Physical Modeling of Spatial Diffusion and Relocation Dynamics of Armed Conflict Prediction

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Summary

This study introduces a new methodology that combines physics, statistics, and PDEs to model political violence. By integrating a wave equation with MLP and LSTM networks, we significantly enhance predictive accuracy, achieving a 56% improvement over the ViEWS benchmark at the PRIO-GRID cell-month level.

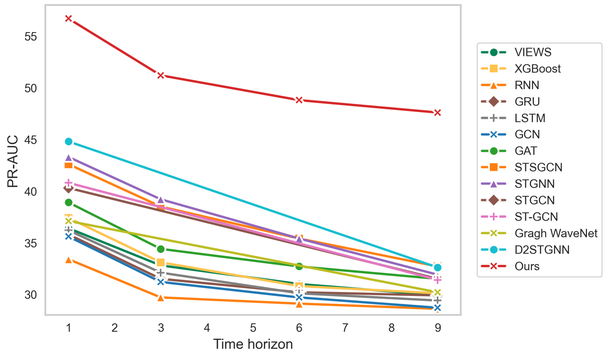


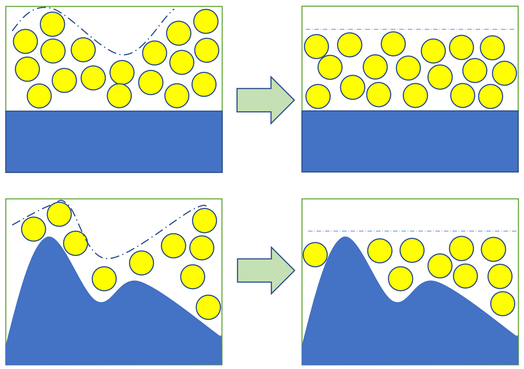
Figure 1. PR-AUC Comparison Over Time. Our model exhibits notable improvements over the baseline models across all evaluation metrics.

Related Works

- **Traditional Conflict Forecasting**: Forecasting at least 1 BRD (Hegre et al., 2019, 2021, 2017); But Simplistic Proxies - lagged binary variables (Muchlinski et al., 2016; Wang, 2019)
- **Spatiotemporal Deep Leaning**: RNN/LSTM/GCN/ConvLSTM/STGCN (Brandt et al., 2022; Chadefaux, 2022; Hegre et al., 2022; Lindholm et al., 2022)
- **Physical-Knowledge Assisting**: Forecasting for extreme precipitation events (Zhang et al., 2023); "Diffusion, relocation, heterogeneous escalation" (Zammit-Mangion et al., 2012)

Motivation

Figure 2. Diffusion As Falling Balls on the Plain or Mountain.



ConflictNet

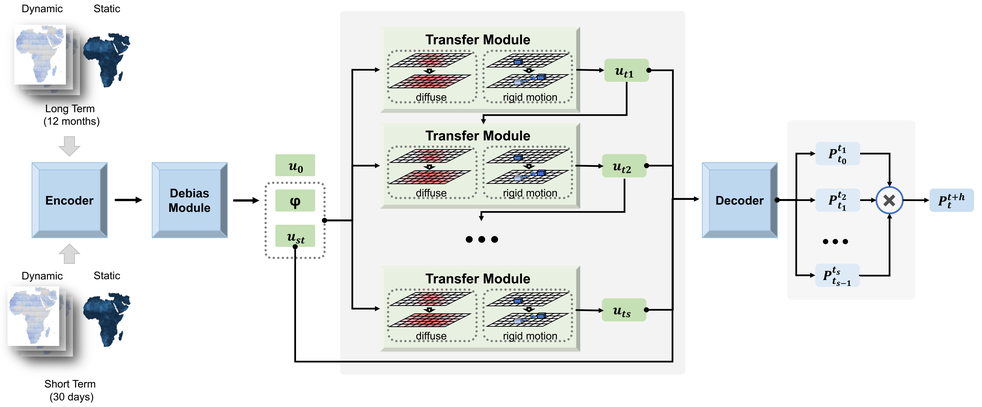


Figure 3. Framework of ConflictNet. Where the encoder integrates dynamic and static features and extracts long-term trends and short-term patterns; the transfer and decoder modules solve the PDE and output the armed conflict probabilities.

Main Results

Table 1. Performance of different methods with $h = 1, 3, 6, 9$ months. We selected 2013, 2016, and 2019 for cross-validation, taking 24 months and showing the average. Bold face indicates the best result of each column and underlined is the second-best.

	PR-AUC %				ROC-AUC %				F_1 %			
	1	3	6	9	1	3	6	9	1	3	6	9
ViEWS	36.4	32.8	31.0	29.9	94.8	92.2	90.4	88.6	34.7	31.4	29.6	28.8
XGBoost	37.4	33.1	30.8	30.1	93.9	93.1	92.4	91.6	35.4	31.4	28.7	27.3
RNN	33.4	29.7	29.1	28.6	92.1	91.6	91.4	91.3	35.7	33.6	32.4	31.9
GRU	35.8	31.5	30.2	29.9	92.2	91.3	91.0	90.8	39.5	36.4	35.8	35.4
LSTM	36.2	32.1	30.1	29.4	92.3	92.0	91.5	91.2	39.4	36.6	35.5	34.8
GCN	35.6	31.2	29.7	28.7	91.8	91.1	90.8	90.5	39.8	36.4	35.5	35.0
GAT	38.9	34.4	32.7	31.5	94.3	94.0	93.5	93.2	40.6	36.1	36.4	35.8
STSGCN	42.6	38.5	35.4	32.7	95.1	94.8	94.6	94.4	42.4	37.2	35.2	36.1
STGNN	43.3	39.2	35.4	31.9	95.2	95.0	94.6	93.9	42.5	38.3	36.1	35.9
ConflictNet	**56.7**	**51.2**	**48.8**	**47.6**	**97.0**	**96.6**	**96.3**	**96.2**	**53.7**	**50.0**	**48.2**	**47.5**

Ablation Study

Table 2. We forecast the 1st month and perform 3-fold cross-validation.w/o de-bias is ConflictNet without De-bias Module. w/o transfer is ConflictNet without Transfer Module.

	PR-AUC %	ROC-AUC %	F_1 %
ConflictNet	56.7	97.0	53.7
w/o de-bias	53.4	96.7	50.6
w/o transfer	40.3	94.9	39.1

Data Splitting

Time	PR-AUC %	ROC-AUC%	F_1%
Spatial Splitting - South / North			
1	51.6	96.3	49.2
9	39.2	95.5	43.9
Temporal Splitting - Before / After 2008			
1	55.5	96.8	51.4
9	44.8	96.0	46.1

Diffusion Dynamics

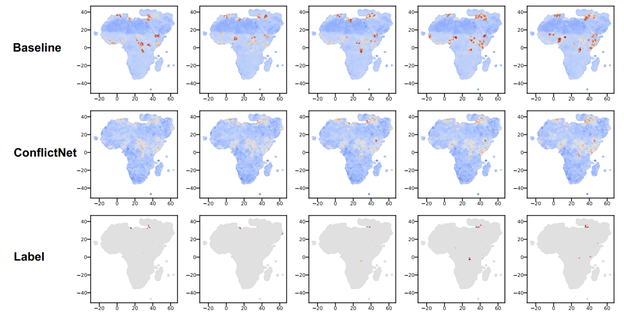


Figure 4. Thermodynamic diagrams depicting the baseline method or ConflictNet conflict factors, along with corresponding labels, in Africa every three months from June 2012 to June 2013. This figure displays the progression of conflict representation diffusion over time, segmented into three-month intervals starting from June 2012.

Feauture Importance

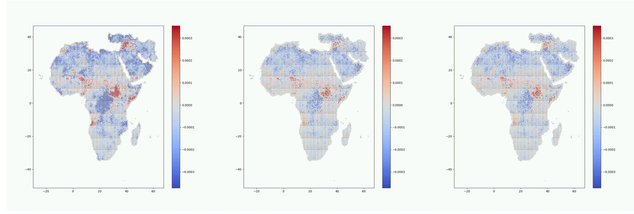


Figure 5. Spatial Heterogeneity in the Impact of State Capacity on Armed Conflict. At the red grids, a state extends its presence when its capacity grows. Within each state, such an increase of control in peripheral regions often encounters resistance from established local non-state powers, leading to civil conflict.

Causal Inference

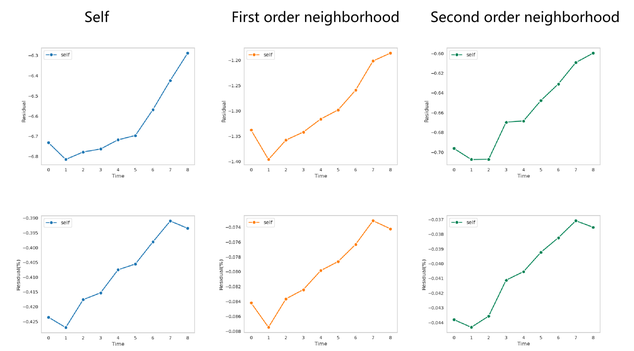


Figure 6. The Influence of State Capacity Decays Over Time. For the central government, the purpose of consolidating its peripheral territory is mainly resource and security, while conflict incidents are unintended consequences that would only occur when local non-state powers resist.

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