Activity 5 BUILD A ROBOT OUT OF HUMANS

Background

Many places on our home planet and elsewhere in the solar system are distant, difficult, and sometimes downright dangerous to reach. Yet we humans want to explore them. Specifically in NASA's MER project, we Earthlings would like to know if Mars, which is now cold and dry, once was wet and warm. Did life begin there, and if so, what happened?

Even places much closer to home have, until recently, been inaccessible and many are still by no means fully explored: the bottom of the ocean, the craters of active volcanoes, the upper edges of the stratosphere. Now for the first time in human history new tools make it possible to study these places still alien and fascinating but not quite so distant any more. In almost every case, exploring them requires a mixture of "machine intelligence" and humans, using robots. (One definition, from a site which explains its derivation from science fiction: "A mechanical device that sometimes resembles a human being and is capable of performing a variety of often complex human tasks on command or by being programmed in advance." http://www.jeffbots.com/dictionary.html) Robots are very powerful tools: they don't get cold and tired. They can perform boring and repetitive tasks for long periods of time without complaining, and they can venture into areas where humans can't. However, robots aren't human: even the best, are severely limited in adaptability and flexibility. For the most part, they can only carry out tasks they were programmed to perform. And in the case of Mars, the precise balance of autonomy (what the robot is programmed and allowed to do solo, by itself) and what is commanded by humans, is complicated by the fact that at their closest Earth and Mars are 8-9 minutes apart, and sometimes are separated by 19-20 minutes in their travels around the Sun. Even radio signals, traveling at the speed of light, take a while to travel between the planets. If a rover, about to roll over a cliff, or smash into a large boulder, required a human to tell it when to stop, exploration would be even more risky than it already is! That's one of the reasons for NASA's research on the sophisticated interplay of human and machine capabilities seen at work in its various telepresence projects, which are attempting to find out how to get the best of both worlds, human and machine intelligence. (See, for an overview, http://ranier.hq.nasa.gov/telerobotics_page/programdesc.html)

Just how easy or how difficult is it to build a robot that can operate on Mars, where the time delay caused by distance means it must function without direct and continual human control? This Activity demonstrates some basic issues in robotics, in a playful way.

Objectives

Through this Activity, participants will demonstrate the ability to:

- Work cooperatively to successfully complete a given task
- Break a complex task into simple, discrete steps
- Design a finite set of communication commands to be used within their team while simulating a non-autonomous robot rover
- Compare the function and role of each member of the human robot team to that of the MER rovers

Vocabulary

Autonomous, and semi-autonomous

Manipulation
Navigation
Mobility
Command
Memory
Simulation

Materials (These amounts would work for up to 25 participants, operating in teams of 5: scale up, or down, accordingly)
10 paper bags, shaped to fit over participants' shoulders, no eye holes
5 paper bags, shaped to fit over participants' shoulders but with eye holes cut out and blinders attached to outside edges of holes, restricting peripheral vision
5 broom handles, or equivalent, long enough for 4 participants to hold onto (Ensure participants regard these as strictly scientific equipment!)
5 sets of objects to be collected and explored: kitchen sponge, children's blocks, plastic bottles of various sizes, a tennis ball, film canister
5 kitchen tongs
1 large cardboard box
1 x 15 ft. electrical extension cord (not to be plugged in! Or rope can be substituted to avoid any chance of electrical mishaps.)
5/6 obstacles (empty chairs will work fine)
1 roll masking tape
1 meter stick
10 pieces of 4 X 4 grid paper

Preparation
Divide participants into heterogeneous (i.e. mixed gender and ability) groups of five. Clear a space in center of room (perhaps 4 meters x 4 meters.) Use tape to mark a 4 x 4 grid on the floor. Label sides of grid with compass directions: N, S, E, W, mark coordinates.

Activities
1. Explain to participants that the purpose of this activity is to simulate the actions of a fully remotely-controlled robot. (Either now or later, explain that MER possesses autonomous capabilities: it's programmed not to fall over a ledge, or crash into a rock, even if its path previously looked safe to an operator down here on Earth.) The robot will be given a task to perform in a previously-unexplored environment (Demonstrate obstacles placed in 4 x 4 grid). Review direction (N, S, E, W) and degrees (right 45, right 90, right 180, etc.)

2. Each team will become a mobile robot or ROVER, controlled by a BRAIN, and must learn the function and limitations of each part of the robot.

3. These are the functions and limitations of each member of the 5-person team:

BRAIN: only the BRAIN may issue commands to the ROVER team operating on the gridded area, and order status checks from the various subsystems. Only BRAIN knows the task to be completed by the ROVER team. BRAIN keeps a record on a gridded sheet of paper of "discoveries" made by the ROVER team.

MANIPULATION: no eyes (closed paper bag), does not talk except under conditions following, carries kitchen tongs to pick things up; only communication allowed for this individual is an observation such as "Bumped into something" (may say this anytime it occurs), "Something between gripper" (only when asked as a response to query from BRAIN, such as "MANIPULATION—status check?")

NAVIGATION: has eye holes; functions to tell location on grid upon verbal request from BRAIN, such as "NAVIGATION: Status?"

MOBILITY: has eye holes, but does not speak. Upon receiving command from BRAIN, MOBILITY will control the ROVER's movement forward or back in a given number of paces, or turn by a given amount (degrees).

VISION: has "forward-only vision" (eye-holes with blinders); will only respond to "VISION: Status?" query from BRAIN and tell what he/she can see (on grid) and distance away from object.

4. Demonstrate the physical set-up for the BRAIN and the ROVER:

> BRAIN sits in chair with back to room.
> The ROVER team holds onto broomstick in following order:
> MANIPULATION, VISION, MOBILITY, and, at the end of the line, NAVIGATION.

5. Discuss communications needs and brainstorm appropriate commands. Have teams work together to generate a list of 12 commands they will use. (These commands should be recorded by team members with a copy submitted to the group leader.)

6. Demonstrate and explain each of two tasks to be completed:

- Task A Pick up and place in cardboard box a designated object from objects scattered on grid.
- Task B ROVER team must find and take the loose end of the long electrical cord (other end tied around chair leg) to the cardboard box and "plug" it into side slit. (To repeat: do NOT plug into an electrical outlet.)

7. Allow the ROVER and BRAIN TEAMS sufficient time to practice commands and movement. Each TEAM should be responsible for deciding which participants have which jobs; jobs may also rotate if there are more than five participants in a group. (If implementing this Activity in school, at least one class period may need to be devoted to practice. If in science center or home, perhaps 15-20 minutes should be allocated.)

8. THE ROVER CHALLENGE
BRAIN chooses "Task A" or "Task B" card from teacher (but is not allowed to tell the ROVER team!). BRAIN directs all action by making STATUS CHECKS and giving COMMANDS;

however, each command uses up "memory" (Unless you and the participants collectively decide otherwise, assume BRAIN uses up 10 memory units per command, and that the ROVER's total memory is 200 bytes: after 10 commands, there's no space capacity for more.) Observers should record memory usage.

Wrap Up

1. Have participants evaluate their success. How could they improve their performance? What commands proved to be most useful, and what were not? Could they build a better robot?

Follow Up Discussion/Journal Entry

Have participant compare their ROVER with NASA's MER. What can MER do by itself? What must MER wait for humans to decide? What does having a human "in the loop," though distant, contribute to the process? Are there any downsides to waiting for human commands?

Are robots, as they appear in science fiction films and stories, as limited as this exercise makes them seem? Have participants suggest reasons why, or why not.

Expand/Adapt/Connect

Suggest that they might wish to reconsider some of these questions after viewing COUNTDOWN TO MARS and other "To Mars with MER" programs, which look in greater detail at the MER mission, and the specific plans for the control of the rovers, combining a certain amount of autonomy or self-control, along with periodic supervision from Earth.

Set up a timed competition between teams of ROVERS as specified in this Activity. The group leader may change the position of the objects in the room between teams, or change the character of the object. For example, a sponge will require a different manipulation technique than a block. (Check out MER's "arm", or Instrument Deployment Device, IDD.)

Videotape the entire exercise for review after its completion (and send to P2K.)

Suggested URLs

http://mars.jpl.nasa.gov/mer/mission/spacecraft_surface_rover.html
An overview of the MER rover, with links to details of the rover's brain, arm, eyes, etc.

http://mars.jpl.nasa.gov/mer/mission/spacecraft_rover_brains.html
MER's "BRAIN" (you can also find descriptions of MER's COMMUNICATIONS and MANIPULATION functions, to compare and contrast with participants' tools: MER is operating with a much more capable arm than one made of "kitchen tongs"!

http://mars.jpl.nasa.gov/mer/mission/tl_surface.html
Overview of MER's surface operations

http://athena.cornell.edu/the_mission/instruments.html
Details on MER's science instruments, from Cornell's ATHENA site, which also has excellent information about all aspects of the mission.

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