A Computational Approach to Growth Modeling Using Linear Recurrence Relations

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Growth processes are ubiquitous across diverse fields, including population dynamics, finance, epidemiology, and technological diffusion. While continuous models such as differential equations are frequently employed to describe these phenomena, real-world datasets, such as quarterly revenue, yearly enrollment, or daily active users, are inherently discrete. This paper proposes a robust computational framework for growth modeling grounded in linear recurrence relations. We move beyond manual iterative methods by formalizing a state-space representation that leverages matrix exponentiation for high-performance forecasting and long-term projection. The methodology encompasses the entire modeling lifecycle: from mathematical formalization and parameter estimation via least-squares optimization to algorithmic implementation in reproducible computing environments. Furthermore, we demonstrate how recurrence-based models can be calculated and evaluated using both synthetic and real-style datasets, providing a granular stability analysis that offers insights into oscillatory and asymptotic behaviors that continuous models often overlook. This framework bridges the gap between discrete mathematical theory and modern computational practice, offering a transparent, scalable, and extensible methodology suitable for both academic research and applied industrial analytics.

Keywords: Linear recurrence relations; growth modeling; computational modeling; state-space representation; discrete-time systems; simulation; data science