Robots:

Walking, Learning, Evolving?

MSCOPE Demonstration Proposal

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1 Concept

Robots exist within popular culture as Hollywood style futuristic technology-gone-wrong or mundane automata assembling cars in a factory. Little is understood of their possibilities and limitations.

Robots are generally machines that people make to do jobs they can't or don't want to do. They can do no more than we can tell them to do but they can be extremely useful. They can replace limbs we have lost, design bridges, even explore from the depths of the sea to outer space. But they can't do any of these things until we first figure out how to teach them either, how to do it or how to learn. We will explore problem solving through robots.

Here we propose 3 possible implementations of the above concept:

1.1 Teaching a Robot to Walk

Project Type: Demonstration
Museum/Venue:MSI, Great Hall
Target Audience: Young Children to Adult

One way we can better understand processes that occur in nature, is to try to recreate them. Take the human leg and the process of walking. By creating a robot that can walk like a person we gain can understand how people walk, both the mechanisms of the leg and the signals that the brian must send to make us walk. This can help us create protheses to help people with injured or missing legs. The work of one professor, Andy Ruina at Cornell University, seems to indicate that walking is a far more automatic process than was once thought. He, along with several others, has created robots that mimic the gait of humans and once set in motion, continue to walk with minimal power or control required.

Big Idea: Teaching a robot to walk helps us learn about how we walk.

The demonstration would consist of a 'walking' robot (See figure 1), that would walk around the great hall and a demonstrator that would follow, present the features that make the robot unique and implications for protheses etc. This would tie in nicely with the body human exhibit. A possible activities could be to have visitors attempt to:

1. Walk without the use of their knees or ankles.
2. Match the robot's stride.
3. Have one visitor give instructions to another on how to walk.

It is also possible to develop this for the Fab. Lab. having participants fabricate their own small robots that mimic human bi-pedal motion. Other materials to enhance the demonstration or fab lab presentation would include High Speed or motion capture photography of people/robots walking in different ways.

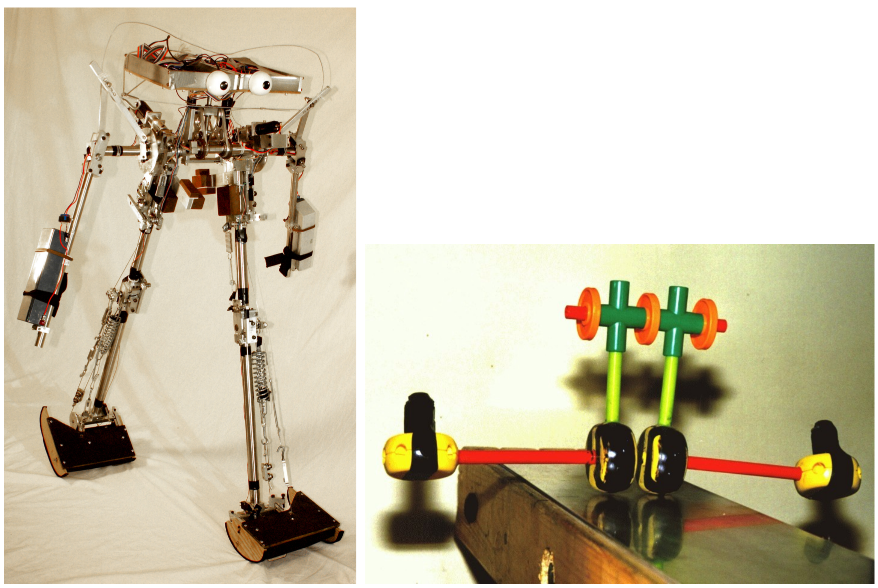


Figure 1: A sample walking robots. Right: Full sized, fully articulated robot that could walk on the floor of MSI. Left: TinkerToy walker that could be created in the Fab.Lab.

Requirements:

Collaboration with Professor Ruina or someone doing similar research in the field., 1 Functional robot, 1 demonstrator.

Evaluation Process:

- Front end evaluation on movement and protheses
- Prototyping of walking robots to find the most robust, accessible
- Several test demonstrations.

1.2 Teaching a Robot To Learn

Project Type: Demonstration
Museum/Venue: MSI, Great Hall or Classroom
Target Audience: Older Children and Adults

This demonstration involves a resilient robot with self-modeling capability. It would connect best with the upcoming mars exhibit. The big idea is: How do you teach a robot to deal with unexpected situations? How would the mars rover recover if it broke a leg? You give the robot a goal (walk), and instead of following a preprogrammed walking routine, the robot teaches itself to walk(See Appendix A). It first uses sensors and random motions, then self-designed test motions to discover what it looks like (how many legs, knees, how strong, etc.). It then uses a computer program to create, test, modify, and retest algorithms that allow it to walk. It succeeds in this endeavor, but comes up with different solutions each time and does not come with solutions we might expect. If damaged, however, the robot can repeat this process and continue to work. The demo emphasizes that know how to learn is a far more powerful tool than any specific facts.

The demonstration would consist of a demonstrator, a robot, and a computer screen. While a demonstrator talked about learning, testing hypotheses, algorithms, applications, and explained what the robot was doing, in the background, visitors could see what what happening in the robot's 'brain' and watch the robot. At first the robot would make small motions (flexing a leg), eventually with would get up and walk across the floor (This happens in a few minutes). The demonstrator could detach a leg, and the process would repeat.

Because of the continuous process, visitors could enter the demonstration at many points. Having a robot walk around the floor would attract attention. The following activity, or one similar, could be done with the visitor to help demonstrate what the robot was doing:

1. Hold up a black box with a common object inside it:
2. Ask people to guess what was in the box just by looking at it
3. Then let them choose what test they would like you to do next: Shake the box, Let them smell the box, Feel how heavy the box is etc.
4. After each test they have to guess, eliminating possibilities and refining their model of what is in the box making the analogy to how the robot builds it's self-model

The demonstrator could then ask them to think up different ways that animals walk: (crabs, spiders, starfish, inch worms, dogs, horses, etc.) and guess how the robot will walk. (It will come up with different solutions each time).

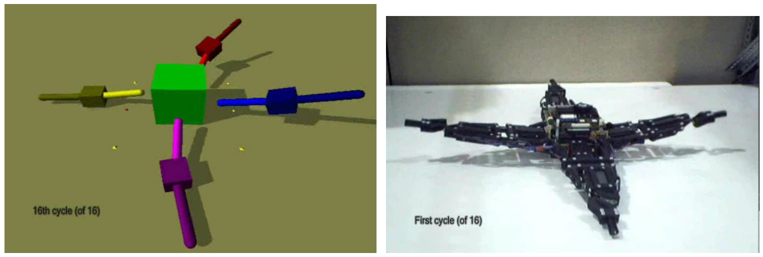


Figure 2: A resilient self modeling robot. Left: The robot's deduced self-image. Right: The robot's actual physical appearance.

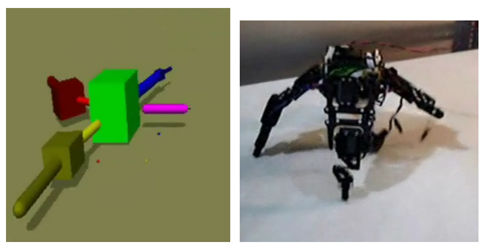


Figure 3: A resilient self modeling robot after damage has ocured. Left: The robot's new self-image. Right: The robot's actual physical appearance. Note that the robot is walking despite damage.

Requirements:

Collaboration with Professor Lipson or someone doing similar research in the field., 1 Functional robot, 1 Computer, 1 demonstrator.

Evaluation Process:

- Front end evaluation on misconceptions regarding robots.
- Evaluate robot on floor for robustness, appearance, interest, etc.
- Several trial demonstrations.

1.3 Evolve Your Own Robot?

Project Type: 1 or more day laboratory program.
Museum/Venue: MSI, Fab. Lab.

Target Audience: School Groups, same audience as the Crime Lab.

We envision a flexible program that could run in the Fab. Lab. and range from a 1 day activity to a several week project. The core of the project is a the combination of a computer program that uses 'genetic algorithms' to 'evolve' walking robots and the ability of the Fab. Lab to print these robots.

The computer program starts with a few simple building blocks (legs and knees, or rods and linear actuators) and a goal (walking the farthest). It then allows, through random mutation and survival of the fittest, walking robots to 'evolve'. The Fab. Lab. could print the designs and have the participants assemble and test their robots or have pre-printed kits of the robot parts and visitors could use the output of the program as a blueprint to build the robots. This core provides the framework to cover as wide or narrow a range of topics as is needed to fill the time (3D printing, evolution (and whether this qualifies as evolution), mechanics, electronics, algorithms and computer programming, computer assisted design, importance of initial conditions, etc.). It also allows the Museum flexibility of topic to highlight any current, future or traveling exhibit such as (Mars exploration, The Body Human, Smart Technologies). We propose to develop a first a 1 day program program and then if there is time and interest, expand it to a several week program consisting of modular lessons.

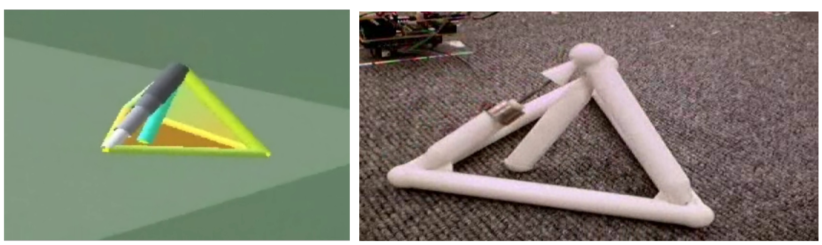


Figure 4: A sample 'evolved' walking robot. Left: Picture from program that created the robot. Right: The robot after 3D printing and installation of linear actuator.

Requirements:

Use of the Fab. Lab. to create the parts, 1 or more computers, Software (open source), a stock of small linear actuators and wire, presentation equipment.

Evaluation Process:

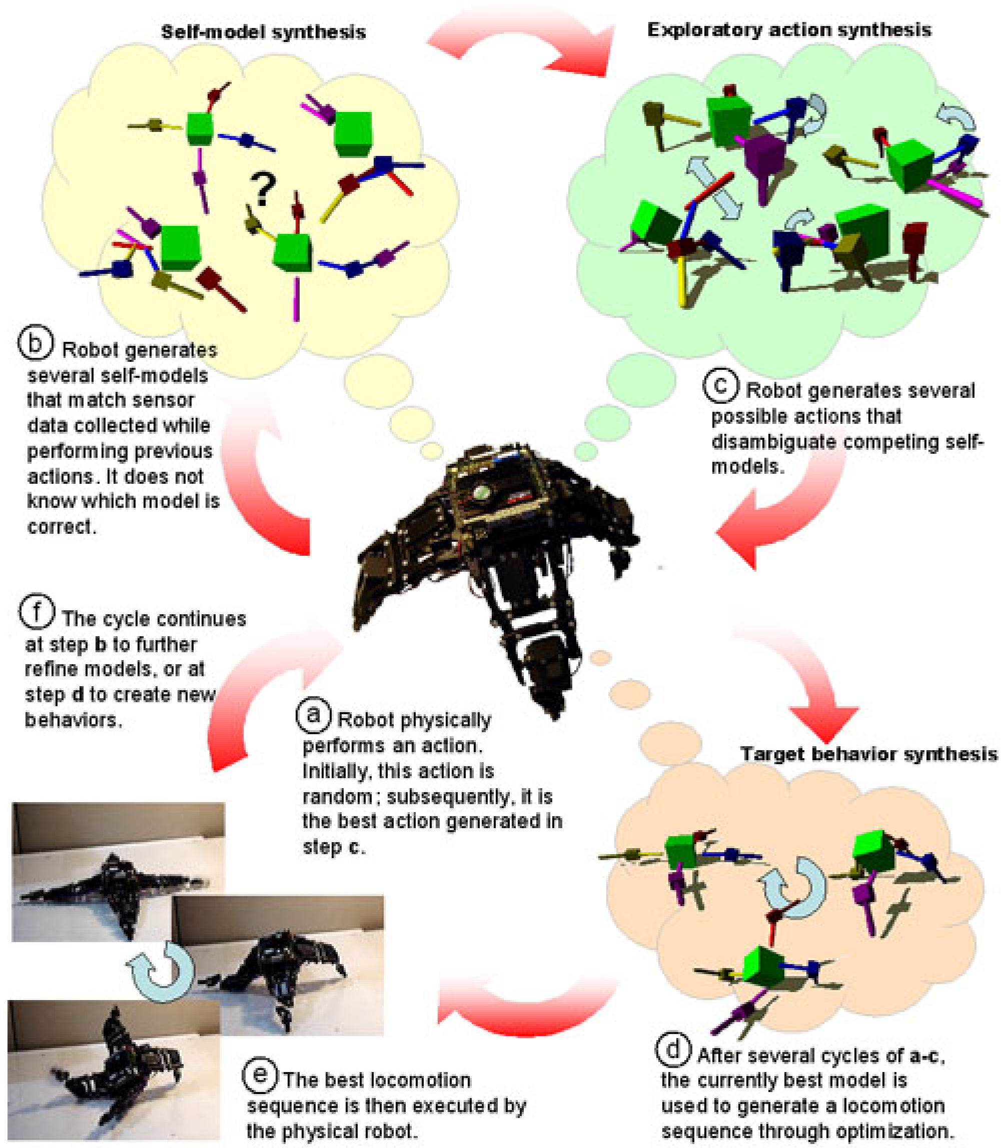
- Confirm our ability to use the technology by creating, printing, and building a test robot in the Fab. Lab.

- Do front end surveys to determine which aspect would be most interesting, are best/least understood, and what is the best approach to the 'connecting to every-day life' aspect of the program.

2 References

1. The Ruina Lab: http://ruina.tam.cornell.edu/
2. The Lipsom Lab: http://ccsl.mae.cornell.edu/
3. The Hornby Lab: http://ic.arc.nasa.gov/people/hornby/
4. The DEMO Lab: http://www.demo.cs.brandeis.edu/
5. The Hatsopoulos Lab: http://pondside.uchicago.edu/oba/faculty/Hatsopoulos/lab/

A Poster Describing the Learning Robot



B Sample Outline for Evolving Robot Lab

1. One Day:

   (a) Introduce ideas of evolution vs. design, programs and algorithms, robots.

   (b) Have students start the program.

   (c) Background on the possible uses of computer assisted design, etc., Talk about initial conditions, and the fact that there can be multiple solutions to a problem.

   (d) Assemble robots using kits of pre-assembled actuators and Fab.Lab. parts and using blueprints of robots from program.

   (e) If time, compare performance of several robots to each other and to their virtual counterparts.

   (f) Tell students how they can continue the development at home/at school in the classroom.

2. Day 1 of a Longer Program:

   (a) Introduce ideas of evolution vs. design, programs and algorithms, robots.

   (b) Have students start the program, choosing initial conditions, etc.

   (c) Elaborate on concepts, explain how the fab lab works, play and algorithm game

   (d) Choose a robot to print.

3. Day 2 of a Longer Program:

   (a) Check on the progress of the robots.

   (b) Cut out pieces of your robot that was printed.

   (c) Learn about linear actuators, wiring, how to download and control the robot.

   (d) Assemble your robot.

   (e) Compare performance of several robots to each other and to their virtual counterparts.

   (f) Tell students how they can continue the development at home/at school in the classroom.