TITLE

Konrad Cybulski

Honours Research Notes

Faculty of Information Technology
Monash University
Australia
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Contents

1 Reading List

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2 Literature Summary

2.0.1 Interactive evolution of equations for procedural models [7]

Sims introduces a method for generating images by using Lisp expressions as individual genotypes for use in an evolutionary process. This method is introduced as extremely extensible in comparison to commonly used genotype expressions: fixed length strings, parameter collections, etc. The method for mutation involves the parsing of Lisp expressions as a tree structure which then adjusted according to the following rules:

- "Any node can mutate into a new random expression."
- "If the node is a scalar value, it can be adjusted by the addition of some random amount."
- "If the node is a vector it can be adjusted by adding random amounts to each element."
- "If the node is a function, it can mutate into a different function."
- "An expression can become the argument to a new random function."
- "An argument to a function can jump out and become the new value for that node."
- "A node can become a copy of another node from the parent expression."

Sims discusses the method by which two individuals in a population mate. This involves the random swap a single node from each parent. If this process results in an invalid genotype (Lisp expression) then the crossover is performed "until a legal expression results". The method of "Genetic cross dissolves" is introduced as a smooth transitional operator of reproduction.

The genotype representation and its corresponding mating/mutation procedure is shown to produce some truly remarkable images through a user-supervised evolutionary process. This involves the user selecting "one or more of [the generated images] for mutation and/or mating to produce the next generation, and the process repeats".

2.0.2 Evolutionary image synthesis using a model of aesthetics [6]

The overarching goal of this research is to investigate the use of multiple aesthetic fitness functions for unsupervised image generation using genetic programming. Those used involved the distribution of colours in the generated images. An existing image is used to determine the frequency distribution of colours as a target which is used as the first of two objective fitness functions. The second uses knowledge that the colour gradients in fine art tends towards a normal distribution.

The mathematical model of aesthetics, as discussed here, bases its colour gradient fitness function on the hypothesis that said normal distribution of colour gradients "has been an implicit aesthetic ideal of many painters throughout history".

The method used for generating images as part of the algorithm is a slight variation of that developed by Sims [7].

This research concludes that the use of "Ralph's bell curve response model" has an aesthetically beneficial impact on the generated images. When omitting the fitness function measuring deviation from the normal distribution of colour gradients, the images produced are resultantly "chaotic or bland, artificial, mathematical, and rarely appealing". When using solely the colour gradient fitness function, without a target frequency distribution, the highest fitness individuals tended toward a "narrow bandwidth of RGB space". Resulting in images that were "not very interesting to the human eye". Target images with a colour frequency distribution that inherently have a high deviation from the normal colour gradient distribution that resulted in "creative tension" were noted as producing "the most surprising results".

3 Research Notes

There exist methods for manipulating graph topologies such that the resulting evolutionary system increases the likelihood with which high fitness individuals fixate [1, 5]. This process involves numerous system factors: edge weighting, birth-death initialisation,

The main paper on which I am aiming to base my research on is that by Pavlogiannis, Tkadlec, Chatterjee & Nowak [1], which among other things, shows evidence of increasing fixation probabilities of advantageous mutants by structuring graph topologies according to a simple heuristic. This involves logically separating a directed graph topology into two parts: a hub, and branches. By doing so, and increasing weights directed towards the hub of a graph, the topology is able to maximise migration activitiy toward a centralised hub, and thus increase the likelihood of fixation for advantageous mutants.

4 Papers/Books

4.1 Creating arbitrarily strong amplifiers of natural selection on graphs [1]

This paper explores one of the fundamental ideas upon which a large portion of the proposed research is based. Graph topology has been shown to have a large impact on the rate of fixation for advantageous mutants [1, 5, 4]. Numerous graph structures have been found that increase the likelihood of fixation above levels expected for a well-mixed population [2, 5]; these are known as amplifiers of selection. While other topologies are known to decrease this likelihood, suppressors of selection. Properties such as distribution of edge weights, edge directionaility [5], and self-loops are also shown to greatly impact fixation probabilities.

As shown by Pavlogiannis, Tkadlec, Chatterjee, & Nowak [1], not only can fixation probabilities be amplified by tuning the properties of a graph topology, but can be constructed arbitrarily. This construction process involves adjusting edge weights to create two sections: a central hub, and a series of branches. The hub is constructed such that the nodes within it are tightly coupled, thus increasing the likelihood an advantageous strategy will fixate. Then propagating through the branches, fixating on the entire graph. This amplification is however dependant on the graph having both directed edges, and self loops. Undirected edges have been shown to inherently suppress mutant fixation [5]. While self loops do not themselves amplify selection in graph topologies, they are a property required to construct an arbitrary amplifier of selection.

5 Research Ideas

With a method for constructing graphs that are arbitrary amplfiers of selection, my primary aim is to leverage this ability to create an evolutionary algorithm that supports generative agents with high fitness.

Use methods discussed in *Evolutionary mixed games in structured populations: Cooperation and the benefits of heterogeneity*. By randomly selecting the game in which agents partake (snow drift, prisoner's dilemma), there is a proportional increase in population heterogeneity which increases cooperation. In terms of a generative evolutionary algorithm, by using multiple fitness functions, randomly chosen, tested against all, or a subset, to determine an individual's overall fitness.

5.1 Generative Evolutionary Algorithms

- Using traditional evolutionary algorithms to generate image generation neural network weight (been done before).
- Vary fitness functions based on graph location: certain node clusters will have a given fitness function that differs from another. An issue arising from this is that we have smaller populations evolving within themselves. If an outside enters a cluster, its fitness in the new population will be, with high probability, extremely low. In the proceeding selection iteration, it will most likely be killed by an insider.

6 Log

6.1 21-28 Jan 2019

I met with Jon McCormack yesterday to discuss potential project ideas and where to begin with my research. Before the meeting I was able to

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