SF2 SEMANTIC FOLDING SENSOR FUSION

SF2 CASE STUDY

SF2 System for Intelligent Water Pump Monitoring

Failure detected 4 days before breakdown

Trained on 220K records in under 15 minutes – on a standard notebook.

52 Sensors monitoring the pump

220,000+ Data points processed

<15 min Training on standard notebook

4 Days Advance failure dectection

THE CHALLENGE – Why Traditional Monitoring AI Fails

A municipal water pump dataset with extensive sensor data but very few downtime events – making early failure prediction difficult for traditional AI:

- **Only 7 failure events (<1%) in 220k records** → not enough for ML
- **No sensor metadata (types, units unknown)** → no feature engineering possible
- **High-dimensional sensor interactions** → impossible to model manually
- **Traditional AI requires large labeled datasets, long training cycles and high compute resources**

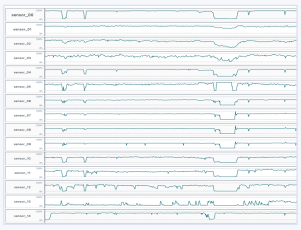
Threshold systems only detect when something has already gone wrong. SF2 detects degredation trends, not just sudden failures.

> The problem is not data availability; it's understanding system behavior.

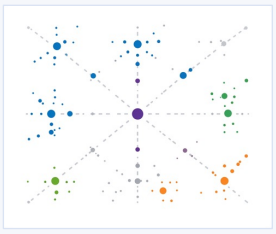
THE SF2 SOLUTION – Decoding the Language of Complex Systems

SF2 converts entire system states into a unique digital fingerprint – essentially a FaceID for machines – that encapsulates the full context and interdependencies of a system at any given moment.

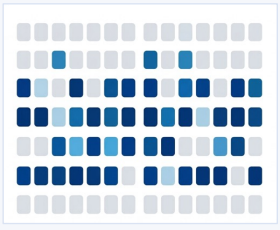
Raw Sensor Data



SF2 Sensor Fusion

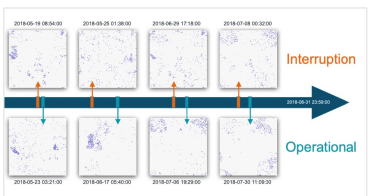


System State Fingerprint

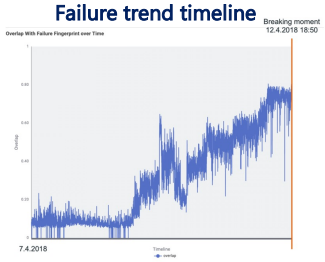


THE RESULT – Predictive Maintenance in Minutes, Not Months

Operational system state versus failure



Failure trend timeline



Proof of Performance

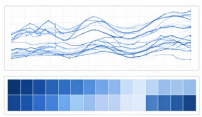
- ✓ Failure trajectory detected **4 days in advance**
- ✓ **Reliable results even with minimal failure data**
- ✓ **Trained** on standard hardware in **~15 minutes**
- ✓ **No system or data science knowledge required**

SF2 makes complex systems understandable — and failures predictable.

HOW SF2 WORKS

1 Data Normalization (Binning)

Raw time-series sensor values are converted into standardized discrete categories (255 bins per sensor) to prepare for semantic mapping.

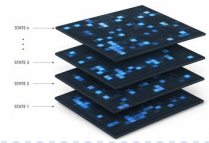


2 Semantic Mapping (Semantic Dictionary)

Using only normal operating data, SF2 learns baseline behavior & natural relationships between sensors, creating a model of healthy operation.

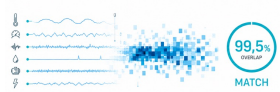
3 Fingerprint Aggregation (Stacking)

Each sensor value is mapped to a sparse binary vector. These are combined into a single system-state fingerprint representing the entire asset.



4 Real-Time Interpretation (Comparison)

Incoming machine states are compared agaibst known patterns to detect deviations and predict trends before failures occur.



Multiple sensor fingerprints are stacked and aggregated into a single representation.
Each timestamp becomes a context that captures the entire system state at that moment.

Why Understanding System State Outperforms Statistical Estimations

SF2 (Deterministic)

- ✓ Accurate state-based monitoring & prediction
- ✓ Detects gradual shifts as they occur
- ✓ No labelled date required
- ✓ 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
- ✗ Detects failures only after thresholds are crossed
- ✗ Requires large labeled datasets
- ✗ Black-box behavior
- ✗ High compute & high-latency processing
- ✗ Mostly cloud-dependent (data & security risk)
- ✗ Not edge-ready

MEASUREABLE BUSINESS IMPACT

Less Downtime
Avoid costly failures before they occur

Faster Time-to-Value
Deploy in days, not months

Predictable Operations
Plan maintenance with confidence

Lower Cost
No heavy infrastructure required

Full Control
100% local, secure and transparent

SF2 makes system states directly comparable in real time. Deviations from normal operation become visible early, enabling planned maintenance and reducing unplanned downtime. This is achieved without predefined thresholds or model retraining. As a result, system behavior remains interpretable even under changing operating conditions. All analysis is performed locally and require no prior knowledge of the physical system, sensor types or failure patterns.

CONCLUSION

SF2 turns noisy sensor streams into a unified live representation of system behavior. In this case study, signs of failure in a municipal waterpump were visible 4 days before breakdown, after training with only 220K+ records and 7 failure events in under 15 minutes on a standard hardware.

Learn more at www.SF2systems.com

FUTURE POTENTIAL – Any machine with sensors can become operationally interpretable

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

SF2 SYSTEMS

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info@SF2systems.com | www.SF2systems.com