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Modelling advection on distance-weighted directed networks

Tuesday, 21 January 2025 09:00 (20 minutes)

We introduce a mathematical model to capture and describe the dynamics of the advection differential equation on distance-weighted directed graphs, with applications to various networked systems. The primary objective of our model is to generalize advection processes—which traditionally describe phenomena like fluid flow or traffic movement—by formulating them within the framework of discrete network structures.

Our approach begins with defining a set of essential properties, or axioms, that any discrete advection operator must satisfy. These axioms ensure that the operator reflects the fundamental characteristics of advection processes in continuous spaces, such as directional flow, conservation properties, and respect for edge weights based on distance. We demonstrate that, under these conditions, there exists an essentially unique operator that fulfills all prescribed axioms, providing a robust and mathematically sound foundation for discrete advection on directed graphs.

To validate our theoretical results, we present both analytical and numerical examples that showcase the operator's behavior under various configurations. As a practical demonstration, we apply the model to simulate traffic flow in a transportation network.

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