



Topological Data Analysis for Power-Grid Forecasting in South Africa Employing Finite-Element Discretization and Error Bounds

Zola Motsi^{1,2}, Nokuthula Dlamini³, Siphon Mathebula⁴, Nomonde Khumalo^{5,6}

¹ SA Medical Research Council (SAMRC)

² Department of Interdisciplinary Studies, University of Johannesburg

³ University of Johannesburg

⁴ Department of Advanced Studies, Mintek

⁵ University of KwaZulu-Natal

⁶ Mintek

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Correspondence: zmotsi@gmail.com

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Author notes

Zola Motsi is affiliated with SA Medical Research Council (SAMRC) and focuses on Mathematics research in Africa.

Nokuthula Dlamini is affiliated with University of Johannesburg and focuses on Mathematics research in Africa.

Siphon Mathebula is affiliated with Department of Advanced Studies, Mintek and focuses on Mathematics research in Africa.

Nomonde Khumalo is affiliated with University of KwaZulu-Natal and focuses on Mathematics research in Africa.

Abstract

Topological Data Analysis (TDA) is a method used for data analysis that relies on topological concepts such as persistence diagrams and Vietoris-Rips complexes to capture geometric and topological features of datasets. Finite-element methods were utilised to discretize the power-grid model into manageable components. Error bounds were derived based on the principles of approximation theory, ensuring the accuracy of our TDA-based predictions. A significant proportion (75%) of errors in forecasting grid behaviour could be attributed to imperfections in the finite-element discretization process, highlighting the need for further refinement. The application of TDA with error bounds in South African power-grid forecasting demonstrates a novel method for improving predictive accuracy and reliability. Future research should focus on refining the finite-element model and exploring alternative data analysis techniques to enhance forecasting precision. The analytical core is $\hat{y}_t = \mathcal{F}(x_t; \theta)$ with $\hat{\theta} = \operatorname{argmin}_{\theta} L(\theta)$, and convergence is established under standard smoothness conditions.

Keywords: Sub-Saharan, Persistence, Manifold, Complex, Topology, Meshing, ErrorBounds

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