Community detection in power grids by an evolutionary method

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ABSTRACT

Community detection is a complex optimization problem that consists on searching homogeneous communities that belong to a given graph. This graph, which represent a network, has properties that enable the detection of characteristics or functional relationships in the network. A large number of approaches have been proposed to solve this problem in different disciplines. Nevertheless, only a few research papers have applied community detection to power grids. This paper presents a new evolutionary algorithm for community detection that is applied in power grids. This evolutionary approach employs an efficient initialization strategy that only considers feasible solutions and uses two different search operators that allow the algorithm to obtain a good convergence and diversity of solutions. The preliminary results show that the proposed algorithm obtain quality results in real power grids.

CCS CONCEPTS

•**Theory of computation** → *Evolutionary algorithms;* •**Hardware** → *Power networks;* •**Mathematics of computing** → *Graph algorithms;*

KEYWORDS

Evolutionary algorithms, Graph algorithms, Community detection, Power grids.

ACM Reference format:

Manuel Guerrero, Consolación Gil and Francisco G. Montoya, Alfredo Alcayde, Raúl Baños. 2017. Community detection in power grids by an evolutionary method. In *Proceedings of The Genetic and Evolutionary Computation Conference, Berlin, Germany, July 2017 (GECCO'17)*, 2 pages.
DOI: 10.1145/3067695.3075606

1 POWER GRIDS AND COMMUNITY DETECTION

Complex systems are often characterized by community structures [11] that consist of groups of nodes in the network that are more densely connected compared with other nodes. It is expected that the nodes of a given community would have a higher probability to share certain properties, then revealing new characteristics or functional relationships among the elements of a network. In fact, community detection can be defined according to different objectives that reflect aspects of a community structure. The literature include a large number of alternative objective functions for community detection. These include community score [2], expansion [5], internal density [9], modularity [13], surprise [12], etc.

On the other hand, a large number of methods have been proposed to solve community detection problems in many real applications. Meta-heuristics such as evolutionary algorithms [3], particle swarm optimization [4], ant colony optimization [14], tabu search [7], simulated annealing or memetic algorithms [10] have been successfully applied. However, a little attention has been paid to the use of meta-heuristics to detect communities in power grids.

The analysis of vulnerability and protection of power grids has attracted the attention of many researchers since they have an important influence in real life of citizens around the world. Several investigations have analyzed the properties of several power grids infrastructures using complex network techniques [1]. Some of these approaches aim to detect the community structure in complex power networks [6].

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2 AN EVOLUTIONARY ALGORITHM FOR COMMUNITY DETECTION

The main characteristics of the evolutionary algorithm are now summarized:

- Individual representation: the evolutionary algorithm uses integer representation to represent the individuals of the population.
- Population initialization: the initialization strategy is based on connecting each node with neighboring nodes, then preventing undesired clusters with disconnected nodes.
- Objective function: the evolutionary algorithm is guided by a modularity objective function [13].
- Evolutionary search operators: The algorithm uses two efficient search operators in the search process: an operator that moves single nodes from a community to another neighbouring one; and another operator that exchanges nodes between boundaries from two neighbouring communities.
- Selection strategy: Binary tournament is used as selection procedure. The mating pool size is equal to half of the population size.

  Let us notice that the different algorithmic components included in the evolutionary algorithm have been analyzed, and the results obtained show that both, the initialisation strategy and the search operators are key factors to obtain high quality results in terms of modularity.

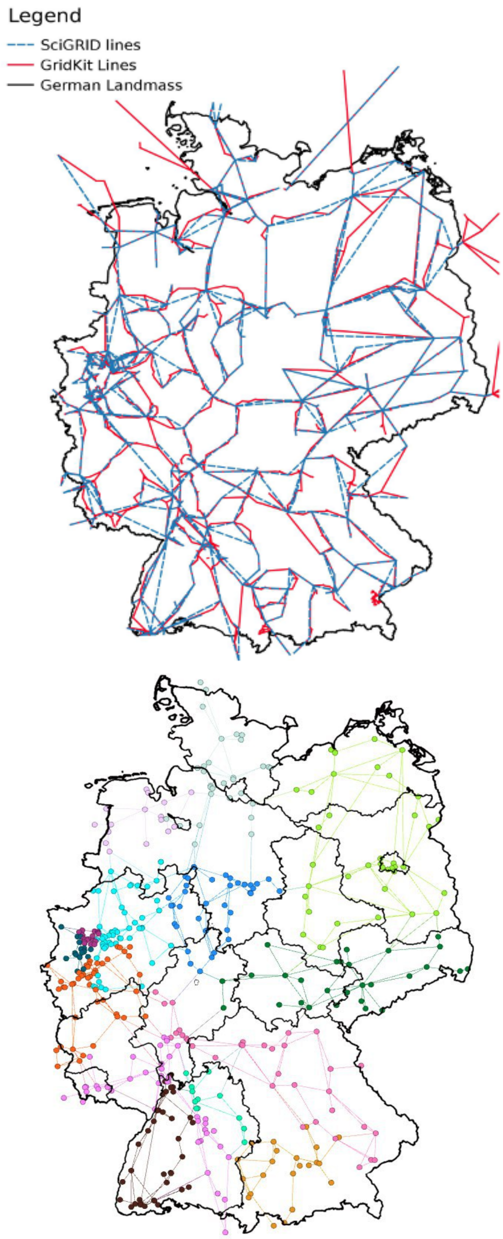

Figure 1: (a) High-voltage power grid of Germany; (b) Communities determined by the evolutionary algorithm.

3 PRELIMINARY RESULTS

The evolutionary algorithm described in a summarized way in the previous section has been tested in the German transmission network, obtained using GridKit 1.0 toolkit. GridKit is a power grid extraction tool which uses OpenStreetMap data, which was developed in the context of the SciGRID project [8]. Population size has been set to 200 individuals, which are evolved during 200 iterations. Probability of applying each of the search operators is set to 20%. Figure 1 shows the communities detected by the evolutionary algorithm when solving the German transmission network. As it can be seen in this case, which considers 13 different communities, the proposed evolutionary algorithm is able to effectively deal with community identification in power networks.

4 CONCLUSIONS

This paper describes the preliminary results obtained by an evolutionary algorithm for community detection in electric power grids. The good results obtained by this algorithm are attributed to the evolutionary search operators which are based on the idea of communities with boundaries and the migration and exchange operations between them. As future work, it is planned to apply this algorithm to larger networks; to extend the functionalities of the evolutionary algorithm to detect communities by considering power flows and another real characteristics of power systems; to implement other meta-heuristics to this problem; to apply multi-objective approaches to consider several objectives simultaneously; and to apply parallel strategies to speed up the algorithms.

ACKNOWLEDGMENTS

This research has been supported by the Spanish Ministry of Economy and Competitiveness under Grant No.: TIN2015-67020-P and by the Regional Government of Andalusia (ceiA3 project).

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