An Artificial Ecosystem Algorithm Applied to the Travelling Salesman Problem

Manal T. Adham
Department of Computer Science
University College London
Gower Street, London, WCIE 6BT, U.K.
M.Adham@cs.ucl.ac.uk

Peter J. Bentley
Department of Computer Science
University College London
Gower Street, London, WCIE 6BT, U.K.
P.Bentley@cs.ucl.ac.uk

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. Typical biology inspired algorithms like GA, PSO, BCO, and ACO, represent candidate solutions as individuals in a population. However, 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 species that have adapted to solve different areas of one problem.

We describe 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 main versions of the AEA are described, the basic AEA and the AEA with species, they are then applied to the Travelling Salesman Problem (TSP).

GECCO'14, July 12–16, 2014, Vancouver, BC, Canada.
ACM 978-1-4503-2881-4/14/07.
http://dx.doi.org/10.1145/2598394.2598438.

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, each individual has a fitness value associated with it. A sequence of individuals forms the solution. ***Species*** represents a population of individuals, each population is a self contained unit.

2.1 Basic AEA

We begin by introducing the Basic AEAS algorithm and apply it to TSP. Then we move onto describing two versions of the AEAS with Species, the AEAS (K-Means) and AEAS (SOM), and apply them to symmetric TSP.

A random population of Individuals is first created, then relative to their fitness values, a sequence of individuals is connected to form a candidate solution. This algorithm has been successfully applied to TSP, where the *Environment* held all the cities, the *Individual* represents a subpath (the movement between two cities) and multiple individuals were connected to form a complete tour, see algorithm 1.

Algorithm 1 Basic AEA - Part I

```
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. AEAS begins by partitioning the overall prob-

Algorithm 1 Basic AEA - Part II

procedure AddIndividuals
  loop
    Select Tm individuals based on their fitness
    Remove Individual with lowest Fi
  until R individuals have been removed
end procedure
procedure RemoveUnfitIndividuals
  loop
    Use crossover to create Individuals
  until R individuals have been added
end procedure
procedure BalanceFitness
  Fu = 0
  loop
    Pick a random pair of individuals i1 and i2
    Fitness of i1 is Fi1; fitness of i2 is Fi2
    if $Fi1 = 0$ and $Fi2 > 0$ **then** $Fi1 = Fi2$
    else if $Fi1 > 0$ and $Fi2 = 0$ **then** $Fi2 = Fi1$
    end if
    Fu++
  until Fu Individual pairs have been picked
end procedure

lem 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 clustering and the Self Organising Map (SOM). AEAS then applies the Basic AEA to each species to form a segment of the overall solution, each species is a unit and solution segments for each species are generated in parallel and on different processors. Finally it combines the results for each segment into a single overall solution. 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 underpinned by the Impossibility Theorem [2] in which no clustering algorithm can satisfy all data clustering axioms.

3. EXPERIMENTS

Two experiments are performed to investigate the Basic AEA and the AEAS ability to solve the TSP for different numbers of cities. Two datasets are used for testing, artificial TSP data created by using equidistant 2D points lying on a circle of different sizes (6, 12, 18, 24, 30, 54) 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 measured the percentage deviation between the mean and optimal tour costs, maximum and average tour cost values, as well as the number of evaluations used to find the optimal tour cost.

The first experiment analyses 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. See Figure 1. 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

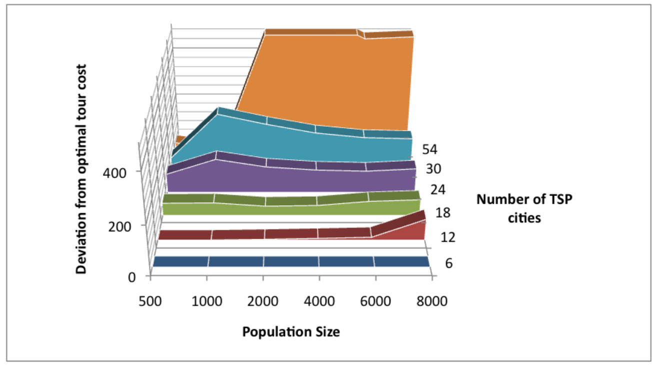

Figure 1: Basic AEA - Affects of population size on TSP problem size

Table 1: Comparative Analysis, results from [3] [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**			

final solution deviated from the optimal value. Results show that the Basic AEA does not scale well with an increased problem size, whereas AEAS was able to solve TSPs with larger numbers of cities.

Table 1 shows the results of AEAS1 (K-means) and AEAS2 (SOM) for different TSPs compared to GA, BCO and IWD. AEAS performs extremely well clearly demonstrating the potential of the approach.

4. CONCLUSION

This work presents the first ecosystem-inspired algorithm designed to take advantage of highly distributed computer architectures and tackle large-scale problems. The Artificial Ecosystem Algorithm (AEA) solves a problem by adapting subcomponents 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. Comparisons of AEAS against the 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] 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.