Mini Review
Volume 16:7, 2022

Journal of Generalized Lie Theory and Applications

ISSN: 1736-4337
Open Access

Multiscale Coordination Dynamics Topological Portraits

William Kalie*
Department of Applied Chemicals and Materials, Ulster University, Northern Ireland, UK

Abstract

On multiple spatiotemporal scales, living systems exhibit complex yet organised behaviour. To investigate the nature of multiscale coordination in living systems, a meaningful and systematic method of quantifying the complex dynamics is required, which is a challenge in both theoretical and empirical domains. The current work demonstrates how combining approaches from computational algebraic topology and dynamical systems can assist us in meeting this challenge. We concentrate on the application of multiscale topological analysis to coordinated rhythmic processes in particular. First, theoretical arguments are presented to demonstrate why certain topological features and their scale dependency are critical for comprehending complex collective dynamics. Second, we propose using persistent homology to capture such dynamically relevant topological information.

Keywords: Computational • Topology • Homology • Dynamics

Introduction

A complex system (for example, a biological, social, or ecological system) is frequently held together by the coordination of many dynamic processes occurring at multiple spatiotemporal scales. However, when confronted with such multiscale dynamics, we lack appropriate tools to describe them in a way that is fair to all relevant scales. We present a topological approach to analysing dynamic patterns generated by multiscale coordinative structures in this paper [1]. Topological methods have been demonstrated to detect dynamic features of systems that exhibit, for example, stable spatiotemporal chaos. In this paper, we use existing computational topology tools, primarily persistent homology, to detect transitions between topological features hidden in complex coordination patterns [2].

The quantitative and systematic investigation of multiscale coordinative structures necessitates the use of data analytic tools that are tuned to capture dynamic features across scales, that is, without predefining a specific scale of analysis or employing a different system of measurement for different scales. The development of such tools is difficult because the measurement must be multiscale in nature as well as dynamically meaningful: it must capture dynamic patterns of coordination as well as the transition between coordination patterns in time (Kelso, 1984, 2009). We propose a multiscale topological approach to this problem in this paper. To resolve them, we study the topological features of the spatiotemporal patterns generated by their interaction rather than individual state variables [3].

When there are many coupled oscillators in the system and the frequency diversity is large, metastable coordination can become quite obscure. Furthermore, traditional methods that work well in low-dimensional, low-diversity environments may become less effective. We demonstrate this point in the rest of the Introduction with two examples of rhythmic social coordination trials from a human experiment (Zhang et al., 2018). Visual examination of the relative phase dynamics can directly interpret metastable coordination of low dimensionality and diversity, but this becomes far more difficult when the dimensionality and diversity are high.

Taps by one person can be seen in real time by others as flashes of specific LEDs, allowing subjects to spontaneously coordinate (i.e. they were not explicitly instructed to coordinate). Each subject is identified by a number ranging from one to eight, which corresponds to a specific touch pad and LED assignment. The tapping frequency diversity was manipulated by pacing each subject for 10 seconds with a separate metronome before they saw each other's behaviour for 50 seconds. The pacing frequency was always the same within the group of subjects numbered, but it could differ between the two groups [4].

Literature Review

In the first example, we show the coordination dynamics between three agents paced with metronomes of the same frequency, which can be visually interpreted through two pairwise relative phases, a crucial coordination variable, coordination among three agents, numbered and, is shown in terms of two phase relations, the system dwells recurrently at an all-inphase pattern, where all taps are aligned in time (duration marked by three black bars; between the bars only 3–4 are inphase with agent 1 wrapping). After 40 seconds, the behaviour changes to a partly inphase, partly antiphase pattern (1-3 inphase and 3-4 antiphase [5].

The recurrence of relative phases captures the dynamic structure of the three-agent example perfectly. The 3 grid between 10 and 40 s represents the main recurring pattern in which all three agents are inphase with one another; the blocks before and after 10 s represent two other patterns. Unlike in, the recurrence plot for the eight-agent example (Fig. 3B) lacks any discernible structure or indications of transition between different coordination patterns. In comparison to, not much useful information is obtained.

We present a novel method for studying metastable coordination patterns based on their topological properties. More specifically, we create multiscale topological portraits of coordination patterns and investigate their recurrence plot, i.e. a topological recurrence plot. In addition, we demonstrate how prominent transitions in a topological recurrence plot reveal the time of transitions in actual coordination patterns in terms of relative phases and instantaneous frequencies.

Discussion

This homology describes not only the topological features of the structure at each scale, but also how these features persist across scales. The actual

---

***Address for Correspondence:** *William Kalie, Department of Applied Chemicals and Materials, Ulster University, Northern Ireland, UK, E-mail: williamdk@gmail.com*

Date of Submission: 02 July, 2022, Manuscript No: glta-22-80637; **Editor Assigned:** 04 July, 2022, PreQC No: P-80637; **Reviewed:** 16 July, 2022, QC No: Q-80637; **Revised:** 21 July, 2022, Manuscript No: R-80637; **Published:** 28 July, 2022, DOI: 10.37421/1736-4337.2022.16.353

barcode of loops computed using persistent homology, which corresponds well to the intuition conveyed in the lower panel; additionally, shows the barcode of connected components, which captures the existence of 14 components at finer scales and 1 component at gross scales. Before delving into the technicalities of persistent homology, we must first consider whether metastable patterns are multiscale structures that can be adequately characterised by multiscale topological portraits [6].

It is important to note that the number of connected components or loops is scale-dependent in this case. At too small a scale, the two curves never cross, resulting in two connected components but no loop. At an excessively large scale, all loops are filled in, resulting in one connected component and no loops. Topological features at intermediate scales can capture the dwell-escape dynamics of metastable coordination. Multiple characteristic scales may coexist when more oscillators coordinate together metastably [7].

Conclusion

Finally, we presented a multiscale topological approach to comprehending metastable coordination dynamics involving multiple agents. We demonstrated, through the analysis of dynamic examples and theoretical discussions, that this method has great potential for characterising complex, multiscale dynamic patterns. More work with simulated time series is needed to progress toward a systematic method of classifying phase transitions in complex collective dynamics, of which this work is a prototype.

Acknowledgement

None.

Conflict of Interest

There are no conflicts of interest by author.

References

1. Zhang, Mengsen, William D. Kalies, JA Scott Kelso and Emmanuelle Tognoli. "Topological portraits of multiscale coordination dynamics." *J Neurosci Methods* 339 (2020): 108672.
2. Baum, Michael, Fabian Erdel, Malte Wachsmuth and Karsten Rippe. "Retrieving the intracellular topology from multi-scale protein mobility mapping in living cells." *Nat Commun* 5 (2014): 1-12.
3. Gamard, Guilhem and Gwenaël Richomme. "Coverability and multi-scale coverability on infinite pictures." *J Comput Syst Sci* 104 (2019): 258-277.
4. Stonedahl, Susa H., Judson W. Harvey, Joel Detty and Antoine Aubeneau, et al. "Physical controls and predictability of stream hyporheic flow evaluated with a multiscale model." *Water Resour Res* 48 (2012).
5. Bemis, Sean P., Steven Micklethwaite, Darren Turner and Mike R. James, et al. "Ground-based and UAV-Based photogrammetry: A multi-scale, high-resolution mapping tool for structural geology and paleoseismology." *J Struct Geol* 69 (2014): 163-178.
6. Chen, Xi. "Application of UAV digital photogrammetry technology in marine topographic surveying and mapping." *J Coast Res* 93 (2019): 674-679.
7. Geng, Weihua and Guo-Wei Wei. "Multiscale molecular dynamics using the matched interface and boundary method." *J Comput Phys* 230 (2011): 435-457.

How to cite this article: Kalie, William. “Multiscale Coordination Dynamics Topological Portraits.” J Generalized Lie Theory App 16 (2022): 353.