Improving Robustness in Social Fabric-based Cultural Algorithms

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Master Thesis Defence

Outline

What is Evolutionary Computation(EC)?

Evolutionary Computation

An abstraction from the concepts of biological evolution and social interactions that is used to create optimization algorithms or methodologies that are used to solve problems. [Eiben and Smith, 2003] EC algorithms are natural-inspired, population-based, iterational and utilize step-by-step improvement approaches.

- Genetic Algorithm
- Cultural Algorithms
- Particle Swarm Optimization
- Ant Colony Optimization

Robustness

Robustness in Evolutionary Algorithms

- The ability to address a vast range of problems with particular qualities with a minimum number of adjustments.
- Self-organized algorithms can learn and adapt themselves to different search landscapes.
- Such strategies improve robustness in population-based algorithms.

Social Fabric

- Social Fabric was proposed by [Ali, 2008]
- The Social Fabric is a dynamic information skin created by the agents interactions in a social context.
- Social interactions between individuals are modeled using an undirected graph $G(V; E)$ [Sterling, 2004].
- In this research work, The Social Fabric approach is used to improve the search behavior of evolutionary algorithms in multi-dimensional search spaces.

Research Motivation

Optimization Problems

- CEC-2015 expensive optimization problem set is used to evaluate the proposed approaches. [Chen et al., 2014]

$$Y = f(x_1, x_2, x_3, \cdots, x_D) \tag{1}$$

For example:

$$f_1(x) = x_1^2 + 10^6 \sum_{i=2}^{D} x_i^2 \tag{2}$$

Reasearch Goals

- In this research work, I am going to improve Cultural Algorithms from three aspects:
- Applying PSO algorithm to current Social Fabric based CAs.
- Introducing a Irregular Neighborhood Restructuring operator to increase the level of diversity.
- Improving the robustness of the Belief Space by introducing a Confidence-based knowledge source inspired from Statistics.
- For the comparison purpose, I am going to use CEC2015 benchmark optimization functions to compare my proposed approaches against already proposed algorithms.

Related Works I

- [Ali, 2008] introduced the idea of Social Fabric as a new influence function in CA by deploying a social network between individuals.
- [Che et al., 2010] replaced the traditional idea of roulette wheel with the vector voting model to determine the controller KS in each iteration.
- [Ali et al., 2012] introduced the neighborhood restructuring in Social Fabric with a two-layered multi-population CA model.
- [Chen et al., 2006] introduced Tribe-PSO algorithm as a multi-tribe population-based algorithm to utilize the parallel nature of evolutionary algorithms.

Related Works II

- [De Oca et al., 2009] investigates different types of heterogeneity in PSO algorithm in three categories: neighborhood, update rule and parameters.
- [Ali et al., 2016] gives a detailed description of Social Fabric based MPCA with neighborhood restructuring. It, also, proves its optimality against different optimization algorithms based on an extended benchmark testbed.

Socially inspired algorithms

Swarm Intelligence

[Kennedy et al., 2001] Socially inspired algorithms(Swarm Intelligence) utilize a population of semi-rational agents(rather than dumb individuals) that have the ability to perceive their surrounding environment and cooperate with other agents in a self-organized manner.
Cooperation happens through communication. The agents communicate in two general ways: Direct and Indirect.

- Cultural Algorithms(CA) [Reynolds, 1994]
- Particle Swarm Optimization(PSO) [Clerc, 2010]
- Ant Colony Optmization(ACO) [Dorigo et al., 2006]

Cultural Algorithms

CAs are composed of three components: Population space, Belief space and Communication protocol.

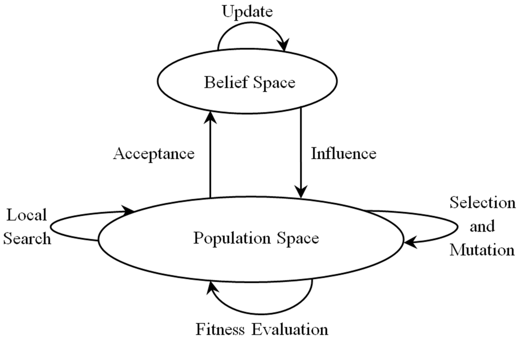


Figure: Cultural Algorithms

Cultural Algorithms

Belief Space

There are five types of knowledge sources in the Belief Space. [Reynolds et al., 2010]

- Situational Knowledge
- Normative Knowledge
- Topographic Knowledge
- Domain Knowledge
- Historical Knowledge

Social Fabric

Social Fabric based CA

- In this model of CA, knowledge sources are allowed to influence the population through layers of networks.
- The interplay of these layers and networks leads us to the concept of "Social Fabric". [Reynolds and Ali, 2008]
- The population is divided into multiple subgroups or tribes. [Ali et al., 2016]

Social Fabric

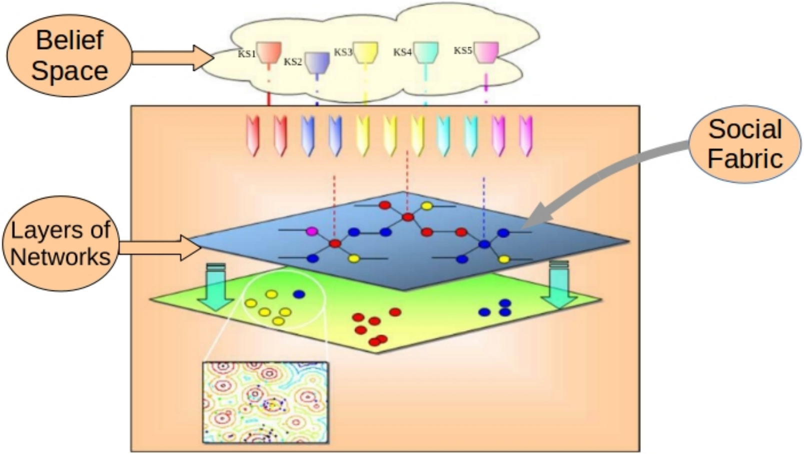


Figure: Social Fabric: [Reynolds et al., 2010]

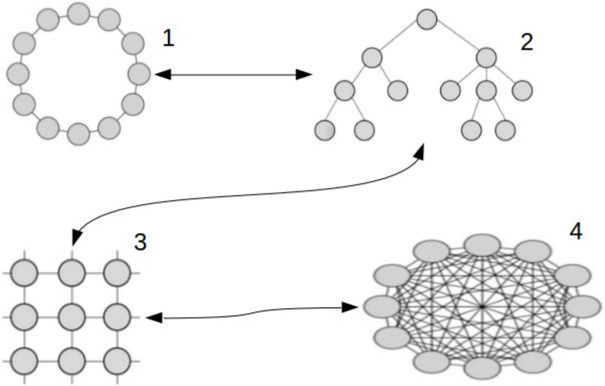
Social Fabric

Figure: Three steps of evolution in Social Fabric

Dynamic Neighborhood Restructuring

Strategic Restructuring

- After a certain number of iterations without any progress in search behavior, the current topology is changed.



Particle Swarm Optimization

- PSO works based on the theory of social learning. Individuals (Particles) move around the search space.
- Such behaviours could be observed in natural groupings such as flocks of birds, colonies of bees, etc.

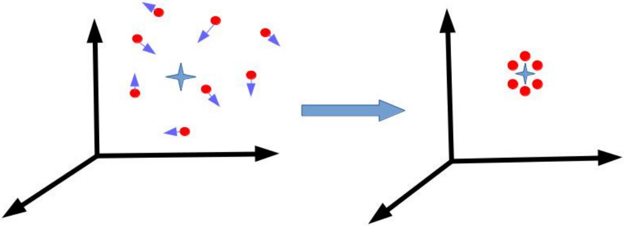
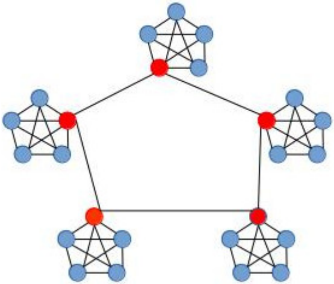


Figure: PSO

Particle Swarm Optimization

Tribe-PSO

- The whole population is divided into independent tribes. [Chen et al., 2006]
- Particles fall into two layers, and the whole process consists of three phases.
- Best particles of each tribe form the upper layer of elites.



Thesis Statement

- In this research work, I am going to improve Cultural Algorithms from three aspects:
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Proposed Approach I

Irregular Neighborhood Restructuring

- Each individual decides to increase/decrease its own neighbourhood size based on its experience.

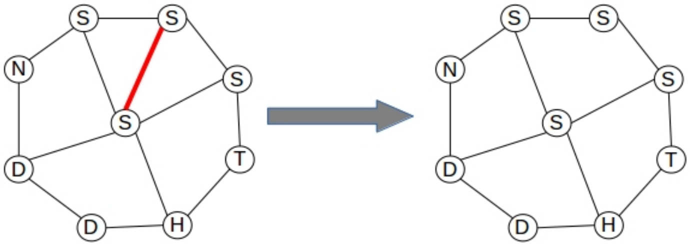

Figure:

Proposed Approach I

Pseudo-Code

```
if fitness(x_i) > bestSoFar_i then
    if stagnationCounter ≥ TiggerThreshold then
        if x_i == x_best then
            index = selected randomly from x_i's neighbourhood
            remove x_index from x_i's neighborhood
        else
            index = selected from {S − x_i'sneighborhood}
            add x_index to x_i's neighbourhood
        end
        stagnationCounter ← 0
    else
        stagnationCounter ← stagnationCounter + 1
    end
else
    stagnationCounter ← 0
```

Proposed Approach II

Confidence-based Normative KS

- The standard normative KS works based on constructing a dynamic range for feasible solutions.
- A confidence interval provides a range of values which is likely to contain a certain percentage of a population.

$$(\bar{x} - q \cdot \frac{\sigma}{\sqrt{n}}, \bar{x} + q \cdot \frac{\sigma}{\sqrt{n}})$$

$\bar{x}$: mean , σ: standard deviation , q: confidence coefficient

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