ROBOT BUILDER

The official publication of the Robotics Society of Southern California
P.O. Box 3227, Seal Beach CA 90740, Meetings the 1st Tuesday @ 7:00 PM at MTI College

UPCOMING EVENTS CALENDAR

MARCH 1991

March 5	RSSC Meeting at MTI College: 7-9 PM. Topic: HAC Sonar and other controls
March 9	RSSC Robot Project Workshop, at Jerry Burton's Laboratory
March 24	ACP Swap Meet
March 26	RSSC Board meeting, at Jerry Burton's Lab.
April 2	RSSC Meeting at MTI College: 7-9 PM Topic: Mobile Robot Navigation
April 6	RSSC Robot Project Workshop, at Jerry Burton's Lab.
April 30	RSSC Board Meeting, At Jerry Burton's Lab.
May 7	RSSC Meeting at MTI College: 7-9 PM Topic: Robotic Intelligence Software
May 11	RSSC Robot Project Workshop, at Jerry Burton's Lab.
May 19	ACP Swap Meet
May 28	RSSC Board meeting, at Jerry Burton's Lb.
June 4	RSSC Meeting at MTI College:7-9 PM Topic: RF Datalink

President's Message

Last month's meeting was great as we had standing room only and had to keep going next door to bring in more chairs. We may have to look into getting a larger meeting room. If anyone has any ideas please let me know. We seem to be growing by about 2 members a month which is terrific, so Joe is looking into a possible site and will give us a report this month.

This month we'll be discussing sonars and sensors in general. The lab following will focus on calibration and the characteristics of the society robot sonars.

Many members seem reluctant to get involved in some of the construction projects going on, since they feel they don't know enough to contribute. The best way to learn is to get on a team and learn while you build. Contact any of the project leaders and get on with it.

Each person has their own idea of how to do something. I am working on navigation and am in the process of developing a model for performing movement experiments. I have discussed my approach and several people have proposed alternate ways of doing the same task. Great, they should develop their approach as well. There is no RIGHT way to do a particular thing. We should encourage as many diverse approaches as possible so that in the end we end up with what works best.

RSSC Board Meeting 29 Jan. 91

The Society monthly board meeting was held 29 Jan. 91 at Jerry Place. The board meetings are held regularly on the fourth Tuesday of the month at 7 P.M. at Jerry's lab. All board members were in attendance at this meeting. Old business included discussion of the ACP Swap Meet. Jerry polled the board members for our goals. The topic of the monthly meeting was discussed. The engineering note book was reviewed. The new bulletin board was discussed. The standing committee reports were read. The hardware committee is still working the Covox voice and HPC board interrupt problem. The electrical committee is at a stand still. The electrical committee is waiting for progress from the other sections. The software group is not making progress. The software team is not working current problems and needs to be focused. Tim Lewis wants to create some software scenarios for RSSCY that we can use for show and tell events. Don Goldin wants to see the overall software system evolve. However, no one in software is working the current integration problems associated with getting the society's robot operating as a unit that we can show off in public and brag on.

Under new business several new projects were submitted for consideration. All projects were accepted by the board. Every one has limited time and resources. The projects will become what every individual makes of then. RSSCY is where it is today, mostly because Mark Frank put all the parts together. Many others did provide hardware and help. Current problems are being solved by the doers within the society. New projects will get done by the people who want to do them. The society is providing an open forum where people with limited resources can contribute their part to a larger design. As individuals, none of us can afford the time, money, or collected knowledge that has gone into RSSCY. The society's robot is a collected project, directed by a planed design and added to by individual effort. I think Tom Carroll as past president and now Jerry Burton as current president of the society have done an excellent job of keeping the society open to everyone. The few limited words here do not convey how much effort is being contributed by a wide active group of members to many parts of the whole robot system the society has designed and built.

At the 4 March general meeting Jerry Burton will discuss the sonar amplitude operation of RSSCY as currently implemented. Jerry has also proposed a project to enhance the sonar operation. It is proposed that the sonar amplitude information that the hardware currently provides can be utilized to improve the ranging operation of RSSCY. At the 2 April general meeting Jerry wants to continue the discussion and show how the sonar is tied into the navigation. A majority of members want to see RSSCY operating as an autonomous machine, being free of tethers and barriers. The software group needs to get up to speed on the navigation software to get it operating. There are a few robots wandering around in a limited environment. However, one of the society's goals is to get robots off the pages of fiction and into the real world. RSSCY is the candidate voted most likely to do it first. JPL, GM, MIT, UCLA, and others have robot like automations. But these folks are not spending their money to create free thinkers. Solving the navigation is the first step in an autonomous robot.

At the 7 May general meeting Roger Ruszkowski will demonstrate an RF link between the robot and a second computer. Getting RSSC off his keyboard and line power monitor are viewed as near term projects that need attention. Current efforts are based on a wireless phone and modem design. Operating range will be limited to the range of the cordless phone. This approach has the advantage of not requiring any FCC licenses. It also provides two way communication......RR

RSSC General Meeting 5 Feb. 91

The Societies general monthly meeting was held 7 Feb. at MTI College. The meeting is held regularly on the first Tuesday of the month at 7 P.M. at the college in Orange. This months meeting was a packed event. Attendance exceeded 35 people. We had some new members who are attracted by our booth at the Jan 27 ACP Swap Meet.

Jerry started the meeting with introductions and welcomes to the new faces. The main topic for the evening was the operation of the HPC board on which RSSCY is based. After a short break old and new business was entertained in an orderly manner. Then things wandered a bit as formal procedures gave way to random access. The meeting adjourned at 9 P.M. and the members vacated the building. I left a large group in the parking lot at 10 P.M. and they vowed to be there when ever I chose to return. Our agreement with the college is that we will leave the building at 9 P.M.. Paid employees would like go home and students have a right to a sense of security about the campus area. We try to be good guest. Coming and going to the meeting we try not to interrupt the classes in session. We do thank the administration for providing us with the meeting space at the college.

Old business started with the engineering note book. Thank you Joe McCord for your Newton inputs. Thanks to Jess Jackson who has collected and reproduced the entire set of news letters. Thanks to John Bedson for the Flexinal Notebook. Thanks to Jerry Burton for the HPC motor control architecture. Thanks to Roland Koluvek for a make your own software controlled digital to analog converter article.

Old business continued with current projects. Discussed were projects to be added to RSSCY. Jerry will explore sonar amplitude in March. The need for a directional microphone design by Tom Carroll was discussed. The need for a charger station was discussed. Tim Lewis is collecting comments for this project. It is part of the independence movement afoot for RSSCY. Jerry is forming a group to work a bumper project for RSSCY. Again this is part of the independence movement. A sensor platform for the head was also discussed. The proposal was to use the parallel port interface card to control stepper motors. The stepper motors would position the head platform. Sensors on the platform include sonar, voice pickup and vision.

Every one was happy with the ACP swap meet event on 27 Jan. Tim Lewis confirmed that he would work up some demonstration software for RSSCY before the next ACP meet. Maybe we will see some of this at the 4 March meeting. We should give Tim some time at the April meeting to show this off to everyone.

Laboratory was set for 9 Feb. The next business meeting was set for 26 Feb. The next general meeting was set for 5 March.....RR

RSSC Robot Laboratory 9 Feb. 91

The Societies Robot Laboratory monthly meeting was held 9 Feb. at Jerry Burton's laboratory. The meeting is held regularly on the first Saturday of the month at 10 A.M. More than 10 members showed up to contribute to activities.

The bulletin board is still not on line and operational. Work is continuing with it. Again more things happen because of what members do for their hobby all month than in what gets done in a few short hours at a society meeting. But the meetings is where it all comes together and is shared with everyone. Jerry has been working hard to establish communication with the board. Our sysop pleads a virus and is trying to purge the board system.

Jerry has his Newton operating again. With help from some sharp eyes a bad solder joint was isolated and newtons head was working again. Jerry is working on the software for his navigation system and demonstrated it. While Jerry's software is plagued with scuds its still the best stuff I have seen running. The software group is talking a lot of vapor ware but Jerry puts his software on the floor and runs it in real time.

No progress has been made with the Covax voice board and the HPC board interrupt collisions. While the Covax voice board is wonderful in a PC its not making any inroads into the RSSCY system. The leading robots in the field today are the Newton class machines using an AT mother board and the HPC motor controller board. The HPC board includes so many features that no one wants to give it up. The Texas Instruments voice board system and several other cards do work with the HPC card. The Newtons are running hard disk cards, video cards, floppy disk controller cards, modem cards, serial interface and parallel interface cards. The Covax card is the only card we have found that does not work in the system with the HPC card.

Networking is still active in the Saturday meetings. Every one brings their pet agenda item to the meetings and poles everyone for thoughts. As the weather improves we'll have to move out of the shop onto the lawn and spread out a bit. The ongoing conversations are pushing against each other. We are unable to share everything with everyone and if you hear yourself missing something in the next conversation you feel split between the two separate nodes. Everyone is trying to get in just as much as we can in the little time we have. Do not let this worry you, come around with your problems and needs and jump right into it with everyone else. When you get started step away from it and continue your conversation. Every one and every thing can be accommodated. We will respect each others rights and quite down when necessary....RR

ACTION ITEMS

These are some of the current items that are needed for the completion or expansion of the club ROBOT development. There was discussion at the RSSC meetings and some have been assigned a task leader.

1. The "DOCKING STATION" has been assigned to Tim Lewis. This station will be used for charging and must have an automatic interconnect. It also requires some type of identifier for the ROBOT as to its location. (See charging station proposal in this issue).

2. An "RF LAN" or computer to computer interconnection. This requirement is needed to assist in the debugging and monitoring of the operation of the mobile ROBOT's computer program. The need is to monitor in real time the sonar transducer outputs so we may know exactly what the ROBOT may be seeing. A secondary need would be to assist in debugging of ROBOT software. Tim Lewis has some data on this item but project still unassigned.

3. "SONAR MONITOR". The proposal was for a hand held receiver that is tuned to the 40 khz sonar output. It would be capable of responding to the transmitted pulses, determine the amplitude and present it on some type of digital or analog display.

4. SONAR BEAM FOCUSING. The present Polaroid transducers have a rather wide (30 degrees) beam spread. To better locate an obstacle, the beam width needs to be focused and reduced to as narrow a beam as possible. See ROBOTEER this issue. Remains unassigned.

5. SONAR RETURN SIGNAL AMPLITUDE. Jerry B proposed this action item at last months general meeting. He needs amplitude information from the sonar return to allow more exact determination of the pointing angle to the reflector or obstacle.

6. HPC ALTERNATE. The source for additional HPC boards seems to be exhausted. The other members and new members that would like to start a ROBOT project need the HPC functionally. The design of this functionally is the subject of this action item. Item unassigned.

7. NEW MOTOR CONTROL BOARD.
(Same as #6)

8. TI VOICE BOARD REPLACEMENT There are a number of members now evaluating the COVOX concept and becoming adept at using the unit. I think the COVOX and the TI boards can't be on the CPU bus simultaneously because they interfere with each others interrupts. This item is being worked by some of the membership and the integration of COVOX into the ROBOT's functionally will be completed shortly.

9. SINGLE BOARD COMPUTER. Need to evaluate the SBC's available leading to selection of a club standard CPU for the various distributed functions implemented on the ROBOT. The electrical and the software groups should handle selection of this item.

10. HEADING SENSOR. Heading sensor is required as part of the design of our autonomous ROBOT system. This is a long term requirement and action remains open at the present time.

11. VOICE RECOGNITION ENHANCEMENT
Tom Carroll submitted this item in the Feb ROBOT BUILDER. Special Interest Group(SIG) to support this item is yet to be formed. Item presently open.

These are the action items for March. As you have ideas and\or potential solutions to any of these problems, call Jerry B or myself, set up a SIG or bring the idea to the general meeting........JJ

DOCKING STATION HARDWARE & SOFTWARE

Proposed by Tim J. Lewis
Submitted Jan 31, 1991

OBJECTIVE: The objective is to create a docking station for the club ROBOT to find it's battery charger, home in on it and plug in for recharging. The task includes both the hardware and software to accomplish the task.

APPROACH: I propose to put an RF and infrared beacon on the charger unit so the ROBOT can find its home environment. Once the charger is located, the ROBOT would use a short range infrared sensor system to provide final guidance to the charger. The docking station will be equipped with an inductive coupling system between the ROBOT and the station so the ROBOT will not have to make physical contact with bare charger contacts to be recharged.

SUPPORT REQUIRED:

ELECTRICAL: The electrical group will need to develop an inductive power coupling. The RB5X ROBOT had this type of pickup and we may be able to get hold of it's operations manual to see how it works. The RF beacon could be a simple FM- Transmitter and receiver system.

MECHANICAL: The mechanical group will need to develop a good design for the docking station. Any ideas the club members may have are welcome.

SOFTWARE: Tim thinks he can write most of the commands to add to the knowledge base to determine if the hard ware is functioning properly. Project may need some test software and the software hooks to integrate this function into the navigation software.

ITEMS IN THE NEWS

Two prototype planetary robots made their debut during 1990.

"AMBLER" is a 12-foot-tall testbed developed for NASA by Carnegie Mellon University, Pittsburgh. It will test technology for robots that may literally walk through rough terrain on the Moon and Mars.

"ROBBY" is a more conventional six-wheeled articulated vehicle, was designed by NASA's JPL, Pasadena, California.
Both robots are equipped with an experimental computerized navigation systems that let them travel autonomously according to preprogrammed general instructions.

SENSORS

This section of the ROBOT BUILDER is to cover various sensors required by an autonomous machine.

The sonar units are being covered by Jerry in his column and at the March meeting (HPC card discussion) at MTI. The sonar beam as produced by the Polaroid transducer has a wide beam (30 degrees) width and therefore can't give the ROBOT the definition and resolution required for adequate obstacle identification.

There are ways to improve the resolution. Focus the sonar beam to achieve a narrow beam. Use IR which can be focused both for the transmission and the reception. Another narrow beam concept would be the development of a laser range finder. The land surveyors have their laser measurement instruments, but the cost is in the multi thousand dollar arena and is unusable for small robots.

What does it take to develop a laser-based ranging device for our robot? Let me cover an overview of three ranging techniques.

The first is the time-of-flight technique. It is the most straight forward of the three techniques. In its approach, a laser pulse is generated and sent out, a time-to-signal converter is simultaneously started; and when the laser pulse returns, the converter is stopped and the signal time is read out. The implementation of such systems is easy at the coarse level, but given the foot-per-nanosecond speed of light, range accuracies of a few inches or better require sophisticated techniques.

One of the problems is the level of the return signal. The outgoing pulse can be sampled easily and used to drive a leading edge detector. Modern ECL logic family is fast enough to provide repeatable operations. The return pulse, on the other hand, suffers the problem of the great variability in the level of the return with range. The transmitted pulse power per square unit goes down with the square of the distance, as does the return.

The second technique is to tone modulate the laser beam. Part of the modulated signal is used as a reference and the phase difference between the transmit and received modulated signal is representative of the distance. Even with modulation frequencies of 10's of megahertz, the phase shifts are only a few degrees per foot. Higher sensitivities can be had by higher modulation frequencies. Diode lasers have been modulated well into the gigahertz range.

The third technique is the FM-CW Laser scheme. This is the same technique used by the FM-CW Radars. The front end contains a laser, a phototector or photomixer and a conventional IF chain, and FM discriminator. Operations are such that a continuous wave transmission with a frequency that is swept in some predetermined fashion over the measurement time interval. The laser travels to the target and returns and the time of flight delay causes it to be at different frequency from that of the transmitter. The difference in frequency is a measure of the distance to the target.

The raw speed of the laser allows hundreds of distance samples to be taken per second. This would certainly help Jerry and his navigation problem.

If any one would like to take on the task of developing a low cost distance measuring unit for the society robot, let Jerry know and we'll give you all the help we can.......JJ

ARTICLE REVIEW

Every month I want to bring you a review of various design articles written about robots. Once again this month I bring you the highlights of another rather different type of robot. This month I'll review the "Basic Educational Robot Trainer" called "BERT" for short.

This is a very interesting machine and much can be learned from reviewing the design. Some of you may even want to build one for yourself.

The need for the BERT project was identified by Karl Brown, an electronics teacher at Vancouver Community College. His goal was to reduce the project complexity of constructing a ROBOT for the first time builders.

He initially ask himself, why did the very simple ROBOTS, even commercial ones require so much training to operate. He decided that this was a real problem and wanted to do something about it.

He did two things. First he developed a menu-driven interactive control language intended to be simple enough for even a ten-year-old to use. And second he developed and tested all the hardware and all the little bits in between. All the circuits have been designed from off--the-shelf components rather than hard to get technology. Most of the mechanical parts selected are inexpensive enough that they can be purchased new as opposed to scrounging through the your junk box. He makes the printed circuit board, the gearbox, and ROM available as a kit.

The complete schematics of BERT are available in the article and these should be enough to assemble the circuit boards.

To program BERT, all you need is a device capable of transmitting ASCII code at 300 baud, with 7 data bits, no parity, and 1 stop bit. Any computer with a serial port or even a serial terminal can be used.

It was interesting in the thought process that developed the BERT concept. He researched and examined many personal ROBOTS presently on the market at that time. The on board electronic controls ranged from a minimum of a couple of driver chips to a complete 68000-based system with megs of RAM. The locomotion was almost without exception by wheels driven by electric motors.

He concluded that innovation was not really needed in the hardware. Rather, he felt that simplification was required in the software. He decided that a different approach was needed. Instead of thinking of a robot as a robot per se, he started thinking of it as mearly another peripheral for a computer. He felt that to make a robot roam around should be no more difficult than making a printer print.

It was very interesting that this design has generated most of the major functions that our ROBOT has on the High Performance Card(HPC). The design of BERT's brain board consists of a Motorola 6802 microprocessor, a 6821 PIA chip used as two(2) 10-bit parallel I/O ports and a SP0256-AL2 speech synthesizer with a 64-word vocabulary .

The program directions are passed to the BERT boards via an RS232C, 300-baud serial interface. The BERT boards flashes LED's for his eyes and has three interrupts for collision detection. The board beeps from one small 8-ohm speaker and speaks from another.

The BERT system has built in test subroutines and can execute 15 different subroutine branch conditions.

The BERT software to perform the lower level functions like feedback-driven motor control routines and all the other functions are written in 6800 machine code and supplied on a preprogrammed EPROM.

This is a very interesting design and I think it has a lot of value to the first time robot builder. The first BERT users group was started in Vancouver, Canada and I'm going to try and receive their news letter if they are still in operation.

This article was found in BYTE magazine, April and May issues of 1987. I'll place a copy in the engineering note book. If you would like a copy of your own, see Roger or your editor and we'll see you get a copy.

The Roboteer

by
Jerry Burton

The primary (actually the only) means the society robot has of determining where things are is through its sonar sensors. The sonars are standard Polaroid ultrasonic transducers. The HPC controller has the ability to read 4 sonars one at a time.

The transducer acts as both the transmitter and receiver. When transmitting it acts as a loudspeaker and sends a short ultrasonic pulse. When receiving it acts as a microphone as it receives the reflected sound wave. The distance is calculated by multiplying half the elapsed time from the transmitted pulse to the received pulse times upon the speed of sound.

The following data concerning the accuracy of is a synthesis of my own experiments with sonar as well as data derived from a paper by Anita Flynn of MIT entitled "Redundant Sensors for Mobile Robot Navigation" 1985.

There are several sources of inaccuracy in Polaroid sonars. First, the beam is quite wide as shown in the radiation pattern shown in figure 1. The horizontal axis is a measure of the reflected beam in decibels. The beam width at the 3 dB point is roughly 10 degrees. However, in actual practice the transducer is sensitive enough to detect echoes of energy transmitted from the sidelobes. In testing, the range-finder can detect a one inch diameter pole up to angle of 40 degrees.

The sonar is capable of measuring distances to an object with a resolution of 0.12 inch through a range of 0.9 to 35.0 feet. The distance measure is not necessarily the distance in the direction the sonar is pointing, since the width of the beam may cause an echo from one edge to be returned before the echo of the centerline. Figure 2 illustrates that although the sensor is pointing in the direction along AB, the measured distance returned is actually AC.

nether measurement error is due to specular reflections on smooth surfaces. Due to the large wavelength of sound, about 1/8th of an inch, many surfaces appear smooth and a beam incident on such a surface does not reflect an echo directly to the sensor. Instead it bounces off at an angle equal to the angle of incidence, and possibly bounces off other objects before being detected. This means the reported range is much larger than it should be.

Figure 3 illustrates this problem. In actual tests against s smooth surface such as sheet rock, specular reflections occur when the sensor was aimed at an angle less than 25 degrees from the surface. Against a rougher surface, such as a cinder block, there were no specular reflections at all.

Other errors come about due to atmospheric effects, such as the change in the speed of sound caused by temperature and humidity changes. The speed of sound is a function of temperature where:

Speed of sound = 331.4 sqrt(T / 273) in meters/second

T is in Kelvin (0 deg Kelvin = -273 deg Fahrenheit)

Distances returned assuming 80 degrees Fahrenheit, but where actual temperature is 60 degrees, will be seven inches too long. Since the robot has the ability to measure temperature it could compensate the multiplier, although it doesn't at present.

The final type of measurement error is due to the sound pulse generated. The pulse is actually a chirp, 1 ms long, of 56 pulses of 4 different frequencies. There are 8 pulses at 60 kHz, 8 pulses at 56 kHz, 16 pulses at 52.5 kHz and 24 pulses at 49.41 kHz. The time of flight measurement begins with the rising edge of the 1st pulse transmitted and ends with the detection of the 1st echo. Figure 4 shows a timing diagram. Four different frequencies are transmitted to compensate for the fact that different types of surfaces absorb energy of different frequencies. With four frequencies, it is more likely that most surfaces will return an echo. However, the echo received is not necessarily associated with the 1st pulse from which the time of flight is measured. In the worst case, an echo from the last pulse adds 1 ms to the actual response time. This error corresponds to about 3 inches of additional distance measurement.

With all these potential errors, why use the sonar ? It is inexpensive, relatively easy to implement, and we don't have much as an alternative. What can be done to clean-up the device so that we can a more accurate measurement ?

By only using returns in the 3 dB range we should could narrow the beam to a 10 degree cone. If in addition to the range, we could get the strength of the return then the wall finding error shown in figure 2 could be avoided by noting that as the sonar is rotated to the maximum return strength, we should be pointing at the wall at exactly a 90 degree angle. This strategy should also help resolve the specular reflection problem.

Another way to improve the overall accuracy is to take multiple readings from several different locations and use some type of smoothing to determine where the obstacles in the robot's path really are. When the sonars are used for obstacle detection a single return within the obstacle detection range of any of the four sonars will cause the move in progress to be aborted. The navigation software then has the job of determining which sonar(s) actually detected an object.

By augmenting the sonar with bump detectors a more reliable means of control should be achieved, since in many cases the sonar does not 'see' what it just ran into. The HPC currently detects collisions by noting that one or the other of the drive motors has stalled. There are a number of strategies that must be investigated to solve this most difficult problem.

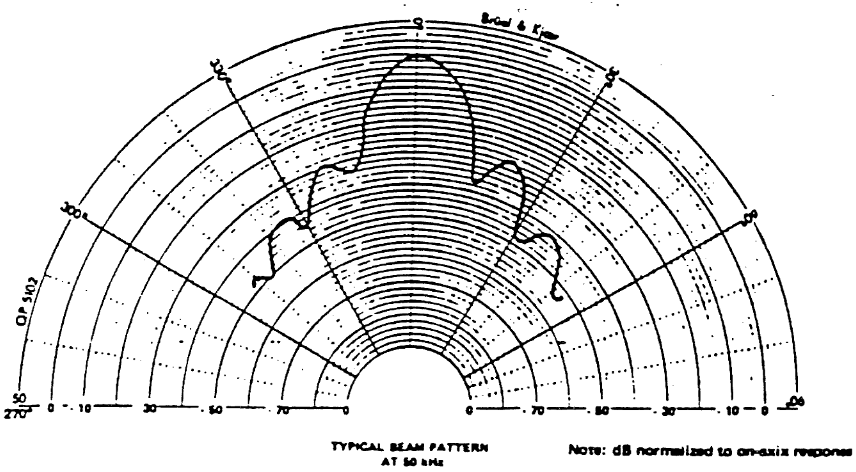

Figure 1:Radiation Pattern of the Sonar Transducer - Polaroid 84

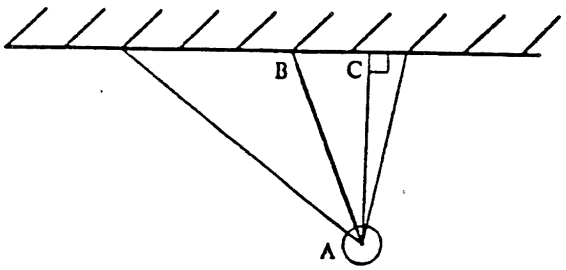

Figure 2:Sensor Measures Shortest Distance to a Wall

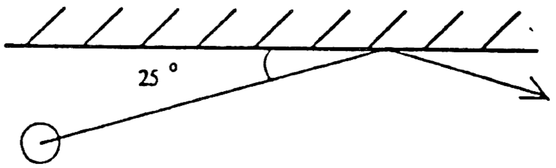

Figure 3:Specular Reflections Off a Smooth Surface

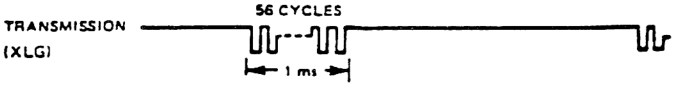

Figure 4:Transmitted Pulse - Polaroid 84

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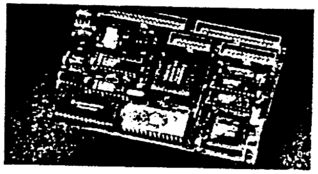

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Rugged Walking Robot

A proposed walking-beam robot would be simpler and more rugged than articulated-leg walkers are, would require less data processing, and would use power more efficiently. The robot would pass over rocks or climb steps 1.7 m high and straddle ditches 1.8 m wide. It would walk at an average speed of 100 m per hour.

The robot would include a pair of tripods, one nested in the other (see figure). It would propel itself by raising, translating, and lowering the tripods in alternation. It would steer itself by rotating the raised tripod on a turntable.

Each of the six legs would include a three-segment telescoping tube with its own geared motor and brakes. An internal cable would drive each telescoping segment. Made of aromatic polyamid, the cables would stay flexible even at extremely low temperatures. The cables would be sheathed, and the segment joints would be equipped with wiping seals to protect parts from dust.

The footpad on each leg would be shaped like an inverted saucer, much like a camel's foot. This shape would compress loose material underneath, thereby aiding locomotion. it would also shed material that fell on the top of the footpad during walking.

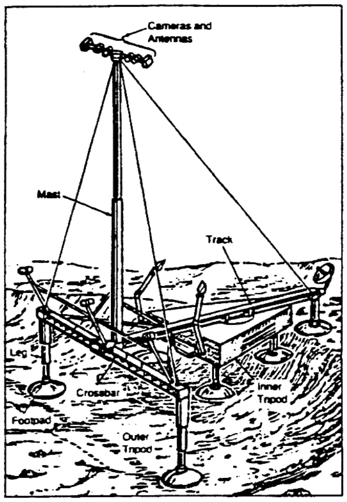
The legs would move only vertically and thus would not kick the ground as articulated legs tend to do. They would, therefore, disturb the soil minimally. The footpads would tilt at ball-and-socket joints to accommodate uneven terrain. The extensions of the legs could be varied independently by the control system either to keep the chassis truly horizontal on a grade for maximum stability or to orient the chassis parallel to the grade to obtain the maximum step size.

The chassis would consist of two beams in a T configuration. The stem of the T would be a track on which the inner tripod would translate with respect to the outer tripod. The translation — on roller bearings — would be nearly frictionless.

The horizontal translation of the tripods would be independent of the vertical motion of the legs. There would, therefore, be no occasion for one actuator to oppose the movement of another — a common phenomenon that wastes power in articulated walkers.

The inner tripod would hold power supplies, communication equipment, computers, instrumentation, sampling arms, and articulated sensor turrets. The outer tripod would hold a mast on which antennas for communication with a remote control site and video cameras for viewing local and distant terrain would be mounted.

Routes would be planned at the remote site. Steps would be planned by the computers on the walker. After human operators at the remote site gain experience with the terrain, they could turn over route-planning authority to the walker over a corridor of limited width and length — say 10 m by 1 km. Five processors, some of which would be redundant at least some of the time, operating at a peak load of a total of 2 million instructions per second, would be needed for navigation.



Members of a Pair of Tripods would alternately raise their legs, slide on horizontal track, and lower their legs. The robot would thus walk across terrain.

This work was done by Stanley J. Larimer, Thomas R. Lisec, and Andrew J. Spiessbach of Martin Marietta Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 30 on the TSP Request Card.* NPO-17825

Agile Walking Robot

A proposed agile walking robot would operate over rocky, sandy, and sloping terrain. It would offer stability and climbing ability superior to those of other conceptual mobile robots.

Equipped with six articulated legs like those of an insect (see figure), the agile walker would continually feel the ground under a leg before applying weight to it. If a leg sensed an unexpected object or failed to make contact with the ground at the expected point, it would seek an alternative position within a radius of 20 cm. Failing that, the robot would halt, examine the area around the foot in detail with a laser ranging imager, and replan the entire cycle of steps for all legs before proceeding.

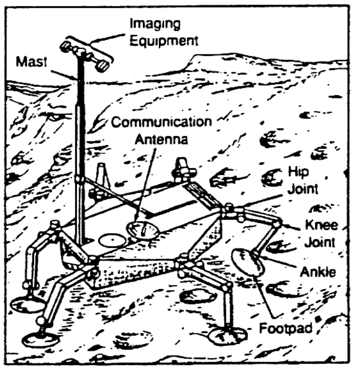
With its legs bent at right angles at the knees — the most stable configuration — the walker would clear objects as high as 0.85 m. However, it would be able to change the knee angle as necessary to lower its body to the ground or raise it 1.65 m above the ground.

The walker could climb steps as high as 2.6 m and would negotiate ditches 3 m wide. It would ascend or descend grades greater than 100 percent on hard surfaces and up to 70 percent on loose sand. Placing three legs at a time in front of the other three, the walker would travel at an average speed of 100 m/h.

The walker would navigate semiautonomously along a corridor specified from a remote control point. It would examine the terrain along its path with the ranging laser imager and video cameras and plot a route that would avoid insurmountable obstacles. As it proceeded along the route, it would select the placement of its feet from video data and adjust the placement as necessary according to locally monitored tactile data. The walker would stop briefly every 10 meters to review the terrain ahead and modify its planned route if necessary.

Its computation load would be somewhat greater than those of the other conceptual robots. Nine processors, each operating at about 1 million instructions per second, would be required for the navigation and control calculations.

A six-leg configuration was chosen because it offers much greater speed and stability than does the four-leg configuration. (Increasing the number of legs to eight would increase speed and stability only slightly, while adding substantially to the complexity and weight.) The legs would rotate horizontally and vertically at hip joints and vertically at knee joints. The ankle joints would flex compliantly. Footpads 0.5 m in diameter would distribute the weight of the walker over large contact areas.



Six Legs would carry the walker over terrain that may be rocky, pitted, steep, and soft.

This work was done by Stanley J. Larimer, Thomas R. Lisec, Andrew J. Spiessbach, and Kenneth J. Waldron of Martin Marietta Corp. for **NASA's Jet Propulsion Laboratory**. *For further information, Circle 134 on the TSP Request Card.* NPO-17874

Rolling Robot

A simple but rugged semiautonomous rover would have large wheels and an articulated body.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed rolling robot would routinely traverse rough terrain, clearing rocks as high as 1 m. It would climb steps 1 m high and span ditches 2.3 m wide.

The drive system would be simple, consisting of four powered wheels and an articulated chassis for steering (see figure). Ordinarily, only two-wheel drive would be used. For negotiating obstacles, soft soil, and loose sand grades, four-wheel drive would be used in combination with yawing and rolling about the axes of the chassis. The rolling and yawing motions would ensure that all wheels make contact with the surface at all times for maximum traction.

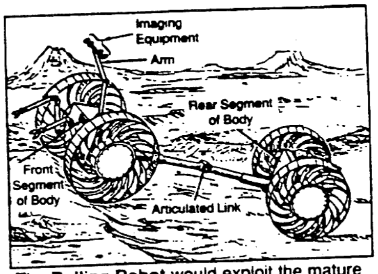
Like other conceptual robot vehicles, the rolling robot would navigate semiautonomously along a corridor specified from a remote control site. The robot would sense the terrain along the corridor, choose a path to avoid insurmountable obstacles, and monitor the state of the vehicle for unexpected hazards.

The robot would be equipped with large wheels 3.25 m in diameter to help it clear large obstacles and to ensure ample traction. The compliant spokes of the wheels would absorb shocks and provide a relatively smooth ride for the body of the vehicle, which would contain navigation and communication equipment. The wheels could be compressed like scrolls to 21 percent of their full volumes for compactness in storage and shipment. When bands holding the stowed wheels were released, the compressed spokes would unfold and expand the wheels to their full diameters.

With laser ranging imagers on its mast, the robot would scan the terrain over the next 30 m before it and select a path. After traveling only 10 m along the path, the robot would plan for another 30-m path. This would ensure that the vehicle would travel only on a path that has been mapped from three different perspectives — from 30, 20, and 10 m away, reducing the incidence of backtracking by making available a path 3 times longer than will be used.

Each time it would plan a path, the robot would select local landmarks 1 m apart along the path, for example, rocks 20 to 200 cm high. As the vehicle traveled, it would note its position with respect to the landmarks and adjust its direction to stay on course. It would also note the time at which it passes a landmark and adjust its speed to stay on schedule.

To detect hazards en route, the robot would view the ground below it with two laser scanners, one directed at a line 2 m in front of the wheels and the other directed at a line where the wheels first touch the ground. The difference between the heights of the vehicle above ground determined by these two scans would serve as an estimate of the compression of the ground by the wheels. If the compression were found to be excessive, the robot would stop and replan its path. It might decide, for example, to lock the rear wheels and fold the link between the segments of the body while driving the front wheels in reverse. This maneuver would generate more than twice the traction of ordinary wheel rolling and could extricate the vehicle from exceptionally difficult situations.



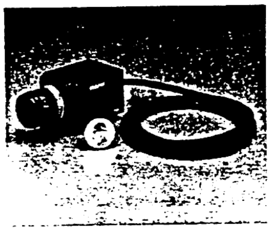
The **Rolling Robot** would exploit the mature technology of wheeled vehicles. Its articulated central link between the segments of the body could yaw ± 65° and roll ±30°. With combined yaw, roll, and four-wheel drive, the robot could crawl slowly to pass over soft or sandy terrain.

The maximum speed would be limited by the speed with which the robot could handle navigation calculations. For an average speed of 100 m/h, five processors, each operating at 1 million instructions per second, would be needed.

This work was done by Stanley J. Larimer, Thomas R. Lisec, and Andrew J. Spiessbach of Martin Marietta Corp. for **NASA's Jet Propulsion Laboratory**

New on the Market

The MDL series of **miniature collimated diode lasers** from LaserMax Inc., Rochester, NY, can be TTL-modulated up to 1 KHz or modulated at 10 Hz with a built-in flash circuit. The 11 mm diameter by 28 mm lasers function on unregulated DC power and are suitable for optical disc interferometry, holography, and alignment.



New **miniature CCD cameras** from PULNiX, Sunnyvale, CA, measure two inches square and operate without support electronics. The TM-7 cameras feature a high-resolution (768H x 493V) 1/2" format interline CCD. Any C-mount lens may be used with the TM-7.

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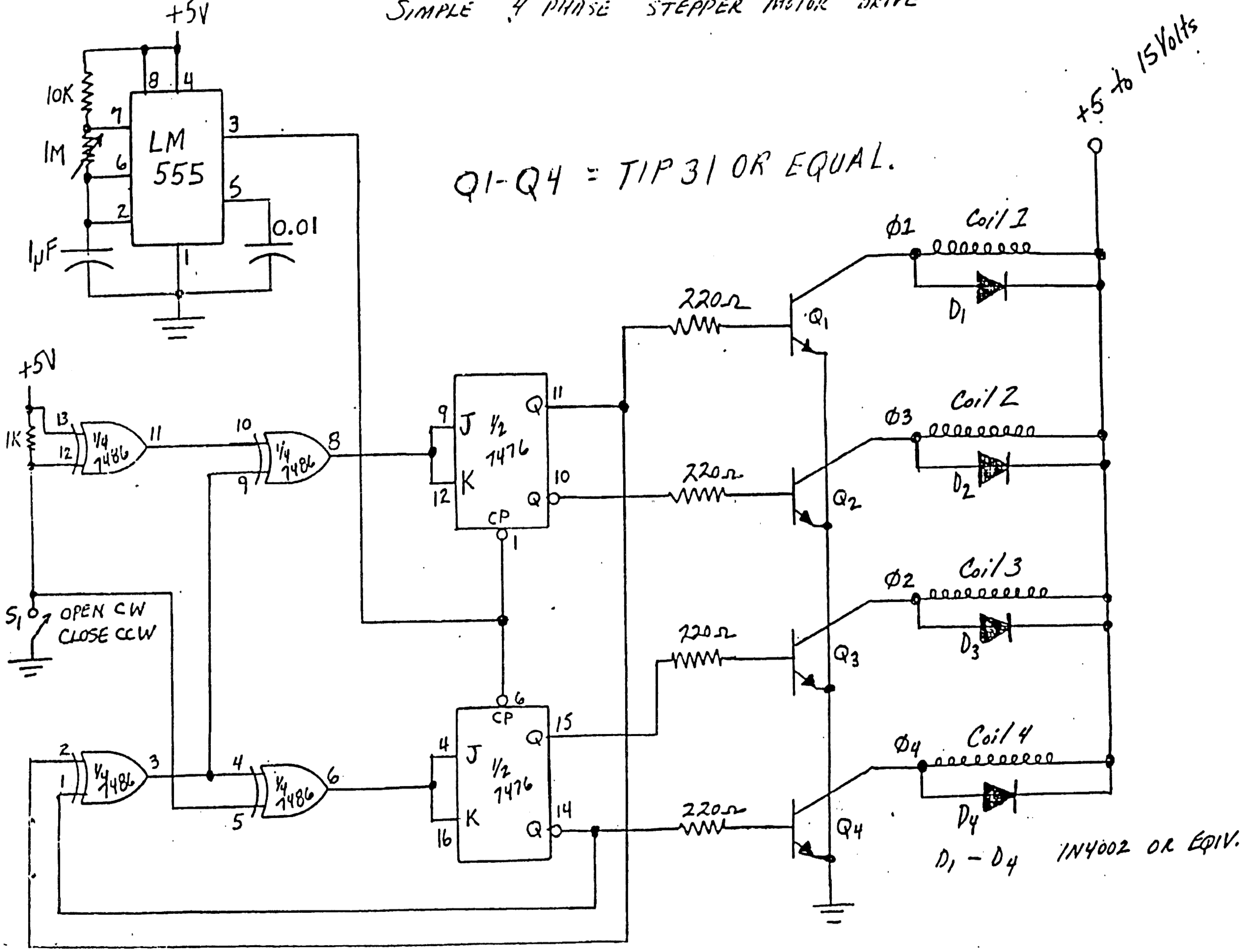
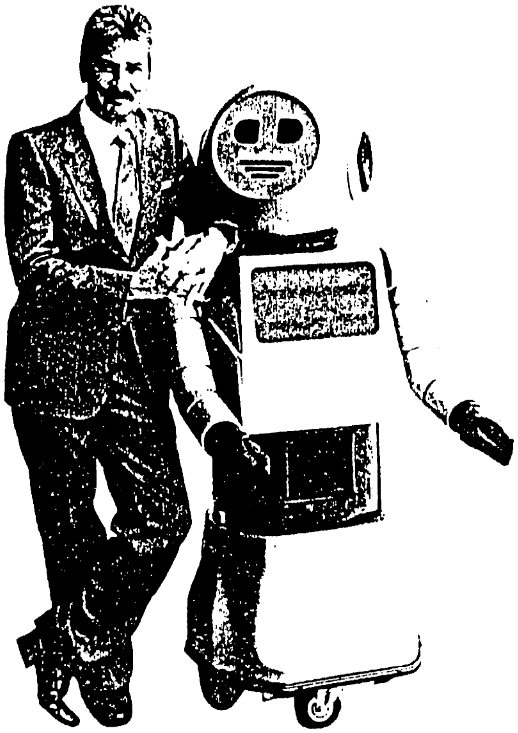


Q1-Q4 = TIP31 OR EQUAL.

D1 - D4 1N4002 OR EQIV.



Dennis is shown here with D & B Showbots owner B.J. Smith. A palm-sized remote control allows B.J. or one of his qualified operators to engineer all of Dennis' movements, speech and hearing from far enough away so that most people do not recognize the operator.

D & B Showbots

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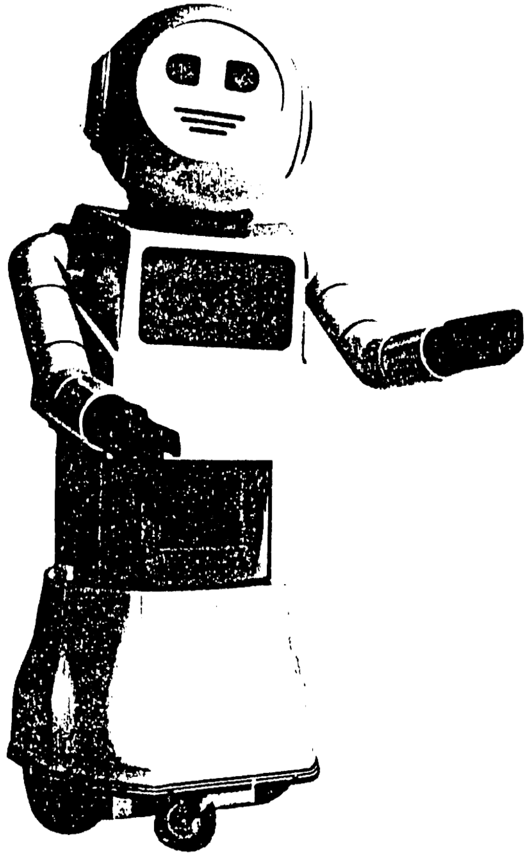

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