Marked temporal point processes for simulating and capturing coordinated behaviour

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In recent years, the rise of social media has accelerated information dissemination. Unfortunately, this has been accompanied by a surge in disinformation — deliberate efforts to mislead and manipulate public perception. Disinformation campaigns, orchestrated to distort facts and sow societal discord, have emerged as one of modern society's most pressing challenges. As the European External Action Service Report [1] highlights, coordinated online activity - particularly in content and timing - significantly enhances the manipulative power of such campaigns. Comprehending these dynamics is crucial for developing effective detection mechanisms to identify and mitigate the impact of disinformation campaigns.

This research investigates the detection of *coordinated inauthentic accounts*. These are characterized by systematic and synergistic actions that anomalously amplify their content compared to authentic user temporal patterns [2]. These patterns can be effectively modelled using marked temporal point processes, stochastic processes that capture event timing, types, and interactions [3]. These processes are particularly well-suited for modelling social media activities, where users perform actions at specific timestamps. We investigate the detection of coordination via the application of marked temporal point processes.

Our approach extends the AMDN-HAGE model [4], which utilises temporal point processes for coordinated behaviour detection and masked self-attention for summarising historical data. We identify two key directions for advancement. First, we propose different clustering techniques that do not require prior knowledge of the number of clusters, like OPTICS. Second, we develop a novel user-to-user self-attention method. This method leverages self-attention weights to better characterise users' behaviours, ultimately improving clustering recovery. Addressing the challenge of limited ground truth data, we evaluate our methods using a hybrid dataset. This dataset combines real tweets from the 2023 Finnish parliamentary elections with synthetically generated coordinated campaign data. Furthermore, we introduce a novel simulation framework based on mutually exciting Hawkes processes, a type of marked temporal point process, to generate realistic social media activity (Figure 1*a*). This method, employing a Bayesian hierarchical structure, enables precise control over key features. These include the number of activities, user behaviour heterogeneity, inauthentic coordination strategy, interaction levels between authentic and inauthentic users (p), and the influence dynamics. The suite also encompasses spammers, inauthentic users engineered solely to amplify specific content ($p = 0$, Figure 1*b*), and sockpuppets, accounts that intensely interact with authentic users to disguise themself ($p = 1$). Thus, this tool suite facilitates a comprehensive evaluation of coordination detection models across diverse scenarios.

The evaluation of our models and state-of-the-art techniques reveals that coordination detection performance is highly dependent on campaign characteristics. No single method is consistently superior (Figure 1*c*). While some methods excel in low-interaction environments, others are more effective in scenarios with higher social engagement. Notably, our user-to-user self-attention model achieves strong detection performance in mixed-interaction scenarios, surpassing many existing approaches. Ultimately, our findings highlight that the effectiveness of the detection methods depends on the characteristics of the considered coordinated campaign. We advocate for the use of our simulation framework in future research to enable rigorous, comprehensive evaluations of coordination detection methodologies. By addressing the limitations of existing datasets and detection methods, this work paves the way for more accurate and adaptable strategies against coordinated manipulation.

Main references:

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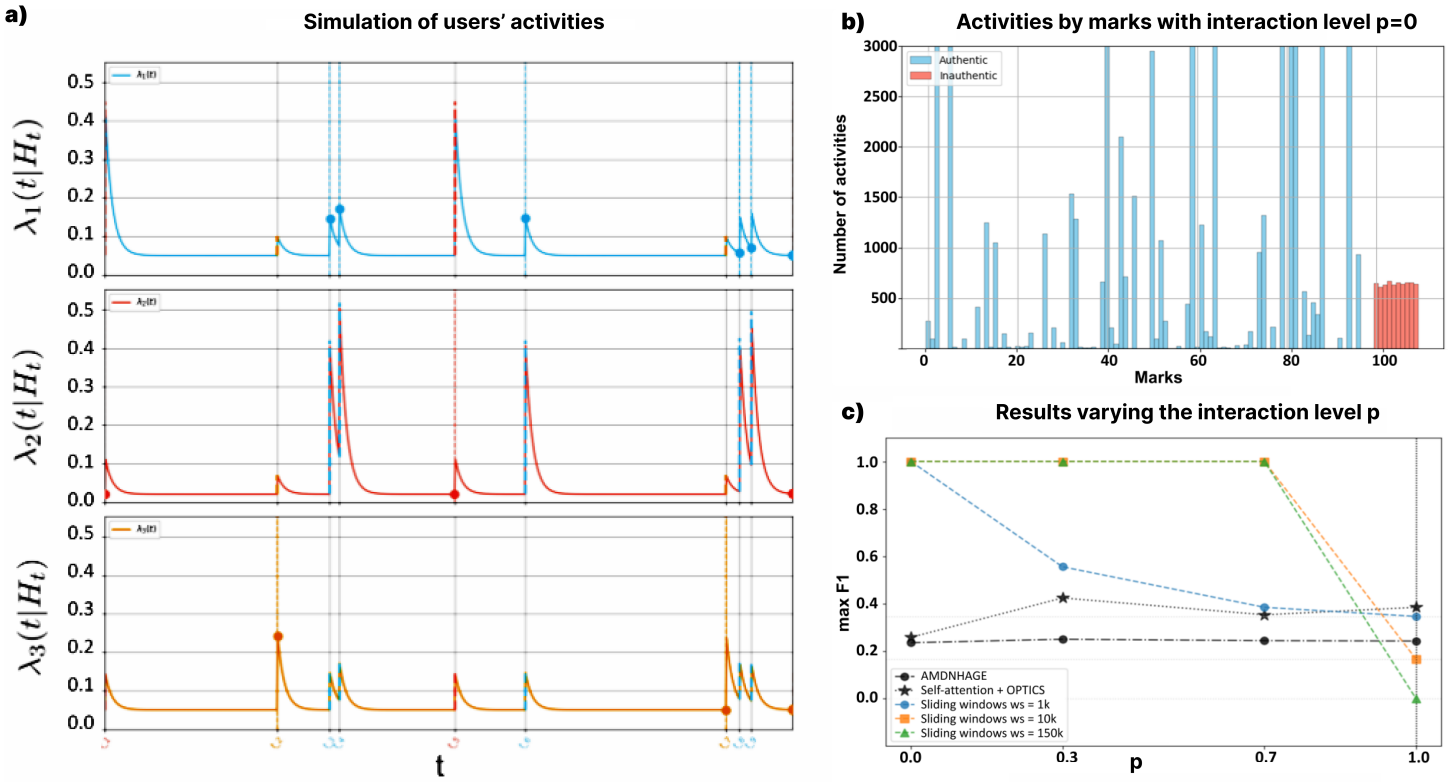

Figure 1: Simulation and detection of coordinated inauthentic behaviour. **a)** Simulation of the activities of 3 users influencing each other via a realisation of a mutually exciting Hawkes process. The solid lines represent the conditional intensity function of the users, which describes the instantaneous rate of event occurrence at a given time, while the users' actions and their influence on other users are represented by the dots and the dashed lines respectively. **b)** Histogram of users' activities generated when authentic and inauthentic accounts do not interact, i.e. interaction level is $p = 0$. Every bar represents the number of activities of the user with the corresponding mark. **c)** Comparison of different coordinated behaviour detection as the interaction level p varies. Each line represents the maximum F1 score of the associated detection method in the four different scenarios.