An Implementation of Artificial Physics Using AIBO Robots and the Pyro Programming Environment

By Ankur Desai

1. Introduction

Historically, the field of robotics has been focused on the use of a single robot capable of a number of complex tasks. However, as the science matured, it became apparent that we were attacking the problem from the wrong angle. Not only are these highly complex robots difficult to build, the fact that a single robot is responsible for so many tasks means that a single malfunction can cause a multitude of problems. In recent years, there has been a shift of focus towards the use of large groups of more simple robots. While it is extremely difficult to design a single unmanned aircraft to take the place of a highly skilled fighter pilot, a large swarm of autonomous unmanned gliders could easily be just as effective.

As robotics begins this trend towards cooperative groups of robots, it has also become necessary to design artificial intelligence systems that are in turn much simpler. Instead of having a wide array of sensors and a powerful on-board computer, artificial intelligences must often rely on the data from a single sensor that can be processed quickly and easily. Thus, many of the current systems used to control groups of robots are based on biological behaviors. For example, the behavior of a flock of birds or a colony of ants can be modeled with a few simple rules. Taking this idea further, one of the newest systems of robot control takes advantage of physical laws of nature, such as the forces of gravity and magnetic attraction. Artificial Physics (AP) can be used to control large groups of robots by simulating physical forces as if each robot were a single molecule.

2. Artificial Physics

One possible behavior for a group of robots would be to arrange themselves into a grid without outside assistance. This could be useful in a number of different ways; for example, a group of satellites could autonomously arrange itself into an antenna array. At first glance, such a behavior would appear to require the use of an external camera capable of tracking all of the robots and directing their movements. However, it can in fact be accomplished by a robots equipped with only a rangefinder and guided by a simulated gravitational force. The robots are programmed to follow a single rule – if two robots are closer than a distance *r*, they repel, if they are further, they attract. If a group of seven robots are set into this environment, it is easy to see how they would eventually form a hexagonal grid (with one in the center). Logically, the robots would settle into a formation that allows every robot to maintain a distance *r* from its neighbors. This elegant solution is the basis of artificial physics.

Forming hexagonal grids is a very basic application of AP. The system is capable of guiding much more complex behaviors with equal ease. For example, imagine a group of robots tasked to patrol an area and keep any intruders from entering. Using AP, the robots could be programmed to behave like the molecules in gas, spreading out evenly across the area. The guard robots would be "attracted" to any intruder that entered the area, and would chase it out. However, since the guards themselves repelled each other, only a few would confront each intruder, so that the other side of the area would never be left exposed. If one of the robots were destroyed, the others would react perfectly, diffusing to fill in the empty space. Once again, AP is able to cleverly and simply solve the problem.

3. Sony AIBO Robots

Since AP treats each robot as a particle, the actual shape and structure of the robot is unimportant. For the purposes of research, the Sony AIBO robot (modeled on a dog) serves as a useful platform. The AIBO was marketed as a toy robot to be used for entertainment, but new software such as Tekkotsu (cs.cmu.edu/~tekkotsu) allows users to circumvent the original programming and directly control every aspect of the AIBO. Using this software, it is possible to gather the raw data from all of the AIBO's sensors, which include a camera, microphones, and three infrared rangefinders. One can also control the AIBO's movement in complete detail, with individual control over each joint. Also, the ability for the AIBO to communicate wirelessly with a single host computer makes them ideal for use in AP.

That said, there are certain

limitations to using the AIBO. Since the design is based on a biological dog, the AIBO is only able to move its head 180˚, meaning it can only gather data about half its environment. In addition, the rangefinder data is not exceptionally accurate, as the robot was not designed for serious research. There are, however, certain ways to work around these limitations. One method is to use a camera to track all of the robots and provide their localization data. While possible, this method adds an unnecessary level of complication, as it requires the use of computer vision and tracking. However, it is also possible to rely on the odometry data from the AIBO. While further testing is necessary to determine how accurate this data is, it is possible that if the initial position of the AIBO is known, the host computer can keep track of the robot’s position by extrapolating based on the robot’s known movements. This is the most likely avenue of experimentation.

4. Python Robotics

As mentioned above, Tekkotsu allows users to control the AIBO in great detail. However, it is often more useful to maintain high-level control. That is, instead of having to manipulate each joint of the robot's legs, it is more effective to pre-program a walking routine and be able to simply direct the robot to move forward or turn. It is this high-level control that Pyro (Python Robotics) is able to provide. By interfacing the Python interpreter with the Tekkotsu library, Pyro allows users to control the AIBO much more easily and interactively. Pyro also provides access to a simple robot simulator environment, so that users can test programs virtually before using them on the actual AIBO. For these reasons, one of the most important tasks in this project is to establish a method of connecting to the AIBO robots from Pyro.

5. Conclusion

This project can be divided into three major components. The first step is to begin experimentation with the Sony AIBO robots in order to determine whether they are suitable platforms for further research. While we are hopeful that the rangefinder and odometry data from the AIBO will prove satisfactory, it is possible that a different robot may be necessary. The second phase is to establish a method of controlling the

AIBO through Pyro. Finally, we will begin to implement an AP system in Python that can be used to control a group of robots.