Towards Adaptive Mutation in Grammatical Evolution

David Fagan
david.fagan@ucd.ie

Erik Hemberg
erik.hemberg@ucd.ie

Michael O'Neill
m.oneill@ucd.ie

Miguel Nicolau
miguel.nicolau@ucd.ie

Sean McGarraghy
sean.mcgarraghy@ucd.ie

Natural Computing Research and Applications Group
University College Dublin
Ireland

ABSTRACT

Adaptive mutation operations have been proposed in Evolutionary Computation (EC) many times and in different varieties, but few have gained widespread use. In nature, mutation rates vary over time, however it has become common practice to use static, widely accepted, values for mutation, particularly in GP-like systems. In this study, an adaptive mutation operation is presented and applied to Grammatical Evolution (GE) over a variety of benchmark problems. The results are examined and it is determined that the new operators could replace the need to specify mutation rates in GE on the problem domains examined.

Categories and Subject Descriptors

I.2 [**Artificial Intelligence**]; I.2.2 [**Automatic Programming**]

General Terms

Algorithms,Theory

Keywords

Adaptive Mutation, Grammatical Evolution

1. INTRODUCTION

In the natural world, mutation rates increase and decrease over the course of time. It has been demonstrated that the ability to have variable mutation rates is desirable when trying to gain a foothold in a new environment [4, 8]. E.Coli Bacteria have been observed to benefit greatly from high mutation rates when establishing themselves in intestines; however, once this initial foothold has been established, the lower mutation rates that take over are the mechanism that helps the bacteria flourish as they preserve the good structures found during the initial period of high mutation.

In EC, it has become common practice to use previously determined, robust, values for genetic operators such as mutation [3]. Whilst many have tried to replicate the natural phenomenon of changeable mutations, few methods have gained widespread acceptance and usage in the community; however, the theory and identification of adaptations has been well described to date [1, 9].

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Previous work [2, 5] has examined mutation in GE, but focused more on applying mutation to different parts of the GE derivation process and analysing mutations behaviour with different chromosome encodings. For the first time this study presents an examination of adaptive mutation operations in GE. A new mutation operation is proposed and performance is compared against the standard mutation operator in GE.

In O'Neill et al. [7], open issues in the field of genetic programming are outlined that provide motivation for the adoption of adaptive search operators. Adoption of good adaptive and self-adaptive operators could remove the clutter from the user and allow for easier take-up of systems. Adaptive search may also prove beneficial with a move towards dynamic environments. The ability to adjust the system to its current environment may provide more efficient search. Many forms of Genetic Algorithms suffer from problems such as bloat, and convergence of a population to a local optima. Adaptive operators may provide the key to help reduce the impact of such phenomena.

2. FITNESS REACTIVE MUTATION

Fitness Reactive Mutation (FRM) is an adaptation of the mutation rate parameter at a population-level, that relies on feedback from the fitness of the population.

In nature, high mutation rates have been shown to allow for bacteria to gain a foothold in a new environment [4, 8]. Once this foothold has been established the smaller rate mutators take hold and retain the knowledge that is needed to survive and eventually flourish. In EC, it can occur that populations converge to a local optimum and lose the diversity needed to escape these optima and continue search. Fitness reactive mutation looks to combine the two ideas above by trying to identify possible local optima and then viewing the situation as a new environment. Once a fitness plateau is detected, FRM ramps up mutation rates to diversify the population in order to explore further in the search space for a better solution and avoid converging on a local optima. If a new optimum is found, it resumes search at a lower mutation rate to try to flourish in this optimum. This can also be considered an exploration - exploitation mutation strategy. It has been shown previously that linking adaptation to fitness values produces more efficient search [6].

$$Slope = \frac{best\ fitness^{finish} - best\ fitness^{start}}{window\ size} \quad (1)$$

Table 1: Avg Best Fitness and Solution Solved for Sym Reg over 100 runs

SR2	No Crossover		Crossover	
	SS	Avg Best	SS	Avg Best
GE 0.01	1	2.12 ± 2.17	1	1.65 ±1.67
GE 0.05	2	0.83 ±0.99	4	0.87 ± 0.96
FRM 2	4	0.83 ±1.05	3	0.90 ± 1.18

To accomplish this idea of avoiding plateaus in the best fitness of the population, a window of fitness values are observed. If the slope of the window, shown in Eq. 1, returns 0, the system knows that it was stuck in a fitness plateau for a certain number of generations depending on the window size in use, and deems this to be the start of converging on a local optimum. To counteract this the system increases the population's mutation rate in 0.01 increments every generation, until the upper mutation rate limit is reached, or the population manages to escape the plateau, at which point the mutation rate is reset to the initial level and the process of monitoring the window begins again.

3. EXPERIMENTAL SETUP

The aim of the study is to assess if the adoption of an adaptive mutation strategy within GE, can match, or enhance, the search performance of the standard mutation operation. Currently, the mutation operation in GE employs a static parameter based approach.

4. RESULTS

A brief selection of results on the Pagie2d SymbolicRegression over 100 runs is shown in Table 1. Originally, a mutation rate of 0.01 was chosen for GE and in this case FRM out performed standard mutation. However this advantage was soon equalised, when a range of mutation rates for GE were examined, as can be seen with GE 0.05 in Table 1. Further results were omitted due to space constraints.

5. CONCLUSIONS AND FUTURE WORK

This paper presents the first results of studies of adaptive mutation in Grammatical Evolution. By taking inspiration from how E.Coli Bacteria behaves when entering a new environment, an adaptive approach to mutation in GE was implemented and tested.

The main conclusion that can be drawn from this paper is that FRM can be viewed as a very good alternative to, or replacement for, the default mutation operation in GE. FRM provides all the performance gains that would be achieved by trying a range of mutation parameters in GE without any of the added computational overhead or knowledge needed to perform such a sweep. Given the trend in EC to use robust, commonly accepted values for these parameters such as 0.01 for mutation, the use of FRM provides several advantages in terms of fitness and solutions found, not to mention the ability for FRM to prevent convergence to local optima rather than global optima in some cases.

Further evaluation of the FRM operator is desirable on problems with a much higher number of generations to allow the operator to go through many cycles of values. The interval between mutation increases needs to be examined. Perhaps some form of, simulated annealing type, schedule could be used once the operator has detected it wants to reset to a lower value. The speed of increase of mutation rates as well as the magnitude of change could also benefit from this.

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