all these concerns in every issue, we hope to address a few of them each month.

In this issue, we've chosen to concentrate on what we consider some important perspectives on self-learning software (see "Evolutionary Adaptive Machine Intelligence"), and to give you a taste of robotics philosophy ("Three New Laws").

Keep in mind that *RB Forum* is your publication, too. In the months to come, we intend to examine many more facets of robotics, and, as always, we invite you to participate.



THREE NEW LAWS

As most robotic enthusiasts know, the fiction of Isaac Asimov is a rich source of inspiration about the ways in which highly advanced robots might ultimately change our world. In *I, Robot,* he presented his well-known "Three Laws of Robotics" — laws which applied to the incredibly capable robots he envisioned.

In another book on robots, *Android Design,* Martin Bradley Weinstein comments:

> "Unfortunately, we are generations away from being able to produce a mechanism anywhere near as sophisticated as Asimov's fiction offers. So it is with apologies and a bow to Asimov that we begin our task of stating ethical restraints for the design of an android in developing our own three laws of 'androidics'...
>
> "1. First, our creations should not be destructive to any part of their environment, including living cohabitants as well as walls and furniture, the breathableness of the air, radiation levels, anything.
>
> "2. Second, our creations should not be destructive to themselves. So we need to include adequate hardware and software protection to assure self-preservation, except where this violates the first 'law.'
>
> "3. Third, we must design an instinct for survival, which translates to self-continuance of operation. The most immediate manifestation of this trait (by way of example) will be a mechanism to assure that low batteries will be recharged before failure..."

RB Robot Corporation heartily endorses Weinstein's new laws. (Source: *Android Design*, Martin Bradley Weinstein, Hayden Book Company, Inc., 1981, p. 19.)

EVOLUTIONARY ADAPTIVE MACHINE INTELLIGENCE: A REVIEW

What a mouthful!

But the term "evolutionary adaptive machine intelligence" (or EAMI), coined by hobby robotics author David L. Heiserman, precisely describes the workable approach to genuine artificial intelligence by which RB learns.

In his book *Robot Intelligence with Experiments,* Heiserman describes the theory of EAMI, and provides a series of computer exercises to allow the experimenter to see for himself how machine intelligence develops; for develop it does.

The "creature" Heiserman devises to demonstrate EAMI is physically only a small square of light on a computer screen — but ultimately it possesses an ability to learn from experience, adapt easily to changing conditions, generalize about its world, and even anticipate future events.

Heiserman is careful to point out that EAMI is very different from the analog approach to artificial intelligence — that is, it makes no attempt to mimic the mechanism of the human brain. Instead, it "lets machines develop in the context of machines."

The word "evolutionary" is used because EAMI represents a process of development from the most primitive stage to the most complex. This is, in a sense, a natural progression; once the initial programmming is provided, a higher level creature (or robot) will inevitably become more competent without any human intervention.

The creature's behavior is referred to as "adaptive" because it eventually develops the ability to respond appropriately, undisturbed, even when it encounters a drastic change in its environment.

Heiserman's scheme is structured so that three levels of development exist in the intelligent machine's evolutionary scale:

1. Alpha-Class creatures respond to their environment with pure reflex; they simply sense contact with an obstacle and move away from it, choosing one of several possible responses at random.
2. Beta-Class creatures also begin life with a reflex response, but they are further equipped with memory, so that they are able to use the knowledge of past successful responses to deal with present conditions.
3. Gamma-Class creatures possess not only memory, but an ability to generalize, and therefore to formulate a theoretical knowledge of the future as well. In other words, their intelligence becomes so well developed that they are able to anticipate changes in their environment.

What follows is a summary of Heiserman's EAMI experiments. These experiments demonstrate the principles on which RB's current intelligence is based. Heiserman encourages others to duplicate his work with their own computers (he includes complete flow charts and programs for each experiment), and even to go beyond his techniques in order to further refine them. Since the RB is equipped with Alpha, Beta, and Gamma software, it provides a starting point for 3-dimensional robotic experimentation, and, of course, users of the RB are likewise encouraged to expand upon the material presented here.

ALPHA-CLASS TECHNIQUES

Using a personal computer with at least 4K of memory, Heiserman's series of experiments begins at the Alpha — or reflex — level.

The square of light which will become Heiserman's "creature" is limited throughout the entire process to a rectangular field drawn on the computer screen. This first Alpha creature is motivated by only one thing — to remain in continuous motion. It is also inhibited by only one thing — the line that forms the boundary of its world.

The creature is programmed with a total of 24 motion codes — 24 different combinations of directions and speeds. At the Alpha level, the motion codes are always selected entirely at random.

Once the creature makes contact with the border, it begins to blink, indicating that it is searching for a motion code that will allow it to resume its travel within the field. When a successful code is chosen, the creature again moves until it encounters the border. This action can continue indefinitely, and it is always characterized for an Alpha creature by random response.

The responses of an Alpha creature can be scored on the computer, to show the number of contacts made with the border figure and the number of "good" moves. The value of the scoring feature is that it demonstrates for future reference the results of random response. In general, the creature chooses a successful motion approximately as often as an unsuccessful one — and, of course, no learning of any kind takes place. The scores of a number of Alpha-Class creatures can be charted, and the chart will show an essentially straight line, representing no increase in success rates, no matter how long the creature is allowed to continue its work.

Compiling such a chart may sound like a thankless task, but it becomes useful for comparison later, when the learning curves of the more intelligent Beta and Gamma creatures are plotted.

At any rate, even the simplest Alpha-Class creature can provide some entertainment. For example, a maze-running game can be devised for it. Even though the action is still only random reflex, some creatures will be luckier in their choices than others, and will therefore work their way through the maze at a faster pace.

The next experiment provides the Alpha creature with an additional capability — that of distinguishing between a continuous light (the border) and a flashing light near the center of the screen.

The creature is programmed to respond to the flashing light differently that it does to the border — not as an obstacle, but as a "nest" where it remains until the light stops flashing. When the light becomes constant, the creature must move away, again using one of its motion codes, chosen at random. This technique has practical applications in that even the "dumbest" of mobile robots who can manage to stumble into a power-source nest can be "fed" without overcharging.

An Alpha creature can be programmed to sense other differences between figures in its environment, and, in an elementary way, to sense its position in the environment according to the placement of these figures. But even with additional sensory information, the Alpha creature is without intelligence.

BETA-CLASS TECHNIQUES

In spite of the characteristic lack of intelligence of the Alpha-Class creature, its existence is necessary for the evolution of the more intelligent machines.

Beta-Class represents the next stage of development.

A Beta-Class creature does exhibit true machine intelligence, because it combines typical Alpha-Class behavior with memory. This creature is motivated to keep moving, too, and like an Alpha its initial responses are random. Since it remembers each of its earlier actions, however, it responds appropriately whenever it encounters a situation it has experienced before. It is actually able to learn.

A Beta creature without experience responds to obstacles randomly at first, but after about 20 to 30 contacts, it begins to establish a pattern of motion, based on the success of its earlier experiences. The creature repeats this pattern — its unique learned solution to the conditions in its environment — over and over again like a habit, until either its memory is cleared, or a change in the environment is introduced to break the pattern.

When the responses of a number of Beta creatures are scored and the scores plotted on a chart, the results are dramatic. The learning curve of a Beta-level machine shows smooth, steady upward progress to the point that a pattern is established.

Breaking the pattern of a Beta creature and observing its reaction is one of the clearest ways to demonstrate the adaptive nature of its behavior.

Since a Beta creature has a rather wide range of possible responses, the pattern it develops will be only one of a great number of potential solutions to the problems it encounters. Furthermore, it is likely that the creature will establish its habit without having encountered all of the situations that might occur in its environment.

For this reason, an established pattern can be broken easily by forcing the creature to use a motion code it has never used before.

When this is done, the creature is temporarily thrown into turmoil. It is forced to return to its original Alpha-like random response approach, and of course, its success score drops.

But the disturbance is only temporary. Beta creatures are intelligent enough to change their minds, and eventually they will work out a new pattern for dealing with the new situation, fully as effective as the first.

In addition, the memory of the original successful pattern is retained, so that the more unfamiliar situations forced upon a Beta creature, the more knowledge it has... all based on experience. Heiserman says that a Beta-Class creature that has been fully trained through repeated disruption of its habits "will end up encountering every conceivable set of environmental circumstances, and there is nothing one can do to the environment to upset the creature."

Impressive as this may be, it is possible to expand Beta level intelligence even more — by providing the creature with confidence.

This can be done simply by allowing the creature to count the number of times each response is successful. As it gains experience, it develops very high confidence levels in the responses that work for it.

When the pattern of a Beta creature with confidence is broken, some interesting things happen. For one thing, because it has "statistical evidence" that a particular response should work, it is more stubborn than a creature without confidence. It will attempt the previously successful response again and again. But each time it is unsuccessful, its confidence level in that response drops. Finally, when it loses confidence in the response altogether, the old habit is broken, and the creature returns to random Alpha-like behavior to find a new solution. It then begins, slowly, to build confidence in the new response.

Although the scoring curves of a Beta creature with confidence are substantially lower than those of a Beta creature without confidence (because of its determination to do what it has learned to believe in), confidence is nevertheless a valuable evolutionary stage to be explored at the Beta level. According to Heiserman, "the objective here is not that of building a machine to solve problems in the fastest and most efficient manner, but rather to give the machine a potential for solving problems no one thought it would ever encounter."

THE INCREDIBLE GAMMA-CLASS CREATURE

By building steadily on the foundation laid down with Alpha and Beta-Class behavior, a machine creature finally evolves which is capable of real generalization based on its own experience — the Gamma-Class creature.

Alpha level creatures perform merely on reflex, and cannot be said to have any real knowledge at all. Beta level creatures, because of their memory, are able to acquire knowledge of the past and the present. "The real hallmark of a Gamma-Class creature," says Heiserman, "is to anticipate events that have not yet occurred. It has the ability to enhance the quality of its present condition by drawing upon remembered experiences and generalizing them to future conditions."

The key to this ability is a refinement of the confidence-level system we encountered with the Beta-Class creature. The superiority of the Gamma-Class creature resides in the simple-sounding fact that it is programmed to be sensitive to high confidence levels.

Suppose, for example, a Gamma-Class creature is programmed to be sensitive to a confidence level of 4. In that case, every time the creature's confidence in a particular response rises to 4, it immediately analyzes every aspect of the situation at hand, identifying the relevant factors, and examining its memory for any past events in which any of those factors played a part.

Then, says Heiserman, "upon discovering the relevant elements of a successful response residing in memory and carrying very low confidence levels, Gamma inserts the successful elements into those places. What works quite well under one set of conditions ought to work just as well under similar conditions not yet encountered on a first-hand basis."

Through this process, the information the Gamma creature has to work with has grown geometrically. It applies the results of its experiences not just to one isolated condition, but, tentatively, to every situation that might be at all similar.

As a result, the Gamma-creature has a whole range of theories about the conditions of its world and the responses most likely to be successful in a given situation — even a situation it has never encountered. The creature rapidly develops a plan for every contingency, and its score for successful responses shows a remarkable learning curve.

In fact, it works so well that it is not easy to upset an experienced Gamma creature. Once it has had time to develop confidence in a number of responses, the creature is prepared for most new situations. Since it has formulated theories or partial theories about potential situations, it adapts far more easily than a Beta creature — and it manages to confirm its theories in the process, gaining even more knowledge.

Even when a Gamma creature is caught without any information and forced back to an Alpha-like random response, it uses whatever results it gains to prepare for another unexpected event. As Heiserman says, "the bottom line is that the Gamma creature is superbly equipped to deal with new circumstances."

LOOKING AHEAD

Heiserman's Alpha, Beta, and Gamma programs are clearly landmarks in the development of machine intelligence. Even more striking, perhaps, is the fact that they are presented in a true spirit of scientific research. The author invites others to build on his work, and suggests a number of directions future experimenters might take in pursuing more advanced levels of machine intelligence.

Heiserman himself writes:

"While there are indeed some distinct advantages to fitting machine intelligence into an actual working model of a robot (see *How to Build Your Own Self-Programming Robot,* TAB Book No. 1241) there are also some advantages to simulating the behavior on the screen of a home computer system. In fact, the two approaches complement one another quite nicely.

"Are you ready to go to work? Good. I'm looking forward to reading about your results in some technical magazines. Who knows? Maybe I'll even be seeing you on TV!"

(Source: *Robot Intelligence with Experiments*, by David L. Heiserman; TAB Books, Inc.; 1981. This book may be ordered through RB Robot Corporation's "Books of Interest"; see enclosed order form for details.)

ABC NEWS SAYS...

"Mention the word 'robot' about 30 years ago, and this was the kind of thing that came to mind: a giant tin can with an infantile walk and lots of dumb flashing lights. It was, of course, just a man in a heavy suit...

"When real robots began appearing in the late 1970's, they turned out to be a lot different; they didn't look at all human and were amazingly simple-minded. But for welding auto bodies or other simple industrial tasks, they proved remarkably efficient.

"Like the computer, robots keep getting a lot better...

"But none of these machines has had much application in the home, and they cost way too much for the average family — up to $80,000, $90,000, or $100,000 a copy...

"Here in the foothills outside Denver, another personal robot is just coming off the assembly lines. Its developers say it will have a number of practical uses. It's called the RB5X and, at an assembled price of $1500, it too is now becoming available in electronics stores across the country.

"RB is programmed using a personal computer... (It is) mainly of interest to the hobbyist or electronics buff. The developers say that soon it will do household tasks that anyone would love to avoid.

"(Joe Bosworth): 'If your robot will vaccuum your rug, and will be your sentry and your security agent, and will be the phone, and will entertain your kids, then all of a sudden you've got a multi-purpose appliance like none you've ever had in your home before.'

"If the RB5X reminds you of another robot (R2D2), it just shows, to reverse a common expression, how much life is now imitating art...

"With these machines coming into use, the age of the personal robot is now dawning. That scares some people, but experts say it shouldn't.

"(Isaac Asimov): 'They'll remove some jobs; they'll create others. Eventually, human beings will be working as hard as ever, but at different jobs: more creative jobs.'

"Sales of personal robots could total $15-20 million in 1983. Analysts say the industry will do hundreds of millions in annual sales by the turn of the century as the personal robot — until recently just science fiction — becomes an ordinary everyday household appliance."

Steve Shepherd
ABC News, New York
January 16, 1983

RB Forum is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303) 279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot. Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptions Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB Robot Corporation
14618 W. 6th Avenue, Suite 201
Golden, CO 80401

RB FORUM

March, 1983 | Published monthly by RB Robot Corp. • Golden, Colorado | Volume 1, Number 3

SPEECH AND OTHER GIFTS

In "Pygmalion," the forerunner of "My Fair Lady," Professor Henry Higgins took in a poorly educated flower girl named Eliza Doolittle and trained her in diction, until he perfected in her what he called "the divine gift of articulate speech."

When Shaw wrote "Pygmalion" 75 years ago, it was unthinkable that anything but a human being might ever have such a gift.

But today we have our own Eliza Doolittles: our robots. And using the same linguistic tool Higgins used, phonetics, we can actually produce speech in them. What is even more remarkable, with ordinary speech we can command them to do our bidding!

This month's *RB Forum* examines the recent developments in speech technology and how it relates to the RB. (See "Speech Recognition" and "Speech Synthesis" in this issue.) We believe that these capabilities are an enormous boon to microrobotics — and we want to share our enthusiasm with you.

SPEECH RECOGNITION: TALKING TO YOUR ROBOT

It's not quite like training a dog to sit, but there are similarities. Now your robot can be trained to recognize your voice, understand you, and respond to your commands.

Thanks to systems like the Shadow/VET, a device produced by Scott Instruments of Denton, Texas, robots and computers are now capable of understanding human speech.

This means that a robot's normal abilities, such as moving in various directions, sounding its horn or flashing its lights, even finding and using its battery charger, can be triggered by simple voice commands. When other optional features are added, like a robotic arm, those movements too can be controlled by human speech.

The VET (for Voice Entry Terminal) was developed, essentially, to promote a more natural, flexible form of communication between human beings and machines, one that does not depend on advanced programming skill. Combining a knowledge of computer science with the science of human speech, Scott Instruments created a system that a person can use to control the computer simply by talking. (At this time, the Shadow/VET is only available for the Apple II microcomputer.)

With this equipment, training the robot in speech recognition is simple. The Shadow/VET interfaces with a personal computer that interfaces to the robot. Using the robot's existing programs in a control mode, the operator speaks a command into his headset. Then, as Scott Instruments explains, the VET terminal digitizes the spoken word and creates a template, or digital picture of that word, which is stored in memory.

To "train" the VET, several prints of each command are made; that is, the operator pronounces the command perhaps six to eight times, allowing a number of templates to be digitized. This is worthwhile because so many characteristics of pronunciation exist in human speech that it is nearly impossible to say the same word twice in exactly the same way. Pitch, tone, speed, emphasis, and the sounds of vowels and consonants in a single word provide a great many variables from the computer's point of view — even though to the human ear the sounds might seem identical. The VET system adjusts well to such differences, and when several prints are made, it further reduces the likelihood of misunderstandings.

Fortunately, the match between pronunciation during training and during operation need not be perfect: the VET recognizes commands in its vocabulary within a fairly wide range. One interesting feature of the system is that, when it is in the operating mode obeying a command, the computer screen shows not only which instruction it is carrying out, but also how closely the voice it has just heard matches the training template.

Although the manufacturer's literature describes a recognition rate with percentages in the high 90s, in actual practice we have been achieving 80 to 90 percent word recognition. This may improve as we gain more experience.

The system has a vocabulary of up to 40 words or phrases on one disk. These can correspond to the commands normally used with keyboard entry. If the robot needs a larger vocabulary, additional 40-word disks can be used.

Because of the differences inherent in pronunciation and voice, the equipment is "speaker-dependent;" that is, it responds reliably only to the voices that have trained it. In personal robotics, of course, this can be an advantage: if, for example, you are developing your robot to act as a home sentry, it should obey you and your family, but it must not accommodate the whims of a stranger!

Speech recognition is currently being used not only in robotics, but also in industry, education, and as an aid to the handicapped.

The implications for experimenters are clear: when your robot recognizes your voice, you have a natural, direct method of control never before possible. You can simply talk to your robot.

The VET system and a Tiny BASIC software package to translate VET recognition on the Apple computer to commands for the RB5X is available from RB Robot Corporation or through your dealer for $895.

SPEECH SYNTHESIS: YOUR ROBOT TALKING TO YOU

Robots can talk to you, too.

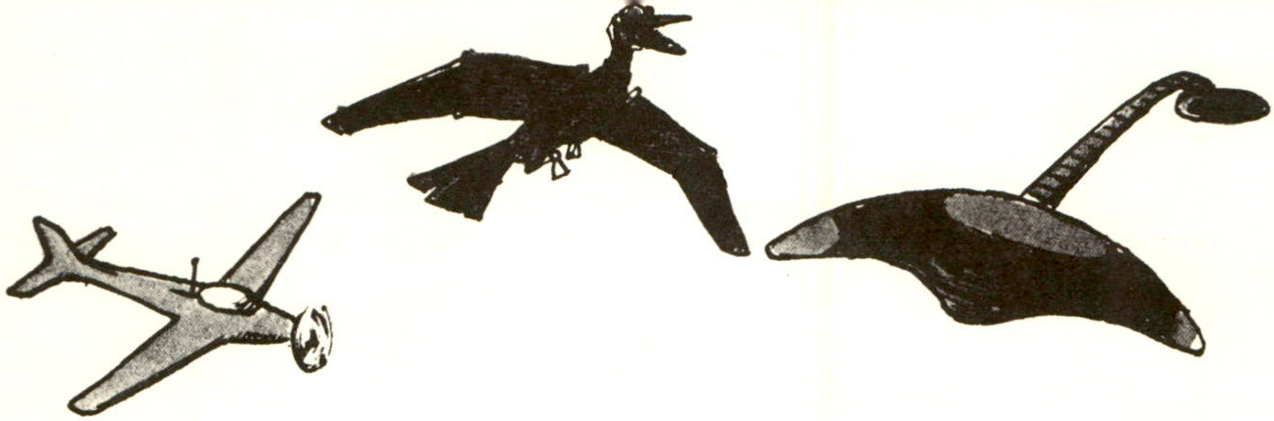
A variety of speech synthesis equipment is currently being offered on the market, providing voices for computers and robots. Some of this equipment can "sing," or generate random nonsense-sentences, or be incorporated into games. But speech synthesis has more serious applications as well, such as communication for those unable to speak and foreign-language education.

Two RB dealers in Texas, Computerland of McAllen and Computerland of Brownsville, recently devised a speech synthesis system for the RB5X. First, a text-to-speech synthesizer ROM board manufactured by Micromint Inc. was installed in the robot. Then, the system was programmed through a computer terminal using an Osborne interface with microlink. The result is a voice for the RB.

Like most speech synthesizers, the Micromint operates on a phoneme system; that is, it produces speech from a table of the 64 phonemes — or distinct sounds — inherent in the English language. The statements to be spoken are programmed phonetically, rather than using ordinary spelling, to ensure correct pronunciation.

According to technician Bill Lonsford of the Brownsville store, once the programming is done, the interface may be disconnected, and the robot can talk whether it is running or standing still. Since the synthesizer requires a three-line loop routine between text statements, Lonsford has found that a pause of a second or two occurs between sentences. Lonsford's system has a potential vocabulary of about 250 words and "sounds like Darth Vader."

Among the factors to be considered in choosing speech synthesis equipment for a robot are differences in intonation, speed, pitch, and volume, and in size of vocabulary. At least one manufacturer advertises software with "grammatical rules" so that text may be entered not in phonemes but in ordinary spelling. Another firm offers a system that digitizes and records language and then plays it back under program control — a method that may improve the quality of the sound, but that inevitably limits vocabulary.



WHAT IS A ROBOT?

As the author of BUILD YOUR OWN WORKING ROBOT, David Heiserman has been hard-pressed by many critics to explain in a single sentence what he means by "robot." Science fiction history notwithstanding, the whole subject is new and ill-defined. So, in about fifteen hundred words, the author makes a stab at definition, carefully sidestepping some issues that make him and many other people uneasy.

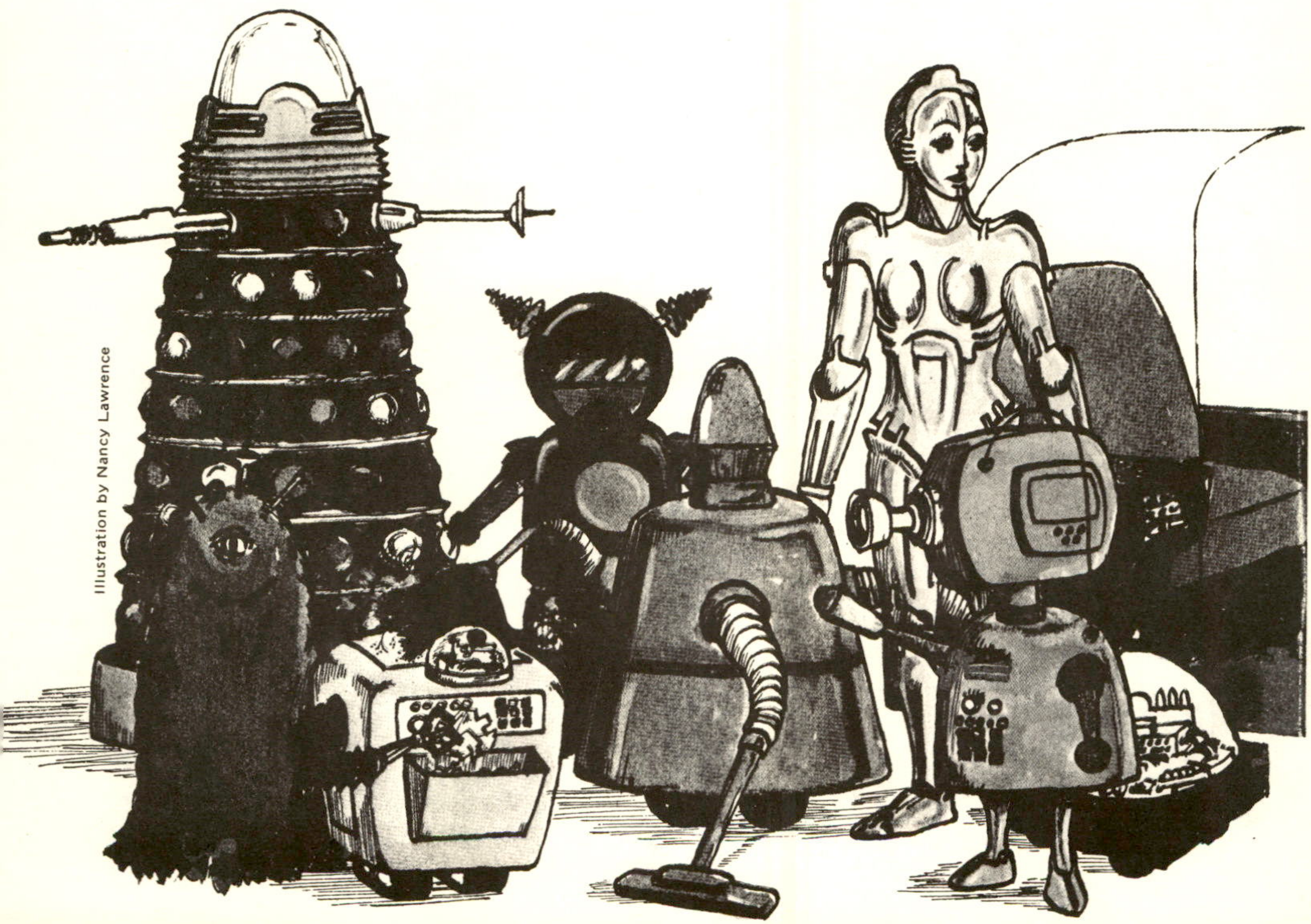
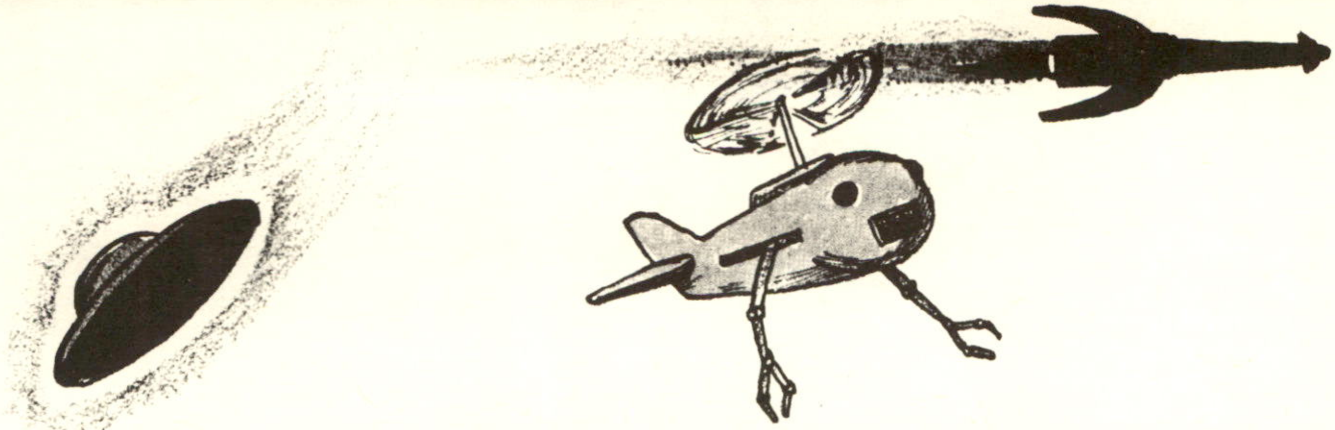


Illustration by Nancy Lawrence



By David L. Heiserman

There appears to be a groundswell of popular interest in robotics these days. Of course imaginary robots have been marching through the pages of science-fiction stories and across film and TV screens for quite a while now. But this new interest is not a matter of pure imagination. Rather, it has all the earmarks of a genuine technological revolution in the making.

The evidence for this new interest in robotics comes from several different sources. Consider the successful formation of a vigorous new organization, the U.S. Robotics Society (USRS). Then look at the growing number of robot-like machines appearing on popular TV talk shows and the evening news these days. Finally, consider the fact that a do-it-yourself book on the subject, *Build Your Own Working Robot* has gone through two printings in a little over one year.

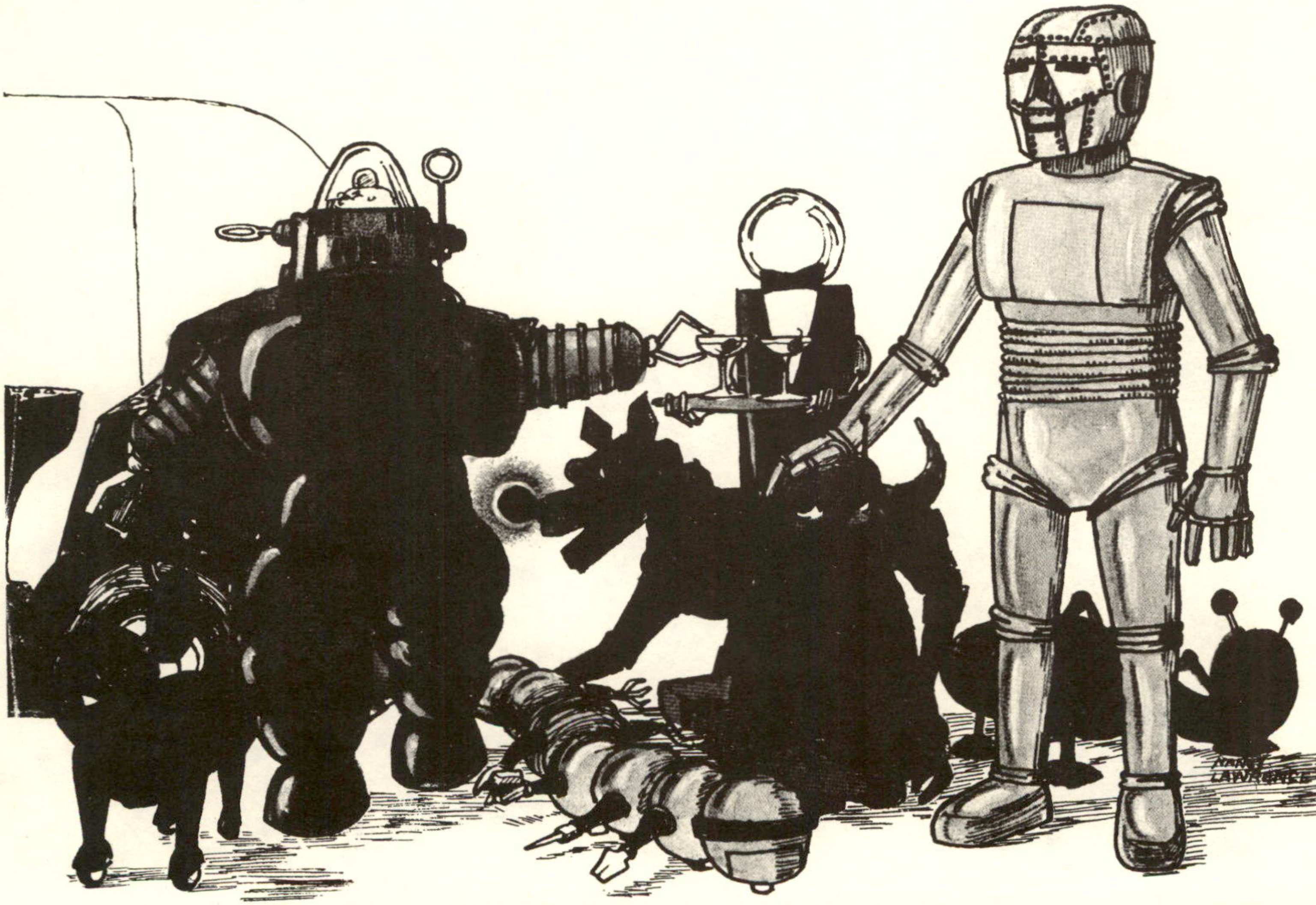
Indeed, it seems that the robots – bona-fide, true-to-life robots – are coming. We are on the brink of a technological revolution that represents the next quantum jump in the evolution of machines. From all available evidence it appears that amateur experimenters, rather than industrial or university researchers, are going to take the initiative.

The Delicate Formative Period

The formative period of any new technology is sensitive. Mistakes or misconceptions in the early going can confuse and misdirect the efforts of well-meaning experimenters for years to come. Unless we are careful about laying the basic philosophical foundations of robotics now, we run the risk of wasting time, effort and money developing machines and concepts that lead nowhere.

This is the time to get the basics of robotics straight; and the logical starting point seems to be working up a good definition of *robot.* Now that's really getting down to basics; but there is a need for carrying an initial analysis to that extreme of simplicity. The term *robot* is a coined expression that doesn't define itself as technical terms often do.

What many people think a robot should be really isn't a robot at all, and it is difficult for such people to understand the legitimate definition as they



try force-fitting it to their existing misconceptions. For that reason, it is perhaps a good idea to spell out first what a robot is *not* – to tear down some old structures and make way for a more useful and exciting one.

What a Robot Isn't

There are two major classes of electromechanical contrivances making something of a stir in the popular media these days. Some of them are quite complex and very interesting machines, but they are not real robots. They are merely imitations – *parabots,* if you will.

One class of parabot calls for having a human operator manipulate the machine by remote control. Would-be roboticists must be misled into believing any sort of remote-controlled machine that is manipulated by a human operator is any more vital to the evolution of machine technology than remote-controlled airplanes. Forget about any machine that relies on the on-line intervention of a human being.

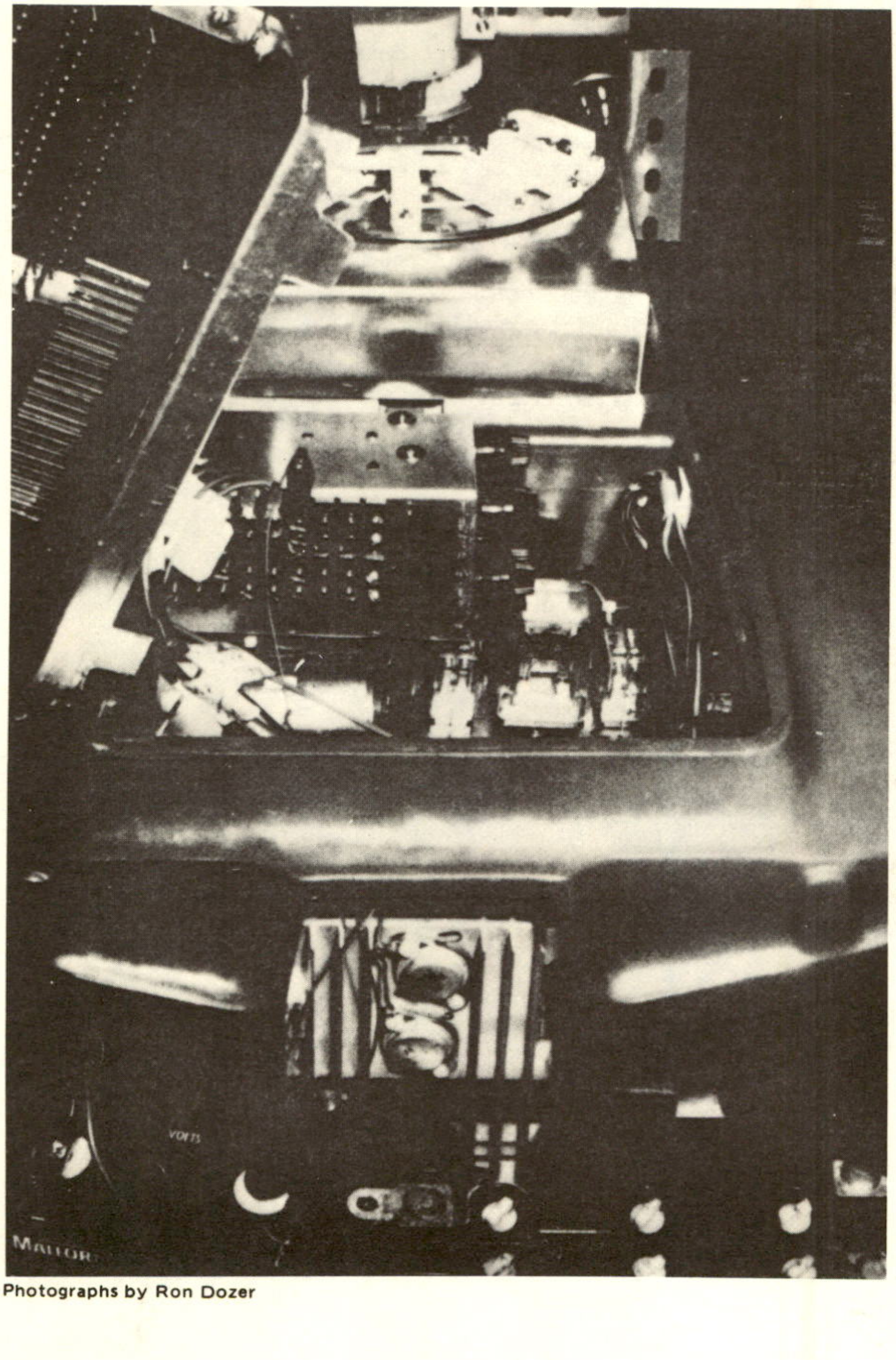
The second major class of parabots simply replaces the remote human operator with a small computer system. It is certainly possible to play an endless variety of sterile computer programs through a cleverly interfaced set of mechanical gadgets and end up with some fascinating effects. All this can be done, however, without really jumping the technological gap into the era of robotics.

ROBOT – A Matter of Semantics

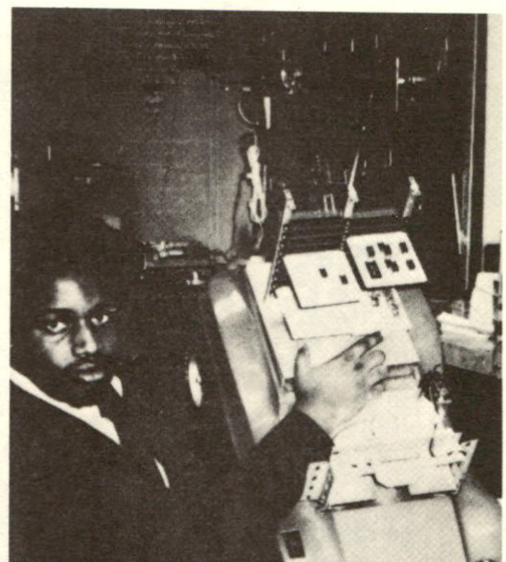
When thinking about real robots, consider two alternate names, *cyborg* and *automaton.* These are the key expressions. The word *cyborg* comes from the same root as *cybernetics* – the science of closed-loop feedback or servo systems pioneered by Norbert Wiener in the 1940's. A robot, then, must have cybernetic features, but that only expresses one aspect of how the job is done. It doesn't really say what a robot is – what separates it from any other class of machine already in existence.

Now consider the term *automation.* This work comes from the same root as *automatic;* but what is even more meaningful is the fact it shares a common heritage with the word *autonomous* – and that word is the key to defining a robot.

A robot must be an autonomous machine; a machine capable of carrying out functions on its own. A typical computer system is not an autonomous machine. As sophisticated as some computers might be, they must interact with a human operator to do anything useful at all. A robot is not a slave, but a "free" machine. It is a free-will machine that can, indeed, obey



Photographs by Ron Dozer



Sherman Kennedy (above), lead technician for the author's Mark-II Buster robot development program, displays the latest results. Robot (left), Mark-II Buster, has a more streamlined power pack and logic system than the original model. When completed the Mod-4 version will exhibit more obvious forms of artificial intelligence.

the commands of a human operator, but only as long as those commands do not violate any higher-priority needs.

Given a command or goal by a human operator, a true robot must be free to execute that command and achieve the goal, freely deciding exactly how to go about it. And whenever the robot is not actively pursuing a goal set by its human operator, it must be free to determine and work toward goals of its own. This is not a flight of fantasy, but a prime example of what a robot – an autonomous cyborg – can and must do. Any machine incapable of exhibiting autonomous behavior is not a robot at all.

Integrative Behavior is the Key

The philosophy behind the construction of a truly autonomous cyborg, as incredible as the concept might seem at first, is not really difficult to implement these days. Buster III, described in *Build Your Own Working Robot,* is an example of a lower-order robot. Buster III can operate without the need for human intervention at all. He can seek out his own battery charger and feed himself when the need arises. He can work his way around most kinds of physical barriers and generally interact with his environment in a fashion that would clearly indicate some underlying intelligence.

Buster's brain is not a conglomeration of discrete, task-performing programs. The system is far more dynamic than is possible with the sort of thinking that goes into building parabots. The brain of a true robot is an integrated network of simple and basic functions that are orchestrated according to on-line environmental conditions and the task set before the machine.

A buster IV system, presently under construction, moves one step higher on the scale of robot technology. This new machine not only reacts in a quasi-rational manner to its environment, but has the capacity for learning how to deal with environment and even altering it if necessary and possible – *as judged by the machine!*

HOW More Important Than WHAT

Putting together the basic working definition of a robot and the integrative technique for implementing that definition, one central theme emerges: It is far more important at this point to think in terms of *how* a robot carries out its tasks than it is to become carried away with *what* it can or cannot do as a result.

What really distinguishes man from other animals? Of course we could point to an infinite variety of political, social, economic and technological achievements through the history of mankind, but all those things merely reflect something deeper in the human makeup. The real essence of man is bound up in how his mind works, rather than what he does as a result. Man is unique in his capacity for rational, imaginative and often highly abstract thought. No other animal has the ability to think, judge and interact with the environment on the same level man does, and so no other animal is capable of exhibiting such a high degree of achievement.

A true robot is to other machines as man is to other animals. If roboticists can shed their current misconceptions, and begin thinking in terms of an autonomous machine equipped with integrated reflex, decision-making and goal-setting mechanisms, we can expect to see a new order of machine exhibiting a rich variety of behavioral modes that make other machines seem to be the lower-class mechanisms they really are. ■

Reprinted by permission of **Personal Computing** Magazine.

In addition to the Micromint, other speech synthesizers now available include: "Voicebox" by the Alien Group, "Echo" by Street Electronics, "The Voice" from Muse Software, "Intex Talker" by Intex MicroSystem Corporation, the Radio Shack TRS-80 Voice synthesizer by Votax, and systems manufactured by Texas Instruments, Commodore, John Bell Engineering, and Mountain Computer.

The talking Texan RB, under the direction of Brownsville's Lonsford, completed its first radio interview in February, stimulating considerable public interest. As experimenters continue to adapt speech synthesis, combining it with other capabilities such as speech recognition and data telemetry, robots will become more and more competent in fulfilling the many roles their owners will assign to them.

Editor's Note:
Although written by David Heiserman for the July/August 1977 issue of **Personal Computing** Magazine, the article "What Is a Robot?", which is reprinted in this issue of **RB Forum**, still expresses a very unique and refreshing viewpoint on how we might wish to regard our future development of robots. We hope you find it as interesting as we have.

WHY TINY BASIC?

Tiny BASIC, a National Semiconductor programming language, is sometimes used in situations that really are not right for it. As a result, misconceptions about Tiny BASIC are common. While the language is not particularly well suited to some of the tasks that people expect general-purpose computers to perform, it is nevertheless excellent for use in robotics.

Tiny BASIC resembles "bigger" BASICs in most respects, but it lacks such features as arrays and real number arithmetic. It is best described as a small special-purpose language, and it can be learned readily by anyone familiar with one of the various microcomputer BASICs currently on the market.

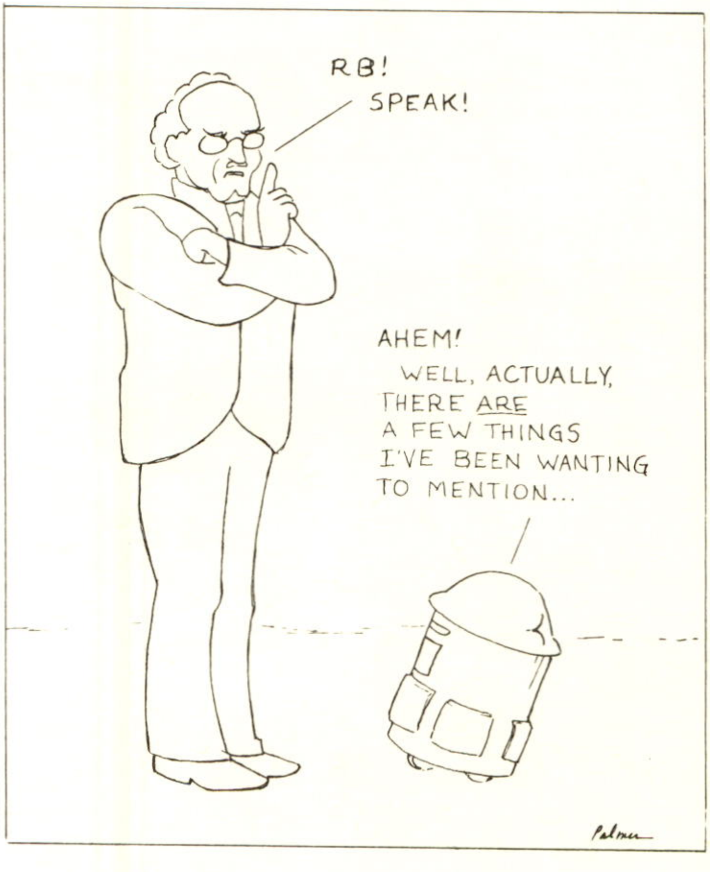
Variables in Tiny BASIC are only one character in length and thus there are a total of 26 unique Tiny BASIC variables available to the programmer — namely the upper-case letters of the alphabet.

This may, at first glance, seem to be a serious restriction, but in practice it seldom is. Tiny BASIC can read and write directly into memory using commands that resemble the PEEK and POKE commands of larger BASICs, and most program data can be stored conveniently and retrieved in this manner.

In general, programs for a robot employ sparse use of variables and arithmetic, and a relatively high use of AND/OR comparison operations to interpret what the robot senses in its environment. Tiny BASIC variables themselves are used primarily to control program loops or to freeze the contents of a constantly changing register that is hardwired to some sensing component. Twenty-six variables are usually more than enough for this purpose.

Robots have some special needs that can be met effectively with Tiny BASIC. Among them:

1. Robots should have direct access to their own memories.
   Robot owners should have the means to peer into these memories, particularly when they suspect that something is wrong with their robot. Tiny BASIC allows direct access to memory for fast input and output.
2. Robots should be able to measure time.
   Robot owners should be able to tell their robots when to do something. Tiny BASIC permits accurate timing.
3. Robots should occasionally be allowed to do things on their own.
   Robot owners should not be expected to have to tell their robots how to do everything.



Tiny BASIC has a built-in random number generator, an indispensable ingredient for autonomous action and for EAMI-style self-learning.

4. Robots need a method of quickly initiating basic survival skills.
   Robot owners need a method of controlling the results. Tiny BASIC allows direct hardware interrupts — a way of cutting through the red tape and implementing a quick change of action when necessary.

In short, while Tiny BASIC is not frequently used elsewhere, it provides a simple, efficient and economical method of controlling a mechanical device (such as a robot) in the fast-paced environment of the real world.

COMING ATTRACTIONS

A new six-minute videotape introducing the RB is now available for viewing in computer stores. Produced by Phil Volpi of Ceavco Telecommunications in Lakewood, Colorado, the videotape describes the capabilities of the RB. To order — or for further information — contact RB Robot Corporation.

The RB5X will be on display at two upcoming conferences:

The 8th West Coast Computer Faire
March 18-20, 1983
San Francisco, California

"Educational Perspectives in Computing"
Second Annual Conference of the
Alaska Association for Computers in Education
April 7-9, 1983
Anchorage, Alaska

RB Forum is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303) 279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot. Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptions Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB Robot Corporation
14618 W. 6th Avenue, Suite 201
Golden, CO 80401

RB FORUM

April, 1983 | Published monthly by RB Robot Corp. • Golden, Colorado | Volume 1, Number 4

RB5X GOES TO CAMP

These days, letters home from summer camp are filled with more than the traditional tales of hiking, canoe trips, and campfire sing-alongs. Today's campers are just as likely to tell of adventures programming and debugging, of Forth, PASCAL, BASIC, and assembler, of graphics, adventure/arcade game writing, LOGO, artificial intelligence, and electronics.

The Original Computer Camps, which computer consultant Denison Bollay began just three years ago, provides children with the usual fare of summer recreation. But they also offer to teach youngsters "how to learn about the computer."

When Bollay opened the first Original Computer Camp in 1980, 100 campers at one camp spent two weeks experimenting with the personal computers that filled one half of the dining hall. By the next year, the number of campers had grown to 350. In 1982, more than 800 campers attended computer camps near Santa Barbara, Lake Tahoe, and in New York State.

This year, preparations are underway to welcome more than 2000 young computer campers, ages seven to 15, to seven sites, including ones in Hawaii, New Hampshire, and near Steamboat Springs, Colorado. For those ages 11 to 16, the Camp also offers a one-month tour/camp in England and Scotland, where, in addition to the computer labs, campers can take advantage of coaching programs in badminton, tennis, gymnastics, volleyball, basketball, soccer, judo, fencing, swimming, archery, and riflery.

This year, The Original Computer Camps will include yet another first: detailed, hands-on instruction in robotics and self-learning programming thanks to the inclusion of the RB5X in the summer activities. Each of the Camps' seven locations will have at least one RB, to provide campers the opportunity to experiment and explore yet another facet of computer technology.

To kick off this year's camping season, The Original Computer Camps recently held a special press review to give the media a taste of what the Camps offer. Held at the Cate School in Carpinteria, California, the preview explored such topics as "Artificial Intelligence and Intuition: Computers Have IQs Too;" "Japan's 5th Generation Computer Project: Cornering the 'Smart' Computer Market;" and "Kids and Computers: Friends Forever." As a finale to the day's events, Cate School students raced two RB5Xs named Woody and Chip through a maze using programs the students wrote themselves.

The Original Computer Camps' Brian Colvin says, "We're interested in helping campers think and develop their logic. And we find the more feedback they get from machines, the better. For example, our instruction in computer graphics is very popular with the kids. And RB5X is going to be just as popular."

Denison Bollay, President of The Original Computer Camps, surrounded by captivated campers.

HEY, MOM, THERE'S A ROBOT IN MY CLASS!

Pam Beane's 4th and 5th graders think about robots a lot. In English class, they study Asimov and his laws of robotics. In art class, they build gleaming robot replicas out of silver cardboard. In math class, they use computers and take field trips to see robotic demonstrations. In social studies, they discuss the place robots will take in their lives.

The children, from John Gill School in Redwood City, California, are fascinated, but they're not in awe, and they're not solemn about it. Robots are a real part of their future, open to scientific inquiry, creative thought, and even good old-fashioned childhood humor.

"What would two robots do on a date?" Ms. Beane asked her class. "Well, they couldn't go swimming," the class decided, "because they'd rust. Maybe their favorite thing would be hanging around arcades."

For the students of the 80s robots are not a frivolous preoccupation. Quite the opposite. The future of robotics, in fact, represents a central issue in the world our children are being educated for.

By the time Beane's students are ready to take their places in business, many of the skills that are now crucial to our way of life will be obsolete. In the year 2000, many people think, robots will be doing much of the work we do now, and new robot-related professions will take precedence over the old. Only when children are familiar with technology as a tool and aware of how to use their individual talents in a high-tech society will they be prepared to succeed.

The classes at John Gill School represent the dramatic change in emphasis occurring in education today, but they are not unique. Since technological literacy is essential for today's children, other schools are using the most advanced equipment they can find to provide the best in education.

DEFINITION OF A GENERAL PURPOSE EDUCATIONAL ROBOT

A self-controlled, self-powered mechanical device that is based upon a microprocessor, able to move about freely in the environment and capable of specific movements and of manipulating certain objects for specific purposes, given predetermined parameters of performance and programmed intelligence. It is able to make decisions about its performance, to accept reprogramming and able to "learn", or adapt, within its context of performance, and within the imperatives of its programmed purpose. It is able to yield to adaptation of a user (customization) and able to respond to communication and to communicate.

Principal Harvey Barnett of Stevens Creek Elementary in Palo Alto acquired a robot to teach primary students logic. Barnett was inspired by the work of Seymour Papert of MIT in developing LOGO as a programming language for children, and especially by Papert's book *Mindstorms: Children, Computers, and Powerful Ideas.*

"When you put a child on a computer and tell him to draw a square, the process is too quick. He can't see where he's gone wrong," says Barnett. But when the child must program a robot to do the same task, any errors are immediately evident. The student has a better idea of where he went wrong, what the program should be and how to correct it. Sizes and shapes and their relationships suddenly become clear.

Competition adds to the learning experience, too. Later this year, the Stevens Creek students plan to hold a Robot Olympics to test their new-found skills. "We'll set up a predetermined pattern on the carpet with tape — a course to follow. The teams of children — 4th to 6th grade levels — will be provided with a grid, a map of the course, and they'll know the measurements involved. Then they'll write programs to get the robot to follow the course. The team with the most successful pattern wins."

Barnett notes that the abilities needed to win the Olympics are academic ones: logic, programming, and math.

Computers to teach these skills are now almost commonplace. Creative Strategies International, a California research firm, predicts that almost a million microcomputers will be installed in American schools by 1985.

Educators everywhere agree that, in addition to readying students for the technological revolution, the computer really expands young minds. Students learn to think for themselves. They find new creative ways to look at a problem. They begin to organize data in more logical ways. They have access to information that might otherwise be lost to them. They instinctively work together to find the best solutions. And perhaps most important, they gain a new level of self-esteem: in seeking and finding innovative answers to their questions, they increase their desire to learn and their respect for their own mental powers.

Robots, being mobile, carry all these advantages literally into another dimension. Dr. David Thornburg, associate editor of *Compute! Magazine* and author of *Every Kid's First Book of Robots and Computers,* comments: "Looking five years ahead, it's pretty obvious that domestic robots will become indispensible in education."

One of Dr. Thornburg's early experiences in classroom robotics shows why.

Thornburg was looking for a way to introduce computers to children at the 2nd to 6th grade level. He started by bringing the popular Big Trak toy — "a marvellous tool for a child," he says — to class. The children reacted unexpectantly.

"There's a high level of awareness of the Big Trak as a toy among boys," he says, "but not so much among girls. It's a question of what's appealing. In the first session, the boys wanted to use the Big Trak immediately, but the girls hung back from it, and gravitated more to the computer. Then I realized that they were operating under what you might call different fantasies. When I got a marker and some newspaper roll ends, and showed them that the Big Trak could draw pictures, the girls became much more interested. The boys had seen it as a sort of military toy, but the girls were interested in using it to create."

Once the children had seen how they could control the device and use it to accomplish a goal, Thornburg moved them up to a computer, introducing a display turtle and a programming language. Most of the students, he said, had trouble with the transition.

It was then that he recognized the need for a real robot. It had to be something "neutral, so that there was no bias with an image" (as happened with the Big Trak), "programmable, mobile, and preferably without wires." The search led him to the versatile, personal robots that were just beginning to be pioneered.

A properly versatile robot proves useful at various levels: for example, in elementary classes, it can be used for social studies, science, and language development; in secondary school for physics and vocational programs. At every level, an educational robot demonstrates mathematics as no other teaching tool can.

Robots are "great for geometry," Thornburg says, and Beane echoes that sentiment.

"They move, so they're perfect for teaching degrees, angles, the shape of a circle, division — all in a fun way," she says. "They can also be used to teach foreign language, logic skills, and of course programming. The child will go into society having learned to control the robot, and the child will have no fear of it, no technophobia at all. They love it!"

It's true that children seem to have no technophobia. Growing up in a computer age, they think of inventions that may frighten their parents as challenging new horizons to explore and conquer. More than a few recognized computer geniuses are in their teens. A great many people under 25 are making new discoveries in the field of robotics.

This can be a bit threatening for some teachers, but the picture is changing. By definition, educators are eager to learn, and programs to fill the technological gap are springing up all over the country.

One of the biggest is the $9.7 million Technical Center in Redwood City, which was established under Governor Jerry Brown. There, teachers learn about electronic advances of every kind. Virtually all universities offer courses, seminars, inservices, and continuing education programs to bring educators up to date on electronic learning methods.

And robotics itself is becoming a distinct field of study in higher education. The New York Institute of Technology in New York State plans to offer an undergraduate degree in robotics. Many universities, most notably Stanford, MIT, and Carnegie-Mellon, are in the forefront of robotics research.

As robots continue to be integrated into our workplaces, our homes, and especially our schools, the changes we experience may well come as pleasant surprises.

As Dr. Thornburg says, "Domestic robots are a tremendous boon. Teachers of the educationally or physically handicapped, for example, have a marvellous resource here. Robots can provide mobility for the homebound and improve the quality of life. . .

"The kneejerk response among some people is that robots will diminish the quality of life, but I see lots of scenarios, and the one that I'm interested in promoting and developing is a positive, helpful future for all kinds of robots."

CHARACTERISTICS OF A GENERAL PURPOSE EDUCATIONAL ROBOT

1. The robot, as an instructional device, must be small, portable, flexible, and programmable.
2. It must be inexpensive, that is, affordable within a school budget.
3. It must be accessible and useful in the elementary, secondary, and postsecondary curricula.
4. The educational robot should interface with computers used in school systems.
5. It should be programmable in a high level language and be able to do specific programmed tasks.
6. The robot should be able to learn from its own experience and function without external control.
7. An essential characteristic of any robot is that it must be able to manipulate objects.
8. It must be self-powered with sufficient power to last throughout an instructional day.
9. The educational robot should be flexible in design and construction so that a variety of peripherals can be included or added.
10. The system should be conducive to user customization.
11. The robot should have the potential for recognition of voice patterns and the ability to use voice in communication.
12. It should be able to communicate (data transfer) with other robots or with computers.
13. The robot should have diagnostic features incorporating visual or audible signals that allow verification of the robot's functions.

RB5X ATTENDS ANCHORAGE EDUCATORS CONFERENCE

RB5X, the "Intelligent Robot" manufactured by RB Robot Corporation, spent April 7 through 9 in Anchorage, educating teachers about the many uses of robots in schools.

Sponsored by the Alaska Association for Computers in Education and the Alaska Department of Education, the conference took as its theme "Educational Perspectives in Computing."

About 400 educators, school district administrators, and members of the general public converged on the Captain Cook Hotel in Anchorage for three days of seminars, workshops, and displays by area vendors. The conference acquainted teachers with the newest computer technology, gave them a forum for the exchange of ideas about the role of computers in education, and presented suggestions on how computers are being used to teach subjects other than those considered strictly computer-related.

During the conference, Abacus North contract programmer Rodger Ellis demonstrated a voice synthesis device for the RB5X. As the robot negotiated its way through crowds using its sonar and tactile sensors, it said "Excuse me" whenever it encountered an onlooker. RB5X's voice is the result of a VOTRAX voice chip, which reproduces the 64 phonemes that make up normal human speech.

PATTERN PROGRAM FOR RB5X NOW AVAILABLE

RB Robot Corporation now has available for Apple owners a package that can be used to program your RB5X to follow a specified pattern through its environment.

Using this program, you can now instruct your RB5X to move from the kitchen to the living room by way of the bedrooms, for instance, as a means of patrolling your home. You simply load the pattern program on your Apple and then describe each piece of the pattern as your computer prompts you. After you finish entering the description, the program produces the complete Tiny BASIC code that your robot needs. The code can then be downloaded from your computer to your robot using whatever communications package you normally use.

To use this pattern program, users need only have:

- An Apple II, Apple II +, or Apple IIe
- 48K of RAM memory
- One or two disk drives
- A disk controller in slot 6
- A communications card
- ASCII EXPRESS "Pro" package or the equivalent

The package is included with RB5X purchases. If you already have an RB5X and do not have a copy of the pattern program, you can request one from your RB5X dealer or direct from RB Robot Corporation. (Enclose $5 handling and media charge.)

RB Forum is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303) 279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot. Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptions Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB Robot Corporation
14618 W. 6th Avenue, Suite 201
Golden, CO 80401

RB FORUM™

June, 1983 Published monthly by RB ROBOT Corp. • Golden, Colorado Volume 1, Number 6

RB5X GROWS UP

One way to view the RB5X™ is to think of it as an infant. Like a human baby, the RB5X is a smaller version of a grown-up robot. Just as an infant evolves and changes as it gains more experience and knowledge, so the RB5X is changing. The RB5X does more today and is more sophisticated than when it first rolled off the production line. Tomorrow it will do even more.

Over the next six months, the RB5X will be doing a great deal of growing. Owners will soon be able to add options to the robot that will greatly expand its capabilities. This issue of the *RB FORUM* introduces the many options that are currently planned and that will be available to RB5X owners before the end of 1983.

The RB Arm

The RB™ arm, introduced at the International Summer Consumer Electronics Show in Chicago, June 5 through 8, has five axes of motion and folds completely inside the robot when not in use. Controlled directly by software or programmed using a separate teaching pendant, the RB arm can lift and carry up to 12 ounces. In addition, it can be programmed to reach around and turn the robot off.

Voice Recognition

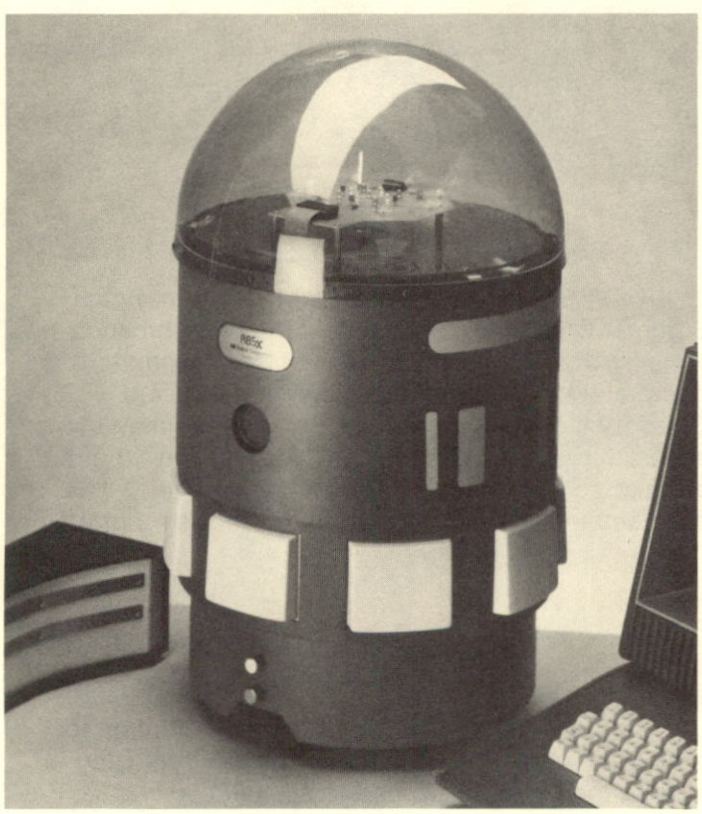
We currently offer a voice recognition option for owners of Apple II+ computers who are interested in making their RB5Xs respond to spoken commands. We are developing an option, using an off-the-shelf speech recognition device and radio communications, that will allow users to communicate directly through their computers to their robots, without a cable hookup. By the end of the year, RB5X will have a fully resident voice recoginition capability. With voice recognition, the RB5X can hear and understand your words and respond with information or with an action to your command.

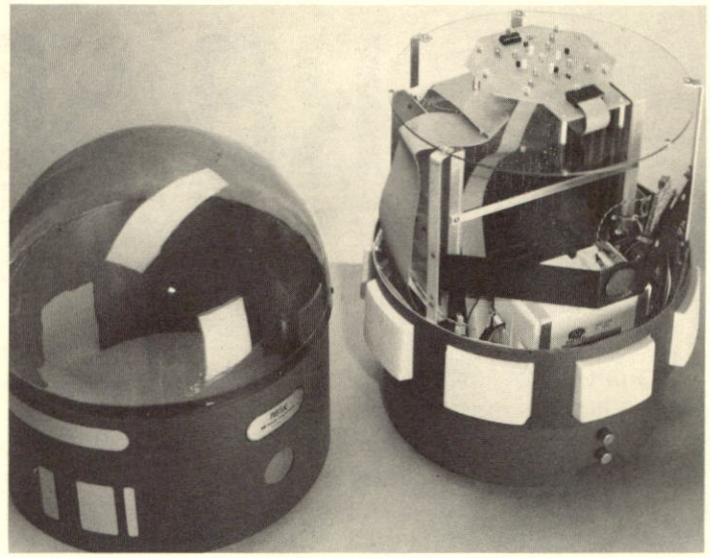
Sound Synthesis

RB5X owners can now use do-it-yourself instructions, available from RB Robot Corporation, to add speech synthesis to their robots. Within the next three months, we will provide a fully supported, off-the-shelf synthesis board that gives RB5X a vocabulary limited only by the size of its memory. The option also includes a speaker inside the robot and a programmable sound generator, enabling the RB5X to reproduce any sound, including music, sirens, and whistles.

LOGO

As part of RB5X's on-going work with teachers, other educators, and students, we are teaching the robot to speak LOGO. Instead of using the standard "turtle" for learning about computer graphics, students will soon have a friendly, versatile robot to use in their studies.





EPROM Options

One of the options currently available for the RB5X is an add-on of 2K EPROM (Erasable Programmable Read Only Memory). We will soon offer options that will exploit this EPROM capability, such as self-diagnostics and robot games.

Vacuum Cleaner

The RB5X vacuum attachment has a variable height adjustment for handling different floor surfaces and carpet textures. With its own motor and batteries, this attachment can be used in conjunction with standard self-learning programs or a pattern program written for a specific environment. Standard replacement bags can be purchased at most supermarkets and variety stores.

Radio Communications

A radio communications option will allow the RB5X to communicate (a) with a computer in the same room, (b) through a modem to a remote computer, or (c) directly to another robot. RB5X-to-RB5X communication will permit one robot to learn something in one environment and communicate what it has learned to another robot.

The RB Trailer

One of the options that will make RB5X an extremely valuable worker is the small trailer that owners will soon be able to add to their robots. For example, an RB with a trailer can be used in the work place to pick up and deliver mail. In the home, it can be used to haul small loads (laundry or groceries) or small children. Using specially written software or its standard self-learning programs, the RB5X can be trained to trace a specific route and to announce its arrival using its horn or a speech synthesis option.

OTHER OPTIONS NOT YET FIRMLY SCHEDULED

Infrared Communication

In addition to radio communications, we are investigating the possibility of remote communication without radio waves, using infrared signals instead. While this is a line-of-sight technique that does not allow communication through walls or around corners, it is an easier system to implement with simpler electronics.

Navigation Techniques

We are currently investigating two methods of robot navigation. The first involves the addition of a compass to the robot and the electronic interpretation of compass readings. The second comprises adding a controlled, rotating sonar sensor, enabling the robot to scan around itself without moving its body.

FIRE DETECTION AND EXTINGUISHING

If you *see* a fire start, chances are you can put it out before it does much damage. The trouble with accidental fires is that they seldom cooperate. A fire usually starts when we least expect it, while people are away from home or sleeping. Given only a few minutes of inattention, it can grow big enough to annihilate everything in its path.

That's the threat that Marc Turner is working to change.

A student at Golden High School in Golden, Colorado, Marc recently took first place in the engineering division of the International High School Science Fair in Albuquerque, New Mexico, competing against students from 12 nations. His winning entry was a system for detecting and extinguishing fire. Now he is taking it a step further: Marc's invention will soon become one of the security features of the RB5X.

Like many good ideas, Marc's evolved out of an earlier experiment. Originally, he built an equally impressive system using pulsed, infrared LEDs to send a voice through light. His detection device perceived the signals and turned them back into voice.

When that project proved successful, Marc began to wonder: would the device also detect heat from a flame? It did.

The prize-winning system resembles conventional sprinkler systems in public buildings, which use a spray nozzle head in the ceiling. Marc's work, however, has some special features. The user can set the sensitivity to distinguish among the heat intensity of, for example, a human being, a hot stove, and a fire. It incorporates a level control based on the speed at which heat rises. If the speed goes past an acceptable level, the device responds. When a fire is detected, the system aims through the flame and squirts water on it until it is extinguished. It also detects whether the fire is out. To ensure that the people in charge are alerted, the device sounds an alarm: a siren rings and lights flash.

The system can be used without drastic changes in environment or lifestyle, too. For example, Marc says, if you have a fireplace, you can simply instruct the system to ignore heat from that source.

When Marc's work is further developed for the robot, it will use CO_2 rather than water. Marc is currently working with a special model of the RB equipped with a tank to extinguish fires. Since the basic RB is designed for easy adaptation, Marc anticipates very few problems in accommodating his device to the robot, and he predicts that it will be ready as an option for RB by this summer.

Marc's contribution to the development of RB as a sentry and home security system is significant. With his help, a robot will soon be able to patrol our homes and businesses for signs of trouble, protecting our property and our families even when we ourselves cannot.

"What can be done by one person, or a small group of people, has increased as technology has advanced. I believe robotics can advance that a lot more." John McCarthy, Director, Artificial Intelligence Laboratory, Stanford University.

CHINESE LION DANCE BLESSES RB5X

RB5X was the center of attention recently at a Honolulu news conference. Held Saturday, May 14, the conference marked RB5X's Hawaiian debut. Between 400 and 600 people attended the event, held from 9:00 a.m. and noon at the Ala Moano Hotel.

The Honolulu event demonstrated RB5X's ability to negotiate its way through crowds using its sonar and tactile sensors to avoid obstacles in its way. The RB5X also spoke to people, thanks to a speech synthesis device added by seventeen-year-old Arnold Tang of Honolulu.

In addition to the robot demonstration, RB5X Hawaii distributor Laureen Farley arranged a Chinese lion dance to bless the RB5X.

The RB5X is available in Hawaii through Laureen Farley, 841 Bishop Street, #1925, Honolulu, Hawaii 96813, (808) 523-0933.

RB FORUM is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303) 279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot.™ Other subscriptions are available for $15/year prepaid. Subscriptions requests should be sent to the attention of the Subscriptions Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB ROBOT

RB Robot Corporation
14618 West Sixth Avenue
Suite 201
Golden, Colorado 80401
(303) 279-5525

RB FORUM™

July, 1983 | Published monthly by RB Robot Corp. • Golden, Colorado | Volume 1, Number 7

PROGRAMMING IN YOUR OWN WORDS

Question: What can a non-programmer do with a personal robot?

Answer: Anything a programmer can do, thanks to applications systems like RB Robot Corporation's new Robot Control Language with Savvy.™

Until recently, average people have had a valid reason for limiting their relationships with robots and computers: there was a language barrier. Computer communication seemed to be a system for the elite, all wrapped up in obscure signs, symbols, and unfamiliar code words that had to be entered in precisely the right order. People complained that they had to learn to "think like a machine." Under those conditions, a computer was intimidating enough; commanding a robot was unthinkable.

> The new Robot Control Language with Savvy . . . has essentially eliminated the robot language barrier.

In recent years, however, programmers and software developers have broken down that barrier for the average person by creating good, clear, simple software to make the home computer a practical, easy-to-use tool. The same is beginning to happen for robots.

The new Robot Control Language with Savvy (RCL for short), developed by Excalibur Technologies Corporation especially for the RB5X, has essentially eliminated the robot language barrier.

RCL™ is based on Excalibur's Savvy — a software development system and programming language designed to respond to ordinary words and phrases, and to associate similar commands. For example, it can be taught (in fact, it can even *conclude*) that the words "go," "travel," and "move" mean the same thing.

The scheme for achieving this is called APRP — Adaptive Pattern Recognition Processing. As Excalibur points out, "APRP has an uncanny knack of figuring out what you 'mean' by a phrase you type if it has some experience with the subject, and has seen phrases like yours before. This allows the operator to control the computer system with loosely phrased language." With APRP, the restrictions inherent in most computer languages simply don't apply. Natural, common sense commands get results. The system becomes increasingly familiar with its operator's vocabulary, not vice versa, and the more it is used, the more it responds to a variety of commands.

Furthermore, the system is not picky about spelling and syntax. If you misspell "counterclockwise," the robot isn't stymied; it matches your command to the sample it already knows, sees the similarity, and turns counterclockwise. And if you forget to enter a step in the program, RCL prompts you: "What do you want me to do now?"

> "APRP has an uncanny knack of figuring out what you 'mean' by a phrase you type if it has some experience with the subject, and has seen phrases like yours before. This allows the operator to control the computer system with loosely phrased language."

Like the Savvy computer system already on the market, RCL is compatible with the Apple II microcomputer. All of the current hardware associated with the RB5X and all of the accessories now under development respond to RCL, including voice recognition and synthesis, vacuuming, and RB5X's robotic arm.

One example of an RCL task incorporated into the system — that of finding and using the battery charger — is listed on pages 2 and 3, along with the same task as it would be written in Tiny BASIC.™ RCL eliminates "computereze" commands — like "Q = @#7802 and #20" — and replaces them with "test for charger contact." And if even the simplified language used here seems too cumbersome, it can be adapted further: "leave if any bumper touched" can become "move away if bumper is touched," or even "if you feel something touching your bumper, move away." RCL is flexible enough to respond to all these commands and to any others associated with them. An operator can actually invent a personal language, unintelligible to anyone but his robot, and can be understood perfectly.

> If you forget to enter a step in the program, RCL prompts you: "What do you want me to do now?"

Most operators, however, choose the words that come most naturally to mind. For example, in controlling RB5X's arm, you might say "Raise elbow 10 degrees" or "Turn wrist 30 degrees to the right." An RCL system familiar with those commands can "intuitively" determine that "lift elbow" and "elevate elbow" mean the same thing as "raise elbow," and that "rotate wrist" is another way of saying "turn wrist."

When an RB5X is equipped with voice synthesis, RCL can become very entertaining, especially if you want to endow it with a strong personality. For example, you might decide to command your RB5X to speak each time it is told to stop. In that case, it could be programmed with not just one standard remark, but with a whole series of statements appropriate to the situation, chosen essentially at random, and surprising you every time. These might include anything from "Your wish is my command" to "Oh, c'mon, let's jog around the block." One command or phrase can trigger any number of different verbal responses, creating the semblance of robot-human conversation. Excalibur calls this capability "The Lamb Project," and has published the procedure in *Machine Intuition* Magazine (November 1982-January 1983).

Late this year, it is expected that RCL will become resident in the RB5X's own microprocessor. At that time, it could be very satisfying to tell a robot "Thank you," "Good," or "Well done" and hear it respond "It was nothing," "You're welcome," or "Glad to help." Or, if things are not going so well, to tell it "No, no" or "Turkey," and hear it say "I'm sorry" or "Well, I've been sick, you know."

Because RCL is conversational, helps the operator through the programming process when necessary, and forgives minor errors, it has particular value in education. Schools that already use the Apple II to enhance their math and logic curricula can make a smooth, pleasant transition to robotics, and those that have committed to LOGO as a programming language will find that RCL works well from LOGO commands.

Because RCL is conversational, helps the operator through the programming process when necessary, and forgives minor errors, it has particular value in education.

As software applications systems continue to be developed, personal robots will become more accessible and more useful to people in all walks of life. Furthermore, robots themselves will become more precise, more reliable, and less expensive. Programmers and software developers are opening up the field of robotics for home use now just as they did with the computer a few short years ago. RCL's natural, intuitive approach is a giant step in that direction.

CHARGER FINDER ROUTINE

Robot Control Language with Savvy™ Text

```
 1 RESET THE ROBOT
 2 INITIALIZE MEMORY
 3 BEGIN A REPEATING PROCEDURE
 4    INITIALIZE MESSAGES
 5    CLEAR ALL VARIABLES
 6    BEGIN A REPEATING PROCEDURE
 7       GO FORWARD
 8       LEAVE IF ANY BUMPER TOUCHED
 9       DOES THE variable R compare = to ZERO
10          LEAVE THIS REPEATING PROCEDURE
11          END TEST
12       REPEAT THIS REPEATING PROCEDURE
13    LEAVE IF TAPE IS SENSED
14    MOVE WITH BETA INTELLIGENCE
15    REPEAT THIS REPEATING PROCEDURE
16 FOLLOW TAPE
17 MAINTAIN CHARGE
```

Tiny BASIC Text

Tiny BASIC Text	Meaning of Text
10 T=10	Number of whole seconds
20 GOSUB 1000	Go wait
30 T=10	Number of whole seconds
40 GOSUB 1000	Go wait
50 @#7803=#98	Initialize I/O
60 N=TOP	Initialize experience block
70 O=TOP+#FF	Initialize inhibition block
80 M=TOP+#200	
90 FOR P=N TO M	
100 @P=#FF	
110 NEXT P	
120 REM START A LOOP	Begin A Loop
130 @#7803=#98	Initialize I/O
140 CLEAR	Clear variables
150 REM START A LOOP	Begin A Loop
160 @#7802=#09	Go forward
170 Y=@#7800	Test for bumper contact
180 IF Y<255 GOTO 230	Exit if any contact
190 IF R<0 GOTO 210	Make a comparison
200 GOTO 230	Exit this Loop
210 REM END HERE	Fall through to here
220 GOTO 150	Repeat this Loop
230 REM EXIT TO HERE	
240 X=#02	Turn on LED 1
250 GOSUB 1100	Go turn on a bit
260 R=@#7802 AND #40	Test for tape sense
270 IF R=0 GOTO 310	Exit if tape sensed
280 GOSUB 2000	Go to Beta Subroutine
290 REM RETURN GOES HERE	Return to here
300 GOTO 120	Repeat this Loop
310 REM EXIT TO HERE	
320 REM START A LOOP	Begin A Loop
330 @#7803=#98	Intialize I/O
340 CLEAR	Clear variables
350 REM START A LOOP	Begin A Loop
360 @#7802=#08	Right forward
370 X=#02	Turn on LED 1
380 GOSUB 1100	Go turn on a bit
390 R=@#7802 AND #40	Test for tape sense
400 IF R=0 GOTO 440	Exit if tape sensed
410 Q=@#7802 AND #20	Test for charger contact
420 IF Q=0 GOTO 440	Exit if charger sensed

Tiny BASIC Text	Meaning of Text
430 GOTO 350	Repeat this Loop
440 REM EXIT TO HERE	
450 Q = @#7802 AND #20	Test for charger contact
460 IF Q = 0 GOTO 800	Exit if charger sensed
470 X = #40	Turn on flashing lights
480 GOSUB 1100	Go turn on a bit
490 T = 0	Initialize
500 DO	Do the following
510 T = T + 1	Math function
520 @#7802 = #09	Go forward
530 R = @#7802 AND #40	Test for tape sense
540 UNTIL (R<>0) OR (T> = 100)	Check exit conditions
550 DELAY 100	Short wait
560 @#7803 = #98	Initialize I/O
570 CLEAR	Clear variables
580 REM START A LOOP	Begin A Loop
590 @#7802 = #01	Left forward
600 X = #02	Turn on LED 1
610 GOSUB 1100	Go turn on a bit
620 R = @#7802 AND #40	Test for tape sense
630 IF R = 0 GOTO 670	Exit if tape sensed
640 Q = @#7802 AND #20	Test for charger contact
650 IF Q = 0 GOTO 670	Exit if charger sensed
660 GOTO 580	Repeat this Loop
670 REM EXIT TO HERE	
680 Q = @#7802 AND #20	Test for charger contact
690 IF Q = 0 GOTO 800	Exit if charger sensed
700 X = #40	Turn on flashing lights
710 GOSUB 1100	Go turn on a bit
720 T = 0	Initialize
730 DO	Do the following
740 T = T + 1	Math function
750 @#7802 = #09	Go forward
760 R = @#7802 AND #40	Test for tape sense
770 UNTIL (R<>0) OR (T> = 100)	Check exit conditions
780 DELAY 100	Short wait
790 GOTO 320	Repeat this Loop
800 REM EXIT TO HERE	
810 GOSUB 2310	Charge maintain routine
1000 FOR S = 1 TO T	Wait T seconds subroutine
1005 DELAY 1000	
1010 NEXT S	
1015 RETURN	
1100 U = @#7801	Turn on a bit @#7801
1105 U = U OR X	
1110 @#7801 = U	
1115 RETURN	
1120 U = @#7801	Turn off a bit @#7801
1125 U = U AND X	
1130 @#7801 = U	

Tiny BASIC Text	Meaning of Text
1135 RETURN	
2000 P = @#7800	Bumper pressed
2010 IF P = 255 THEN P = 251	Sonar treated as bumper #1
2020 V = @(N + P)	Check experience block
2030 IF V<>#FF GOTO 2100	Try action
2040 V = RND(1,14)	Pick random action
2050 IF (V = 3) OR (V = 12) OR (V = (0 + P)	Pick another
2100 @#7802 = V	Try action
2110 T = 2	Number of whole seconds
2120 GOSUB 1000	Go wait
2130 D = 200	Cancel sonar test
2140 IF (@#7800<>#FF) OR (D<95) GOT	Not successful
2150 @(N + P) = V	Successful
2160 CLEAR	Clear variables
2170 GOTO 290	Back to main program
2200 @(0 + P) = V	Not successful
2210 GOTO 2040	
2310 REM START A LOOP	Begin A Loop
2320 REM START A LOOP	Begin A Loop
2330 Q = @#7802 AND #20	Test for charger contact
2340 IF Q = 0 GOTO 2560	Exit if charger sensed
2350 P = 0	Initialize
2360 REM START A LOOP	Begin A Loop
2370 P = P + 1	Increment Loop count
2380 @#7802 = #09	Go forward
2390 DELAY 100	Short wait
2400 @#7802 = 0	Stop all motion
2410 Q = @#7802 AND #20	Test for charger contact
2420 IF Q = 0 GOTO 2540	Exit if charger sensed
2430 IF P<>5 GOTO 2520	Make a comparison
2440 @#7802 = #06	Reverse
2450 DELAY 1000	Short wait
2460 @#7802 = #09	Go forward
2470 T = 1	Number of whole seconds
2480 GOSUB 1000	Go wait
2490 DELAY 100	Milliseconds to wait
2500 @#7802 = 0	Stop all motion
2510 P = 0	Initialize
2520 REM END HERE	Fall through to here
2530 GOTO 2360	Repeat this Loop
2540 REM EXIT TO HERE	
2550 GOTO 2320	Repeat this Loop
2560 REM EXIT TO HERE	
2570 X = #04	Turn on LED 2
2580 GOSUB 1100	Go turn on a bit
2590 DELAY 1000	Short wait
2600 @#7803 = #98	Initialize I/O
2610 GOTO 2310	Repeat this Loop
2620 REM EXIT TO HERE	

END OF PROGRAM

HELPFUL HINTS

Shimming the Motor Wheels

If your RB has trouble maneuvering over carpet edging or other low obstacles, you can solve the problem by installing shims between the motor mounting tabs and the baseplate. The shim can be either a 10-32 nut or a #10 flat washer. Shims should be put over each of the three studs, even though only two will have nuts on them.

Keeping RB5X's Batteries Charged

If you find that your RB5X seems to lose its charge quickly or does not take a charge at all, it may be that the batteries have discharged below 5.4 volts. This should never be allowed to happen, as there may be irreparable damage to the batteries themselves.

To avoid this situation:

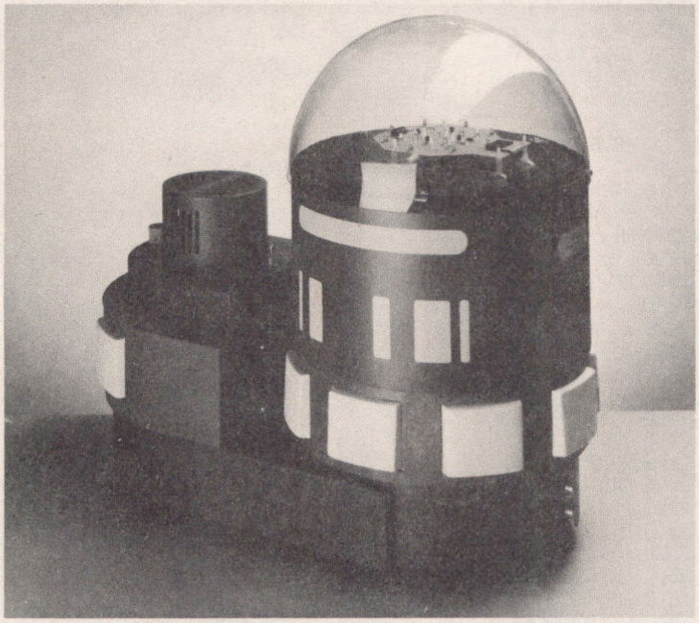
- Don't run the robot for long periods of time without recharging.
- Keep the robot in its charger, with its power switch OFF, when it is not in use. Recharge with the power switch ON only when the robot is under software control that keeps it "snuggled up" to the nest.

Notice that the lower light on the charger nest comes on when the charger is plugged into a 110-volt AC source. The upper light comes on when the robot makes contact with the charging strips *and* when its batteries are low enough to take a charge at full current but are not below 5.4 volts.

VACUUM CLEANER: AN UPDATE

Practically everybody would like a robot to do the vacuuming. It's one of those dreary, routine chores that shouldn't be inflicted on humans. And after all, the robot is down there moving around the floor anyway; why not have it do a little cleaning in the process?

Last month's *RM FORUM* announced the availability of the RB5X vacuum attachment for delivery this fall.



The option has its own motor and batteries, attaches to the lower skirt of the robot, and can be adjusted to the appropriate height for various floor surfaces and carpet textures.

There are currently two ways for the RB5X vacuum to find its way around. You can tell it how to do the job with a pattern program written especially for the room in question, or it can teach itself through the robot's standard self-learning programs. And more research is going on.

Humans still have an advantage, at least at the present time, because they know when the furniture has been moved and when the kids have left teddy bears (or nails!) on the living room floor. The ultimate vacuuming robot will have to be very perceptive to compete with that.

Several refinements of the RB5X's vacuuming hardware and software are currently being considered. Among them are the addition of an on-board electronic compass to give the RB5X a sense of direction; the installation of a second sonar sensor, mounted on the robot's dome and designed to rotate continually, seeking out obstacles and changes in the environment; and the addition of light, infrared, or radio frequency sensors that enable the RB5X to establish points of reference in a triangular pattern, thereby developing a map of the environment.

Using these methods, or similar ones, the RB5X may soon be cleaning up around home with a minimum of supervision.

RB FORUM is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303)279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot.™ Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptons Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB ROBOT

RB Robot Corporation
14618 West Sixth Avenue
Suite 201
Golden, Colorado 80401
(303) 279-5525

RB FORUM™

August 1983 Published monthly by RB Robot Corp. • Golden, Colorado Volume 1, Number 8

THE CHALLENGE OF THE ARTIFICIAL ARM

Fingers, wrists, hands and arms are certainly among the most useful and crucial tools we humans have. With them, we can thread a needle, throw a baseball, paint a picture, and lift a piano all in one day (although few of us do), and still come back for more. The list of tasks we can accomplish with our hands and arms is almost endless.

Naturally, the design of a mechanism that performs such a rich variety of work is complex. And naturally (human ingenuity being what it is), there are those who are dedicating their time to reproducing the complex human hand and arm in the form of a machine.

This issue of the **RB FORUM** *gives a general view of some current artificial arm technology—both in the field of robotics and in the field of biomedicine. In a sense, the two differ greatly: an arm designed to work alone is worlds away from an arm designed to function as part of a human being. But in a larger sense, the two fields complement each other. Each is based on a respect for the model that inspired it, the human arm; and each can benefit from the discoveries of the other.*

In future issues, we will examine artificial arms more fully; for now, it is enough to define the challenge the artificial arm presents.

NEW DIRECTIONS IN PROSTHETICS

It was like a nightmare, but it was real. A 10-year-old girl caught her hand in a kitchen grinder. Ultimately her hand had to be amputated.

Nothing can take away the pain or the loss, of course. She will never have that hand again, and she will never forget.

But she will have two useful hands.

Attached to her wrist, where the amputation occurred, is a cybernetic hand that responds to her mental commands with full movement of the fingers and even some sensation: she can actually feel her artificial hand touching, grasping and releasing objects.

Biomedical technology has advanced to the point that a prosthesis like the one worn by the little girl can work in harmony with the nervous system.

The device is myoelectrical; that is, the movements of the hand are controlled by nerve impulses from the brain itself. In turn, the brain—with the help of a subcutaneously implanted microprocessor—receives signals from the hand.

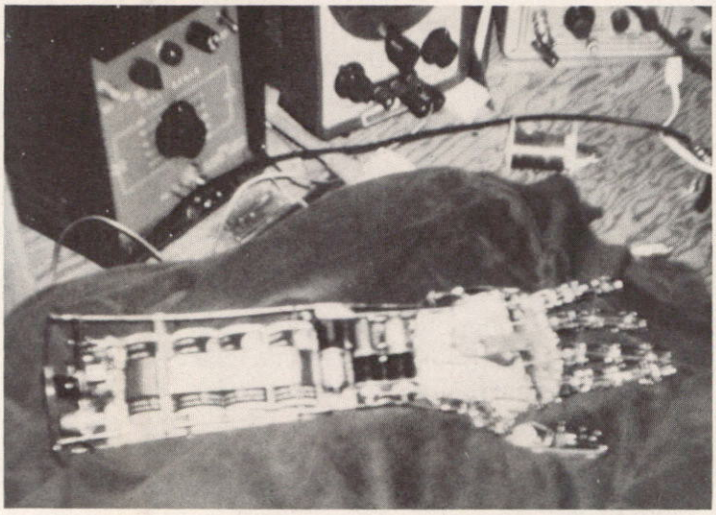
That system, based on an implanted chip, is not on the market yet, but chances are it soon will be. According to Robert Erra of Business Concepts Corporation in Denver, which owns proprietary rights to the device, it is undergoing patent appplications at the moment. Nevertheless, it has been installed on a number of patients.

...she can actually feel her artificial hand touching, grasping, and releasing objects.

Erra describes its workings this way: "A chip is inserted below the surface of the skin. This sends a radio signal—a mirror image of the nerve impulse that it picks up—and the nerve noise is filtered out or selected. The impulse is then converted from an analog signal to a digital signal."

The filtering process is vital; unclear or irrelevant signals can easily produce the wrong responses. That's where the special features of the microprocessor are needed.

"Using this chip," says Erra, "once the filtering is accomplished and the commands are interpreted, motors are turned on, batteries are activiated, and the commands are executed."



The hand, Erra says, "is actually a hand. It has a latex skin, full independent movement of the fingers, some opposition in all the fingers, and it can imitate all basic movements of the hand."

Response time is slower in an artificial hand or arm than in a natural arm, taking a second or more, but research is continuing to improve that function and others.

One of the most surprising features of the system is its ability to feel. Sensation in cybernetic prostheses is accomplished by the technique of biofeedback. In biofeedback, nerves and muscles are retrained. A patient who has experienced nerve damage can learn to compensate by using the nerves that are still intact in new ways. Appropriate responses are reinforced, and gradually the body learns to interpret the new sensations as spontaneously and accurately as it did the original, natural ones.

Biofeedback also plays a part in one of the best-know cybernetics limbs available—an arm created by researchers at the University of Utah.

According to Newsweek (July 12, 1982):

> *"The so-called 'Boston elbow' developed by four Boston-area universities and research centers, and the 'Utah arm' are motor-driven elbows and arms made mostly from lightweight plastic and graphite. The limbs have a built-in rechargeable battery pack, microelectronic circuitry and a series of electrodes that attach to the shoulder muscle. Using biofeedback, amputees learn to control the device much as they would a normal limb. The brain sends signals to the muscles to move, and when they contract in response, they produce impulses that can be detected by the electrodes on the skin's surface. From there, the signals are relayed to the artificial limb and translated into motion. To lift a heavy object (up to 50 pounds), the amputee simply increases the muscle tension. 'It can't play the violin or piano,' says Stephen Jacobsen, developer of the Utah arm. 'But it allows someone to use his limb.' "*

In some respects, artificial limbs are more easily adapted to children than to adults. For one thing, the demand for heavy lifting is not as great; for another, the nerve impulses in children are more easily detected.

But because cybernetic technology is growing rapidly, children who are using the most advanced prostheses available today may have even more sophisticated equipment to look forward to as adults. Whether or not these devices ever reach the full versatility of human limbs, they have already become a tremendous boon to people like the 10-year-old amputee who would be far more severely handicapped without them.

THE ARM OF A ROBOT

Most industrial robots are really robotic arms. The reason is simple: no mechanism in nature lifts, moves and manipulates objects more efficiently than an arm.

There are as many variations on the robotic arm as there are tasks for it to do. For example, the arm of the Viking lander had a scoop-like hand to gather samples of Martian soil. General Motors' famous automobile painting robots have spray-nozzle hands. Some robotic arms are designed primarily for heavy lifting, others for pick-and-place precision, still others for the greatest possible range of motion. The pertinent characteristics always depend on the robot's job.

In addition to large specialized industrial arms, there are several small tabletop robotic arms on the market, suitable for a variety of tasks. Some are used for light assembly work, and some for personal experimentation.

In general, though, personal robots seldom consist of just an arm. Robotic arms are stationary, and the ability to move throughout the environment is often the most interesting and valuable job a personal robot is called upon to do.

"The *manipulative imperative* tells us that an android must be able to provide something like hands and fingers in order to qualify as an android. To coexist with us in our environment, it has to be able to maneuver objects designed to be maneuvered by humanlike appendages. But even if we didn't *have* to give the android this capability, you have to admit—it's handy."

Martin Bradley Weinstein
Android Design
Hayden Book Company, 1981

But an arm is a wonderful thing for a personal robot, too. A robot with an arm can do much more than a robot without one.

One of the newest features of the RB5X is an arm of its own, which folds completely inside the robot, is fully programmable, capable of self-learning, and of course, designed for maximum versatility.

Since robotic arms need a sense of their location, the RB5X's arm is equipped with limit switches at the extreme positions of each joint. These provide a mechanical stop and a signal to the computer when the arm has reached its "home" position or the limit of its travel.

Some robotic arms are designed primarily for heavy lifting, others for pick-and-place precision, still others for the greatest possible range of motion.

Another important mechanical feature of the RB5X's arm is the inclusion of stepping motors. In addition to preventing the arm from "burning out" with a load that's too heavy, the stepping motors allow consistent control. Stepping motors are digital in effect; that is, you control them by pulsing them. A given number of pulses indicates a given location. Therefore, when the motors are pulsed rapidly, as the computer can do, the arm moves to exactly the desired position.

There are two ways of programming the arm: either directly by software, or with a separate teaching pendant that attaches by cable, when needed, to the robot. This can be used to teach the robot to execute movements, and once the movement is learned, the pendant can be detached. The pendant also allows the operator to control the arm manually.

Among the software provided especially for the arm is a demonstration routine and a "learn-and-play-back" program used with the pendant.

" 'In robotics, this has been something of a holy Grail,' says John Purbrick of MIT.

"The subject in question goes by many names: touch or tactile or pressure sensing, and robot or automatic or artificial skin among them. The names all refer to the same problem, which is how to build a machine that can, when it touches another object, identify that object and guide interactions with it. . .

"Many experts believe that touch sensing is utterly essential to the next wave of industrial automation. . .

" 'The present state of the art is primitive,' Professor Leon Harmon at Case Western Reserve University wrote in 1980. 'The field is wide open.' "

Technology Illustrated
April, 1983

Programming the arm yourself is very similar to programming any other part of the robot using Tiny BASIC(TM)[1]. In Robot Control Language (RCL) with Savvy(TM)[2], special arm-movement commands in ordinary English ("move the forearm up. . ."; "rotate the wrist. . ."; "open the hand. . .", etc.) make this programming particularly simple.

The two-fingered gripper opens to 2¾ inches, and is capable of lifting 12 to 16 ounces. And, finally, the arm can be programmed to reach around and turn the robot off.

Like the RB5X itself, its arm is engineered for easy adaptation. Additional hands may be among future developments. Another possibility for the future is a sensor system to let the robot know when it is about to grasp an object, and how much pressure to use.

And of course, more than anything else, future development depends on the jobs RB5X owners find for the arm to do.

1 **Tiny BASIC** is a registered trademark of National Semiconductor Corp.

2 **Savvy** is a registered trademark of Excalibur Technologies Corp.

RB5X ARM
SPECIFICATIONS

Construction:	Aluminum
Degrees of freedom:	5
Operational angular coverage	
Rotation of body (robot):	360 degrees
Rotation of shoulder joints:	Shoulder joint 1:300 degrees Shoulder joint 2:200 degrees w/shell
Rotation of elbow:	270 degrees
Rotation of wrist:	350 degrees
Grasp of hand:	Maximum opening to 2¾ inches
Lifting capacity:	12-16 ounces
Maximum operating speed:	1¼ inches/second at tip of hand
Control section	
Drive motors:	5 stepping motors
Speed control:	Manual selection of 3 speeds
Axial control:	Software can control all stepping motors at once
Interfaces:	Connects with RB5X bus
Programming languages:	Tiny Basic(TM) or RCL with Savvy(TM)
Power supply:	6-volt DC batteries with 15 amp-hour capacity
Accessories:	Teaching pendant and instructions

HELPFUL HINT
ROBOT MAINTENANCE

While the RB5X has been designed to be as trouble free as posible, some minimum maintenance is required. An occasional drop of oil on the ends of the gear-reduction shafts minimizes wear. Do not oil the motor shaft; it is permanently lubricated when manufactured.

Since even robots get dirty, they, at times, need cleaning. Use only mild soap and clean water to cleanse the exterior surfaces. Do not immerse the robot or any part of it in water, and avoid splashing water inside the robot. Do not use abrasive cleaners, synthetic detergents, or liquid cleaners. Some agents can cause the plastice parts to ultimately crack. Be safe! Use only mild hand soap.

COMING ATTRACTIONS

INTERNATIONAL PERSONAL ROBOTICS CONGRESS SCHEDULED FOR APRIL IN ALBUQUERQUE

The city of Albuquerque, New Mexico, will be the site for an International Personal Robotics Congress (IPRC), scheduled for April 13 through 15, 1984. Albuquerque Mayor Harry Kinney announced the Congress recently at a press conference in his office.

Expected to draw between 3,000 and 5,000 robot enthusiasts from around the world, the Congress will offer displays, exhibits, seminars, a number of cultural events portraying the history and mythology of personal robots, and an opportunity for robot enthusiasts to display their creations and to enter them in various robot competitions.

A steering committee has been formed to direct the Congress. It consists of Douglas Bonham, head of the educational division of the Heath Company, which manufactures the Hero I home robot; Joe Bosworth, steering committee chair and president of RB Robot Corporation, which produces the RB5X Intelligent Robot(TM); Russ Eberhart, robot retailer; Tom Frisina, president of Androbot, which offers Topo and B.O.B.; and Nels Winkless, robotics writer.

Joseph Engleberger, consultant in the field of industrial robotics, and David Heiserman, author and researcher in the field of artificial intelligence and personal robotics, are among those scheduled to conduct seminars during the Congress.

For further information, please call the International Personal Robotics Congress at (303) 278-0662 or write IPRC at 1547 South Owens Street, #46, Lakewood, Colorado 80226.

"The technology of robot arms and hands is moving forward rapidly. Scientist and students at MIT have built a robot arm with fourteen joints, three elbows and hydraulic 'muscles.' The arm is operated with its own arm computer.

"In Japan, scientists have invented a powerful, flexible hydraulically powered hand that can do many things the human hand can do. The three fingers of the hand are like a human's thumb, index finger and middle finger. The fingers, with a total of twelve joints, can do many complex tasks, such as tie a knot or fasten buttons. And, of course, they can use chopsticks. . .

"Some scientists speculate that robots equipped with advanced vision and touch will someday have enough hand-to-eye and hand-to-hand coordination that they will come equipped with twenty arms—each with telescoping forearms and rotating wrists. . .

"Robot arms are an exciting part of any hobby robot because they enable the robot to interact with—and change—its environment."

Fred D'Ignazio
Working Robots
Elsevier/Nelson Books, 1982

RB FORUM is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303)279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot.TM Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptons Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB ROBOT

RB Robot Corporation
14618 West Sixth Avenue
Suite 201
Golden, Colorado 80401
(303) 279-5525

RB FORUM™

July, 1983 | Published monthly by RB Robot Corp. • Golden, Colorado | Volume 1, Number 7

PROGRAMMING IN YOUR OWN WORDS

Question: What can a non-programmer do with a personal robot?

Answer: Anything a programmer can do, thanks to applications systems like RB Robot Corporation's new Robot Control Language with Savvy.™

Until recently, average people have had a valid reason for limiting their relationships with robots and computers: there was a language barrier. Computer communication seemed to be a system for the elite, all wrapped up in obscure signs, symbols, and unfamiliar code words that had to be entered in precisely the right order. People complained that they had to learn to "think like a machine." Under those conditions, a computer was intimidating enough; commanding a robot was unthinkable.

The new Robot Control Language with Savvy . . . has essentially eliminated the robot language barrier.

In recent years, however, programmers and software developers have broken down that barrier for the average person by creating good, clear, simple software to make the home computer a practical, easy-to-use tool. The same is beginning to happen for robots.

The new Robot Control Language with Savvy (RCL for short), developed by Excalibur Technologies Corporation especially for the RB5X, has essentially eliminated the robot language barrier.

RCL™ is based on Excalibur's Savvy — a software development system and programming language designed to respond to ordinary words and phrases, and to associate similar commands. For example, it can be taught (in fact, it can even *conclude*) that the words "go," "travel," and "move" mean the same thing.

The scheme for achieving this is called APRP — Adaptive Pattern Recognition Processing. As Excalibur points out, "APRP has an uncanny knack of figuring out what you 'mean' by a phrase you type if it has some experience with the subject, and has seen phrases like yours before. This allows the operator to control the computer system with loosely phrased language." With APRP, the restrictions inherent in most computer languages simply don't apply. Natural, common sense commands get results. The system becomes increasingly familiar with its operator's vocabulary, not vice versa, and the more it is used, the more it responds to a variety of commands.

Furthermore, the system is not picky about spelling and syntax. If you misspell "counterclockwise," the robot isn't stymied; it matches your command to the sample it already knows, sees the similarity, and turns counterclockwise. And if you forget to enter a step in the program, RCL prompts you: "What do you want me to do now?"

"APRP has an uncanny knack of figuring out what you 'mean' by a phrase you type if it has some experience with the subject, and has seen phrases like yours before. This allows the operator to control the computer system with loosely phrased language."

Like the Savvy computer system already on the market, RCL is compatible with the Apple II microcomputer. All of the current hardware associated with the RB5X and all of the accessories now under development respond to RCL, including voice recognition and synthesis, vacuuming, and RB5X's robotic arm.

One example of an RCL task incorporated into the system — that of finding and using the battery charger — is listed on pages 2 and 3, along with the same task as it would be written in Tiny BASIC.™ RCL eliminates "computereze" commands — like "Q = @#7802 and #20" — and replaces them with "test for charger contact." And if even the simplified language used here seems too cumbersome, it can be adapted further: "leave if any bumper touched" can become "move away if bumper is touched," or even "if you feel something touching your bumper, move away." RCL is flexible enough to respond to all these commands and to any others associated with them. An operator can actually invent a personal language, unintelligible to anyone but his robot, and can be understood perfectly.

If you forget to enter a step in the program, RCL prompts you: "What do you want me to do now?"

Most operators, however, choose the words that come most naturally to mind. For example, in controlling RB5X's arm, you might say "Raise elbow 10 degrees" or "Turn wrist 30 degrees to the right." An RCL system familiar with those commands can "intuitively" determine that "lift elbow" and "elevate elbow" mean the same thing as "raise elbow," and that "rotate wrist" is another way of saying "turn wrist."

When an RB5X is equipped with voice synthesis, RCL can become very entertaining, especially if you want to endow it with a strong personality. For example, you might decide to command your RB5X to speak each time it is told to stop. In that case, it could be programmed with not just one standard remark, but with a whole series of statements appropriate to the situation, chosen essentially at random, and surprising you every time. These might include anything from "Your wish is my command" to "Oh, c'mon, let's jog around the block." One command or phrase can trigger any number of different verbal responses, creating the semblance of robot-human conversation. Excalibur calls this capability "The Lamb Project," and has published the procedure in *Machine Intuition* Magazine (November 1982-January 1983).

Late this year, it is expected that RCL will become resident in the RB5X's own microprocessor. At that time, it could be very satisfying to tell a robot "Thank you," "Good," or "Well done" and hear it respond "It was nothing," "You're welcome," or "Glad to help." Or, if things are not going so well, to tell it "No, no" or "Turkey," and hear it say "I'm sorry" or "Well, I've been sick, you know."

Because RCL is conversational, helps the operator through the programming process when necessary, and forgives minor errors, it has particular value in education. Schools that already use the Apple II to enhance their math and logic curricula can make a smooth, pleasant transition to robotics, and those that have committed to LOGO as a programming language will find that RCL works well from LOGO commands.

Because RCL is conversational, helps the operator through the programming process when necessary, and forgives minor errors, it has particular value in education.

As software applications systems continue to be developed, personal robots will become more accessible and more useful to people in all walks of life. Furthermore, robots themselves will become more precise, more reliable, and less expensive. Programmers and software developers are opening up the field of robotics for home use now just as they did with the computer a few short years ago. RCL's natural, intuitive approach is a giant step in that direction.

CHARGER FINDER ROUTINE

Robot Control Language with Savvy™ Text

```
 1 RESET THE ROBOT
 2 INITIALIZE MEMORY
 3 BEGIN A REPEATING PROCEDURE
 4    INITIALIZE MESSAGES
 5    CLEAR ALL VARIABLES
 6    BEGIN A REPEATING PROCEDURE
 7       GO FORWARD
 8       LEAVE IF ANY BUMPER TOUCHED
 9       DOES THE variable R compare = to ZERO
10          LEAVE THIS REPEATING PROCEDURE
11          END TEST
12       REPEAT THIS REPEATING PROCEDURE
13    LEAVE IF TAPE IS SENSED
14    MOVE WITH BETA INTELLIGENCE
15    REPEAT THIS REPEATING PROCEDURE
16 FOLLOW TAPE
17 MAINTAIN CHARGE
```

Tiny BASIC Text

Tiny BASIC Text	Meaning of Text
10 T=10	Number of whole seconds
20 GOSUB 1000	Go wait
30 T=10	Number of whole seconds
40 GOSUB 1000	Go wait
50 @#7803=#98	Initialize I/O
60 N=TOP	Initialize experience block
70 O=TOP+#FF	Initialize inhibition block
80 M=TOP+#200	
90 FOR P=N TO M	
100 @P=#FF	
110 NEXT P	
120 REM START A LOOP	Begin A Loop
130 @#7803=#98	Initialize I/O
140 CLEAR	Clear variables
150 REM START A LOOP	Begin A Loop
160 @#7802=#09	Go forward
170 Y=@#7800	Test for bumper contact
180 IF Y<255 GOTO 230	Exit if any contact
190 IF R<0 GOTO 210	Make a comparison
200 GOTO 230	Exit this Loop
210 REM END HERE	Fall through to here
220 GOTO 150	Repeat this Loop
230 REM EXIT TO HERE	
240 X=#02	Turn on LED 1
250 GOSUB 1100	Go turn on a bit
260 R=@#7802 AND #40	Test for tape sense
270 IF R=0 GOTO 310	Exit if tape sensed
280 GOSUB 2000	Go to Beta Subroutine
290 REM RETURN GOES HERE	Return to here
300 GOTO 120	Repeat this Loop
310 REM EXIT TO HERE	
320 REM START A LOOP	Begin A Loop
330 @#7803=#98	Intialize I/O
340 CLEAR	Clear variables
350 REM START A LOOP	Begin A Loop
360 @#7802=#08	Right forward
370 X=#02	Turn on LED 1
380 GOSUB 1100	Go turn on a bit
390 R=@#7802 AND #40	Test for tape sense
400 IF R=0 GOTO 440	Exit if tape sensed
410 Q=@#7802 AND #20	Test for charger contact
420 IF Q=0 GOTO 440	Exit if charger sensed

Tiny BASIC Text	Meaning of Text
430 GOTO 350	Repeat this Loop
440 REM EXIT TO HERE	
450 Q=@#7802 AND #20	Test for charger contact
460 IF Q=0 GOTO 800	Exit if charger sensed
470 X=#40	Turn on flashing lights
480 GOSUB 1100	Go turn on a bit
490 T=0	Initialize
500 DO	Do the following
510 T=T+1	Math function
520 @#7802=#09	Go forward
530 R=@#7802 AND #40	Test for tape sense
540 UNTIL (R< >0) OR (T>=100)	Check exit conditions
550 DELAY 100	Short wait
560 @#7803=#98	Initialize I/O
570 CLEAR	Clear variables
580 REM START A LOOP	Begin A Loop
590 @#7802=#01	Left forward
600 X=#02	Turn on LED 1
610 GOSUB 1100	Go turn on a bit
620 R=@#7802 AND #40	Test for tape sense
630 IF R=0 GOTO 670	Exit if tape sensed
640 Q=@#7802 AND #20	Test for charger contact
650 IF Q=0 GOTO 670	Exit if charger sensed
660 GOTO 580	Repeat this Loop
670 REM EXIT TO HERE	
680 Q=@#7802 AND #20	Test for charger contact
690 IF Q=0 GOTO 800	Exit if charger sensed
700 X=#40	Turn on flashing lights
710 GOSUB 1100	Go turn on a bit
720 T=0	Initialize
730 DO	Do the following
740 T=T+1	Math function
750 @#7802=#09	Go forward
760 R=@#7802 AND #40	Test for tape sense
770 UNTIL (R<>0) OR (T>=100)	Check exit conditions
780 DELAY 100	Short wait
790 GOTO 320	Repeat this Loop
800 REM EXIT TO HERE	
810 GOSUB 2310	Charge maintain routine
1000 FOR S=1 TO T	Wait T seconds subroutine
1005 DELAY 1000	
1010 NEXT S	
1015 RETURN	
1100 U=@#7801	Turn on a bit @#7801
1105 U=U OR X	
1110 @#7801=U	
1115 RETURN	
1120 U=@#7801	Turn off a bit @#7801
1125 U=U AND X	
1130 @#7801=U	

Tiny BASIC Text	Meaning of Text
1135 RETURN	
2000 P=@#7800	Bumper pressed
2010 IF P=255 THEN P=251	Sonar treated as bumper #1
2020 V=@(N+P)	Check experience block
2030 IF V<>#FF GOTO 2100	Try action
2040 V=RND(1,14)	Pick random action
2050 IF (V=3) OR (V=12) OR (V=(0+P)	Pick another
2100 @#7802=V	Try action
2110 T=2	Number of whole seconds
2120 GOSUB 1000	Go wait
2130 D=200	Cancel sonar test
2140 IF (@#7800<>#FF) OR (D<95) GOT	Not successful
2150 @(N+P)=V	Successful
2160 CLEAR	Clear variables
2170 GOTO 290	Back to main program
2200 @(0+P)=V	Not successful
2210 GOTO 2040	
2310 REM START A LOOP	Begin A Loop
2320 REM START A LOOP	Begin A Loop
2330 Q=@#7802 AND #20	Test for charger contact
2340 IF Q=0 GOTO 2560	Exit if charger sensed
2350 P=0	Initialize
2360 REM START A LOOP	Begin A Loop
2370 P=P+1	Increment Loop count
2380 @#7802=#09	Go forward
2390 DELAY 100	Short wait
2400 @#7802=0	Stop all motion
2410 Q=@#7802 AND #20	Test for charger contact
2420 IF Q=0 GOTO 2540	Exit if charger sensed
2430 IF P<>5 GOTO 2520	Make a comparison
2440 @#7802=#06	Reverse
2450 DELAY 1000	Short wait
2460 @#7802=#09	Go forward
2470 T=1	Number of whole seconds
2480 GOSUB 1000	Go wait
2490 DELAY 100	Milliseconds to wait
2500 @#7802=0	Stop all motion
2510 P=0	Initialize
2520 REM END HERE	Fall through to here
2530 GOTO 2360	Repeat this Loop
2540 REM EXIT TO HERE	
2550 GOTO 2320	Repeat this Loop
2560 REM EXIT TO HERE	
2570 X=#04	Turn on LED 2
2580 GOSUB 1100	Go turn on a bit
2590 DELAY 1000	Short wait
2600 @#7803=#98	Initialize I/O
2610 GOTO 2310	Repeat this Loop
2620 REM EXIT TO HERE	

END OF PROGRAM

HELPFUL HINTS

Shimming the Motor Wheels

If your RB has trouble maneuvering over carpet edging or other low obstacles, you can solve the problem by installing shims between the motor mounting tabs and the baseplate. The shim can be either a 10-32 nut or a #10 flat washer. Shims should be put over each of the three studs, even though only two will have nuts on them.

Keeping RB5X's Batteries Charged

If you find that your RB5X seems to lose its charge quickly or does not take a charge at all, it may be that the batteries have discharged below 5.4 volts. This should never be allowed to happen, as there may be irreparable damage to the batteries themselves.

To avoid this situation:

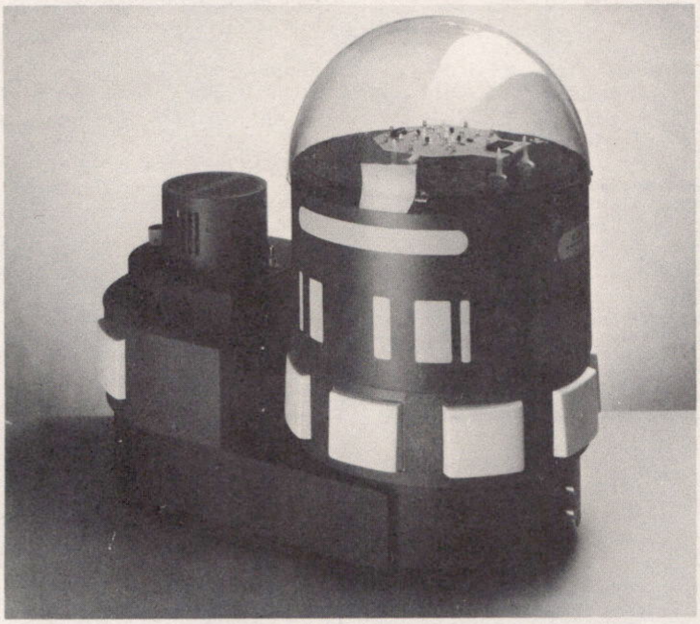
- Don't run the robot for long periods of time without recharging.
- Keep the robot in its charger, with its power switch OFF, when it is not in use. Recharge with the power switch ON only when the robot is under software control that keeps it "snuggled up" to the nest.

Notice that the lower light on the charger nest comes on when the charger is plugged into a 110-volt AC source. The upper light comes on when the robot makes contact with the charging strips *and* when its batteries are low enough to take a charge at full current but are not below 5.4 volts.

VACUUM CLEANER: AN UPDATE

Practically everybody would like a robot to do the vacuuming. It's one of those dreary, routine chores that shouldn't be inflicted on humans. And after all, the robot is down there moving around the floor anyway; why not have it do a little cleaning in the process?

Last month's *RM FORUM* announced the availability of the RB5X vacuum attachment for delivery this fall.



The option has its own motor and batteries, attaches to the lower skirt of the robot, and can be adjusted to the appropriate height for various floor surfaces and carpet textures.

There are currently two ways for the RB5X vacuum to find its way around. You can tell it how to do the job with a pattern program written especially for the room in question, or it can teach itself through the robot's standard self-learning programs. And more research is going on.

Humans still have an advantage, at least at the present time, because they know when the furniture has been moved and when the kids have left teddy bears (or nails!) on the living room floor. The ultimate vacuuming robot will have to be very perceptive to compete with that.

Several refinements of the RB5X's vacuuming hardware and software are currently being considered. Among them are the addition of an on-board electronic compass to give the RB5X a sense of direction; the installation of a second sonar sensor, mounted on the robot's dome and designed to rotate continually, seeking out obstacles and changes in the environment; and the addition of light, infrared, or radio frequency sensors that enable the RB5X to establish points of reference in a triangular pattern, thereby developing a map of the environment.

Using these methods, or similar ones, the RB5X may soon be cleaning up around home with a minimum of supervision.

RB FORUM is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303)279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot.™ Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptons Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB ROBOT

RB Robot Corporation
14618 West Sixth Avenue
Suite 201
Golden, Colorado 80401
(303) 279-5525

RB FORUM™

August 1983 Published monthly by RB Robot Corp. • Golden, Colorado Volume 1, Number 8

THE CHALLENGE OF THE ARTIFICIAL ARM

Fingers, wrists, hands and arms are certainly among the most useful and crucial tools we humans have. With them, we can thread a needle, throw a baseball, paint a picture, and lift a piano all in one day (although few of us do), and still come back for more. The list of tasks we can accomplish with our hands and arms is almost endless.

Naturally, the design of a mechanism that performs such a rich variety of work is complex. And naturally (human ingenuity being what it is), there are those who are dedicating their time to reproducing the complex human hand and arm in the form of a machine.

This issue of the **RB FORUM** *gives a general view of some current artificial arm technology—both in the field of robotics and in the field of biomedicine. In a sense, the two differ greatly: an arm designed to work alone is worlds away from an arm designed to function as part of a human being. But in a larger sense, the two fields complement each other. Each is based on a respect for the model that inspired it, the human arm; and each can benefit from the discoveries of the other.*

In future issues, we will examine artificial arms more fully; for now, it is enough to define the challenge the artificial arm presents.

NEW DIRECTIONS IN PROSTHETICS

It was like a nightmare, but it was real. A 10-year-old girl caught her hand in a kitchen grinder. Ultimately her hand had to be amputated.

Nothing can take away the pain or the loss, of course. She will never have that hand again, and she will never forget.

But she will have two useful hands.

Attached to her wrist, where the amputation occurred, is a cybernetic hand that responds to her mental commands with full movement of the fingers and even some sensation: she can actually feel her artificial hand touching, grasping and releasing objects.

Biomedical technology has advanced to the point that a prosthesis like the one worn by the little girl can work in harmony with the nervous system.

The device is myoelectrical; that is, the movements of the hand are controlled by nerve impulses from the brain itself. In turn, the brain—with the help of a subcutaneously implanted microprocessor—receives signals from the hand.

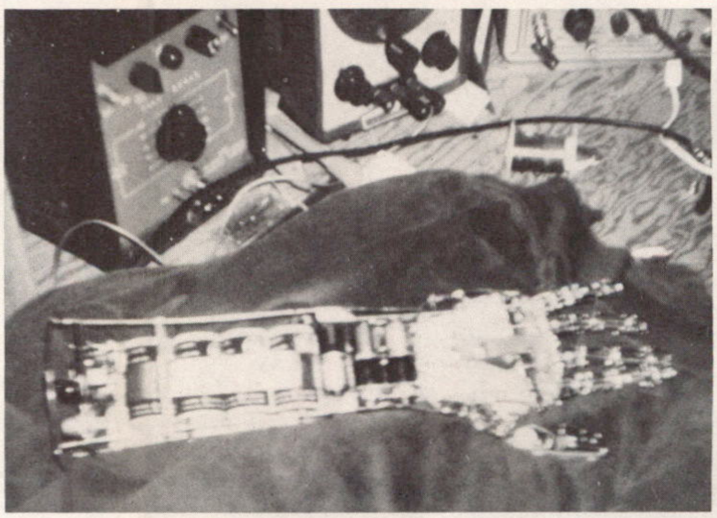
That system, based on an implanted chip, is not on the market yet, but chances are it soon will be. According to Robert Erra of Business Concepts Corporation in Denver, which owns proprietary rights to the device, it is undergoing patent appplications at the moment. Nevertheless, it has been installed on a number of patients.

...she can actually feel her artificial hand touching, grasping, and releasing objects.

Erra describes its workings this way: "A chip is inserted below the surface of the skin. This sends a radio signal—a mirror image of the nerve impulse that it picks up—and the nerve noise is filtered out or selected. The impulse is then converted from an analog signal to a digital signal."

The filtering process is vital; unclear or irrelevant signals can easily produce the wrong responses. That's where the special features of the microprocessor are needed.

"Using this chip," says Erra, "once the filtering is accomplished and the commands are interpreted, motors are turned on, batteries are activiated, and the commands are executed."



The hand, Erra says, "is actually a hand. It has a latex skin, full independent movement of the fingers, some opposition in all the fingers, and it can imitate all basic movements of the hand."

Response time is slower in an artificial hand or arm than in a natural arm, taking a second or more, but research is continuing to improve that function and others.

One of the most surprising features of the system is its ability to feel. Sensation in cybernetic prostheses is accomplished by the technique of biofeedback. In biofeedback, nerves and muscles are retrained. A patient who has experienced nerve damage can learn to compensate by using the nerves that are still intact in new ways. Appropriate responses are reinforced, and gradually the body learns to interpret the new sensations as spontaneously and accurately as it did the original, natural ones.

Biofeedback also plays a part in one of the best-know cybernetics limbs available—an arm created by researchers at the University of Utah.

According to Newsweek (July 12, 1982):

> *"The so-called 'Boston elbow' developed by four Boston-area universities and research centers, and the 'Utah arm' are motor-driven elbows and arms made mostly from lightweight plastic and graphite. The limbs have a built-in rechargeable battery pack, microelectronic circuitry and a series of electrodes that attach to the shoulder muscle. Using biofeedback, amputees learn to control the device much as they would a normal limb. The brain sends signals to the muscles to move, and when they contract in response, they produce impulses that can be detected by the electrodes on the skin's surface. From there, the signals are relayed to the artificial limb and translated into motion. To lift a heavy object (up to 50 pounds), the amputee simply increases the muscle tension. 'It can't play the violin or piano,' says Stephen Jacobsen, developer of the Utah arm. 'But it allows someone to use his limb.' "*

In some respects, artificial limbs are more easily adapted to children than to adults. For one thing, the demand for heavy lifting is not as great; for another, the nerve impulses in children are more easily detected.

But because cybernetic technology is growing rapidly, children who are using the most advanced prostheses available today may have even more sophisticated equipment to look forward to as adults. Whether or not these devices ever reach the full versatility of human limbs, they have already become a tremendous boon to people like the 10-year-old amputee who would be far more severely handicapped without them.

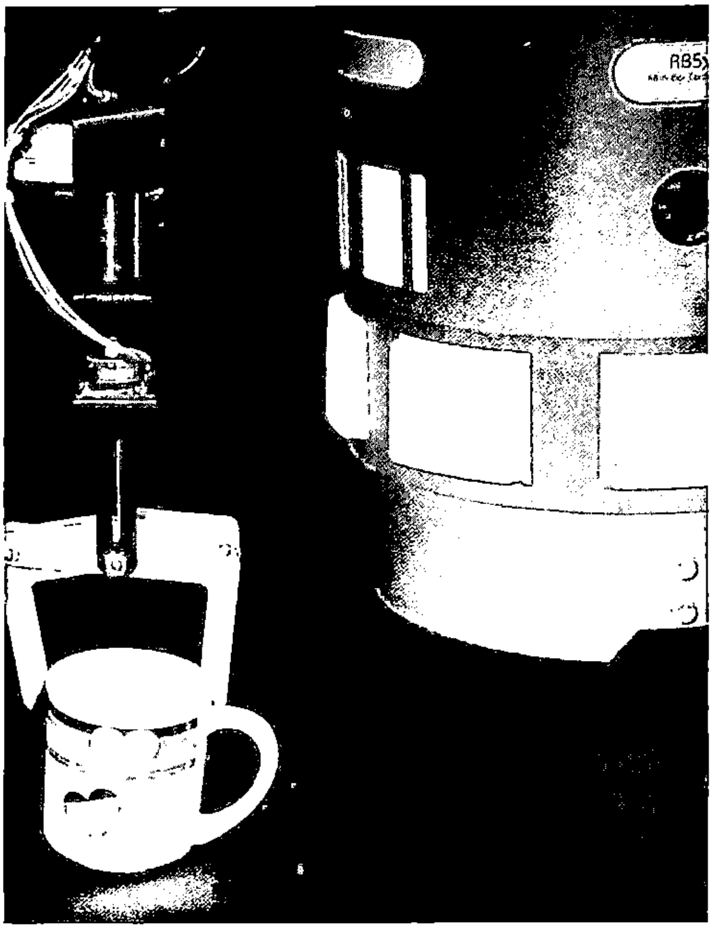
THE ARM OF A ROBOT

Most industrial robots are really robotic arms. The reason is simple: no mechanism in nature lifts, moves and manipulates objects more efficiently than an arm.

There are as many variations on the robotic arm as there are tasks for it to do. For example, the arm of the Viking lander had a scoop-like hand to gather samples of Martian soil. General Motors' famous automobile painting robots have spray-nozzle hands. Some robotic arms are designed primarily for heavy lifting, others for pick-and-place precision, still others for the greatest possible range of motion. The pertinent characteristics always depend on the robot's job.

In addition to large specialized industrial arms, there are several small tabletop robotic arms on the market, suitable for a variety of tasks. Some are used for light assembly work, and some for personal experimentation.

In general, though, personal robots seldom consist of just an arm. Robotic arms are stationary, and the ability to move throughout the environment is often the most interesting and valuable job a personal robot is called upon to do.



"The *manipulative imperative* tells us that an android must be able to provide something like hands and fingers in order to qualify as an android. To coexist with us in our environment, it has to be able to maneuver objects designed to be maneuvered by humanlike appendages. But even if we didn't *have* to give the android this capability, you have to admit—it's handy."

Martin Bradley Weinstein
Android Design
Hayden Book Company, 1981

But an arm is a wonderful thing for a personal robot, too. A robot with an arm can do much more than a robot without one.

One of the newest features of the RB5X is an arm of its own, which folds completely inside the robot, is fully programmable, capable of self-learning, and of course, designed for maximum versatility.

Since robotic arms need a sense of their location, the RB5X's arm is equipped with limit switches at the extreme positions of each joint. These provide a mechanical stop and a signal to the computer when the arm has reached its "home" position or the limit of its travel.

Some robotic arms are designed primarily for heavy lifting, others for pick-and-place precision, still others for the greatest possible range of motion.

Another important mechanical feature of the RB5X's arm is the inclusion of stepping motors. In addition to preventing the arm from "burning out" with a load that's too heavy, the stepping motors allow consistent control. Stepping motors are digital in effect; that is, you control them by pulsing them. A given number of pulses indicates a given location. Therefore, when the motors are pulsed rapidly, as the computer can do, the arm moves to exactly the desired position.

There are two ways of programming the arm: either directly by software, or with a separate teaching pendant that attaches by cable, when needed, to the robot. This can be used to teach the robot to execute movements, and once the movement is learned, the pendant can be detached. The pendant also allows the operator to control the arm manually.

Among the software provided especially for the arm is a demonstration routine and a "learn-and-play-back" program used with the pendant.

" 'In robotics, this has been something of a holy Grail,' says John Purbrick of MIT.

"The subject in question goes by many names: touch or tactile or pressure sensing, and robot or automatic or artificial skin among them. The names all refer to the same problem, which is how to build a machine that can, when it touches another object, identify that object and guide interactions with it. . .

"Many experts believe that touch sensing is utterly essential to the next wave of industrial automation. . .

" 'The present state of the art is primitive,' Professor Leon Harmon at Case Western Reserve University wrote in 1980. 'The field is wide open.' "

Technology Illustrated
April, 1983

Programming the arm yourself is very similar to programming any other part of the robot using Tiny BASIC(TM)[1]. In Robot Control Language (RCL) with Savvy(TM)[2], special arm-movement commands in ordinary English ("move the forearm up. . ."; "rotate the wrist. . ."; "open the hand. . .", etc.) make this programming particularly simple.

The two-fingered gripper opens to 2¾ inches, and is capable of lifting 12 to 16 ounces. And, finally, the arm can be programmed to reach around and turn the robot off.

Like the RB5X itself, its arm is engineered for easy adaptation. Additional hands may be among future developments. Another possibility for the future is a sensor system to let the robot know when it is about to grasp an object, and how much pressure to use.

And of course, more than anything else, future development depends on the jobs RB5X owners find for the arm to do.

1 **Tiny BASIC** is a registered trademark of National Semiconductor Corp.

2 **Savvy** is a registered trademark of Excalibur Technologies Corp.

RB5X ARM
SPECIFICATIONS

Construction:	Aluminum
Degrees of freedom:	5
Operational angular coverage	
Rotation of body (robot):	360 degrees
Rotation of shoulder joints:	Shoulder joint 1:300 degrees Shoulder joint 2:200 degrees w/shell
Rotation of elbow:	270 degrees
Rotation of wrist:	350 degrees
Grasp of hand:	Maximum opening to 2¾ inches
Lifting capacity:	12-16 ounces
Maximum operating speed:	1¼ inches/second at tip of hand
Control section	
Drive motors:	5 stepping motors
Speed control:	Manual selection of 3 speeds
Axial control:	Software can control all stepping motors at once
Interfaces:	Connects with RB5X bus
Programming languages:	Tiny Basic(TM) or RCL with Savvy(TM)
Power supply:	6-volt DC batteries with 15 amp-hour capacity
Accessories:	Teaching pendant and instructions

HELPFUL HINT
ROBOT MAINTENANCE

While the RB5X has been designed to be as trouble free as posible, some minimum maintenance is required. An occasional drop of oil on the ends of the gear-reduction shafts minimizes wear. Do not oil the motor shaft; it is permanently lubricated when manufactured.

Since even robots get dirty, they, at times, need cleaning. Use only mild soap and clean water to cleanse the exterior surfaces. Do not immerse the robot or any part of it in water, and avoid splashing water inside the robot. Do not use abrasive cleaners, synthetic detergents, or liquid cleaners. Some agents can cause the plastice parts to ultimately crack. Be safe! Use only mild hand soap.

COMING ATTRACTIONS

INTERNATIONAL PERSONAL ROBOTICS CONGRESS SCHEDULED FOR APRIL IN ALBUQUERQUE

The city of Albuquerque, New Mexico, will be the site for an International Personal Robotics Congress (IPRC), scheduled for April 13 through 15, 1984. Albuquerque Mayor Harry Kinney announced the Congress recently at a press conference in his office.

Expected to draw between 3,000 and 5,000 robot enthusiasts from around the world, the Congress will offer displays, exhibits, seminars, a number of cultural events portraying the history and mythology of personal robots, and an opportunity for robot enthusiasts to display their creations and to enter them in various robot competitions.

A steering committee has been formed to direct the Congress. It consists of Douglas Bonham, head of the educational division of the Heath Company, which manufactures the Hero I home robot; Joe Bosworth, steering committee chair and president of RB Robot Corporation, which produces the RB5X Intelligent Robot(TM); Russ Eberhart, robot retailer; Tom Frisina, president of Androbot, which offers Topo and B.O.B.; and Nels Winkless, robotics writer.

Joseph Engleberger, consultant in the field of industrial robotics, and David Heiserman, author and researcher in the field of artificial intelligence and personal robotics, are among those scheduled to conduct seminars during the Congress.

For further information, please call the International Personal Robotics Congress at (303) 278-0662 or write IPRC at 1547 South Owens Street, #46, Lakewood, Colorado 80226.

"The technology of robot arms and hands is moving forward rapidly. Scientist and students at MIT have built a robot arm with fourteen joints, three elbows and hydraulic 'muscles.' The arm is operated with its own arm computer.

"In Japan, scientists have invented a powerful, flexible hydraulically powered hand that can do many things the human hand can do. The three fingers of the hand are like a human's thumb, index finger and middle finger. The fingers, with a total of twelve joints, can do many complex tasks, such as tie a knot or fasten buttons. And, of course, they can use chopsticks. . .

"Some scientists speculate that robots equipped with advanced vision and touch will someday have enough hand-to-eye and hand-to-hand coordination that they will come equipped with twenty arms—each with telescoping forearms and rotating wrists. . .

"Robot arms are an exciting part of any hobby robot because they enable the robot to interact with—and change—its environment."

Fred D'Ignazio
Working Robots
Elsevier/Nelson Books, 1982

RB FORUM is published monthly by RB Robot Corporation, 14618 W. 6th Avenue, Suite 201, Golden, CO 80401, (303)279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot.™ Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptons Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB ROBOT

RB Robot Corporation
14618 West Sixth Avenue
Suite 201
Golden, Colorado 80401
(303) 279-5525

RB FORUM™

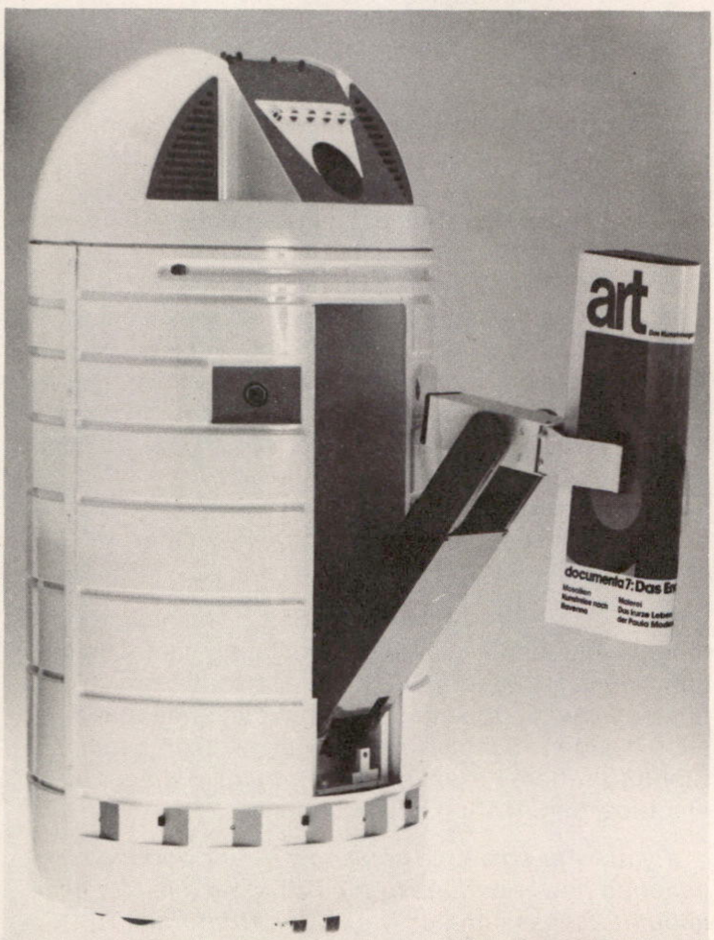
September, 1983 | Published monthly by RB Robot Corp. • Golden, Colorado | Volume 1, Number 9

VARIATIONS ON A THEME: RB5X ENHANCEMENTS FROM HAWAII AND GERMANY

The story's been told many times. But when the first personal computer was introduced to the public, many people nodded in admiration at the accomplishment of its inventors, and then scratched their heads and asked, "Yes, but what can you do with it?"

Software was scarce; the hardware was just a hint of what it would eventually become. But as soon as people began using these early machines, they began developing their *own* software; they began inventing their *own* hardware innovations. And soon the personal computer was doing a great many, remarkable things.

The same phenomenon is beginning to occur in the personal robot industry. The question you're most likely to hear once people have been introduced to their first home robot is, "Yes, but what does it do?"



Toby, The German Robot!

However, no sooner have some people asked the question than they have begun formulating answers for it.

Over the past few months, RB Robot Corporation has been a delighted witness to some exciting new adaptations for the RB5X™ personal robot.

The first of September, members of RB Robot's staff traveled to the International Audio and Visual Show in Berlin to take a look at a German variation of the RB5X. This show, which takes place every two years, attracts

. . .RB5X shared the stage with a European cousin named Toby.

500,000 consumers, retailers, and manufacturers from Europe and around the world, who are interested in showing and seeing the latest in home entertainment technology and telecommunications.

Not only was RB5X introduced to the European community at a bilingual press conference, but the robot shared the stage with a European cousin named Toby.

A variation on RB5X's basic design, Toby is the product of a Hamburg firm called Rainbow. Kurt Beer, Rainbow's president and Toby's creator, uses RB5X electronics and motor wheel assemblies, but has given Toby a new look.

The most notable difference between Toby and RB5X is probably the absence of the translucent dome so familiar to the American robot. Toby is also a bit taller and slimmer than RB5X, with a body of molded plastic. RB5X's eight bumpers have been replaced by infrared sensors around Toby's lower edge.

Instead of RB5X's standard single sonar sensor in the front, Toby has one sonar detector close to its top that points forward and two smaller ones below pointing to the sides. A line of five LEDs (light emitting diodes) on the front will flash in time to Toby's voice, once its speech synthesis is developed. Speakers have

. . . Rainbow entered into an agreement with RB Robot to purchase RB5X components, which they will use in their production of Toby.

already been included on the front of Toby's opaque dome, which also contains space for gas and smoke detectors, under development by Rainbow. A specially designed lucite tray fits into holders under the dome.

Toby's arm and gripper have fewer joints (degrees of freedom) than RB5X's, and fold vertically inside the robot instead of horizontally as in the American version. But Kurt Beer's technician, Eggert Schutt, has already created a built-in watering-tank option for Toby that allows the robot to dispense water to houseplants.

A teaching pendant and accompanying software make it easy to program Toby for specific patterns and tasks. An on/off key on the back plate, near the reset and power switches, makes Toby truly personal.

Toby and Rainbow president Kurt Beer.

After a great success at the International Audio and Visual Show, Rainbow entered into an OEM (original equipment manufacture) agreement with RB Robot to purchase RB5X components, which they will use in their production of Toby. There is also likely to be some cross-licensing of products, as options developed for one robot will fit the other.

And in Hawaii. . .

Arnold Tang, a recent graduate of Punahou High School in Honolulu, spent the summer developing some other RB5X enhancements.

Tang doesn't own a computer, but has nonetheless been working with them for the past six years. Until very recently, computers were practically non-existent in classrooms in Hawaii, so he started out working on the computer in the front office of his elementary school and later on the 20-year-old Hewlett-Packard owned by Punahou High School. His fascination with computers translated itself into his winning of Punahou's coveted Computer Science Award, which culminates a school-wide competition and goes to the student who is the undisputed leader in both hardware and software.

Arnold Tang (with the lei), presents RB5X to a group of interested children and adults.

Then this spring, Arnold was introduced to the RB5X and immediately began transferring his knowledge and enthusiasm to this new field.

One of his first developments was a voice synthesizer, which he introduced to a gathering of 600 people in May, even before RB Robot Corporation had released its voice package. Then came a special light board that fits around RB5X's standard LED plate. Tang's board contains two rings, each with 60 LEDs. One LED ring pulsates forward or backward depending on which direction the robot is going. The second is a visual indication of the robot's speaking, flashing in concert with speech information going to the speech card.

. . . One of his first developments was a voice synthesizer. . .

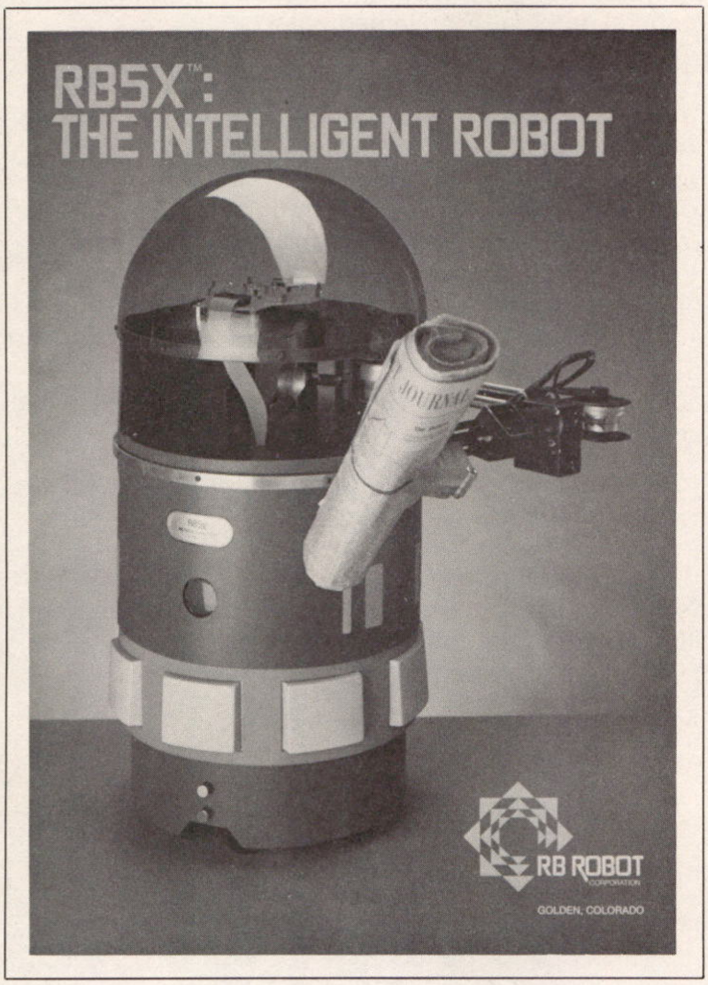
As a result of his work with RB5X, Tang has been much in demand as speaker, translating his technical knowledge into information that everyone from businesspeople to school children can understand. A National Merit Scholar, Tang begins work this fall at Stanford, where he will study computer engineering, electrical engineering and economics.

If you — or someone you know — are working on adapting new functions to the RB5X, we'd like to hear about it. Please contact The Editor, ***RB Forum****, RB Robot Corporation, 18301 West 10th Avenue, Suite 310, Golden, Colorado 80401, (303) 279-5525.*

RB5X POSTERS NOW ON SALE

The first two RB5X posters are now on sale from RB Robot Corporation. Both posters measure approximately 22" x 36". One shows the RB5X holding the *Wall Street Journal*; the other is a reprint of a recent ad appearing in *Creative Computing* and *Popular Computing*, picturing the RB5X holding slippers and conversing with a shaggy dog.

These posters are sold as a set for $6.00, which includes postage and handling. To order, send your check or money order to RB5X Posters, RB Robot Corporation, 18301 West 10th Avenue, Suite 310, Golden, Colorado 80401.



RB ROBOT CORPORATION MOVES ITS HEADQUARTERS

September 24 was moving day at RB Robot Corporation, which recently consolidated its operations in the Foothills Business Park in Golden, Colorado. RB Robot's new headquarters are now housed in 13,890 square feet of manufacturing, warehouse, and office space; the company holds an option on about 4,500 more square feet.

Beginning September 28, visitors are welcome at the new offices on Wednesdays and Fridays at 4:00 p.m. for tours of the new facility. If you've always wanted to visit a robot factory, please join us. For further information or to arrange a tour, contact Carolyn McCants at (303) 279-5525.

RB ROBOT SEEKS INDEPENDENT SOFTWARE DEVELOPERS

RB Robot Corporation is seeking creative games, "scripts", educational activities, and helpful in-home task programs written for the RB5X Intelligent Robot™ and intended for use by either children or adults.

Selected programs will be produced, packaged, and distributed by RB Robot through its nationwide retail dealer network, and their developers paid standard industry royalties. Developers must produce commercial quality software, written in Tiny BASIC to be run on Apple, IBM, Radio Shack, or other leading personal computers.

Software packages will be evaluated on the basis of:

- Creative application of RB5X capabilities
- Appeal
- Effectiveness
- Error handling
- Documentation
- Ease of use

For further information, please contact Deborah Waldo, RB Robot Corporation, 18301 West 10th Avenue, Suite 310, Golden, Colorado 80401, (303) 279-5525.

ROBOT APPRECIATION KIT BRIDGES THE INFORMATION GAP

Beginning in October 1983, RB Robot Corporation will be offering its *Robot Appreciation Kit,* designed to answer more of your questions about home robots in general and the RB5X in particular.

Priced at $19.95 and available from local RB5X retailers or direct from RB Robot, the *Robot Appreciation Kit* contains an overview of the field of personal robots; article reprints from current periodicals; product literature on the RB5X; a copy of the July 1983 issue of *RB Forum*, which discusses Robot Control Language™ with Savvy®; a questionnaire and free *RB Forum* subscription offer; two RB5X bumper stickers; an RB5X poster; a copy of Isaac Asimov's book, *EIGHT STORIES FROM THE REST OF THE ROBOTS*; and a copy of the RB5X *Reference Manual*, less the technical appendices.

The price of the kit is refundable if you purchase an RB5X before February 28, 1984.

For further information or for the name of the RB5X dealer nearest you, contact the Marketing Department, RB Robot Corporation, 18301 West 10th Avenue, Suite 310, Golden, Colorado 80401, (303) 279-5525.

Savvy is a registered trademark of Excalibur Technologies Corp.

RB FORUM is published monthly by RB Robot Corporation, 18301 W. 10th Avenue, Suite 310, Golden, CO 80401, (303)279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot.™ Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptons Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB ROBOT

RB Robot Corporation
18301 West 10th Avenue
Suite 310
Golden, Colorado 80401

RB FORUM™

October 1983 | Published monthly by RB Robot Corp. • Golden, Colorado | Volume 1, Number 10

RB5X™ AT COSI

If you're curious about the world, run, don't walk, to COSI.

COSI—the Center of Science and Industry in Columbus, Ohio—is dedicated to discovery. It's a place to take a coal mine tour or grow a tadpole into a frog, to investigate solar energy or explore the phenomenon of black holes, to pet a boa constrictor, predict the weather, build a time capsule, test your heart, and make paper from scratch. And now it's a place to learn about robots too.

"Gizmos"

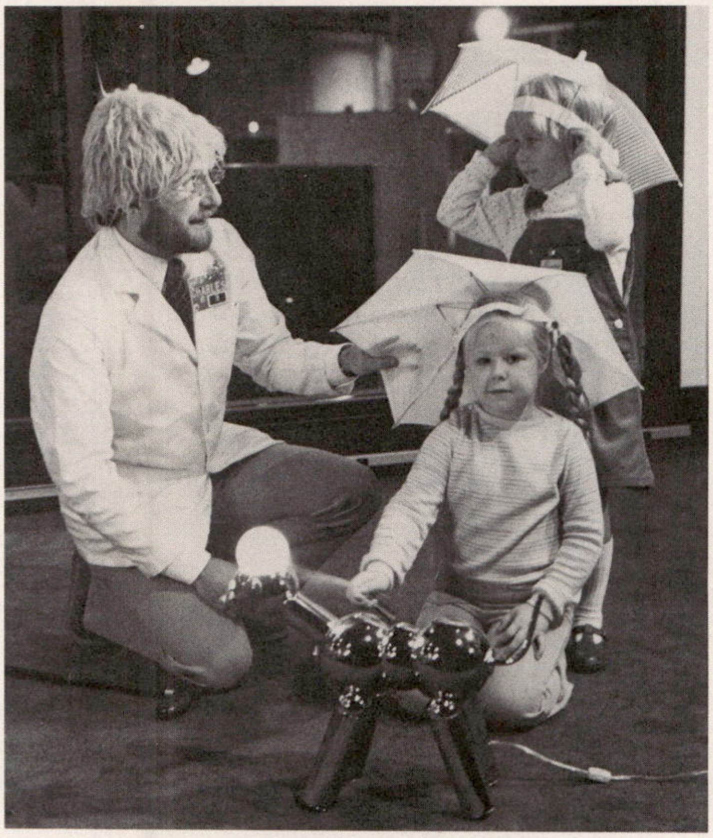
This year's Super Summer Science Show at COSI presented both a personal robot (the RB5X) and an industrial robot (Cyro 820 from Advanced Robotics) to several thousand visitors. According to Stephanie Martin, Program Development Specialist for COSI's education staff, the RB5X that spent the summer at COSI demonstrated to onlookers a number of its abilities, including speech synthesis and sonar ranging, as part of the museum's special floor exhibit. In addition to mingling with the crowd, RB5X introduced itself, and even sang. The other robot, Martin said, Cyro 820, is an industrial robotic arm. Since it's very heavy, it was exhibited on stage behind a glass wall to ensure the safety of the crowd. Its performance included "dancing" to music from a laser-disc sound system and drawing a series of optical illusions.

The showcase featuring the robots was called "Gizmos: High Technology Comes Home," and it stimulated so much serious interest in robotics among the students who saw it that the RB5X and the Cyro 820 have become a permanent, active part of COSI's educational program.

The Robot Support Team

Martin says that beginning this fall, high school student volunteers will take responsibility for the RB5X. A Robot Support Team, composed of students between the ages of 14 and 20, will make sure that the robot remains in good operating condition, demonstrate it to COSI visitors, and undertake special projects in robotics.

The team, Martin explains, is chosen from among COSI's many high school and college volunteers, who work at the center on weekends and during school vacations. In helping out at COSI, they earn both academic credit and COSI badges, based on the number of hours of service. After 1000 hours of volunteer work, a student is awarded a life membership to COSI. Over 150 young people were listed as student volunteers last year.



From this group, COSI's educational staff chooses the Robot Support Team. The students' interests and their previous work at the center are the main factors in the choice.

The initial team, predictably, includes students who have some experience in computer programming, but they all list a variety of other interests as well. Among these interests are academic subjects like math, physics, and reading, and extracurricular activities like drafting, sailing, skating, and volunteering to help the handicapped. The group is diverse and highly motivated.

At COSI, the Robot Support Team members have contributed their time in a variety of ways. They have served as tour guides, facilitated workshops for children, helped in the building of exhibits and in the presentation of shows. All of them see the project in robotics as an opportunity to increase their knowledge.

Creative Robotics

In their early work with the robot, the team will become familiar with its current capabilities: its sensors, programs, self-learning system, and voice synthesis. They will work with all of its options, including the arm, and prototypes of the electronic compass, and fire-fighting demonstrator. Since RB5X's summer work at COSI incorporated many of these features, the team has had some experience at the outset.

As the learning process develops, the COSI staff, as well as technicians and educational specialists from RB Robot Corporation, will provide guidance to the team. Ultimately, team members will propose their own special projects for programming the robot. Once an idea is approved, the students will be responsible for putting it into action.

Future Opportunities

In time, COSI's Robot Support Team members may travel to other facilities where additional research in robotics is being conducted. These trips, too, will encourage creative work. Not only will the students learn what others are doing, but they will be allowed to contribute their own insights and experiences.

Following COSI's lead, other museums are incorporating programs that feature the RB5X. Among these are the Space Center in Alamogordo, New Mexico, the Museum of Science and Industry in Chicago, and the Pacific Science Center in Seattle, Washington.

The Pacific Science Center staff plans to use the robot as part of its "van program"—a microcomputer outreach to school districts throughout Washington State. In that program, two mobile units are employed to instruct students and teachers in the use of the Apple microcomputers on board. The people who now benefit from the van program will soon be given experience with the RB5X as well.

Training programs like these benefit everyone involved. The students at COSI, for example, will be among the first to see new developments in the RB5X—and, in turn, they will contribute innovative programming of their own. It all goes to show once again that the field of personal robots holds exciting potential for anyone—regardless of age—who has the interest to explore it in a creative, imaginative way.

HOW COSI CAME TO BE

When the RB5X was made a permanent attraction at the Center of Science and Industry (see related story in this issue of the *RB FORUM*), it became part of a long, proud tradition of culture and education in Columbus.

COSI's home is Memorial Hall, a fine old classical-style, brick-and-stone building in the heart of the city. Dedicated in 1906, the building has housed hundreds of expositions, concerts, athletic programs, school functions and memorial services over the years.

By the late 1950s, however, the building's years of service had begun to take their toll. Although the structure itself was sound, it was in need of restoration—and also in need of a plan for the future. Local citizens and officials searched for a way to use Memorial Hall to its best advantage.

Between 1959 and 1961, study committees appointed by the Franklin County Historical Society explored the possibility of establishing a cultural and historical center in Memorial Hall that would incorporate the best features of science museums around the country.

Eventually, both public funds and private contributions were amassed for the project, under the leadership of the County Commissioners. According to Evelyn M. Graham and Myron T. Siefert, authors of a book on the building's history, an editorial in the *Columbus Dispatch* on October 31, 1962, commented that the plan would "meet a definite educational and cultural need to the community. The new Center will promote and encourage science education among children and adults. We are living in an exploding technological age where science can no longer be learned by memory. . .A science, industry and history

RB ROBOT INTRODUCES ROBOTICS BULLETIN BOARD

For those of you who actively use computer remote bulletin board systems (RBBS) accessible from your own personal computer with a telephone hookup (modem), RB Robot Corporation announces an RBBS that caters to those interested in exchanging information relating to the field of robotics.

Available Monday through Friday from 6:00 p.m. to 8:00 p.m. (Mountain time) and 24 hours a day on weekends and holidays, this RBBS allows RB5X owners and other interested parties to send and receive private mail, to post or read public interest messages, and to load or download programs with ASCII or XMODEM protocols.

RB Robot's bulletin board may be accessed by calling (303) 279-5657; we hope to have a toll-free, 800-number available soon. The board is currently operating at 300 or 1200 baud, 7 data bits, 1 stop bit, and even parity; or 300 or 1200 baud, 8 data bits, 1 stop bit, and no parity.

museum with stimulating exhibits teaches children to think and promotes a healthy relationship among families. . .A Center of Science, Industry and History is truly a magnificent investment in the future."

Today, more than 20 years later, that investment is yielding rich returns. COSI employs a large staff of professional educators, and its list of members, donors, contributors, and volunteers is in the thousands.

The permanent exhibits at COSI include (to name only a few): the history of flight, from hot air balloons to NASA capsules and satellites; historical vending machines; perception and optical illusions; Mobius strip; the street of yesteryear; crime prevention; veterinary medicine; the kitchen of tomorrow; and the story of birth.

The museum also offers a planetarium, a weather station, an "earth theater," and an energy lab. COSI's staff introduces special programs monthly, and the summer workshops offered each year provide unique insights into science, history, and art for everyone from preschool age up.

In 1973, the building was given a third floor and a new solar extension at the entrance, which serves to protect the historic front. The solar area also houses large exhibits, including transportation displays like the Wright Brothers' airplane and Apollo and Gemini capsules.

The future for COSI looks bright. As its supporters proclaim, it's "a place with things you can't discover anywhere else."

RB5X APPEARS IN SHARPER IMAGE

The Holiday 1983 issue of *The Sharper Image Catalog* features the RB5X in a full-page ad on the inside back cover.

Specializing in high-technology, electronics products, *The Sharper Image* chose the RB5X after a careful competitive evaluation of personal robots now on the market. *The Sharper Image* is in its sixth year of business and will do over $150 million in business this year. The Holiday 1983 issue has gone out to a mailing list of over 7 million households.

RB: PHONE HOME

"Hello?"

"Hi. This is RB5X. Is your robot home?"

Although the conversation doesn't go quite that way, robots are placing and receiving telephone calls now.

Personal robotics pioneer David L. Heiserman has recently developed both hardware and software adaptations to allow two RB5Xs to communicate by phone.

Heiserman describes the sequence of events this way: "When an RB places a call, the first thing he'll do is see if another RB answers. If it isn't an RB on the other end, the robot will do a routine for the human. If an RB does answer, the two of them can go into a mode to exchange information."

Last month, two robots had a transcontinental telephone conversation. An RB5X at COSI in Columbus, Ohio, telephoned an RB5X at the Museum of Natural History in Denver, Colorado, and the two established voice communication.

"We found that long-distance phone lines are difficult," says Heiserman. "Since then, we've modified the system to a more conservative design." The purpose of the new approach is to allow robots to transfer high speed digital data on long-distance telephone. By the end of October, according to Heiserman, this goal should be accomplished.

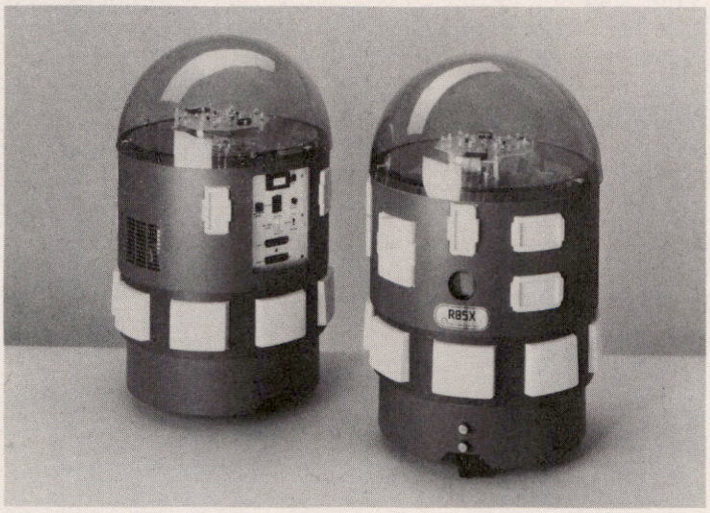
The same communications capability makes it possible to load programs without using a cable. It also allows two robots to interact without direct human intervention: they can exchange pleasantries or data, or one robot can ask the other to do something.

And you too can call RB5X—although you can't always catch him at home. Heiserman explains that an RB5X is usually connected to his office telephone on weekends. "You'll hear the phone ring once," he says. "Then there's about a 10-second delay while the robot decides whether or not it's another RB calling." If it's a human, RB5X will introduce itself and perhaps sing a little song.

If you'd like to have a chat with a robot, the number is (614) 885-2308. Heiserman notes, though, that the RB5X probably won't be connected to the phone indefinitely, so don't put off calling too long!

RB ROBOT CORPORATION INTRODUCES RB5X ENHANCEMENTS

Beginning with October shipments, the RB5X Intelligent Robot™ has a slightly different look, which corresponds to some important new capabilities.



The most noticeable new enhancement to the RB5X is a series of cutouts in the upper body. Covered by removable plastic caps, these cutouts accommodate hardware attachments, which RB5X owners either construct themselves or purchase from RB5X dealers. The robot now also comes standard with a speaker grille for those who want to add voice to their RB5X.

In addition, the interface panel on the back of the RB5X has been greatly improved to provide a number of useful capabilities. There is a socket for plugging in optional 2K or 4K software modules, including a self-diagnostic module that now comes standard with new RB5Xs. This module runs a check of the RB5X's batteries and motor functions as soon as owners unpack the robot and switch it on. This software, which is contained in EPROM (erasable, programmable read only memory), also includes a series of short programs—such as the robot's standard Beta with sonar self-learning code— that may be accessed by pressing combinations of bumpers. RB Robot is in the process of developing additional software modules, which will soon be available through RB5X dealers.

New RB5Xs now contain an automatic battery shutoff circuit that protects the robot's batteries from draining beyong the point where they can be recharged. Owners can also check the battery charge level by reading the new LED (light-emitting-diode) bar on the interface panel.

The upgraded RB5X is available from a growing network of dealers throughout the United States and Canada, and in Europe and South America, and retails in the U.S. for $1795. Upgrade kits for adding these enhancements to existing units are available from RB5X dealers or directly from RB Robot for $300 each.

RB FORUM is published monthly by RB Robot Corporation, 18301 W. 10th Avenue, Suite 310, Golden, CO 80401, (303)279-5525. Subscriptions are sent free of charge to owners of the RB5X Intelligent Robot.™ Other subscriptions are available for $15/year prepaid. Subscription requests should be sent to the attention of the Subscriptions Department, RB Forum, at the above address. Comments and suggestions for future issues should be addressed to the attention of the Editor.

RB ROBOT

RB Robot Corporation
18301 West 10th Avenue
Suite 310
Golden, Colorado 80401