A Robot Society on Mars

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INTRODUCTION

I teach students who are labeled as “gifted and talented” and are preparing for careers in science, mathematics, engineering and technology. The school focuses on two major areas: robotics and space. These students are involved in many projects and competitions. They become very technically proficient.

We hope that these students are being prepared to become useful members of society. Our goal is to make them responsible citizens. We fill their heads with a huge number of facts and have them perform many academic tasks. We test them. The state tests them. The federal government will soon be testing them. Those who succeed learn how to play the game. But do we really prepare them to take their place in society?

All of these factors entered in my decision to create this unit. I want to create an educational experience that will take them from where they are to a new place. I want them to think beyond equations and formulas. I want them to look at society and the future creatively. I want them to dream about what could be.

This unit involves no building and no hands-on learning. There is no equipment. There are only concepts. The concepts, however, are at the state of the latest thinking on major questions in both robotics and space. Some concepts are based on experimentation. Others are purely theoretical. The line between science and science fiction may become blurred.

The unit itself will be taught in our Individualized Learning Center as an enrichment course. Students who excel and go beyond the standard curriculum will be given an opportunity to complete this unit. It will be on a CD-ROM. Access to websites in a school creates too many problems. An ample supply of resources for research material will therefore be provided.

There is just too much material to be included in this document. This document will only outline the unit. As soon as possible, the first version of the unit will be available. To obtain a copy, e-mail me at pisciella@txucom.net.

Introduction to Unit

Now we are ready for a journey into the future. The year is 2030. The decision has been made to create a new society. That society will exist on Mars. The conditions on Mars, however, are too hostile for human survival. An expeditionary force must be sent to create a colony for human habitation. The costs and dangers involved in sending humans rules out that option. The advances in robotics make the choice obvious: the expeditionary force will consist of robots.

The robots must create a colony that has the entire infrastructure necessary to sustain human life. This includes food, water, energy, protection from the harsh environment, and emergency back-up systems. The cost of transporting the materials for this infrastructure is too high. Therefore, all of the materials used will be extracted from the Martian surface.

The distance from Earth to Mars can be as much as 400 million kilometers. Two-way communications at the speed of light could take 40 minutes. Remote control at this distance becomes an impossibility. Autonomous robots are therefore the only answer.

Even the cost of transporting all of the robots to carry out the construction of the colony is too much. The initial robots therefore will have the capability of reproduction. That may be one of their initial tasks.

Tasks are too complex to be carried out by independent robots. The robots must be able to work together to perform tasks. This concept is called cooperative robotics. It will be one of the major issues in this unit.

The robots will not know everything about Mars. Conditions may be different than expected. Therefore, the robots must be able to change their own programming. This is the essence of artificial intelligence. As the robots become more intelligent, they make a startling discovery. They do not need humans. The robots decide to create their own society. They decide that Earth is the human planet. Mars is for robots.

These are the major issues of this unit. The students will need to have background information before attempting the task. A brief summary of this information follows. The background information is not in enough detail. The purpose is to raise the issues and pique interest so that students can do further research.

What is Mars Like?

Mars is the fourth planet from the Sun. It is much colder than the Earth due to its distance from the Sun and the lack of a sufficient atmosphere to retain the heat caused by solar radiation. The thin atmosphere causes huge variations in temperature from day to night. Temperatures can rise to as high as 70 degrees Fahrenheit (21 degrees Celsius) on the surface during the hottest days. Even this temperature is a bit deceptive. The surface temperature falls off rapidly with altitude. While the surface temperature may on the hottest days be temperate, the temperature just a few meters up (like at eye level) may be below the freezing point of water (32 F or 0C). At night the temperature drops off to about minus 150 degrees Fahrenheit (minus 90 degrees C).

The Martian day is slightly longer than the Earth day (24 hours 37 minutes). The Martian year, however, is much longer (686 days). The orbit of Mars is much more elliptical than the Earth, leading to a variation in seasons in the hemispheres.

The gravity on Mars is less than 40% of that on Earth (3.71 m/sec^2 for Mars compared to 9.8 m/sec^2 for Earth). This means that structures do not need to be as strong to withstand gravity.

The atmosphere is about 95% carbon dioxide. Less than 2% of the atmosphere is oxygen. The atmosphere is less than 1% of that on Earth (from 4 to 7 millibars compared to an average of 1013 millibars on the Earth). It gets so cold on Mars that the atmosphere literally freezes out as solid carbon dioxide (dry ice).

The only surface water known to exist on Mars is frozen at the poles. There is evidence of sufficient water below the surface. This water would be essential to the survival of humans on Mars. The surface contains a large amount of iron oxides (rust) that causes the planet to be called the Red Planet. The surface contains a large amount of craters and can be best described as rocky.

What Will the Robots Look Like?

Life on Earth is extremely diverse. The size, shape and structure of life depend on the tasks that life needs to survive. With robots, the issue is function. Robots need to perform their functions in a reliable and efficient manner. Their design should take into consideration the conditions on Mars. Based on these issues, the robots should meet certain design considerations. They are summarized below.

Center of Gravity

The center of gravity must be located so that the robots don't "flip over" when they move over rough terrain. If a robot is tilted, it will flip over when a vertical line through the center of gravity is outside the edge of the robot. From the drawings below, it is clear that this center of gravity should always be as low as possible:

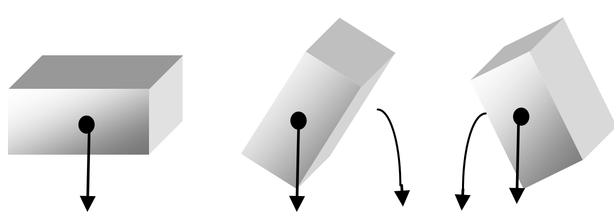

Figure 1: Low Center of Gravity

In Figure 1 above, the center of gravity is low. When the object is tilted at a fairly high angle, it still will return to original position (center object). When the angle is large enough, it will flip on its back (object on right). With a tough terrain, the robot with a low center of gravity can be tilted by a rock or an incline that is fairly steep without flipping over. Flipping over can be a “terminal disease” for a robot.

In Figure 2 below, the high center of gravity can cause an object to flip over fairly easily.

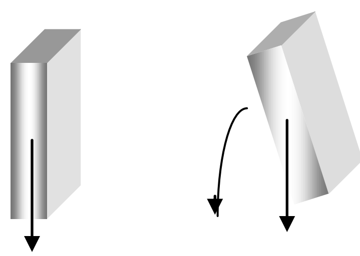

Figure 2: High Center of Gravity

There is also a question of the horizontal position of the center of gravity. This is especially important when picking up objects. The use of counterweights on arms can solve this problem. In Figure 3 below, the robot on the left can become unstable. By using counterweights, the robot can remain stable (robot on right).

Figure 3: Use of Counterweight

Mobility

Human-like robots would have a difficult problem moving on the Martian terrain. Their high center of gravity would make them highly unstable. It takes a long time for humans to learn to walk. This becomes an even more difficult task for robots. There are several alternatives. Here is a preliminary list:

Ride on Wheels

Wheels can be made very stable. Their weakness comes when encountering a “step.” The wheels will stop whenever the object they encounter is higher than the radius of the wheel. When using wheels for rough terrain, the wheels should be large. They should also be soft so that they conform to shape of the obstacle. The disadvantage of wheels is that a large wheel creates a high center of gravity (as in sports utility vehicles). In Figure

4 below, the wheel to the object on the left cannot go over the obstacle; the center wheel can, but it leads to a “bouncy ride”; and the wheel on the right (large and soft) provides a soft and smooth ride over the obstacle.

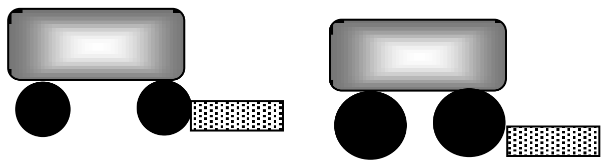

Figure 4: Wheels

Use Tracks

Tracks are used on tanks to overcome rough terrain. They can have a lower center of gravity. Their primary disadvantages, are the cost, complexity and weight. The track technique is illustrated in Figure 5.

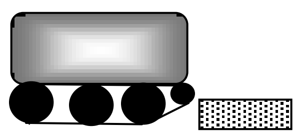

Figure 5: Tracks

Walk like an insect

Roaches and ants are very stable and have a very low center of gravity. Their walking style, however, is complex and requires synchronization. They also will have a problem with carrying loads. Figure 6 below is an example of an insect-like robot.

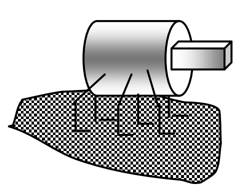

Figure 6: Insect-like Robot

Order of Tasks

The order of tasks is important. The list below is only a suggested path. The important concept in developing a task order is the justification. Students should justify their order. This is a very high level skill. It should also lead to very interesting discussions. Here is a preliminary list that could serve as a starting point:

Map the area

Robots need an accurate database of the surface and all obstacles. The first step is to begin with an initial map of the region that they will work. This map must be constantly updated as construction proceeds. The map must also be very interactive so that the robots can avoid other robots.

Construct the infrastructure

This is the first phase of the work to be done by the robotics expeditionary force.

Create a semiconductor manufacturing plant

This plant will create solar arrays first. Once the robots get these arrays operational, they will have the energy source necessary to stay in operation. The second task here is to create the computer circuits needed for new robots.

Mine for water

Water is essential in many manufacturing processes.

Create an iron and other metals manufacturing plant

The material needed for building the robots is the first priority. The next priority is to create the materials for the infrastructure.

Create a robotics manufacturing plant

The robots are needed to construct the infrastructure.

Artificial Intelligence

What does artificial intelligence mean? There are many definitions. Many are too simplistic for the tasks of the Mars Robot Society. I believe that the robots of today possess little intelligence. They are expert systems. That means that they are pre-programmed by an expert. They will continue to do the same thing time after time if they encounter the same set of conditions. If that causes problems, the problems are repeated ad infinitum. The only way to fix the problem is to have the expert be there on Mars. Since that is not possible in this scenario, expert systems will not serve the purpose.

I've thought about this question for a very long time (decades). My definition of robotic artificial intelligence is that the robot can reprogram itself. The computer nerds of the late 1970s and early 1980s called this "self-correcting code." The computer could change its own programming based on the results of experimentation. This self-correcting code only works at the lowest level of programming, machine language. It requires the ability to change the actual bytes of the program. All of the higher-level languages prevent you from doing this because the program often crashes. The trade-off between low-level and high-level programs is ease of use versus control.

Even this type of artificial intelligence is not enough. The changes made still follow a set of rules. If the change method needs changing, the robot is out of luck. A higher level of artificial intelligence is to allow the robot to learn not only from its mistakes, but to learn from the errors it makes in trying to correct its mistakes.

An even higher level of artificial intelligence would be for the robot to test various methods of error correcting. It could then find the best way to approach problems. This indeed would be a very intelligent robot.

This is not yet the highest level of artificial intelligence that I can think of. There is one higher level that I know of. What if the robot could think about its own processing? This is called metacognition. It could then develop new processes to make its intelligence growth more efficient.

Where did I come up with my model of artificial intelligence? Believe it or not, I developed these ideas in education classes. I became a teacher in the early 1970s, having taken absolutely no education courses. I had spent the decade of the 1960s in undergraduate and graduate engineering courses, mostly studying computers and their possible applications. The big “Aha” came in a class on Bloom’s taxonomy and metacognition. I thought that if human abilities could be described in these terms, why can’t robotic artificial intelligence?

Expert systems are knowledge, comprehension and application. That may sound very familiar. That’s the Texas Assessment of Academic Skills (TAAS). Educators found that they could teach practically anybody these skills and suddenly we had an abundance of recognized and exemplary schools. What was missing was the ability to do anything useful. So while we excel in TAAS, Texas remains forty-ninth in the Scholastic Aptitude Tests (SAT) ahead of only Louisiana. I want my robots and my students to be useful.

Analysis involves breaking a problem into its small parts and solving each part. This is “self-correcting code.” With analysis skills, students can pass the Texas Assessment of Knowledge and Skills (TAKS) and the Stanford 9. They will also do fairly well on the SAT. Robots too can have a much more likely chance of survival.

Synthesis allows for creative solutions of problems. Students who are able to synthesize in all of their academic classes can survive and thrive in college. Robots that can create new solution methodologies can become very valuable to a society of robots.

Evaluation will allow the highly motivated student to seek the “best” solution to a problem based on criteria developed by the student. This is pure graduate school “stuff.” A robot with the ability can be very human-like.

Metacognition is very controversial for robots. I define metacognition as the ability to think about one’s own thought processes. When I began to do this in college, everything suddenly fell into place. Every subject suddenly became easier. For robots to think about themselves may cross the line separating robotics from real life. Science fiction really kicks in. What would these robots design themselves to look like? Would they look human-like or be of a more functional design? Would the robots fight or argue? Would there be a power struggle for leadership? Are the problems in society inherent in nature or in the nature of society?

Students can’t answer these questions with authority. There are no right answers. Luckily, there are no wrong answers. When students deal with the questions in this unit, they will not be evaluated according to correctness, but by the justifications they give.

There are many other definitions of artificial intelligence. Most of these involve the interaction between humans and robots. In my robot society, robots do not have to interact with humans. For example, the ability to speak and recognize speech is of little value in the robot society. About the only thing the robots must communicate to humans on Earth is “We’re done!”

Fuzzy logic and neural networks are two areas of advanced research into artificial intelligence that are very popular. The research is very far beyond the level of this unit. The concepts, however, are simple. The students can use the concepts without totally understanding all of their ramifications.

A highly advanced student might want to study in these areas as a research topic. This may help students decide what they wish to pursue in college. For the rest of the students, a basic conceptual understanding may make their design of a robot society more meaningful. The concepts of fuzzy logic and neural networks are discussed below.

Fuzzy logic

The world of digital logic is based on a crisp demarcation from one state to another. Everything is either true or false. There are no gray areas. Imagine a real world like this. The weather forecast would be rain, with a high of 60 degrees, and winds out of the southwest at 10 mph. What if the temperature reached a high of 61 degrees, or it rained only in the morning or the winds varied from 9 to 12 miles an hour? The forecast would be completely wrong and the forecaster would be called a liar. People understand that the weather forecast is designed to be close, not perfect. The computer with crisp logic does not. This problem is addressed by fuzzy logic.

Fuzzy logic states everything in terms of a probability distribution. There is an 80% probability that the temperature will be between 57 and 63 degrees. There is a 70% chance that it will rain sometime today. The winds will vary between 0 and 20 miles an hour, but there is a 70% chance that the average will be between 8 and 12 mph. Fuzzy logic is designed to better describe the real world because the real world is not exact.

The major use of fuzzy logic in robotics would be in object identification. Rocks could vary from a few centimeters to several meters across. Their shape could be approximately oval. They would always be on the ground. The robot could make a reasonable guess that an object is a rock from its properties in fuzzy logic. Effective use of fuzzy logic would mean that one robot could deliver a beam for construction to another robot rather than to a rock.

Neural networks

Neural network research is based on the concept of neurons in living organisms. The neurons "fire" (emit a certain voltage) when they receive a signal that reaches a certain threshold. The input signal can be from several other neurons. The output voltages from each neuron can be different.

When this concept is applied to computer circuits, the term is neural networks. An example may help illustrate the concept. Assume that a certain neural node has a threshold of 6 volts. Its inputs come from four other nodes that have outputs of A =1, B=2, C = 3, and D = 4 volts when they reach threshold voltage. Figure 7 below is an illustration of this small neural network.

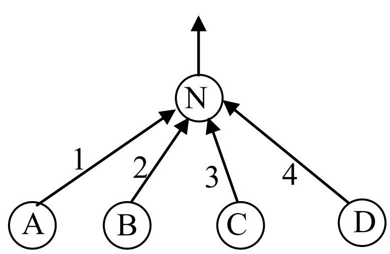

Figure 7: Neural Node

The node, N, will fire if any of the following combinations fire: A,B,C; A,B,D; A,C,D; B,C,D; B,D; or C,D. If node N's threshold were reduced to 5 volts, firing would require a minimum of D with and other node; or C with B or D; or B with A and C. Changing the threshold of N is one way of modifying the logic.

Another way to modify the logic is to modify the weighting of A, B, C, and/or D. The weighting can be negative, causing one node to inhibit firing of node N. In Figure 8 below, the B node produces a negative 2 volts when fired. If node N's threshold were 6 volts, only a combination of A,C,D would allow the threshold to be reached if B is fired.

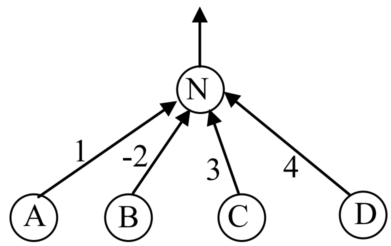

Figure 8: Neural Network with Inhibit Weighting

Robots can modify their programming and "learn" by merely modifying weighting in their neural circuits. This makes using neural network logic a possibly useful technique in providing a level of artificial intelligence.

The Mars Robot Society

In human society, communication is very difficult. The diversity of cultures and languages can lead to many misunderstandings. The same sounding word in different contexts has totally different meanings. The statement "I have to do two tasks too!" has three different meanings for the same homophone (to, two, too). Using a human language for robots would not be the answer. The robots should use a computer-type language to communicate. Every "word" has a precise meaning. There can be no miscommunications. The language used in this unit will *look* like English. It really is only the English translation of computer code.

The language is computer code. What is the structure of the society? I have chosen two concepts from computer science: object-oriented programming and parallel processing. These concepts will be modified to meet the needs of our robot society.

Object-Oriented Programming

Object-oriented programming divides the parts of the program into objects. These objects communicate information to and from other objects. Each object is encapsulated. *How* a task is performed by one object is not the concern of the other objects. Their only concern is that the task is completed. The objects can be considered "black boxes" with inputs and outputs.

An example is a weather forecast. You turn on your television and they tell you it is going to rain. If the forecasts prove reliable, the way that the forecast was made is of little concern. They may have consulted a Ouija Board; sent their dog out to see if it became wet; or used a supercomputer with a complex set of partial differential equations from atmospheric physics. All that you care about is that it is reliable. Your input was to turn on the television. The output that you received was the forecast.

The objects that make up a program can be classified according to what they are and what they do. In object-oriented programming, the objects are therefore placed in classes. In education circles, this is an easy concept.

When I first began to study object-oriented programming, I immediately visualized a robot society. Each robot would be an object. The robots would communicate with each other to complete a project. Only the robot performing a task cares about *how* a task is completed. All of the other robots only need to know that the task was completed.

Parallel Programming

A processor in a computer can really do only one task at a time. Modern processors can do a billion or more tasks in one second. The processor operates so fast that computer users believe that it is doing many tasks simultaneously. This is called multitasking. In a society of robots, the robots could be just remote control devices that depended on instructions from one central processor. This could become a communications nightmare in a complex project.

A simpler model is to distribute the processing into each robot. Each robot could then receive orders to perform a task; figure out how to do the task; complete the task; and reply when the task is completed. This concept is both the essence of object-oriented programming and parallel processing.

Societal Structure of Robots

What could be the societal structure of the robots? I would suggest the hierarchal structure. The structure could be defined as the following:

Society Leader

The society leader defines the tasks of the colony design. It allocates resources in the proper quantity and at the correct time to perform the major tasks most efficiently. The society leader communicates with project leaders to determine when tasks are complete and when assistance is needed from other project leaders. The communications are simple. Some examples are:

Do this project (type of project).
Project is done.
Need supplies (amount).

Project Leaders

The project leaders run the major projects (map the region, build robot manufacturing plants, build manufacturing plants, build the infrastructure, run plants, provide supplies, etc.). The project leaders communicate with the society leader and supervisors to assure efficient completion of projects.

Supervisors

The supervisors assure that the components of the projects are performed effectively. They communicate with the project leaders and the worker robots.

Worker Robots

The worker robots are designed to perform specific tasks. Their design depends upon the task they are designed to perform. They communicate with the supervisors.

Hierarchy Illustration

The hierarchy is illustrated in the Figure 9 below:

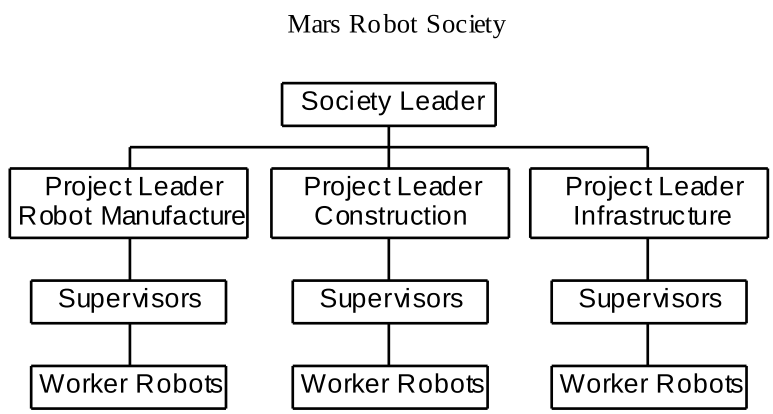

Figure 9: Hierarchy

There may be a tendency to view the hierarchy as similar to human society. This would be a mistake. Each robot is designed to perform a different task. There is no salary. There are no raises. Robots are neither hired nor fired. There is no prestige. Remember this is an emotionless society (maybe). It's like creating a society of Dr. Spocks (Star Trek) and taking the logic to the extreme.

How Robots See and Know Where They Are

The ability of the robots to "see" their surroundings is a major issue in the robot society. Every possible object and obstacle must be part of a database. When an object is scanned, it must be compared to a large database. The ability to differentiate between an object and its surroundings is beyond the level of this unit. The type of scanning is also beyond the level of this unit. These two topics are often advanced graduate and post-doctoral research topics. In this unit we will assume that objects can be scanned and differentiated from their surroundings. Our task will be to understand how they can be identified.

The robots are moving and the objects may be at any distance or orientation. Therefore, the shape and size of the visual picture are highly variable. The work with virtual reality can come to our rescue. In virtual reality programs, objects are stored as a set of polygons arranged in a three-dimensional matrix. The polygons are stored as sets of connected vectors in three-dimensional space. Distance is simulated by scaling the vectors and applying vanishing point transformations. There are matrix equations to simulate rotation about three axes (roll, pitch, and yaw). Rays are drawn from simulated light sources to produce shadowing. The result is very good simulations in computer games.

The robots will need to reverse the procedure. The object will be viewed. It will be compared to objects in its database. The objects will be stored in the form of virtual reality objects. The database will be organized according to a multitude of criteria. The most likely objects will be chosen from the database in order of the probability that they are the object scanned. Each object in turn will then be rotated and scaled and the best match is found. This clearly will require very high-speed computers with enormous memories. This is probably the most programming intensive operation that the robots will do.

The robots must always know where they are. The Global Positioning Systems (GPS) can provide our best model. The robots can set up three beacons at three edges of the region. The robots can determine the direction of the three signals. By extending lines from the three directions, the robots can find where they are at any time. Figure 10 below illustrates the concept.

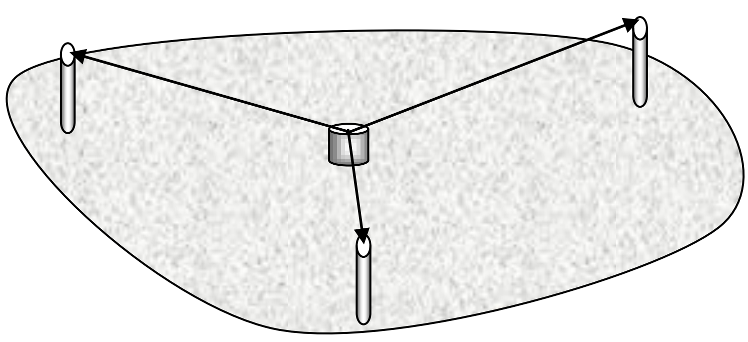

Figure 10: Finding Robot's Location

Making Robots "Human"

The science fiction research will involve reading and viewing how science fiction writers see robots in the future. One of the most famous depictions of robots was in the movie, *Star Wars.* The movie had two "stars" that were robots, R2-D2 and C-P30. These robots were on opposite ends of the spectrum. C-P30 was almost human in nature and spoke. R2-D2 looked very much like the standard depiction of robots and did not speak. They both exhibited sophisticated intelligence.

Most robots are "expert systems." The robots will always do the same thing under the same conditions. The robots do not learn. The definition of expert systems according to *The McGraw-Hill Illustrated Encyclopedia of Robotics and Artificial Intelligence* is:

> ...a method of reasoning in Artificial Intelligence (AI). Sometimes this system is called rule based.... The heat of the device is a set of facts and rules... The rules are of the logical form "If X then Y" similar to many of the statements in high-level programming languages (143).

In *The Science of Star Wars,* the author Jeanne Cavalos states that the robots exhibit intelligence beyond expert systems:

> Both Artoo and Threepio appear to have certain areas in which they are 'experts,' such as translation and piloting an X-wing, but they also exhibit a great flexibility to function usefully in a wide variety of circumstances. So they can't be exclusively rule-based systems (87).

Cavalos later states that their ability to learn indicates that these robots must be based on neural networks. This seems to be a new idea. However, I recently discovered a book entitled *Bionics: The Science of Living Machines.* Authored by Daniel S. Halcy, this book was published in 1965 and therefore pre-dates the first personal computers. He stated that in 1960:

> ... the Air Force was particularly in three aspects of living prototypes:
>
> 1. The sensory receptors of animals
> 2. The integrating action of their nervous systems
> 3. The storage and retrieval of information
>
> All of these capabilities would find applications in man's artificial systems, particularly as these systems become more complicated. Nature seems a master of organized complexity and it was logical that man turned to it for instruction.

If robots can think, what other properties would they need to possess to be self-aware? Jeanne Cavalos believes that they would have possessed emotions. She states on page 96, "The most amazing thing about R2-D2 and C-P30 is how human they seem. They each have strong personalities, and constantly convey emotions." Are emotions and the ability to learn enough for robots to form their own society? That is a question that will be left to students to grapple with.

"LESSONS" FOR THE UNIT

This unit is designed as a project for enrichment. There will be no "lessons" as such. The student will be provided with a faculty resource who will provide assistance and guiding. The project that evolves from this unit will be presented by the student to a group of experts in the field. The student will defend the project much like graduate students defend a thesis. These conditions are set forth in Texas Education Agency guidelines for enrichment activities that help the student qualify for a distinguished diploma.

Rather than lessons, it is much more useful to provide the student with a research plan along with criteria for each part of the research plan. A suggested plan is described as a guideline. An individual plan can be developed in joint consultation between the student and the faculty resource person.

Part 1: The Technical View

1. The students will study the information as to the conditions on Mars. They will list the alternatives and the advantages and disadvantages of each alternative. The students will choose the location of the colony site and defend that choice through objective arguments.
2. The students will use the information relating to the human needs for the colony and the needs of the robot society. Based on these needs, the students will develop a design concept for the colony and its infrastructure.
3. The students will develop a timeline for the robot society to create the colony. This timeline will contain milestones.
4. The students will decide what materials and robots to bring to the colony; decide what robots can be built in situ (on site); and what materials can be used in situ to construct the colony.
5. The students will design robots to perform each function on the colony. They will explain the reasons for the particular design of each robot.
6. The students will develop the hierarchy of the robot society and determine how many robots of each type will be at each step of the hierarchy.
7. The students will develop an object-oriented language to be used in the hierarchy and the messages to be passed between the robots.
8. The students will estimate a failure rate for the robots and produce a plan to replace these robots.
9. The students will describe the type of artificial intelligence to be used by the robots.
10. The students will state the techniques that will be used to identify objects and to determine the location of each robot.

Part 2: The Science Fiction Kicks In

This section should begin with the viewing of the original *Star Wars*, *2001: A Space Odyssey,* and *Artificial Intelligence.* These movies will give the students a good mindset. The students then will be asked to write a short story about robots that rebel and form their own society. This short story should be 15 to 20 pages single-spaced size 12 Times New Roman font with one inch margins.

The above is only a preliminary list that will be modified as the project proceeds. The most important factors are that students be able to do effective research; use analysis, synthesis, and evaluation skills to complete the project; and to be able to defend their choices in both written and oral form. The sophistication required to produce a realistic project and then write a short story is probably not yet developed in even the best and brightest students. This project is a learning experience and should be evaluated as such.

As an aid in the writing of the science fiction paper, several questions may be asked. The following questions might serve as a sample:

- Are all robots created equal? Are some robots more equal than others (*Animal Farm)?*
- Are R2D2 and 3PO equal or is there a natural leader and follower?
- What traits would a leader possess in a robotic society? Would all robots ask to have these abilities?
- Would there be battles of leadership?
- Would the robots seek to protect themselves against humans? Would humans seek to destroy a robot society?
- In human societies (and perhaps in animal societies) those who control scarcities tend to control the society. Would this happen in a robot society?
- What factor does emotion play in struggles for leadership?

ANNOTATED BIBLIOGRAPHY

This list is provided for teachers. The students will primarily use the material on a CD provided to them. The material for teachers is in book form. The material for students will be provided as PDF documents to overcome problems with different computer platforms.

This annotated bibliography is divided by subject area. A similar division will occur on the student CD.

Conditions on Mars

Carr, M.H. *The Surface of Mars.* Yale UP, 1981.

Although the book is a bit dated, it provides one of the most authoritative works on the conditions on Mars.

Carr, M.H et al. *Viking Orbiter Views of Mars.* NASA, 1980.
This book is also a bit dated. It covers, however, all of Mars major features with photographs and easy to read text. the pictures and data were provided by the Viking Orbiters. This book is available in a free on-line version and will be on the student CD.

Cattermole, P. *Mars the Mystery Unfolds.* Oxford UP, 2001.
This is a modern book. There is little difference between the data presented here and that of the three books above. It is written in a more easily understandable form.

Viking Lander Imaging Team. *The Martian Landscape*.
This is another book that is dated. It provides close-up pictures of the Martian surface taken by the Viking Landers. This book is available in a free on-line version and will be on the student CD.

Science Fiction about Space and Space Inhabitants

Benford, G. & G. Zebrowski. *Skylife: Space Inhabitants in Story and Science.* Harcourt Inc., 2000.
This is an anthology of works by many famous authors on space colonies.

Cronin, T.W. *As it is on Mars.* Tharsis Books, 2001.
This is yet another science fiction book on the first manned mission to Mars.

Cavelos, J. *The Science of Star Wars.* St. Martins Griffin, 2000.
This book represents a study of just how scientific the science fiction of *Star Wars* is or could be. It is highly understandable with examples.

Jackson, R.R. *The Mars Transmission.* Keeper & Sol., 1999.
This is a science fiction story with a message: start manned missions to Mars. It starts with an alien transmission from Mars that puts manned missions on the agenda.

Krauss, L.M. *The Physics of Star Trek.* Harper Perennial. 1995
This book represents a study of just how scientific the science fiction of "Star Trek" is or could be. It contains a vast amount of concepts of advanced physics and therefore is less understandable than the book above.

Zubrin, R. *First Landing.* Ace Publishing, 2001.
This book is a scientific science fiction about the first landing of humans on Mars.

Colony Infrastructure

Prado, M. *Permanent.* Phong Ton Enterprises, 1998.
This book discusses the feasibility of using material from asteroids to create colonies in space. Similar concepts can be used to do the same thing on Mars.

Robotics Zubrin, R. *The Case for Mars.* The Free Press, 1996.
This book is considered one of the most authoritative books on creating a permanent settlement on Mars.

Artificial Intelligence and Programming

Cawsey, A. *The Essence of Artificial Intelligence.* Prentice Hall, 1998.
This book provides a simple overview of various aspects of artificial intelligence. Its value is in its brevity.

Fischler, M.A. and O Firschein. *Intelligence: The Eye, the Brain, and the Computer.* Addison-Wesley, 1987.
This book is an excellent text on intelligence and vision. It represents a scholarly approach to intelligence and its relationship to artificial intelligence.

Ford, Andrew. *Modeling the Environment.* Island Press, 1999.
This book provides modeling techniques for dynamic modeling of environmental systems. While not specifically object-oriented programming, it provides bridges between problem-solving programming and environmental issues.

Halacy Jr., Daniel S. *Bionics: The Science of Living Machines.* Holiday House, 1965.
This book talks about the origins of neural networks. It therefore provides historical perspective.

Johnson, C. J. & C. Brown. *Cognizers: Neural Networks and Machines that Think.* John J. Wiley & Sons, 1988.
This book provides a primer for the concepts of neural networks and how they can be utilized in computers for developing artificial intelligence.

Weisfeld, Matt. *The Object-Oriented Thought Process.* Sams Publishing, 2000.
This book provides an overview of the object-oriented thought process. It offers explanations of object-oriented programming rather than code.

Yan, Y., M. Ryan, and J. Power. *Using Fuzzy Logic.* Prentice Hall, 1994.
This book provides a primer on fuzzy logic and its applications in software design.

Robotics

Gibilsco, S. *The McGraw-Hill Illustrated Encyclopedia of Robotics and Artificial Intelligence.* McGraw-Hill, 1994.
This book provides an alphabetical listing of descriptions of terms used in robotics and artificial intelligence. It is a very good reference book.

Jones, J. and A. M. Flynn. *Mobile Robots: Inspiration to Implementation.* A.K. Peters, 1993.
This is a practical hands-on approach to designing autonomous robots. It was written by professors from Massachusetts Institute of Technology, the originators of robotics competitions for college students. These competitions have expanded to many colleges and universities throughout the nation.

McComb, G. *Robot Builders Bonanza.* Tab Books, 1987.
This book provides practical ideas for building cheap, inexpensive robots. It should help in the design of robots for this unit.

Schodt, F.L. *Inside the Robot Kingdom.* Kodansha International, 1988.
This book describes various robots in Japanese industries. It is valuable in providing ideas about robot construction.