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Evolutionary Development of Path Planning Algorithms

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This paper describes the use of evolutionary software techniques for developing both genetic algorithms and genetic programs. Genetic algorithms are evolved to solve a specific problem within a fixed and known environment. While genetic algorithms can evolve to become very optimized for their task, they often are very specialized and perform poorly if the environment changes. Genetic programs are evolved through simultaneous training in a variety of environments to develop a more general controller behavior that operates in unknown environments. Performance of genetic programs is less optimal than a specially bred algorithm for an individual environment, but the controller performs acceptably under a wider variety of circumstances. The example problem addressed in this paper is evolutionary development of algorithms and programs for path planning in nuclear environments, such as Chernobyl.

The objective of this evolutionary software development is to create a useful control program for collision-free path planning in radioactively hazardous environments. Evolutionary techniques are used to develop both genetic algorithms and genetic programs that navigate a model autonomous rover through such an environment to a defined goal, then to a final destination point. An example of such an operation would be the retrieval of an object near the Chernobyl reactor core and transport of it to a drop-off point at a reprocessing station.

The environment consists of a two-dimensional Cartesian space containing the goal, the final destination, various physical obstacles, and various radiation obstacles. The physical obstacles are impenetrable so that a rover attempting to move into the Cartesian coordinate occupied by the physical obstacle will "bounce" back, and will be "hurt" accordingly. The radiation obstacles may be penetrated, but only at a cost of "hurting" the rover quite substantially. The radiation obstacles also "hurt" the rover in an inverse square relationship, so that as the rover passes a distance away from a radiation obstacle, the obstacle will generate "pain" for the rover based on the relationship (constant * 1/r^2).

The genetic algorithm was used to solve the path planning problem through a known terrain. By allowing rover motions such as left, right, up, and down, the genetic algorithm created a path from the initial location to the goal, then to the destination by ordering a certain number of the above moves. The genetic program was allowed each of the above motions, as well as the motions "remain still", "move forward", "move back", and "move to goal". "Move forward" moved the rover in the direction it had just moved, while "move back" moved the rover back one space. The genetic program was also allowed to compare sensory information to supplied constants by utilizing an "if less than or equal to" statement. The sensory information consisted of distance and direction of nearest obstacle, strength and direction of largest radiation source, and direction of goal.

The evolutionary software randomly created an initial population of individual algorithms, tested these individuals for fitness, then, over a predetermined number of generations, combined parts of the best individuals of each generation to produce the next generation of individuals. The genetic algorithm was implemented as an array of moves, while the genetic program created algorithms that were implemented as parse trees. Each node in these parse trees consisted of either comparative statements that branched into if or else structures, or moves. Each branch of the tree terminated in a move. A number of genetic algorithms were developed for several different environments. In each case, the genetic algorithm successfully navigated through the known terrain, reaching first the goal, then the destination point, while avoiding the physical obstacles and minimizing exposure to the radiation obstacles. The genetic program created an algorithm that successfully navigated three different terrains, in each case reaching the goal, then the destination, while avoiding the physical obstacles and prolonged exposure to the radiation obstacles. The algorithm created by the genetic program was then utilized on a terrain that it had not experienced during training, where it successfully navigated to the goal and destination, while avoiding the physical and radiation obstacles. Thus, the algorithm created by the genetic program is more robust than the genetic algorithm, and is capable of navigating through some unknown terrains.

Future work will entail further training of the genetic program, with the objective of developing algorithms that are more robust and capable of correct operation in a large number of environments.

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