Incremental Genetic Programming via Genetic Transposition

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ABSTRACT

Genetic transposition is a process of moving sequences of DNA to different positions within the genome of a single cell. Inspired by the role of genetic transposons in biology, we introduce a genetic transposition inspired mechanism in genetic programming (GP). This mechanism, a simple variation from seeding in incremental evolution, provides a more effective approach to the evolution of systems with multiple features.

Categories and Subject Descriptors

[Artificial Life/Robotics/Evolvable Hardware]

General Terms:

Algorithms, Design, Reliability, Experimentation.

Keywords

Genetic transposition, seeding, genetic programming, Snakebot

1. INTRODUCTION

Discovered by Barbara McClintock in maize, the *transposons* are sequences of DNA that can move around to different positions within the genome of a single cell, in a mechanism called *transposition* [1]. In the process, they can cause mutations and change the amount of DNA. It is recognized that the transposons facilitate the evolution of increasingly complex forms of life by providing the creative playground for fast mutations where the latter could experiment with developing novel genetic structures without damaging the already well-functioning genome [4].

In this paper we propose a new approach to incremental evolution by seeding. Inspired by genetic transposition, we use the seed to create only part of a new individual. We speculate that it might be more efficient to evolve partial solutions to a target system and later on incrementally join these solutions to form a complete system. The proposed mechanism of incorporation of multiple features is based on seeding the initial population of GP via genetic transposition (GT). Using GT, the seed (a partial solution) does not form the whole genome of an individual, but only part of it. We believe that, similar to the nature, the latter would offer the opportunity to preserve the genetic makeup of the already well-functioning features intact, while incrementally "upgrading" it with the coevolution of the new abilities.

Seeding of the initial population by means of including the previously evolved successful (or partially successful) solutions has been shown to be an effective way of improving the efficiency

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of simulated evolution. For example, Nolfi et al. [3] evolve the controller of simulated robot and then re-evolve the obtained results on real robots to accelerate the evolutionary process.

The main inspiration of our work was the incorporation of new features to the sidewinding Snakebots [6]. In an earlier work it was observed that the direct evolution of sensing and fast moving Snakebots was much more challenging than the evolution of fast moving Snakebots with no sensing abilities. It was also observed that the evolved Snakebots with sensory abilities exhibit locomotion traits that are pertinent to the sensorless locomotion.

From another perspective, our work is inspired by the discoveries in the neurobiology suggesting that the complex navigation behaviors of species in nature can be achieved through an appropriate real-time modulation, controlled by the sensory inputs, of the generic neural signals produced by sensorless central pattern generators (CPG) [2]. Within this context, we would like to investigate whether (i) the separation of the genotype into two parts, mimicking the natural CPG and its modulation via sensory processing, respectively, and (ii) evolving these two parts in two consecutive stages would contribute to the improvement of the efficiency of evolution of the Snakebot.

The remaining of this document is organized as follows. Section 2 provides a brief explanation of GT. Section 3 discusses the experimental results, and Section 4 draws the conclusions.



Figure 1: The initial and final forms of GP trees when three of the different evolution approaches described are used.

2. GENETIC TRANSPOSITION IN GP

Incremental evolution has been shown to improve the efficiency of simulated evolution, and as well as improving existing solutions, incremental evolution has been applied to improve the performance of evolution in finding solutions from scratch. A technique, termed by Perry as "population enrichment" [5], has been demonstrated to be more efficient in discovering solutions in GP (than canonical GP). "Population enrichment" is a form of seeding that is closest to GT. The main difference in these methods is the form of initialization, where in the "population enrichment" the seed is a complete individual (see Stage 2a in Figure 1), while in the proposed GT the seeded genotype only forms a part of the genetic makeup of a newly created individual in the initial evolutionary population (see Stage 2b in Figure 1).

The implementation of GT (Stage 2b) along with canonical GP (Stage 1) and GP with classical seeding (Stage 2a) is shown in Figure 1. Both GT and classical seeding need to make use of a preliminary seed, and in our case this seed comes from a previously evolved partial solution (Stage 1).

3. EXPERIMENTS

The Snakebot is evolved applying three different evolutionary approaches: (i) Canonical GP (single stage approach), (ii) Typical seeding (two-staged approach), and (iii) Genetic transposition (two-staged approach). The experimental conditions are as detailed in [6]. For each approach we executed 16 independent runs. The experimental environment and the trajectory of a sample best-of-run Snakebot can be seen in Figure 2.

The experimental environment (Figure 2) is formed of a straight narrow corridor (the width is the same as the length of the Snakebot) that has two groups of tall boxes that protrude to about 40% of the width of the corridor. In addition, part of the corridor is covered by many, randomly located and sized, small boxes that are designed to create a rough terrain and noisy environment for the sensors. The length of the corridor is set to seven times the length of the Snakebot. Starting from one end of the corridor, the aim of the bot is to reach the other end within the given time-span.



Figure 2: The moving trajectory of the central segment and the center of gravity (COG) of a sample best-of run Snakebot, evolved by incremental GP with GT.

The results (summarized in Table 1) demonstrate the increase in the efficiency of GP when incremental evolution techniques are used. Futhermore, the GT mechanism is shown to drastically increase the effectiveness of GP in finding successful solutions. The efficiency of GP is improved by more than 8 fold when GT is used in comparison to classical seeding.

We speculate that the proposed approach allows the evolution to experiment with the way of processing the sensory signals without the risk of damaging the already evolved, fast locomotion control. Therefore, GT could facilitate the protection of the already evolved beneficial building blocks from destructive genetic operations. Conversely, since the locomotion control comprises 100% of the genotype of the bots created via typical seeding, any incorporation of the sensing information as a result of a genetic operation would most likely damage this control.

Our results can be seen as an evidence of the computational benefits of mimicking the neurobiological concept of achieving complex navigation behaviors through sensory-controlled modulation of CPG. The moving trajectory of a sample best of run bot (Figure 2) illustrates the emergence of the following abilities of the bot: (i) fast locomotion (clearing the corridor), that is (ii) not hindered by rugged terrain (overcoming small boxes), (iii) following obstacles that cannot be overcome (walls), and (iv) circumnavigating obstacles that cannot be overcome (tall boxes).

Table 1: Statistics of the experimental results.

	Canonical GP	GP with Seeding	GP with Genetic Transposition
Average Fitness	40.8	69.9	104.1
Median Fitness	34	66.5	101
Number of Successful Runs (out of 16)	1 (6%)	1 (6%)	8 (50%)

4. CONCLUSION

The evolution of a modular sidewinding Snakebot in a challenging environment with multiple forms of obstacles is a demanding task. It was shown that by dividing the task into two subtasks, implemented as two consecutive evolutionary stages, can significantly improve the evolutionary performance.

A biologically inspired technique, GT, was introduced to further improve the evolutionary process. It was shown that GT offered a significant improvement over typical seeding when applied to the evolution of an actively sensing and fast moving Snakebot. The experimental results demonstrate that when GT is used the evolution of a fast sidewinding Snakebot with obstacle avoidance properties becomes more reliable and less timeconsuming. The presented technique serves as a new approach to incremental evolution of multiobjective problems.

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