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Nonprogressive Diffusion on Social Networks: Approximation and Applications

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Nonprogressive Diffusion on Social Networks: Approximation and Applications

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Nonprogressive diffusion describes the spread of behavior on a social network, where agents are allowed to reverse their decisions as time evolves. It has a wide variety of applications in service adoption, opinion formation, epidemiology, etc. Two common approaches to analyzing network diffusion are: microfounded methods, which capture the detailed network topology and the stochastic evolution of agent states but often lead to computational challenges, and macroscopic methods, which simplify the diffusion process.

Our work bridges these two approaches in the context of nonprogressive diffusion. We investigate nonprogressive diffusion through a micro-founded, dynamic and stochastic model, which captures local network effects and individual heterogeneity. Within this model, we propose the Fixed-Point Approximation (FPA) scheme to approximate the limiting adoption probability of each agent. To validate this approach, we develop a nontrivial "fixed-point sandwich" technique, establishing an insightful error bound. This bound indicates its superior performance for large and dense networks, which are otherwise challenging to simulate.

We also introduce novel network structure metrics to gauge the performance of the FPA scheme: the *inverse in-degree centrality* and the *inverse in-degree density*. These metrics provide valuable insights into both node-level and network-wide characterizations, serving as reliable indicators for the performance of FPA in diverse network configurations. Our large-scale empirical studies highlight the FPA scheme's superior performance over a wide range of networks. It achieves a mean absolute percentage error of less than 3.48% among all tested real-world networks while concurrently accelerating computation by factors ranging from 70 to 230, compared with traditional simulation methods.

Moreover, the FPA scheme further paves the way for optimizing operational decisions, such as the influence maximization problem in the nonprogressive diffusion context. It allows for straightforward problem formulation and algorithm development, that are not just computationally efficient but also yield near-optimal solutions.

A full version of this paper can be found at:
https://drive.google.com/drive/folders/1N7nb38tIGaru7Nvnl9AHxoOBceE1-irJ?usp=share_link.

CCS Concepts: • **Theory of computation → Social networks**; **Exact and approximate computation of equilibria**.

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