COMP702 Design & Specification

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Open-Source Temporal Networks Library

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Abstract

This article outlines the specification and design of an Open-Source Temporal Networks library. The document consists of several key sections; an introduction to the subject area; a detailed specification of the library and what it aims to achieve; the design process and proposed architecture; a project plan for the remaining work; a summary of the necessary requirements and skills needed to complete the project. The ultimate goal of the project is to develop a convenient library for the modelling and analysis of temporal networks to aid in the study and research of many real-world applications and systems.

1 Introduction

Temporal networks are prevalent across many systems in the modern world, be it natural, social, technological, financial or industrial. A few examples of temporal networks include public transport[5], human interaction[6], stock markets[3] and wireless sensors[4]. These examples show that a diverse amount of systems can be modelled as a temporal network, or are inherently so. The analysis of such networks can yield new and useful information that was previously not obvious from the raw data. A convenient library which allows for such network modelling and analysis would prove very useful for multiple disciplines and domains.

A static network can be represented as a graph, consisting of nodes and edges. In its simplest form, a graph is a set of points interconnected with lines, where each line connects a pair of points. The graph connectivity is defined in the incidence function, which associates edges and node pairs[1]. Mathematically, a graph G is an ordered triple of nodes, edges and the incidence function:

$$G = (V, E, \psi) \qquad V = (a, b, c) \qquad E = (x, y, z)$$

$$\psi(x) = (ab),\ \psi(y) = (ac),\ \psi(z) = (bc)$$

A graph may be undirected, where an edge z connecting nodes b and c does not specify a direction, meaning the edge is valid for both directions bc and cb. Conversely, a directed graph (digraph) has directional edges. Like the undirected graph, the incidence function describes the relationship between edge and nodes;

$$\psi(xy) = (x, y)$$

where edge xy connects nodes x and y, with node x being the source and node y the sink[2]. The edges of the graph can hold information (such as weights) that describe the relationship/connections between nodes. Such a graph is known as a labelled graph.

In a temporal graph, each edge has a label which indicates some measure of time (discrete or continuous). This could be the start time(s) of when the edge is active, along with a duration of how long the edge is active. A temporal graph can be described as a graph whose connections change over time. The nodes of the graph remain static, while the edges update as time changes. A temporal graph can also be perceived as sequence of static graphs with an (unchanging) set of nodes. Other edge labels could correspond to temporal information if interpreted correctly[7]. In the discrete time case, the temporal graph can be presented as a static graph $G = (V, E)$ with each edge labelled with a list of natural numbers corresponding to when that edge is active. A simple example of a temporal network can be created using a train timetable. The nodes represent stations and the edges represent the railway routes connecting the stations. Each route has a direction (departure station, arrival station) and a departure time associated with it.

2 Specification & Aim

Outline in detail the specification of the project. Outline what the project aims to achieve. Include how project aims to achieve analogues Networkx status for temporal network analysis.

3 Design Overview

Outline in detail how the project will be designed and how you came to this decision(s). Show diagrams of object-oriented code design. Explain how and why design decisions were made.

4 Project Plan

Outline the timeline of the project. Include Gantt chart and reference to Gantt planning.

5 Requirements & Skills

Outline what will be required to complete the project and any skills necessary. Outline new skills expected to be acquired.

A Appendix

List of Figures

List of Tables

References

[1] J. A. Bondy, Graph Theory With Applications, Chapter 1. GBR: Elsevier Science Ltd., 1976.

[2] J. A. Bondy, Graph Theory With Applications, Chapter 10. GBR: Elsevier Science Ltd., 1976.

[3] L. Zhao, G.-J. Wang, M. Wang, W. Bao, W. Li, and H. E. Stanley, 'Stock market as temporal network', Physica A: Statistical Mechanics and its Applications, vol. 506, pp. 1104–1112, Sep. 2018, doi: 10.1016/j.physa.2018.05.039.

[4] K. Römer, Temporal Message Ordering in Wireless Sensor Networks. 2002.

[5] R. Gallotti and M. Barthelemy, 'The multilayer temporal network of public transport in Great Britain', Sci Data, vol. 2, no. 1, p. 140056, Dec. 2015, doi: 10.1038/sdata.2014.56.

[6] S. Lee, L. E. C. Rocha, F. Liljeros, and P. Holme, 'Exploiting Temporal Network Structures of Human Interaction to Effectively Immunize Populations', PLoS ONE, vol. 7, no. 5, p. e36439, May 2012, doi: 10.1371/journal.pone.0036439.

[7] O. Michail, 'An Introduction to Temporal Graphs: An Algorithmic Perspective', arXiv:1503.00278 [cs], Mar. 2015, Accessed: Jun. 29, 2020. [Online]. Available: http://arxiv.org/abs/1503.00278.

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