Chaos, Solitons and Fractals 147 (2021) 110945

Contents lists available at ScienceDirect

Chaos, Solitons and Fractals

Nonlinear Science, and Nonequilibrium and Complex Phenomena

journal homepage: www.elsevier.com/locate/chaos

Novel methods for creating an earthquake complex network using a declustered catalog

Ammar Shahraki Ebrahimi*, Elham Yavari[1], Toktam Khatibi[2]

School of Industrial and Systems Engineering, Tarbiat Modares University, Jalal Al-e-Ahmad, Tehran, Iran

ARTICLE INFO

Article history:
Received 28 November 2020
Revised 3 March 2021
Accepted 2 April 2021

Keywords:
Earthquake network
Declustered catalog
Community structure
Scale-free network
Hierarchical Community Structure

ABSTRACT

In recent years, complex networks have been used as new tools to study patterns in earthquake data. Although various methods have been developed to construct earthquake networks, there is still a long way to use this approach as a complete framework for analyzing seismicity. This research develops novel methods for building earthquake networks and investigates the patterns that they could reveal. The proposed methods use a specific declustered catalog and define nodes based on main shocks and edges on aftershocks' period or sequence. Another method is offered to convert the resulted networks, as earthquake networks, to epicenters networks. The catalog of Iran's earthquakes from 2006 to 2018 is used to produce earthquake networks using the above-mentioned methods. The resulted networks are scale-free and hierarchical with community structure, as expected. Some nodes' features in the networks are shown correlated with the magnitude of the related event. Most patterns and features are preserved while converting the earthquakes network to epicenters network. Proposed methods better capture a region's seismic features into a complex network with a more precise relationship between seismological laws and network characteristics and can help develop perfect seismicity analyzing framework based on complex networks.

1. Introduction

Earthquakes cause lots of damages and loss of lives in many countries. In recent decades, natural disasters have killed an average of 4,000, and have affected about 55,000 people a year in the Alpine-Himalayan earthquake belt region [1]. Large earthquakes have killed tens of thousands of people and have left tens and hundreds of people homeless [1,2]. Earthquake damage increases psychological and behavioral disorders in survivors [3,2]. A better understanding of this phenomenon could help to reduce its costs and injuries. One way to comprehend the earthquake's underlying dynamics is by investigating its event sequence [4]. However, events' temporal and spatial distribution is complicated and forms clusters on faults [5].

Modeling earthquake event sequence as a complex network can reveal new patterns in the data. These networks capture spatial and temporal event dependencies, and their structural properties confirm that they are not random [6]. Researchers believe that the network's patterns are related to the nature of the earthquake phenomenon [7,8]. They have shown that such patterns are associated with the seismicity of the area under study [6,9,10], and striking a significant earthquake makes some changes in these properties [11,12,9].

Different network construction methods produce different complex networks from different perspectives and exhibit various patterns in the earthquake catalogs. A more sophisticated construction method can reveal more seismicity related patterns. For developing a complex network, the first step is defining vertices and edges. Researchers have used two general methods for building earthquake networks [10]. Abe and Suzuki [6] have proposed the first method of earthquake network construction that divided the three-dimensional volume of the area under consideration into equal small cubic cells. In their method, a cell was regarded as a node if at least one earthquake was placed in it, and an edge would connect the two nodes in which two consecutive shocks occurred. In the second method, an event itself has been considered a node, and edges have been defined using the correlation between events [13–15]. Networks have been erected using this approach were scale-free [14] and small-world [15]. In another study [16], tree-like graphs have been produced for each seismic cluster using

* Corresponding author.
E-mail addresses: ammar.shahraki@modares.ac.ir (A. Shahraki Ebrahimi), e.yavari@modares.ac.ir (E. Yavari), toktam.khatibi@modares.ac.ir (T. Khatibi).
[1] www.modares.ac.ir/~e.yavari.
[2] www.modares.ac.ir/~toktam.khatibi.

https://doi.org/10.1016/j.chaos.2021.110945
0960-0779/