Expert Systems with Applications 36 (2009) 5157–5161

Contents lists available at ScienceDirect

Expert Systems with Applications

journal homepage: www.elsevier.com/locate/eswa

An application of the genetic programming technique to strategy development

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ARTICLE INFO

Keywords:
Strategy development
Genetic programming (GP)
Co-evolution process
Imaginary enemy

ABSTRACT

In this paper, we will apply genetic programming (GP) and co-evolution techniques to develop two strategies: the ghost (attacker) and players (survivors) in the Traffic Light Game (a popular game among children). These two strategies compete against each other. By applying the co-evolution technique alongside GP, each strategy is used as an "imaginary enemy" from which evolves (is trained in) another strategy. Based on this co-evolutionary process, these final strategies develop: the ghost can effectively capture the players, but the players can also escape from the ghost, rescue partners, and detour around obstacles. The development of these strategies has achieved phenomenal success. The results encourage us to develop more complex strategies or cooperative models such as human learning models, cooperative robotic models, and self-learning of virtual agents.

1. Introduction

In the past decades, human beings tried to develop computer intelligence such that the computer would possess powerful abilities in both computation and inference. However, it is very difficult for a computer to automatically generate effective strategies. In this paper, we will apply co-evolution and genetic programming (GP) techniques to develop two strategies: the ghost's and players' strategies in the Traffic Light Game. Experimental results show that the generated strategies satisfy the requirements within the simulated world. Some of the strategies are similar to those we use, while others among them had achieved phenomenal success.

GP is one kind of artificial intelligence technique which applies a genetic algorithm (Goldberg, 1989; Holland, 1975) to programming. To accomplish this, initially, a set of computer programs are randomly generated. These then breed and give birth to a growing population using the Darwinian principle of survival of the fittest. This new population of programs is generated by evolutionary operations (replication, crossover, and mutation) carried out on the program trees. Two program trees (parents) would generate two offspring after using the crossover operation, and some offspring with higher fitness would survive (meaning they would be selected into the next generation). Based on Darwinian Theory, the offspring will satisfy the predefined conditions to greater and greater degrees. This technique is also suitable for developing strategies. Fig. 1 shows a simple example of applying the crossover operation to two strategy trees and of the generated offspring the two which have the highest fitness survive (selected) into the next generation.

Traditionally, we solve a problem by using a top-down methodology. A problem is often decomposed into sub-problems which are then solved and the solutions of which are then assembled to form the solution to the overall problem. The top-down approach is similar to the divide-and-conquer technique that often calls for less effort than the amount of effort that would have been required to solve the original problem without the aid of the decomposition process. However, some problems may exist in this approach for strategy development: first, the top-down approach for strategy development by human beings is subjective. Different views of the same problem held by different people generate different results. What then is the optimal strategy? There is no reliable answer. Second, humanly developed strategies often have "blind spots" in them. Some of actions in strategies designed by human beings may be useless and would become "dummy" actions in the developed strategy.

Another approach, strategies developed by genetic programming techniques, is a bottom-up methodology. The defined functions and actions are combined automatically and dynamically to form a strategy for solving a particular problem. Based on the evolution principle, some good (optimal or near optimal) strategies with the highest fitness value would evolve. However, the bottom-up approach for developing strategies may also involve some problems: first, the process of evolution from a set of functions and actions into a good strategy often requires a lot of time, especially for a large set of functions and actions. Second, the generated results may not suit the real problem if the fitness function had not been defined well.

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doi:10.1016/j.eswa.2008.06.066

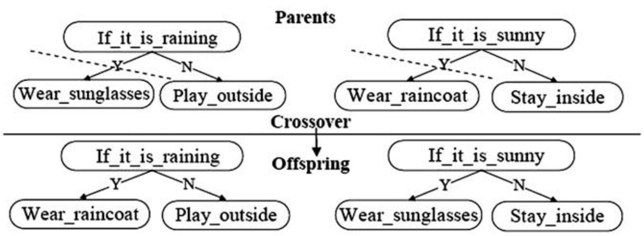

Fig. 1. Two strategy trees are generated by crossover operation and the offspring which have the highest fitness survive into the next generation.

To overcome these two problems, we apply some techniques during the evolutionary process. The first problem can be improved by restricting the height of the strategy tree during the evolutionary process. Then the complexity is limited and the evolutionary process is more effective. To solve the second problem, we check the equivalence between the fitness function and the optimal solution of the problem. If the highest value of the fitness function is equal to the optimal solution and the higher fitness value is the better solution to the problem, then the fitness function properly represents the solution to the problem.

We will apply the GP technique and co-evolution processes to evolve two sets of strategies, those of the ghost and players in the Traffic Light Game. The Traffic Light Game is popular among children. In this game, each gamer takes on the role of either the ghost (attacker) or a player (survivor) and runs around in a predefined area. The ghost chases players in this area, and the players must run away from the ghost and rescue their partners who are stuck in a "red light" state. When the ghost touches a player who is in a "green light" state, the game ends. So it is that the players want to cooperate with their partners in order to survive longer. The rules of the Traffic Light Game are as follows:

(1) At the beginning of the game, one player is selected to be the ghost and the others are the players.
(2) Initially, the players are all in the "green light" state and can move freely in the predefined area. A player can call "red light" at any time to enter a safe state where the ghost cannot hurt them. However, it is a restricted state; when a player calls "red light", that player must stop moving and squat down (locked). He cannot voluntarily leave the red light state.
(3) The "green light" players can move to rescue the "red light" ones by touching them at which point the state of the "red light" players returns to "green light".
(4) The game ends either when the ghost touches a player who has not called "red light" in time or when all of the players have become stuck in a "red light" state with no one to rescue them. In the latter case, the one who first called "red light" becomes the ghost in a replay of the game.

In this GP based research (Andre, Bennett, & Koza, 1996; Cheang, Leung, & Lee, 2006; Cho, Cho, & Zhang, 2006; Hoai, McKay, & Essam, 2006; Koza, 1992; 1994; Miller & Smith, 2006; Nakamichi & Arita, 2005; Negnevitsky, 2004; Sun & Chen, 2000; Sun, Tsai, & Lai, 2001) applied to the Traffic Light Game, strategies of the ghost and players co-evolve. In this simulated world, ghost and players can adapt their strategies according to their conditions and circumstances which cause their strategies to evolve. Toward the end of the co-evolution processes, very good strategies have evolved among the ghost and players. Some of these strategies achieved phenomenal success. The experimental results encouraged us to apply the proposed technique to other fields such as learning strategies or robotic control in the real world.

2. GP for strategy development

2.1. Strategies

In the Traffic Light Game research, we expected that the ghost and players would be able to develop some good strategies through evolution. In the virtual world of this game, there are some fixed-obstacles (flower clusters) and some temporary ones ("red light" players). The ghost needs to evolve a strategy for detouring around these obstacles to chase the nearest "green light" player until all players call "red light" or a "green light" player is touched by the ghost (see Fig. 2).

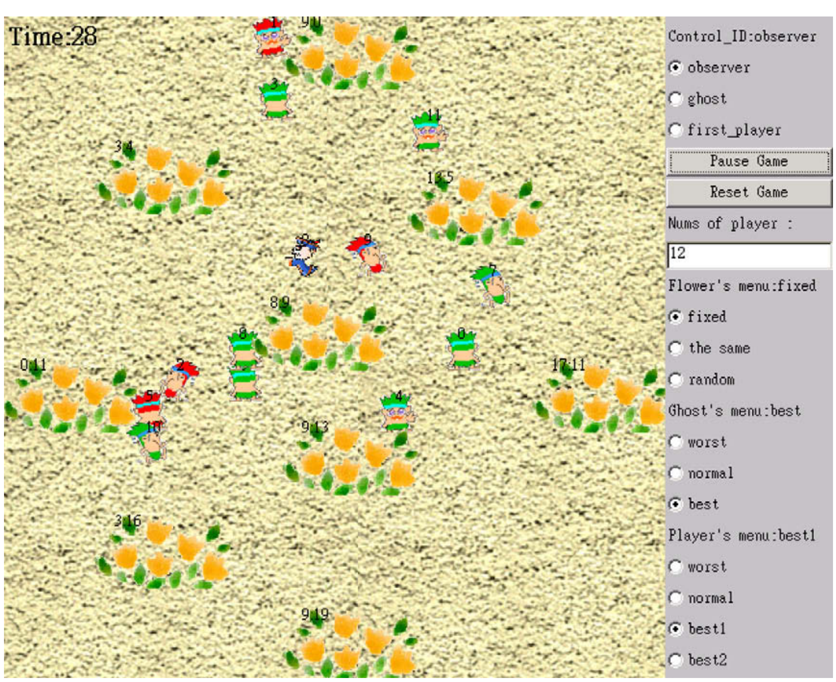

Fig. 2. The interface of the simulated world.