ウェブサイト公開用

（様式 10）

（海外特別研究員事業）

令和 3 年 4 月 28 日

海外特別研究員最終報告書

独立行政法人日本学術振興会 理事長　殿

採用年度　H31

受付番号　201960152

氏　　名　杉下 佳辰

（氏名は必ず自署すること）

海外特別研究員としての派遣期間を終了しましたので、下記のとおり報告いたします。

なお、下記及び別紙記載の内容については相違ありません。

記

1. 用務地（派遣先国名）用務地：ニューヨーク州立大学バッファロー校（アメリカ）

2. 研究課題名（和文）※研究課題名は申請時のものと違わないように記載すること。

多層ネットワーク解析に基づく交通システムのリスクマネジメント

3. 派遣期間：平成・令和　31　年　4 月　1 日　～　令和　3　年　3　月　31　日

4. 受入機関名及び部局名

受入機関名：　ニューヨーク州立大学バッファロー校

部局名：　数学科

5. 所期の目的の遂行状況及び成果…書式任意　**書式任意（A4 判相当 3 ページ以上、英語で記入も可）**

（研究・調査実施状況及びその成果の発表・関係学会への参加状況等）

（注）「6. 研究発表」以降については様式 10－別紙 1～4 に記入の上、併せて提出すること。

I have worked on the following three research topics.

A) Recurrence in the evolution of air transport networks

B) Opinion dynamics on tie-decay networks

C) Growth model for water distribution networks with loops

A) Recurrence in the evolution of air transport networks

Changes in air transport networks over time may be induced by competition among carriers, changes in regulations on airline industry, and socioeconomic events such as terrorist attacks and epidemic outbreaks. Such network changes may reflect corporate strategies of each carrier. In the present study, we propose a framework for analyzing evolution patterns in temporal networks in discrete time from the viewpoint of recurrence. Recurrence implies that the network structure returns to one relatively close to that in the past. We applied the proposed methods to four major carriers in the US from 1987 to 2019. We found that the carriers were different in terms of the autocorrelation, strength of periodicity, and changes in these quantities across decades. We also found that the network structure of the individual carriers abruptly changes from time to time (see Figure 1). Such a network change reflects changes in their operation at their hub airports rather than famous socioeconomic events that look closely related to airline industry. The proposed methods are expected to be useful for revealing, for example, evolution of airline alliances and responses to natural disasters or infectious diseases, as well as characterizing evolution of social, biological, and other networks over time.

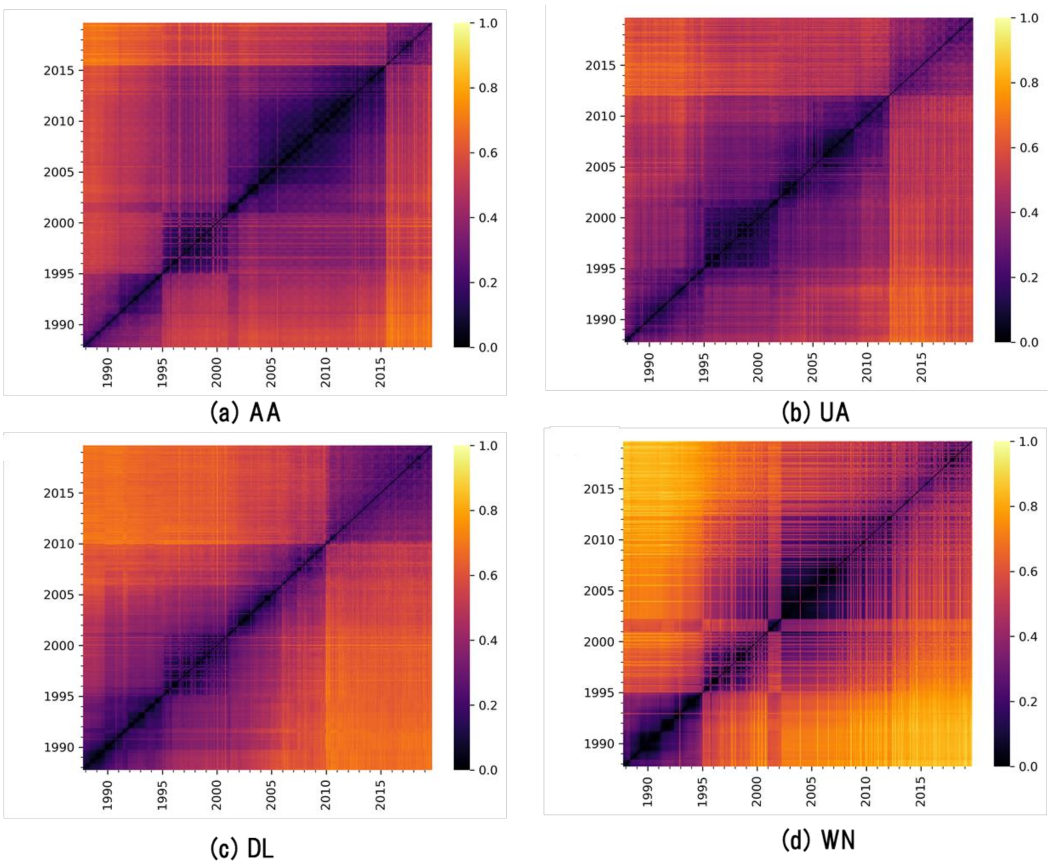

Figure 1. Network-distance matrices. (a) American Airlines, (b) United Airlines, (c) Delta Air Lines, and (d) Southwest Airlines.

Related Publications

1. Kashin Sugishita and Naoki Masuda, Recurrence in the evolution of air transport networks, Scientific Reports, 11, 5514, 2021.
2. 杉下佳辰, 航空ネットワーク構造の時系列変化, ネットワーク科学セミナー2020, オンライン, 2020 年 12 月. ［口頭発表］
3. Kashin Sugishita, Recurrence in the evolution of air transport networks, The 5th Japan-US Science Forum in Boston, Online, November 2020.［flash talk］
4. Kashin Sugishita and Naoki Masuda, Structural evolution of US airline networks, NetSci 2020, Online, September 2020. ［oral presentation］

B) Opinion dynamics on tie-decay networks

In social networks, interaction patterns typically change over time. We study opinion dynamics in tie-decay networks in which tie strength increases instantaneously when there is an interaction and decays exponentially between interactions. Specifically, we formulate continuous-time Laplacian dynamics and a discrete-time DeGroot model of opinion dynamics in these tie-decay networks, and we carry out numerical computations for the continuous-time Laplacian dynamics. We examine the speed of convergence by studying the spectral gap of combinatorial Laplacian matrices of tie-decay networks. First, we compare the spectral gaps of tie-decay networks from empirical data with those for corresponding randomized and aggregate networks. We find that the spectral gaps of the empirical networks tend to be smaller than those of the randomized (see Figure 2) and aggregate networks. Second, we study the spectral gap as a function of the tie-decay rate and time. Intuitively, we expect small tie-decay rates to lead to fast convergence, because the influence of each interaction event between two nodes lasts longer for smaller decay rates. Moreover, as time progresses and more interaction events occur, we expect to observe convergence to proceed. However, we demonstrate that the spectral gaps need not decrease monotonically with respect to the decay rate or increase monotonically with respect to time. Our results highlight the importance of the interplay between the times that edges arise and decay in temporal networks.

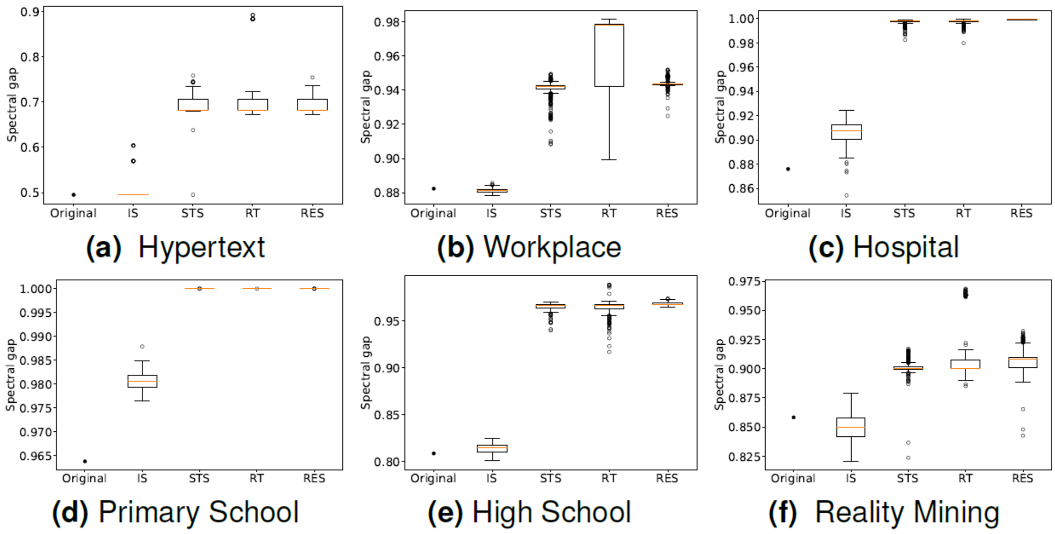

Figure 2. Comparison of the spectral gap of M(T) between the original and randomized networks.

Related Publications

5. Kashin Sugishita, Mason A. Porter, Mariano Beguerisse-Díaz, and Naoki Masuda, Opinion dynamics on tie-decay networks, arXiv preprint, arXiv:2010.00143, 2020
6. Kashin Sugishita, Mason A. Porter, Mariano Beguerisse-Díaz, and Naoki Masuda, Opinion dynamics in tie-decay temporal networks, Third Northeast Regional Conference on Complex Systems (NERCCS 2020), Online, April 2020. [poster presentation]
7. Kashin Sugishita, Mason A. Porter, Mariano Beguerisse-Díaz, and Naoki Masuda, Opinion dynamics in tie-decay networks, NetSci-X 2020, Tokyo, Japan, January 2020. [oral presentation]

C) Growth model for water distribution networks with loops

Water distribution networks (WDNs) expand their service areas over time. These growth dynamics are poorly understood. One facet of WDNs is that they have loops in general, and closing loops may be a functionally important process for enhancing their robustness and efficiency. We propose a growth model for WDNs which generates networks with loops and is applicable to networks with multiple water sources. We apply the proposed model to four empirical WDNs to show that it produces networks whose structure is similar to that of the empirical WDNs (see Figure 3). The comparison between the empirical and modeled WDNs suggest that the empirical WDNs realize a reasonable balance between cost, efficiency, and robustness. We also study the design of pipe diameters based on a biological positive feedback mechanism. Specifically, we apply a model inspired by *Physarum polycephalum* to find moderate positive correlations between the empirical and modeled pipe diameters. This result suggests that the distribution of pipe diameters in the empirical WDNs is closer to an optimal one than a uniformly random distribution. However, the discrepancy between the empirical and modeled pipe diameters also suggests that we may be able to improve the performance of WDNs by following organizing principles of biological systems.

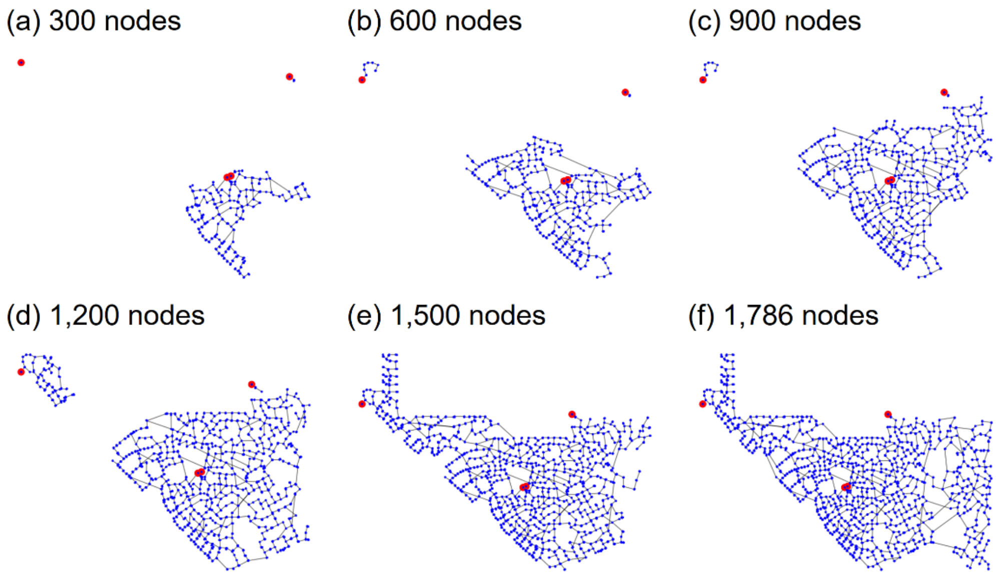

Figure 3. Visualization of the network growth in the case of Colorado Springs.

Related Publications

8. Noha Abdel-Mottaleb, Kashin Sugishita, Naoki Masuda, and Qiong Zhang, Bio-inspired water distribution network design, Fourth Northeast Regional Conference on Complex Systems (NERCCS 2021), Online, March 2021. [poster presentation]

9. Kashin Sugishita, Noha Abdel-Mottaleb, Qiong Zhang, and Naoki Masuda, A growth model for water distribution networks with loops, Conference on Complex Systems (CCS 2020) Online, December 2020. [poster presentation]