CS 206 Evolutionary Robotics

Final Project — Written Report

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a. The first section should describe your goals: what you were trying to evolve your robot (or robots) to do? How did your deliverables move you toward that goal? How close did you get to your goal?

My goal is to build a robot with four wheels to shoot a ball into a hole, and then the robot should learn to shoot one ball to collide with the other ball into a hole. My deliverables were developed as follows. The first deliverable was the report. Second, a robot with four wheels was built and it succeeded to move forward and turn its direction. Third, an environment with a robot, a ball, and four holes were built. Fourth, the robot started to shoot one ball into a hole. In this deliverable, genetic algorithm was applied, and it succeeded. This task was planned to be in the fifth deliverable in origin.

From the fifth deliverable, all deliverables were moved up. Originally, I should apply genetic algorithm in the fifth deliverable, build the second environment in sixth, search the environment in seventh, start to shoot and let two balls collide in eighth. As a result, fifth, I started to work on the second environment with two balls. In addition, the fitness function was changed to achieve the goal, but it failed to complete the task. Sixth, some sensors were created to fix the fitness function. The robot succeeded only a few times, because the fitness function was not strong enough for the robot to evolve. Seventh, I tried to fix the fitness function, but the robot tended to shoot both balls; or it shot one ball, but both balls failed to fall into holes. Eighth, the first environment where there is only one ball was deleted, because I realized that the robot should do different tasks in two environments. However, even with the deletion, the robot still could not complete the task appropriately. Finally, the environment was

narrowed to shorten the distance between balls and holes to solve the problem of weak force, and the possibility of success were increased. Also, I changed the fitness function slightly.

After nine deliverables, as a result, I have succeeded to achieve my goal but only the second environment with two balls was maintained.

b. **The second section should describe implementation details: how did you code up your final project? What was your strategy?**

The whole project was built based on the genetic algorithm in assignment 10, so there are seven python files: constants, environment, environments, geneticAlgorithm, individual, population, and robot. The major changes for my project are in the robot, the environment, and the individual. Therefore, I will explain my implementation in these three parts.

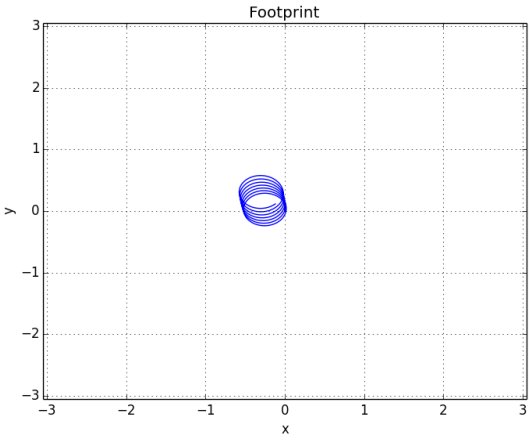
First, the robot's task is to move and shoot a ball. Four wheels were separated to left and right groups. The robot turned because the speed of left wheels was different from right wheels. Also, because it should only move forward instead of backward, the lo value of joints in wheels was set to be -3.14159 and the hi value was set to be 3.14159*2. To shoot a ball, a light sensor was put in the robot's body, so it can shoot the ball with a light source.

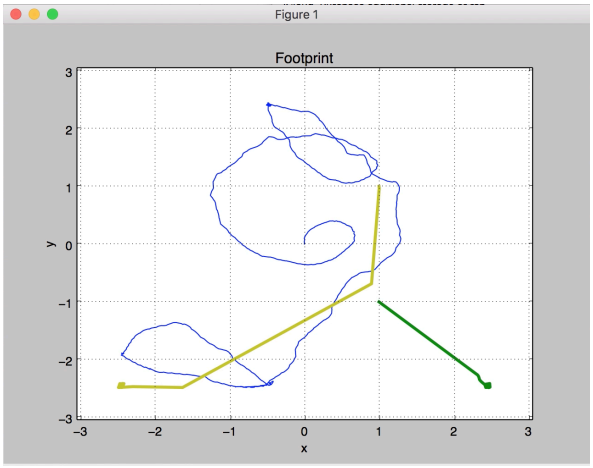
Second, in the environment, I built two balls, a box as the floor, and several boxes beside the floor for four holes. The first ball was set to be a light source for the robot to shoot, and the second ball had a light sensor and a position sensor for the collision of two balls and to detect if it fell into a hole. There were also four light sensors to check if the first ball was in a hole.

Third, in the individual file, all sensor data were obtained and printed to easily adjust the fitness function. My fitness function contains four parts. The first is the maximum value for the light sensor in the robot, which shows if the robot shoots the ball. This value is only multiplied by 10, because this task is easy to happen. The second is the last value of light sensors in holes,

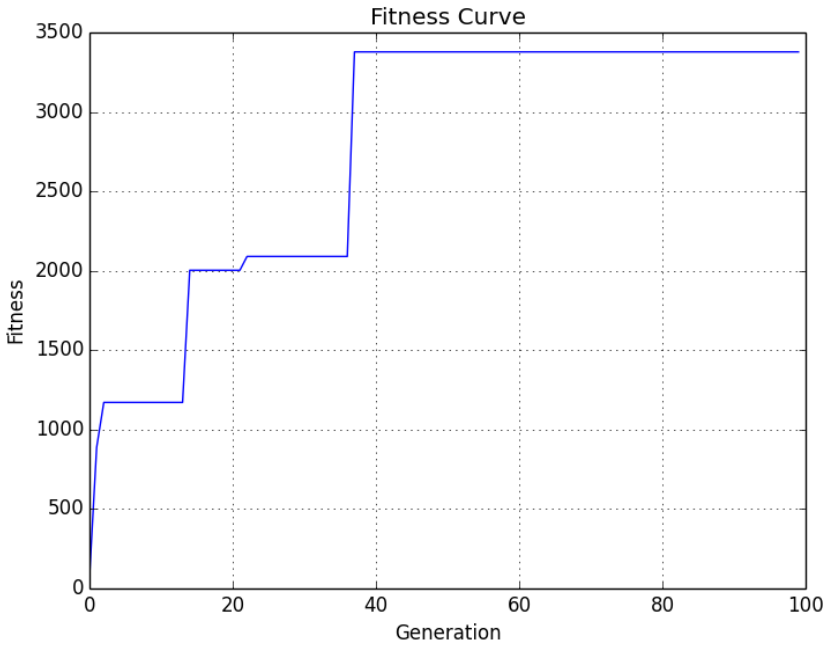
which detects if the first ball falls into a hole. This value is multiplied by 30, because it is a more important to let the ball fall into a hole. The third is the maximum value for the light sensor in the second ball, which shows if two balls collide. This value is multiplied by 200, because the collision of two balls is the essential task, which needs to be much more significant. The fourth is the last value of z-position sensor in the second ball to check if it falls into a hole. The fitness value will be added by 700 if this value is lower than 0.4, which shows that the position of the ball is lower than the floor, so it is in a hole.

c. **The third section should provide some results. Most importantly, you should demonstrate that evolution did in fact occur: show that an evolved robot did better than a randomly-generated robot in some way. You may want tø include fitness curve graphs here, footprint graphs, and/or screenshots of the robot in its virtual environment.**





The left footprint figure shows that before evolution, the robot only went in circles and did not touch any ball. The right figure shows that after evolution, the robot succeeded to shoot the first ball, and the first ball also collided with the second ball. Finally, two balls both fell into different holes.



This figure shows how fitness value changed after evolution. The fitness value increased along with the evolution of robot after 100 generations. The population size is 10.

d. **In the final section, you should demonstrate that you've thought carefully about your final project. What was surprisingly difficult? What was surprisingly easy? If you had another year to work on this project, how would you expand your project? What new features would you want Pyrosim to have to achieve this? Which aspects of the expanded project do you think would be relatively easy, and which difficult?**

There are three difficulties in this project. First, the tau values in the motor neuron of joints in wheels were set as 0.7. If tau values of wheels were smaller, the force of the robot would be too weak to shoot balls into holes. If the values were larger, then the robot would be unstable. I narrowed the environment to fix this problem, but the result still failed to complete the task sometimes because of this problem. Second, to implement the collision, I used the new version of Pyrosim, which is possible to cause the explosion of all objects when the robot falls into a hole and results in a high fitness value. Third, my project includes three small goals: the

robot shoots a ball, the ball collides with the other ball, and two balls fall into holes. Therefore, even if I have multiplied all sensor values by different numbers, it still cannot succeed every time.

The easy part of this project is that I can only change previous assignment of genetic algorithm to achieve my goal, which is the benefit of object-oriented programming. Also, because I chose to build wheels instead of legs, I did not need to evolve the robot to move.

If I had another year to work on this project, I would try to detect the positions of balls and holes and calculate the angles for shooting. After calculation, the robot should shoot a ball in a much stronger way, push the ball to collide with the other ball, and let it fall into a hole according to the angles of each objects like the billiard game. In this way, the robot would try to shoot the ball instead of pushing the ball. Also, two balls could roll into holes more directly without any slow moving along the walls. Because in the real billiard game, balls are not supposed to roll along walls for a long time like how my current project did. If it is possible, I would also try to put several balls on the floor simultaneously.

To achieve the new goal, I will need the feature of steadier movement. I thought using wheels could make the robot move easily without falling or jumping, but it was still not stable enough for my project. In addition, the sensor to detect the angle of an object will be needed for the calculation. Furthermore, for the robot to shoot a ball more directly, Pyrosim should be able to give an instant force to the robot. If there are these three new features, this project will be more possible to succeed.

If I am building the extended project, I think the most difficult problem to solve is the calculation. After obtaining angles of balls and holes, it is complicated to combine all angles and conclude a path for the robot to shoot a ball. Even if the number of population and the number

of generation are set incredibly high, the goal will be still too difficult to achieve if there are only sensors of angles. However, if I still use the light sensors and position sensors, it can still be able to succeed. Therefore, I will add some angle sensors and maintain original sensors, and the result may be better than now.