# Nonlinear Opinion Dynamics for Event-Based Intelligent Sensors

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## 1 Introduction

Event-based cameras are revolutionary visual sensors that respond to changes in light intensity asynchronously rather than continuously sampling vision at a fixed frame rate. The asynchronous nature of event-based cameras brings high temporal resolution, reduced motion blur, and a wide dynamic range, while consuming minimal power. These features make them ideal for real-time applications in dynamic and complex environments.[3],[2]

However, despite these advantages, event-based cameras face significant limitations, the most notable being the lack of in-sensor event processing. Without the ability to process events directly within the sensor, large volumes of raw event data must be transmitted for external processing, leading to inefficiencies in bandwidth usage and increased computational demands. Furthermore, the absence of local processing often results in redundant or noisy events being transmitted.

## 2 Proposed Approach

To address this, we propose a novel approach that introduces a networked layer of decision-making cells, one for each pixel, to dynamically filter and prioritize events. The dynamics of these cells is based on the Fast and Flexible Nonlinear Opinion Dynamics with Modulatory Interactions (M-NOD) model. This model enables robust and adaptive collective decision making in networked systems. Each cell in the decision-making layer makes the decision to either let trough or block incoming events based on its and neighboring cells' states, the event rate at the corresponding pixel, events from neighboring pixels, and the overarching sensory computational goal.

Thus, in our model events are processed directly at the sensor level, filtering out irrelevant data before transmission and reducing bandwidth and computational load downstream the sensor. The M-NOD model's modular structure adapts to varying sensory computation needs by reconfiguring parameters and/or network topology. Inspired by neural dynamics, the system performs adaptive spatiotemporal nonlinear filtering to implement fast and tunable visual event processing and broadcasting, e.g., low-level static and dynamic (movement) image segmentation, and redundancy and noise reduction. Our approach is close in spirit to [1] but with key difference of replacing spiking neural networks with robust and adaptive decision-making dynamics.

The Fast and Flexible Nonlinear Opinion Dynamics (M-NOD) model is defined by the following equations:

$$\tau \dot{x}_i = -x_i + b_i + S\left(\sum_{j=1}^{N} a_{ij}\left(u_0 + \sum_{k=1}^{N} m_{ijk} x_k^n\right) x_j\right), \quad i = 1, \ldots, N \tag{1}$$

$$\tau \dot{\mathbf{x}} = -\mathbf{x} + \mathbf{b} + S\left(\left(u_0 \mathbf{1}_N \mathbf{1}_N^T + \tilde{M}(\mathbf{x})\right) \odot \mathbf{A} \cdot \mathbf{x}\right) \tag{2}$$

The timescale $\tau$ determines how quickly the filter responds to incoming events. The state vector $\mathbf{x} = [x_1, x_2, \ldots, x_N]^T$ represents decision-making cell layer states. The bias vector $\mathbf{b}$ models external inputs, particularly including stream of events. The interaction matrix $A = [a_{ij}]$ defines influence strength between pixels, while the modulatory term $\tilde{M}(x)$ adjusts interactions dynamically based on the states of other agents. This means modulatory interactions allow one agent's state to influence how much impact another agent has, creating context-sensitive and adaptive behavior and the sigmoidal function $S(x)$ smooths and bounds the system's responses. For further details see the reference article[4]. The model is ideal to capture complex, adaptive dynamics, ideal for filtering event-based camera data.

## References

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