MULTIMODAL DETECTION OF FIREBALL EVENTS USING GEOSTATIONARY LIGHTNING MAPPER DATA AND GROUND-BASED ALL-SKY IMAGERY

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INTRODUCTION

Detecting atmospheric fireballs supports science and recovery, but satellite (GLM (Global Lightning Mapper)) and ground cameras (DFN (Dessert Fireball Network) / GFO (Global Fireball Observatory)) struggle with limited coverage and data heterogeneity. A multimodal ML pipeline integrating both sources enables more accurate, robust event classification. Foundational work included clustering confirmed fireballs and highlighting real data cross-matching challenges; initial prototypes used synthetic data [1],[2],[3].

MATERIALS AND METHODS

GLM metadata and all-sky camera imagery were sourced from NOAA, DFN, etc [1],[2]. Synchronization relied on timestamp matching and a 500 km (4.5°) buffer for TOPCAT spatial alignment. NASA Fireball API events were clustered by altitude, velocity, and energy (K-Means). The ML pipeline fused ResNet18-processed images and tabular features via PyTorch/XGBoost, combining features for classification. Synthetic samples supported baseline testing when real matches were unavailable [4]. Binary classification: Class 1—confirmed fireballs; Class 0—background/noise. Table 1 lists metadata fields.

RESULTS AND DISCUSSION

Synthetic multimodal data yielded ~60% accuracy and an F1-score of 0.67 for fireballs using XGBoost (Table 1). Discriminative features included energy, confidence, and brightness. No matches were found between real GLM and GFO datasets using relaxed cross-matching, underlining integration complexity. Figure 1 outlines the processing pipeline.

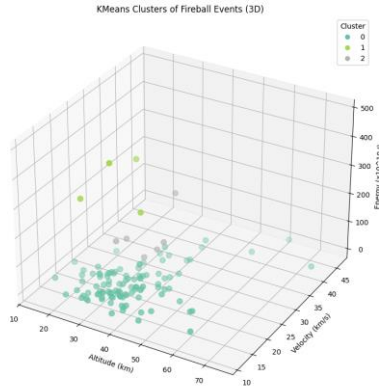

Fig 1 Three-dimensional cluster plot showing grouping of NASA Fireball API events by altitude, velocity, and energy, visualizing intrinsic event patterns for downstream classification.

CONCLUSIONS

The pipeline confirms joint tabular/image ML supports baseline fireball candidate identification. Synthetic clustering reveals distinct event groups. Future work focuses on refining fusion techniques and real-world matching for enhanced classification and real-time inference.

REFERENCES

[1] NOAA GLM Science Overview. GOES-R Series Program Office. www.goes-r.gov/spacesegment/glm.html, 2025.
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Table 1: Classification performance metrics of the XGBoost model on synthetic multimodal fireball event data, showing precision, recall, F1-score, and support for each class and overall accuracy.

Class	Precision	Recall	*F1-score*	*Support*
0	0.50	0.50	0.50	8
1	0.67	0.67	0.67	12
Accuracy			0.60	20