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A methodology framework for bipartite network modeling

Chin Ying Liew[1], Jane Labadin[2*], Woon Chee Kok[2] and Monday Okpoto Eze[3]

*Correspondence:
ljane@unimas.my

[1] Mathematical Sciences Studies, College of Computing, Informatics and Media, Universiti Teknologi MARA, Sarawak Branch, 94300 Kota Samarahan, Sarawak, Malaysia
[2] Faculty of Computer Science and Information Technology, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia
[3] Department of Computer Science, Babcock University, Ilishan-Remo, Ogun State, Nigeria

Abstract

The graph-theoretic based studies employing bipartite network approach mostly focus on surveying the statistical properties of the structure and behavior of the network systems under the domain of complex network analysis. They aim to provide the big-picture-view insights of a networked system by looking into the dynamic interaction and relationship among the vertices. Nonetheless, incorporating the features of individual vertex and capturing the dynamic interaction of the heterogeneous local rules governing each of them in the studies is lacking. The methodology in achieving this could hardly be found. Consequently, this study intends to propose a methodology framework that considers the influence of heterogeneous features of each node to the overall network behavior in modeling real-world bipartite network system. The proposed framework consists of three main stages with principal processes detailed in each stage, and three libraries of techniques to guide the modeling activities. It is iterative and process-oriented in nature and allows future network expansion. Two case studies from the domain of communicable disease in epidemiology and habitat suitability in ecology employing this framework are also presented. The results obtained suggest that the methodology could serve as a generic framework in advancing the current state of the art of bipartite network approach.

Keywords: Graph theory, Individual-based modeling, Complex network, Habitat suitability, Epidemiology, Disease modeling, Dengue, Irrawaddy dolphin, Heterogenous

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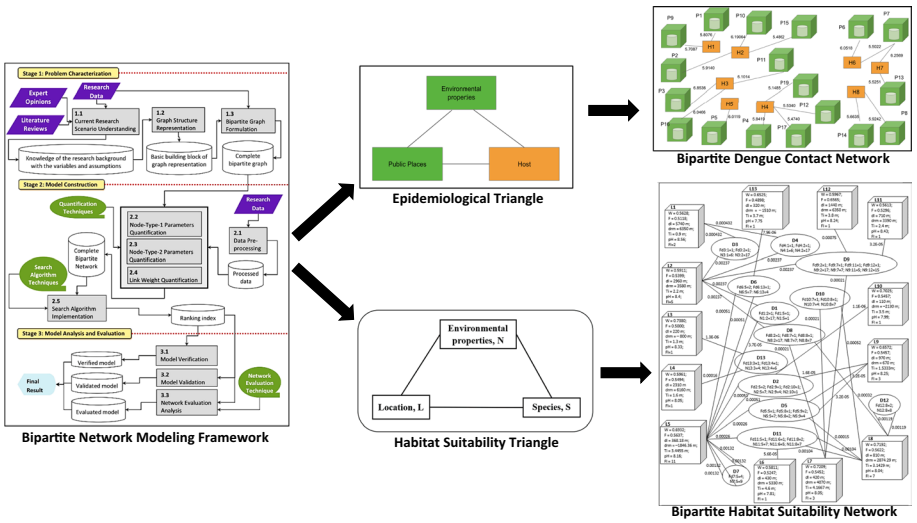
Graphical Abstract



Introduction

The bipartite network approach applies network theory that has its basis in graph theory (Harary 1969). This graph-theoretic network approach commonly focuses on the properties, the structural dynamics, and the relationship between the structure and function of real-world networks like social networks, transportation systems, collaboration networks, epidemiology and the Web and Internet structures which are regarded as emergent fields of network science by Barabási (2013). A bipartite network consists of nodes of two different natures with links joining only between unlike nodes. It is also referred to as an affiliation or two-mode network (Kevork and Kauermann 2022). The heterogeneous nature of the bipartite network makes it a realistic model of the real-world system and applicable across a wide range of research fields, particularly in the studies related to science and technology (Valejo et al. 2021). It is commented as capable of providing insightful representation from mutualistic networks in ecology to trade networks in the economy (Saracco et al. 2015).

In the well-cited review paper by Newman (2003) on the structure and functions of complex networks, a bipartite network is regarded as both a preference network under the category of information or knowledge network and a type of network under the social network category among the four network categories given. Most of the studies that apply the bipartite graph or bipartite network approach focus on the statistical properties of the structure and behavior of these networked systems under the domain of complex network analysis. The emphasis is to delve into the properties of networks that discusses features like, but not limited to, the small-world effect, transitivity or clustering, degree distribution of the vertices in the network, characteristics of community within a network, resilience of a network, assortativity of the connection between vertices, network clustering that considers the density of edges among vertices and groups with different clustering structure, and navigation within a network (Baumgartner 2020; Derudder 2021; Ducruet and Beauguitte 2014; Kevork and Kauermann 2022).