FireChain: A Satellite-Driven Deep Learning System for Autonomous Wildfire Response

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Wildfire response depends on three tasks that currently operate in isolation: detecting fires, forecasting where they will spread, and deciding where to send crews. Existing detection relies on static brightness temperature thresholds that miss most small fires. Spread prediction requires hours of manual input preparation before a single simulation can run. No operational tool translates a spread forecast into a crew deployment recommendation. This research developed FireChain, a three-layer deep learning system that connects all three tasks using only publicly available satellite data and federal fire records. The first layer trained a ConvLSTM on one-hour temporal sequences of GOES geostationary satellite scans across four spectral channels, with derived brightness temperature difference and smoke-edge features, plus static context including fuel type, terrain, humidity, and lightning activity. The second layer forecast fire spread at four time horizons using a U-Net with temporal attention encoder, trained through a four-stage curriculum spanning synthetic simulator outputs and real satellite-observed perimeters, with physics-based loss penalties enforcing monotonicity, continuity, rate-of-spread ceilings, and wind alignment. Conformal prediction produced uncertainty bounds at three coverage levels, which the third layer used as time-window constraints in a routing optimizer that scored candidate fireline locations using an XGBoost model trained on federal fireline effectiveness records. FireChain showed earlier mean detection latency relative to the operational satellite product and competitive spread prediction against the published benchmark. Routing recommendations favored historically effective fireline locations above all tested ablation baselines.

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