SF2 SEMANTIC FOLDING SENSOR FUSION

SF2 CASE STUDY

SF2 Systems for Early Detection of 5xx Server Outages

Predictive maintenance for IT environments through semantic system-state monitoring

100 Sensor Features fused simultaneously

16,354 Records analyzed

0.024% 5xx Event Rate in the dataset

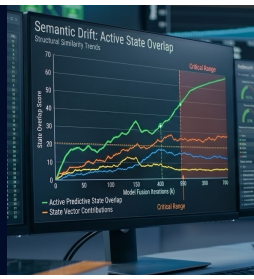
59 min Lead Time before first 5xx incident

THE CHALLENGE – The Invisible Risk in Complex IT Infrastructure

Modern cloud platforms and web applications generate thousands of infrastructure, network, and database metrics every minute. While this data is vital for keeping systems online, its massive scale and chaotic nature make it difficult to isolate true failure warning signs using traditional methods:

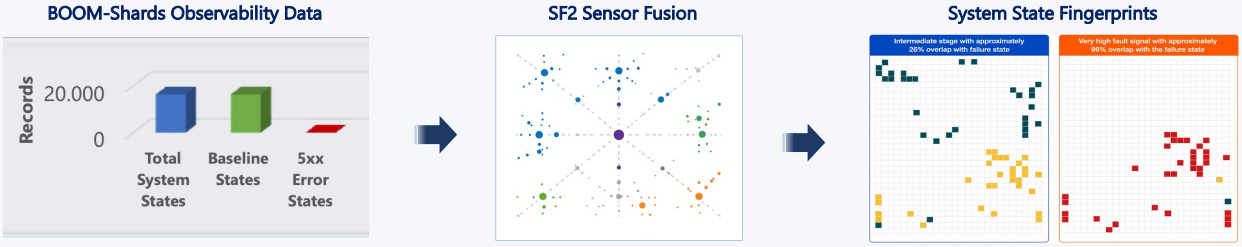
- **Reactive Threshold Alerting** → Legacy monitoring setups trigger warnings only *after* a metric breaches a critical line. By then, a user-facing outage or service degradation is already actively occurring.
- **Severe Data Scarcity** → Server outages are inherently rare events, providing very limited failure examples required for conventional ML models.
- **High Forecasting Complexity** – Trying to calculate and simulate exact future metric behaviors requires massive amounts of historical data and constant manual tuning of complex settings. This creates fragile models that are easily thrown off by real-world changes and are difficult to maintain reliably in production.

The core question is:
Can the progression toward a critical 5xx event be identified as semantic drift *before* the failure becomes visible to threshold-based legacy monitoring?

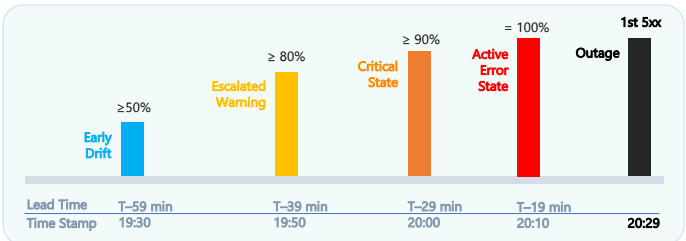


THE SF2 SOLUTION – Making Complex Runtime States Operationally Visible

Instead of analyzing individual metric channels or trying to extrapolate mathematical curves into an uncertain future, SF2 transforms raw IT telemetry into digital state fingerprints. This study evaluates structural drift across telemetry matrices using real-world multi-sensor data from the Datadog BOOM dataset*.



THE RESULT – Early Warning Despite Having Only 4 Failure Events



The structural similarity between the live system state and the stored 5xx error fingerprint increased steadily, revealing a clear progression toward failure well before the first outage occurred.

Proof of Performance

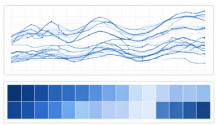
- ✓ **59 minutes explicit early warning -** Progression toward the fault state became clearly visible nearly an hour before the first native 5xx error point registered.
- ✓ **High confidence detection -** 80% failure-state match was detected 39 minutes before failure, with critical 90% level reached 29 minutes before legacy monitoring reacted.
- ✓ **Ultra-low compute footprint –** A single workstation can effortlessly monitor thousands of failure signatures per second simultaneously using SF2.

SF2 transforms observability metrics into an intelligent early warning system for proactive outage prevention.

HOW SF2 WORKS

1 Data Normalization

Raw observability metrics are converted into standardized discrete categories to to align different data channels into comparable semantic contexts.

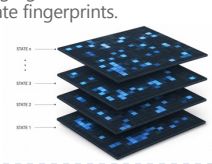


2 Semantic Mapping (Semantic Dictionary)

SF2 creates a spatial representation space ("Retina") grouping similar machine contexts and mapping hidden relationships across features.

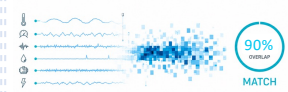
3 Fingerprint Aggregation (Classifier)

Feature states are converted into Semantic Fingerprints representing the system's overall state and aggregated into reference fault-state fingerprints.



4 Real-Time Identification (Comparison)

The overlap of incoming system fingerprints is continuously checked against the known "5xx Error" reference pattern.



SF2 transforms observability data into a digital representation of the overall system state and applies semantic mapping to remain robust against noise and sensor drift.

Why Semantic System-State Representation Outperforms Statistical AI

SF2 (Deterministic)

- ✓ State-based monitoring & early warning
- ✓ Works with extremely rare fault events
- ✓ Eliminates massive, manually-labelled training data need
- ✓ Explainable and reproducible
- ✓ Real-time, low compute
- ✓ 100% data sovereignty
- ✓ 100% edge-capable / offline – real-time on any device

Model-centric AI (Probabilistic)

- ✗ Uncertain approximations
- ✗ Requires large numbers of fault examples
- ✗ Requires large labeled datasets
- ✗ Black-box behavior
- ✗ High compute & high-latency processing
- ✗ Mostly cloud-dependent (data & security risk)
- ✗ Not edge-ready

MEASURABLE BUSINESS IMPACT

Earlier Incident Response
Investigate and stabilize systems before customer-facing outages occur

Reduced Downtime
Defend against service disruptions, failed transactions, SLA penalties, and emergency escalation

Faster Root Cause Analysis
Use explainable system-state fingerprints to accelerate troubleshooting and remediation

Edge-Ready
Analyze telemetry locally without cloud dependency or data transfer requirements

Lower Monitoring Complexity
Reduce alert noise, dashboard sprawl, and the need for complex forecasting models

Lower Operational Costs
Reduce incident management overead and emergency response activities

CONCLUSION

SF2 converts complex, un-synchronized observability data into a consistent real-time map of system health. In this case study, an impending 5xx server outage became clearly visible up to 59 minutes before the first recorded error event—despite having only four fault instances available to learn from. This framework gives DevOps teams a reliable, low-latency window to shift workloads, scale instances, and prevent severe service disruptions entirely.

*) Data Source Note: The experiment utilized un-synchronized multi-sensor time-series telemetry shards (such as infrastructure shard ds-1-T and database shard ds-2-5T) reconstructed from the Datadog BOOM Dataset.

Learn more at www.SF2systems.com

FUTURE POTENTIAL – Any sensor-rich digital system can become operationally interpretable

- Industrial Manufacturing
- Chemical & Process Industry
- Pharmaceutical Industry
- Industrial Equipment
- Automotive Systems
- Energy Infrastructure
- Water & Utilities
- Smart Buildings
- Digital Infrastructure
- Mobility & Transportation

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