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BUYER'S GUIDE TO

Personal Robots

MARK J. ROBILLARD

The robots are coming! The robots are coming! Find out when, and what form they'll take, in this informative survey of the personal-robot field.

ONCE FOUND ONLY IN INDUSTRY AND THE laboratory, over the past decade the computer has become a fixture in the vast majority of households. Now, the robot stands on the verge of making a similar transition; just as the "personal" computer is now commonplace, soon the "personal" robot will be found in many homes.

Personal robots hold the promise of creating even greater excitement than the computer. With their capabilities of movement and manipulation, personal robots have the potential to interact extensively with every member of the family. Blasphemous as it might seem, robots might even replace the family dog in some households.

So where are all of these robots? How close are we to that robot "explosion?" What are the capabilities of the robots that are currently available? Where can you obtain such a robot? Those are just some of the questions that we'll answer in this article.

What is a personal robot?

Most of you are probably familiar with the uses of robots in industry. Numerous television and film documentaries, most notably on PBS, have shown industrial robot-arms painting cars in Detroit or removing blistering-hot liquid from a furnace in Pennsylvania. Those examples depict the industrial use of robotics to improve production under somewhat hazardous factory conditions. But robot arms are not the entire realm of robotics. For that matter, robot arms, though most common, do not represent the only possible industrial application of robotics. Indeed, the possibilities are almost endless.

The same can be said for a "personal" robot. A personal robot can take almost any form, as long as it does not require an "industrial" environment in which to operate (not too many of us have pneumatic tubing, etc. running throughout our homes).

All of us can think of possible applications for mechanical slaves around the house. Some of the more obvious uses would be mowing the lawn, washing clothes and taking out the garbage. Others include vacuuming the carpets and walking the dog. Unfortunately, the scope of those applications is too ambitious—beyond the capability of most currently available robots; and that is severely limiting the market.

By the mid 1980's, hundreds of thousands of people owned personal computers. But many of those computers, particularly the less expensive ones, eventually wound up in the back of the closet. Once the novelty of the new machine wore off, the reality was that only a relatively small number of people had a real need for a computer in the home; for everyone else, it was a device without an application. The situation with personal robots is very different. There, we have many applications, but no machine yet that is capable of performing more than a few of them.

In mid-1982, a company called RB Robot, operating in Golden, Colorado, introduced the first commercially available personal robot. The *RB-5X* looked to be little more than a trash can with wheels and a clear plastic top. A closer look revealed that that machine was equipped with collision sensors and a full-fledged microcomputer system that could be programmed in BASIC.

The *RB-5X* was basically a toy for the dedicated hardware experimenter. Its mechanical abilities were not much more refined than a radio-controlled car. The microcomputer could only be programmed by using an external dumb terminal—something that is not found in most households. But it did provide a starting point for would-be robot experimenters.

Shortly after the birth of the *RB-5X*, the Heath company announced the birth of what was to become the best-selling personal robot to date, the *Hero 1*. That robot, like the *RB-5X*, was equipped with a motorized base and microcomputer. However, included with the package were several sensors for measuring light, sound, motion, and distance. Those, and the addition of an arm and voice-synthesis module, placed the *Hero* more firmly into the category of what everyone thinks of when the word "robot" is mentioned. Much like early personal computers, the *Hero* could be programmed via a keypad.

If one were to plot a time-line of the history of personal robots versus that of the PC it would show that the *Hero* is the robotic equivalent of the *Altair* microcomputer.

Since those beginnings several things have happened. Many other firms have entered the market with robot kits and completely assembled units. A Texas-based marketing-research firm, Future Computing, has forecast that the personal robotics market would be larger than that for the personal computer, and that that market was about to "take off." Many small firms entered the market with kits and assembled units.

In 1984, a magazine survey showed that there were 18 viable robotics products and manufacturers to choose from. Those products ranged from simple two-wheeled remotely operated devices called "turtles" to large-android-like, sophisticated robots. Many of the fledgling robotics firms were exceedingly small, some operating out of their owner's homes, or sharing space with other companies. Some sold only a few units; others, like Androbot, sold several hundred. In the latter case, Androbot's main product, called *Topo*, appeared to be an ideal robot system. It was large (the size of a six-year-old child) and, it had a unique drive-wheel system. The initial units ran via a special interface to an Apple *II* computer. They came with a disk of software routines that allowed the user to control the robot's motion via the computer's joystick.

One obvious limitation of the *Topo* was that it was incapable of undirected motion. Androbot promised to correct that problem in a proposed robot named *BOB*; that name was an anagram for *B*rains *O*n *B*oard. While full details were not released, indications were that the robot would be equipped with on-board microprocessors. Those microprocessors would analyze the data from "vision" sensors and use that data to control the robot's motion. Using that system, the robot reportedly would be able to seek out or follow its owner, even in a crowded room.

But, then what? The robot was not to be equipped with any manipulative capabilities (it had no "arm"), so what did it do when it approached the owner? Its only ability was to tell a joke, via a voice-synthesis circuit, from a stored library.

Obviously, such hardware is not sufficient to launch a new marketplace. The chief problem remains one of supplying the hardware that will perform an application that many people want. It is the opposite of the problems in the computer industry where the hardware exists, but finding an appropriate application is difficult.

Of the companies currently producing robots, Heath has done well because they designed their robots to be used as teaching tools, and they support them with a wealth of excellent study courses. Others have tried to produce either a general-purpose motorized toy that can only move and slightly entertain, or, on the other extreme, a high-priced replacement for a 95-cent joke book.

Today, despite optimism and high hopes, the personal robotics industry is unstable, to say the least. Of those companies that have already introduced robot products, about half have faded from the scene altogether, or are not currently in a position to adequately service the consumer. There are, of course, new manufactures appearing (and unfortunately disappearing) on the scene all the time.

Even large companies are not immune to the vagarities of the current market. Several toy companies have introduced robot products. Those products are *not* toys; many compare favorably with the RB and Heath robots already mentioned. The forerunner among that group were Ideal and Tomy. The mechanics in their products were elegant; and because toy companies are so cost-conscious, all the mechanical parts were designed to have multiple functions.

IDEAL TOY'S *Maxx Steele*.

Tomy's *Omnibot* series of programmable robots is now the leader in the field with three entries. Ideal marketed a programmable version of the popular cartoon character Maxx Steele. That robot was designed specifically for upgradability. It had an Atari-like cartridge port for add-ons and a serial interface to its RF remote-controller. The documentation suggested that an expansion port and a sonar interface would be available in the future.

Now, that future seems to be a long way off. In November of 1985 the division of Ideal responsible for *Maxx Steele* was sold off, thereby burying the product.

Our survey

To find out the state of the market, we contacted over 20 personal-robotics manufacturers. Their products were investigated—we followed the same steps that you would in purchasing a personal robot. All products mentioned in this article were available for general sale at press time. The prices quoted were accurate at the end of 1985. In all but one case, the author has actually viewed and/or tested the product listed.

Obviously, all the features of each

product could not be listed in tabular form; however the most prominent features are listed in Table 1. Also, each product is described in more detail below. All of the robots have been listed in one of four general categories; arms, turtles, rovers, and miscellaneous. All the arm products are just that. They contain no provision for mounting a base or other rover-like features. Turtles are small rover-like machines that are slaved to a personal computer. They require a cable, power supply, and some software running in the host computers. Rovers are complete robot systems that contain an on-board microcomputer and the ability to maneuver about a room. Some, but not all, include arms as well as other advanced features such as voice I/O and vision-sensor systems. In "miscellaneous" we will look at some robot products that do not fit into our other categories.

Arms

The Rhino Robots (3204 N. Mattis Ave., Champaign, IL 61320) *XR* series arms are 5-axis machines and include grippers. Built using aircraft-grade aluminum, those robots are of fine quality. The motors that run the arm are servo type; they are DC motors that have integral optical encoders. Pulses from the encoders tell the microcomputer controller of the position of the arm. The motors drive the linkages through a series of chain drive belts. The robot has the heaviest lifting capabilities of any similarly priced product—almost three pounds.

The arms themselves are only a small part of the entire automation system that is supplied. Simple ASCII commands are used to operate all motors; a microprocessor-based control is located in the base of the arm. Interaction with the "outside world" is provided via an RS-232 interface.

Several other robot devices and services are offered by Rhino. For instance, they provide indexing tables and controllable conveyer belts. With those, it is possible to create a complete, working assembly-line operation.

One note on all of that: Rhino quality does not come cheap. Figure on spending about two thousand dollars for a very basic set of materials.

Microbot's (453 Ravendale Drive Mountain View, CA 94043) *Alpha* arm was the fist to arrive in the personal robot field. It is similar to the *XR* Series from Rhino. However, all the motors are stepper types and the arm is moved via a cable system; that cable system is much like the ones used by the toy steam-shovels that you may have played with when you were young. The arm mechanics are enclosed in a rather attractive package. The arm can be computer-controlled via an RS-232 interface.

The *Alpha* arms, like those from Rhino, are high-quality units. The most significant difference between the two is the use of stepper motors in the *Alpha*; that allows for a greater degree of repeatability. (That is important if repetitious tasks, such as those found on an assembly line, are to be performed). Despite their relatively high cost, there is no other product currently on the market that will do if you have a serious interest in arms or manipulators. Those arms are miniature versions of the ones found in industry.

Turtles

Frank Hogg Labs (Regency Tower, Suite 215, 770 James St., Syracuse, NY 13203) has been supplying software and accessories to users of 6800 family of microprocessors for many years. Recently they've introduced an excellent turtle for the TRS-80 *Color Computer*. Called *Nomad*, that turtle comes complete with a well-written manual and a wealth of demonstration programs. The *Nomad* itself is equipped with a two-stepper-motor drive and an on-board ultrasonic ranger. The software extends the BASIC already in the computer to allow for motion commands. Considering its $250 price, the *Nomad* stacks up as quite a value.

The *Nomad* is by far the easiest turtle to control to date. It is much more sophisticated than the earlier devices that you might be familiar with. Typically, those were little more than DC motors and four micro switches connected to a computer. Although those devices sold well to schools investigating the benefits of the LOGO programming language, they were useful for little else.

Even more sophisticated is Rhino Robot's *Scorpion*. That unit is the most full-featured turtle on the market today. In fact we hesitate to classify it as a turtle because it has on-board "intelligence". But it still needs to be linked to a host computer for control, and it requires an external 12-volt, 5-amp power source.

The most prominent features of the *Scorpion* are its software command set, and its vision scanner. The latter has the ability of scanning an area in front of the robot and reporting the varying light levels encountered.

The on-board "intelligence" that we mentioned consists of a 6502-based controller and 2K of RAM. The RAM stores both the commands sent to it and the samples of ambient light taken by the controller. The on-board computer can be expanded, but the interface uses the old KIM standard.

Perhaps the most serious drawback of the unit is that it is only available in kit form. Normally that would not present a problem, especially to regular readers of **Radio-Electronics**; however, the assembly documentation is absolutely terrible. As such, its assembly can only be recommended for someone with a great deal of project building experience.

Rovers

Artec Systems' (9104 Red Branch Rd., Columbia, MD 21045) *Gemini*, which is shown on the cover of the magazine, is one of the more advanced personal rovers available.

The unit features an advanced on-board 65C02-based control system. Altogether there are three microprocessors. One is used as the main control computer; it is supplied with 64K of ROM and 56K of RAM. A second 65C02 is used to control the sound functions (voice I/O, sound generation, etc.); it has 25K of ROM and 16K of RAM. The third microprocessor is the motion-control computer; it is supplied with 2K of ROM and 24K of RAM. Its navigation system includes 9 ultrasonic collision-avoidance sensors. In addition, there is an LCD readout and detachable keyboard for programming in BASIC, and provisions for the addition of an on-board mass-storage device (either wafer tape or 3.5-inch floppy disk). *Gemini* will seek out its charging base when its batteries run low.

The machine performs well and its documentation is excellent. For those who want to build their own variation of the *Gemini*, the manufacturer will sell all the parts that go into it separately, including the shell! Unfortunately there is no arm yet available for the unit.

Heath (Benton Harbor, MI 49022) is the IBM of the personal-robot world. It's *Hero* family ranges from a preprogrammed pet-like robot, named *Hero Jr.*, to the most sophisticated robot commercially available today—*Hero 2000*. All Heath robots come in pre-assembled and kit form.

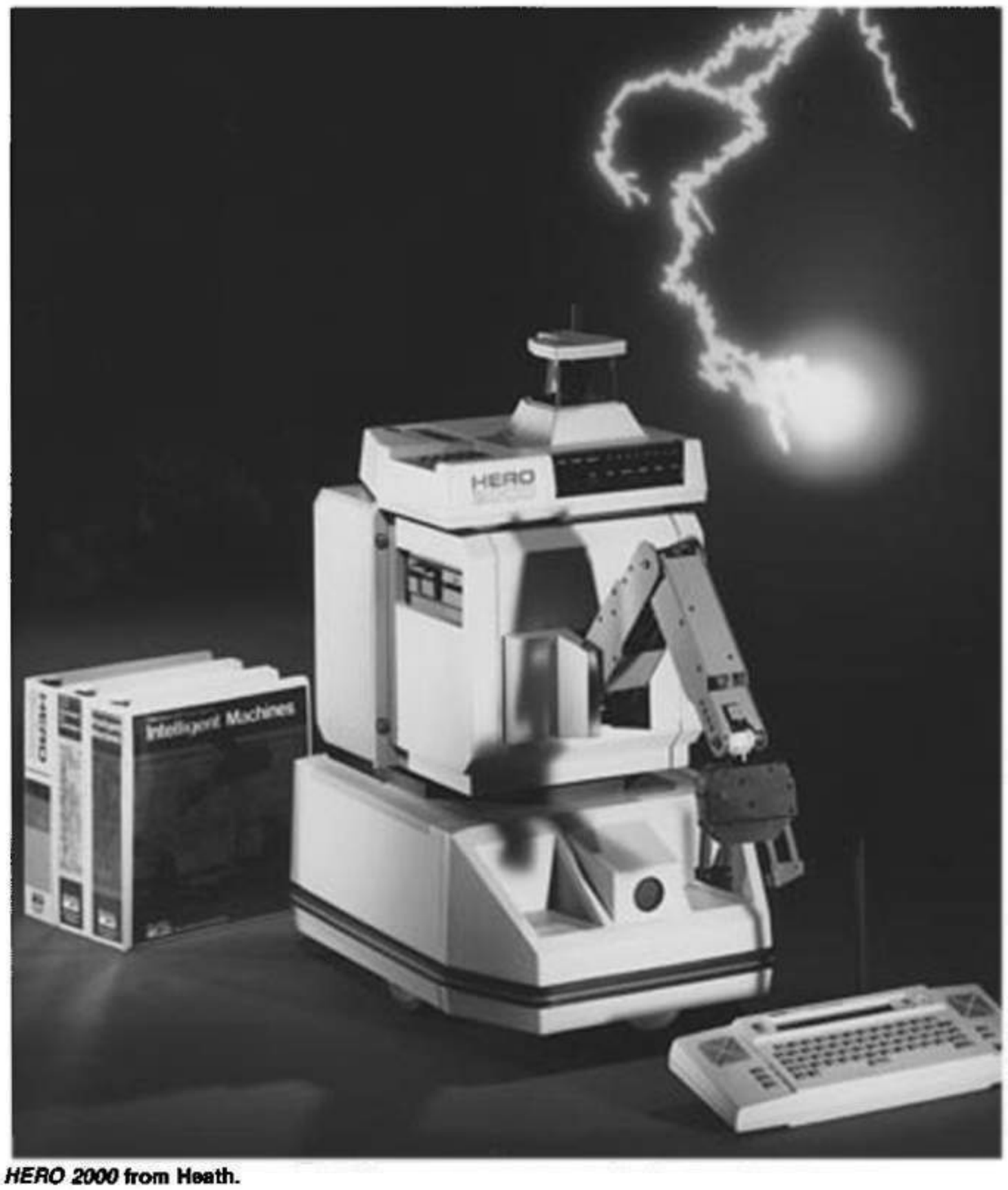
TABLE 1—

Manufacturer	Model	CPU Type	Memory	Drive System	Interface	Arm	Voice	Lift Capacity
ARCTEC SYSTEMS	GEMINI	65C02	56K	4 wheels DC servo	multiple	no	yes	none
FISHER AMERICA	ROBOT COMPUTING KIT	none	none	2 mini motors	multiple	see text	no	N/A
FRANK HOGG LABS	NOMAD	TRS80 Color	none	2 wheels DC stepper	TRS80 Color	no	no	none
HEATH COMPANY	HERO 2000	8088	24K up to 576K	DC servo	remote RF, RS232C	option	yes	1 lb
HEATH COMPANY	HERO 1	6808	4K up to 56K	DC and stepper	remote RF, RS232C	option	option	1 lb
HEATH COMPANY	HERO Jr.	6808	2K	DC and stepper	remote RF, RS232C	no	yes	none
IDEAL div CBS TOYS	MAXX STEELE	65C02	4K	2 wheels DC servo	remote RF	yes	yes	1 lb
MICROBOT INC.	ALPHA	none	none	DC stepper motors	RS232C	yes	no	1 lb
NINTENDO	ROB	N/A	N/A	N/A	none	yes	no	N/A
RB ROBOT INC.	RB-5X	INS8073	8K, 16K	DC motors	RS232C	option	option	1 lb
RHINO ROBOTS INC.	XR	8748	none	DC Servo	RS232C	yes	no	2.2 lbs
RHINO ROBOTS INC.	SCORPION	6502	2K	2 wheels DC stepper	RS232C	no	no	none
ROBOT SHACK	X-1	none	none	DC motors	none	no	no	none
ROBOT SHACK	Z-2	none	none	large DC motors	none	no	no	none
ROBOT SHACK	Z-1	none	none	DC motors	none	no	no	none
ROBOT SHACK	DROID BUG	none	none	DC motor	none	no	buzzer	none
TOMY	OMNIBOT 2000	N/A	audio tape	DC motors	remote RF	yes	recorded	1 lb
TOMY	OMNIBOT	N/A	audio tape	DC motors	remote RF	manual	recorded	none
TOMY	VERBOT	N/A	N/A	2 wheels DC motor	voice input	yes	input	4 oz
TTC CORPORATION	HEAROID	N/A	N/A	DC motors	remote RF	manual	input	4 oz

The *Hero Jr.* sports a 6808 microprocessor and a ROM that has been programmed with a selection of songs and activities. With the addition of an optional ROM cartridge adapter, the robot can accept a BASIC language cartridge that allows the user to program its action much like its older brother, *Hero 1*. Other options include an RF remote console for putting the robot through its paces without need of a connecting cable, and a number of pre-programmed demonstration and utility cartridges.

As mentioned, the *Hero Jr.* is a scaled-down version of the *Hero 1*. In its basic form, the latter computer is supplied with just 4K of RAM, but that can be expanded to 56K through an optional internally-mounted board. That robot comes equipped with practically every sensor you could want, including sonic ranging. Options include a somewhat limited-use arm, a Votrax SC01-based voice synthesizer, and an RF remote- control console. That console mimics the one mounted on the robot itself (that is located in the "head" area). Via the remote console, a wireless link between a host computer or terminal and the robot can be established. Among the available options are a limited version of BASIC and complete training courses in industrial electronics and robot applications. The courses are particularly worthwhile; you might want to consider obtaining them separately if you build your own robot. As an example, the applications course provides a wealth of robotics experiments, ranging from simple vision projects to tactile sensing.

The newest addition to the family is the most powerful robot available. It has many times the capabilities of the *Hero 1*, and costs only slightly less than twice as much! That robot is the *Hero 2000*. Unlike Heath's other robots, that unit makes use of 80C88 microprocessors; it comes with 24K of RAM, expandable to 576K. An internal expansion bus has slots for up to 12 expansion boards. Individual microprocessors are used to control a variety of functions, ranging from operating the ser-



***HERO 2000* from Heath.**

PERSONAL ROBOT COMPARISON CHART

Expandability	Other Features	Price
Apple Bus	Sonic ranging, keyboard, disc drive	assemb. $6995 kit $3595
Can be combined w/other Fisher kits	10 project kit	N/A
None	Sonic ranger, extension to Color Basic	assemb. $250
S100-like Bus	Complete robot system, optional disc drive, MS DOS-like operating system	assemb. $4500 w/arm kit $3000 w/arm
Memory and serial boards etc.	Complete courses on hardware, BASIC, Demo ROMS, RF remote option	assemb. $1700 kit $800
Cartridge port, external sensors	Built-in games, songs expandable with BASIC cartridge, RF remote option	kit $400
Cartridge port	Serial interface to remote controller, built in games, programming language	assemb. $399
None	Full feature arm with 6 degrees of freedom	N/A
N/A	Part of videogame system	N/A
44 pin Bus, many options	Sonic ranger, tactile sensors, robot programming languages, courses	assemb. $2540 (base, voice) $1395 w/arm
None	Full feature arm with 6 degress of freedom	N/A
KIM Bus	Optical scanner, 8 tactile sensors	kit $299
Can add complete computer	Robot base motors and structure plus controls for 25 lb robot	kit $399
Can add complete computer	Robot base motors and electrical controls for 100 lb robot	kit $250
Can add complete computer	Robot base motors and electrical controls only for 25 lb robot	kit $150
None	Wired robot bounces off objects and changes direction	kit $130
External sensors for light, etc.	Built-in tape recorder. One arm powered, head moves, optional computer interface	assemb. $399
None	Built-in tape records program steps. Two arms are manually operated	assemb. $199
None	Programs by training commands using remote microphone	assemb. $60
External sensors for light etc.	Built-in tape records program steps. Voice recognition through wireless mic	assemb. $299

vo-motor base-motion system to determining distance from an object via ultrasonics. The arm offered with the unit compares favorably with the ones offered by Rhino and Microbot. Rounding out the features are a self-recharging power supply and a sophisticated voice-synthesis system.

Heath's major difficulty with that robot may be in the area of marketing. The *Hero I's* limited mechanical abilities disappointed many, and it may be hard to convince would-be buyers that there truly is a difference. There is! See the robot in action and you're sure to want one, even if it does cost around $3000.

Tomy Toys (901 E.233 St., Carson, CA 90749) is the largest selling toy robot manufacturer. Several years ago, they introduced a mechanical arm that is now sold exclusively through Radio Shack stores. Their family of true robots ranges from an inexpensive voice-operated unit to a sophisticated double-armed remotely-operated one.

Verbot, the voice-activated unit, is a small (under 12-inches) robot with a pair of arms and a dome head. Inside is a microprocessor-based voice-recognition system. The user pushes one of the operation-function buttons on the front of the robot, then speaks the command word. Thereafter, speaking that word will activate that function. The functions that can be activated in that manner include motion in the four basic directions (left, right, front, and back) and a grasp and release command for picking up very light objects with the arm. *Verbot* is technically sophisticated, yet its cost is fairly low (around $50).

Shortly after the introduction of *Verbot*, Tomy came out with the first member of the *Omnibot* series. That robot was taller than *Verbot* and sported an internal audio-

TTC's *Herold*.

cassette recorder/player that could be used to store commands sent to the robot via its RF remote-command module (included). The unit has two manually-operated arms and the ability to receive your voice through a wireless microphone built into the RF remote.

That initial *Omnibot* still was limited by its small size. Recently, Tomy introduced a much larger version, called the *Omnibot 2000*. It has two arms with very functional three-fingered grippers. Unfortunately only one of the arms is powered. In addition, the robot comes with a unique tray for serving beverages. The robot can activate the tray, which has built-in cup holders; those holders move the cups under the robot arm automatically.

Although the expansion capabilities of the series do not match those of the *Hero* series, there should be plenty for the hobbyist to explore. Tomy plans on introducing both an infrared sensor and a sonic ranger.

The TTC Corporation (2009 East 233rd St., Carson, CA 90810), a spin-off from Tomy, is also offering a robot, called *Hearoid*, that has many of the features of the *Omnibot* and the *Verbot*. In addition, an optional videocamera is available; that opens up some interesting applications in the area of security.

RB Robot (14618 W Sixth Ave., Suite 115, Golden, CO 80401), is still producing the *RB-5X*, the first personal robot. That unit, of course, has gone through a number of changes and enhancements over the years. The current version is as expandable as the *Hero 1*. To go into detail, the *RB-5X* uses an INS8073 microprocessor. That National Semiconductor IC is set up to execute a version of Tiny BASIC. Programming is done via an external terminal or host computer. Communication is via an RS-232 interface. The robot comes with 8K of RAM; that can be upgraded to 28K. The on-board system can be expanded via add-on cards; a 44-pin card-edge connector has been provided for that. Sensors include a Polaroid ultrasonic rangefinder, and an infrared transceiver.

Lately, RB has been in reorganization following some rough business climates. Their main thrust now is aimed at the educational market, which has been perceived by the company as the only real avenue left in the field. To go along with that, an entire robot-learning course has been developed along the same lines as the industrial courses offered by Heath.

Robot Shack (PO Box 582, El Toro, CA 92630) provides plans and parts for a number of robot systems. Those systems would have to be considered low-end or experimental in nature, however. Further, though the company would appear to be a good source for robot parts, etc. at first glance, closer examination reveals that that might not be the case.

The company offers four robots in all. Their *Droid Bug* is an electro-mechanical motorized unit with a bumper switch.

FISHER AMERICA'S *Robotic Computing Kit*.

When the bumper contacts an object, the motors reverse direction. That "robot" has no provision for adding any type of computer control.

The *Z-1* appears to consist of a motor from a Milton-Bradley *Big-Trak*, some wheels, and six switches. Those switches are all that comprise the robot's "control system." At $149.00, you might find that you can do much better scrounging the parts on your own.

The *Z-2* is not much better. For $249 you get two heavier duty motors (available on the surplus market for about $24.00 apiece), the same switch package as the *Z-2*, and about $10.00 worth of furniture castors and hook-up wire.

Finally, the *X-1* adds some lights, sound effects, and a device called a "function cycle timer." It costs $399.00.

Miscellaneous robots

Fisher America's (Parsec Research, Drawer 1766, Freemont, CA 94538) Fischertechnik *Robot Computing Kit* offers a fascinating introduction to the world of robotics for someone who is completely new to the field. Resembling somewhat the *Lego* plastic construction blocks we all played with as children, that product includes the parts and plans to build 10 computer-controlled robotic projects including a sorting system, materials lift, computer plotter, and a "teachable" robot arm. An interface for connection to an IBM *PC*, a Commodore, or Apple computer is also provided, as is a disk of BASIC programs designed to help the novice computer programmer the most from his creations.

YOU CAN PLAY VIDEOGAMES with *ROB*, from Nintendo.

Finally, computers, for the most part, first entered our home in the form of entertainment devices (i.e. video games). Perhaps robots will follow the same path. Consider, for instance, the Nintendo (4820 150th Ave NE, PO Box 957, Redmond, WA 98052) *Entertainment System*. One of the hot gifts this past holiday season, that product is essentially a video game. However, several of the system's games made use of a limited robotic device. That device, called ROB (*R*obotic *O*perating *B*uddy) has a light-sensing system and limited gripping and lifting capability, but not much else. The robot is incapable of motion; it is mounted on a stationary base. Still for many it provides a first exposure to the world of robotics.

The state of the industry

For better or worse, that's the current state of the market. Of course, we may have missed one or two new or less-prominent manufacturers, but all of the main players have been represented here.

What can we look forward to next? Right now, things seem to be in a holding pattern. The philosophy of most of the manufacturers seems to be to pack as much hardware as they can in a box, and leave it to the public to put it to some type of use. As a result, most of the products announced or released in the past three years have not been widely accepted by the public.

For the most part, educational institutions have purchased the lion's share of the really sophisticated units, and consumers have bought the toy robots for their kids. Have any of those products advanced the state of personal robotics? The sad answer is no. None of the numerous applications we listed earlier are being addressed. University researchers will tell you that we are decades away from a robot that can clean house. With that attitude, it might take centuries to get a viable robot maid.

Then again, we are talking about a market that could be larger than the personal-computer market. That means that there are fortunes to be made here. Although things have been slow until now, it should take just one miracle to kick-start the robotics industry! **R-E**