Multiobjective Group Search Optimization Approach for Community Detection in Networks

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ABSTRACT
Various evolving approaches have been extensively applied to evolve densely connected communities in complex networks. However these techniques have been primarily single objective optimization techniques, which optimize only a specific feature of the network missing on other important features. Multiobjective optimization techniques can overcome this drawback by simultaneously optimizing multiple features of a network. This paper proposes MGSO, a multiobjective variant of Group Search Optimization (GSO) algorithm to globally search and evolve densely connected communities. It uses inherent animal food searching behavior of GSO to simultaneously optimize two negatively correlated objective functions and overcomes the drawbacks of single objective based CD algorithms. The algorithm reduces random initializations which results in fast convergence. It was applied on 6 real world and 33 synthetic network datasets and results were compared with varied state of the art community detection algorithms. The results established show the efficacy of MGSO to find accurate community structures.

KEYWORDS
Community Detection, Complex Networks, Evolutionary Algorithms, Group Search Optimization, Modularity

1. INTRODUCTION
Complex social connections between entities/people of real world society, such as interactions between people in an organization/school, can be represented as network or graph structures. Such graphs possesses the properties of small world networks. Small world networks are highly clustered, have small average shortest path and most of the nodes are neighbours of each other. An important characteristic of such complex networks is the presence of closely knit communities of nodes which are difficult to visualize directly. Communities in real world complex networks are defined as subgroups of individuals having dense intra-connections within their subgroups as compared to inter-connections across other subgroups of individuals. Identifying such communities can give a clear picture of structural as well as behavioural characteristics of the networks under study. Communities of people in an organizational network who share their gaming interests, communities of likeminded buyers in retail shopping network, communities of research scholars across universities who share their research interest or communities of school children requiring special focus in a school children interaction network etc. are example of some of the communities in real world social connection networks.
Specific Community Detection (CD) algorithms are required to identify such communities as they are not explicitly visible. Nodes in real world complex networks are densely interconnected. High density of edges (connections) between nodes of such network makes evolution and segregation of close knit communities a computationally extensive (NP hard) task (Chen et al., 2014). Thus heuristics are incorporated in CD algorithms to evolve communities with better fitness and provide approximate solutions. Research has been directed towards developing better heuristic methods for the detection of accurate community structures in complex networks. This paper proposes a new evolutionary based Multiobjective Group Search Optimization (MGSO) algorithm to evolve communities by simultaneously optimizing multiple objectives instead of optimizing single objective to evolve more comprehensive communities.

The paper is organized as follows: section 2 presents the state of the art techniques used for community detection followed by its definition as an optimization problem in section 3. Section 4 presents the proposed MGSO solution methodology with an in-depth experimental analysis of the work done in section 5 followed by conclusion in section 6.

2. LITERATURE REVIEW

Detecting perfect communities of closely knit entities from complex networks have always been a keen area of interests among researchers. Figure 1 illustrate the broad categorization of the core algorithmic techniques discussed in literature for the related problem.

The initial methods to detect communities were structural which focused on finding a specific structure like cliques (fully connected subgraph), K-cores (K number of connections for a node in a subgraph) or n-cliques. These methods forced various structural restrictions on the networks and failed to evolve communities where cliquish structures or K-connections were missing.

Closely related to Community Detection methods are graph partitioning methods (Alpert et al., 1999). The classic graph partitioning methods aims at finding either balanced or equal sized partitions. The graph partitioning based methods consists of Spectral Bisection (Pothens et al., 1990) and Kernighan-Lin (KL) (Kernighan & Lin, 1970) algorithms. Spectral Bisection initially divides a network into two communities and iteratively bisect them to generate multiple communities. KL algorithm divides the overall network into two groups of randomly chosen vertices and tries to maximize a quality function q by repeatedly swapping the vertices. Spectral Bisection requires the number of communities to be fixed a-priori and KL algorithm require sizes of the groups to be fixed a-priori.

Yet another way of detecting communities is through the density based methods. The density based methods (Ankerst et al., 1999; Ester et al., 1996) are able to detect hierarchical community structures of arbitrary shapes and sizes. These approaches detect hubs and outliers even in the presence of noise. Gong et al. (2014b) proposed heuristic density based CD approach which forms varied partitions using various combinations of parameter values. The algorithm applies classification, mergence, decomposition and recombination to report final communities. However, algorithms based on these approaches require manual parameter specification to define clusters which are difficult to determine.
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