An Artificial Ecosystem Algorithm Applied to the Travelling Salesman Problem

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ABSTRACT

An ecosystem inspired algorithm that aims to take advantage of highly distributed computer architectures is proposed. Our motivation is to grasp the phenomenal properties of ecosystems and use them for large-scale real-world problems. Just as an ecosystem comprises of many separate components that adapt together to form a single synergistic whole, the Artificial Ecosystem Algorithm (AEA) solves a problem by adapting subcomponents such that they fit together and form a single optimal solution. AEA can be differentiated from typical biology inspired algorithms like GA, PSO, BCO, and ACO, as they represent candidate solutions as individuals in a population. This is because AEA uses populations of solution components that are solved individually such that they combine to form the candidate solution. Like species in an ecosystem, AEA has different species that represent sub-parts of the solution, these species evolve and cooperate to form a complete solution.

1. INTRODUCTION

The natural evolution of species does not take place in a vacuum. Co-evolving species share their environments and form an ecosystem; a self-regulating complex of interactions that share the common goal of long term survival in the environment. When a holistic view is taken, each ecosystem is a carefully evolved balance between all species, that have been adapted to solve different areas of one problem.

We propose an Artificial Ecosystem Algorithm (AEA) that solves a problem by adapting subcomponents such that they fit together to form a single optimal solution, akin to the way an ecosystem consists of many separate components that adapt to form a single synergistic whole. AEA comprises of species representing sub-parts of the solution that evolve and cooperate with each other. In this way the AEA is designed to take advantage of highly distributed computer architectures. Two varients are described, the basic AEA and AEA with species, then apply to the Travelling Salesman Problem (TSP).

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2. ARTIFICIAL ECOSYSTEM ALGORITHMS

The ***Environment*** encapsulates the physical non-living environment that the Individuals will be interacting with, usually formulated as the optimisation problem to be solved. An ***Individual*** is an organism that represents segments of the solution to the problem, where each individual stores a fitness value. A sequence of individuals forms the solution. ***Species*** represents a population of individuals.

2.1 Basic AEA

We describe the basic algorithm, and then how it is applied to the TSP. We then introduce the Artificial Ecosystem Algorithm with Species. Two variations of the AEAS are described: the AEAS (K-Means) and AEAS (SOM), and their application to the TSP.

A random population is first created then, depending in their respective fitness values, individuals are connected to form a candidate solution. This algorithm has been successfully applied to TSP, where the *Environment* holds all the cities. An *Individual* represents a subpath (the movement between two cities). Multiple individuals connected together form the solution, see algorithm 1.

Algorithm 1 Basic AEA

```
Initialise; Environment E, Population P
Set iteration counter to 1
loop
    Pick a random individual iI as the first piece of solution
    loop
        Select Tn compatible individuals
        Find individual i2 with highest Fi
        Add i2 to overall solution and update Pi and Gi
    until overall solution is complete
    Update Potential Parents
    Update Fi for all individuals in the solution
    RemoveUnfitIndividuals
    AddIndividuals
    BalanceFitness
    Evaluate overall solution
    Increase Iteration counter
until stopping criteria is met
```

2.2 AEA with Species

In AEAS different species of individuals focus on different parts of the overall problem. The solution is now formed from a sequence of individuals that originate from different species, see algorithm.

AEAS begins by partitioning the overall problem into segments, where a species will address each segment. For a problem such as the TSP, this can be achieved using clustering algorithms to find groups of neighbouring cities; here we used K-Means clusterer and the Self Organising Map. AEAS then applies the Basic AEA to each species, and finally combines the results for each segment into a single overall solution. In parallel each instance of the AEA may be executed on a different processor, where those individuals represent fragments of the current solution segment only.

AEAS may use any suitable method for problem decomposition, it may not always be evident which clustering algorithm will be superior for a given problem. This is underlined by the Impossibility Theorem [2] in which no clustering algorithm can satisfy all data clustering axioms.

Algorithm 2 AEA with Species

```
Initialise Environment E
loop
    Decompose problem into small tractable segments
    for each segment do
        Create a population Ps of individuals
    end for
    for each species do
        Apply Basic AEA
    end for
    Connect all the segments to form a complete solution
    Evaluate overall solution
until stopping criteria is met
```

3. EXPERIMENTS

Two experiments performed in order to investigate the ability of AEA and AEAS to solve the TSP for different numbers of cities. The data used for testing includes: artificial TSP data (Equidistant 2D points lying on a circle of different sizes was constructed) and real TSP data from TSPLIB. For each dataset 30 independent runs are executed. The termination criteria set is no improvement in the optimal solution for 1000 iterations. We measure the deviation from the optimal tour cost, maximum and average tour cost values, as well as the number of evaluations used to find the optimal tour cost.

The first experiment is to analyse the effects of population size on a given problem size. Results showed that smaller population sizes provided solutions closer to the optimal, whilst larger population sizes made it harder to find good quality individuals to assemble into good overall solutions. Basic AEA struggled to cope with larger problems but AEAS provided considerably improved results.

The second experiment compares the number of evaluations used in order to find the solution and by how much the final solution deviated from the optimal value. Results show that the Basic AEA does not scale well with an increased problem size, increasing the number of evaluations required to build a solution and deviating from the optimal tour cost. Whereas AEAS scaled very well with increased problem size.

It is important to examine the capabilities of this new method in the context of results reported in the literature for other bio-inspired algorithms applied to TSP. Table 1 shows the results of AEAS (K-means) and AEAS (SOM) for different TSPs compared to GA, BCO and IWD. AEAS performs extremely well clearly demonstrating the potential of the approach.

Table 1: Comparative Analysis, results were taken from [4] [1]

File	Opt	AEAS1	AEAS2	GA	BCO	IWD
Eil51	426	**445.5**	452	445.8	447.8	471
Eil76	538	**555**	569		559	
Eil101	629	670.3	**631.6**			

4. CONCLUSION

This work presented the first ecosystem-inspired algorithm, designed to take advantage of highly distributed computer architectures and tackle large-scale problems. Just as an ecosystem comprises of many separate components that adapt together to form a single synergistic whole, the Artificial EcoSystem Algorithm (AEA) solves a problem by adapting subcomponents of a problem such that they fit together and form a single optimal solution. Experiments showed that smaller population sizes were more effective, and that the use of species in AEAS to solve segments of the solution enabled the algorithm to find better solutions compared to AEA. Indeed comparisons of AEAS with performance of other more established bio-inspired methods provided very encouraging results.

5. REFERENCES

[1] Divya Gupta. Solving tsp using various meta-heuristic algorithms. *International Journal of Recent Contributions from Engineering, Science & IT (iJES)*, 1(2):pp–26, 2013.

[2] Jon Kleinberg. An impossibility theorem for clustering. *Advances in neural information processing systems*, pages 463–470, 2003.

[3] Gerhard Reinelt. TsplibÑa traveling salesman problem library. *ORSA journal on computing*, 3(4):376–384, 1991.

[4] Gohar Vahdati, Mehdi Yaghoubi, Mahdieh Poostchi, and S Naghibi. A new approach to solve traveling salesman problem using genetic algorithm based on heuristic crossover and mutation operator. In *Soft Computing and Pattern Recognition, 2009. SOCPAR'09. International Conference of*, pages 112–116. IEEE, 2009.