

SPARK: Smart Building Fire Prediction And Risk Analysis



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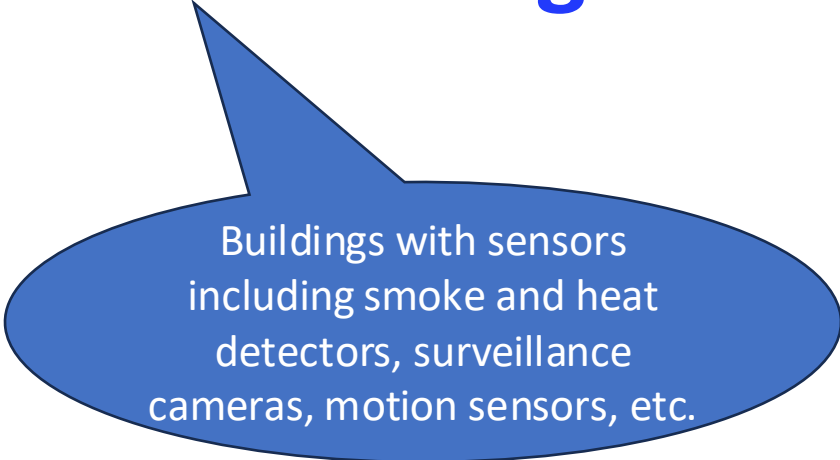
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- Objective
- Existing Works
- Our Contribution: SPARK
- Experiment Results
- Conclusion

**Can we develop a system/technique
for fire prediction in smart buildings?**

A blue speech bubble with a black outline, pointing upwards towards the main text. It contains white text describing smart building sensors.

Buildings with sensors
including smoke and heat
detectors, surveillance
cameras, motion sensors, etc.

Existing Work for Fire Prediction in Smart Buildings

Prior Works

Static Sensing

- Consistent sensing
- Low latency alarms
- Blind spots
- Outages reduce coverage
- Ignores building connectivity

Dynamic Sensing

- Can reach unsafe zones
- On demand
- Intermittent/latency-prone
- Noisy and less accurate

Infra-agnostic fusion

- Employs different sensor types
- Robust to missing sensors
- Cannot anticipate indirect spread
- Lacks multi-hop diffusion

SPARK

Integrates **heterogeneous sources** (static, dynamic, and human) and **room attributes** to accurately predict **fire spread in smart buildings**

SPARK Accuracy $\approx 96\%$ (for 10 floor buildings with 20 rooms on each floor)

SPARK: Algorithm Overview



- Phase 1: **Modeling** a building
- Phase 2: Sensor **data collection**
- Phase 3: Sensor data **normalization** and **fusion**
- Phase 4: Fire **propagation** (room attributes and neighbors)
- Phase 5: Risk-Zone **Clustering**

SPARK: Phase 1 - Modeling a Building

Convert buildings into graphs

- Rooms → Nodes
- Connection → Edges

Structural Adjacency Graph

- Walls
- Doors, windows
- Corridors

Airflow Adjacency Graph

- Vents
- HVAC
- Ducts/channel

Final Adjacency Graph

- **Set Weight** → structural and airflow graph
- **Aggregate** the graphs

Room/nodes attributes

Flammability

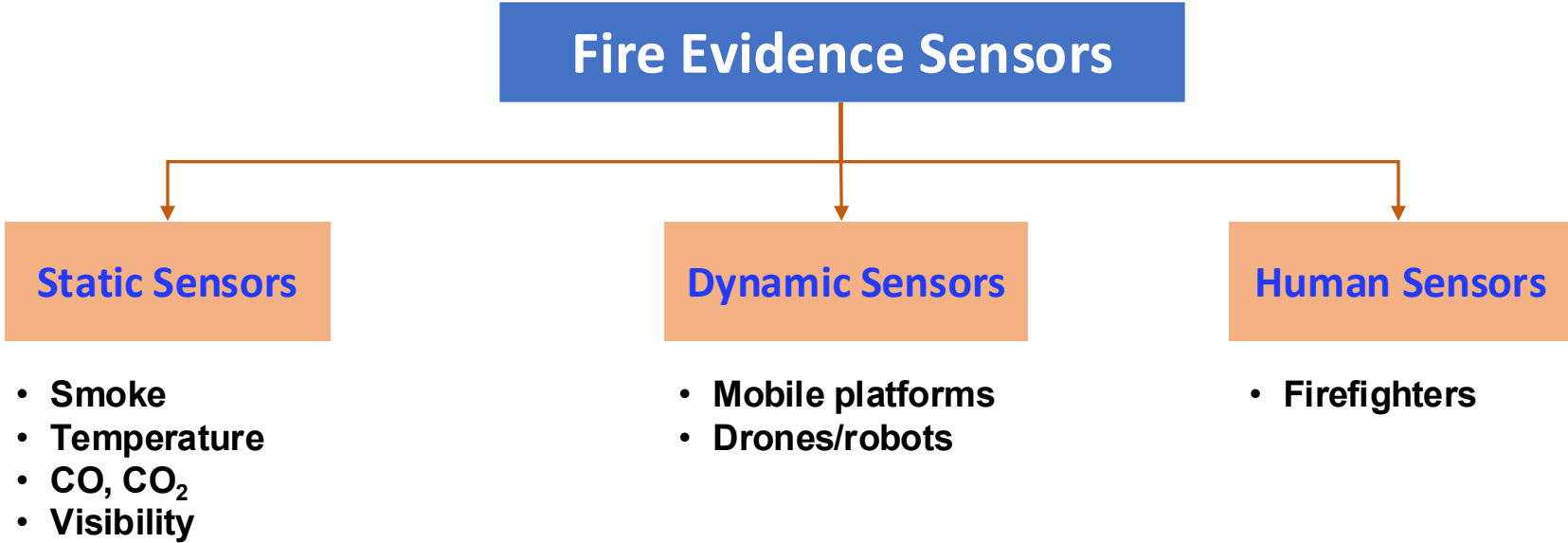
- **Combustible materials**, e.g., paper, gasoline

Criticality

- Operational importance
- Human occupancy

SPARK : Phase 2 – Sensor Data Collection

Fire Evidence Sensors



```
graph TD; A[Fire Evidence Sensors] --> B[Static Sensors]; A --> C[Dynamic Sensors]; A --> D[Human Sensors]; B --> B1[Smoke]; B --> B2[Temperature]; B --> B3["CO, CO2"]; B --> B4[Visibility]; C --> C1[Mobile platforms]; C --> C2[Drones/robots]; D --> D1[Firefighters];
```

The diagram is a hierarchical flowchart. At the top is a blue rectangular box with the text "Fire Evidence Sensors" in white. A horizontal line extends from the bottom of this box, with three vertical arrows pointing down to three separate orange rectangular boxes. The first box on the left is labeled "Static Sensors" in blue text and contains a bulleted list of four items: "Smoke", "Temperature", "CO, CO₂", and "Visibility". The middle box is labeled "Dynamic Sensors" in blue text and contains a bulleted list of two items: "Mobile platforms" and "Drones/robots". The third box on the right is labeled "Human Sensors" in blue text and contains a bulleted list of one item: "Firefighters".

Static Sensors

- Smoke
- Temperature
- CO, CO₂
- Visibility

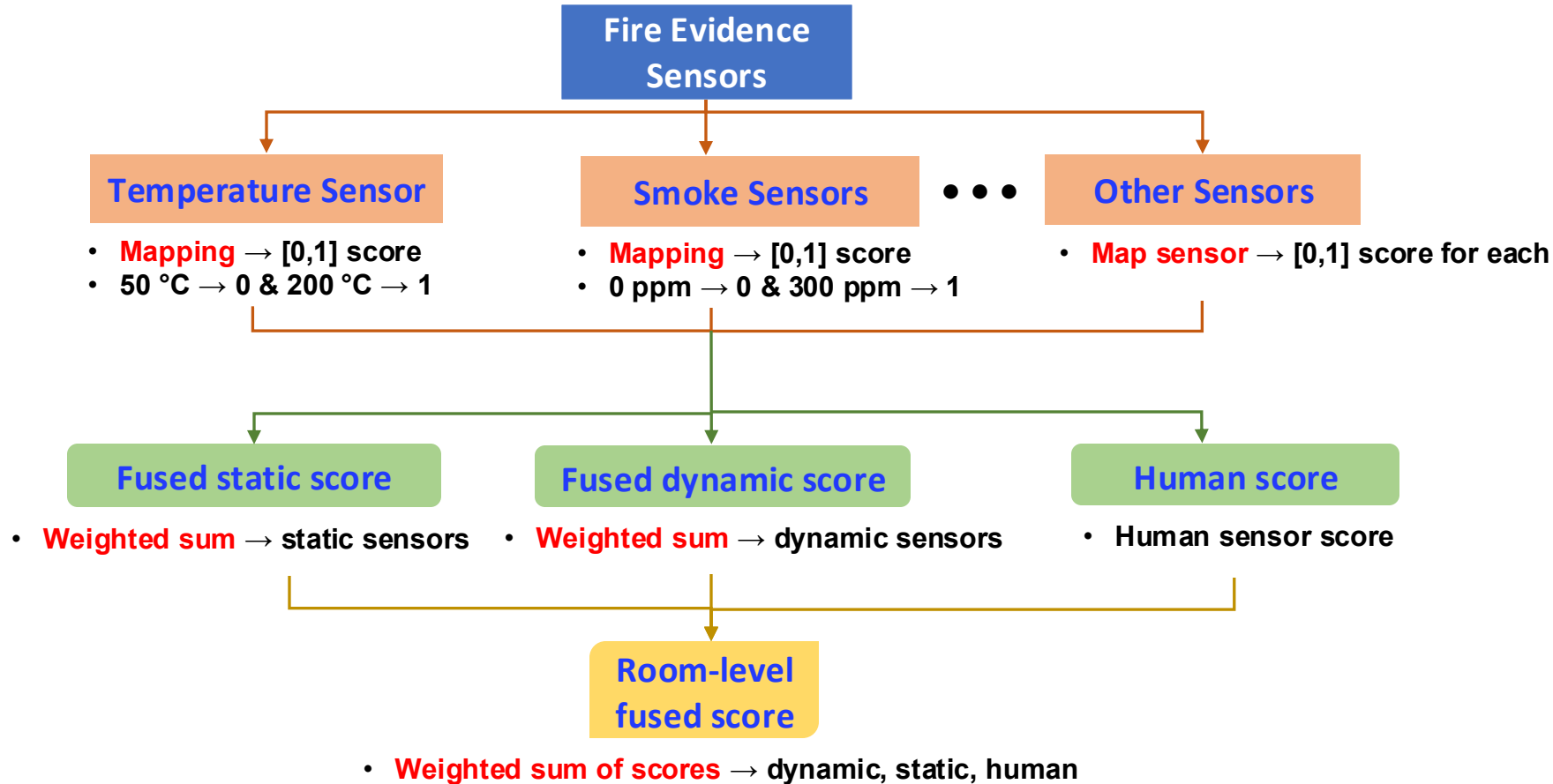
Dynamic Sensors

- Mobile platforms
- Drones/robots

Human Sensors

- Firefighters

SPARK : Phase 3 – Data Normalization and Fusion



SPARK : Phase 4 – Fire Propagation

Room-level
fused score

Attribute
adjusted score

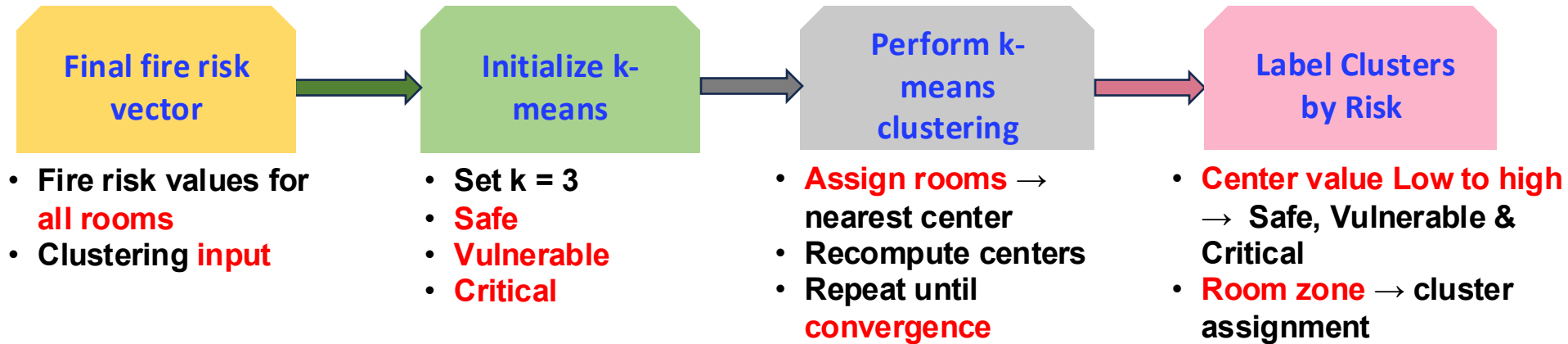
Immediate
neighbors
adjusted score

Multi-hop
neighbors
adjusted score

Final fire risk

- **Room Attributes** → flammability, criticality
- **Scale score** → combine factors and multiply
- **Find neighbors** → use adjacency graph
- **Aggregate** neighbor scores
- **Row-normalized** adjacency graph
- **Attenuation** factor
- **Graph diffusion** → multi-hop propagation
- **Final multi-hop neighbor & attribute adjusted risk**

SPARK : Phase 5 – Risk-Zone Clustering



Experiment Results



- **Simulator:** NIST Fire Dynamics Simulator (FDS)
- **Layouts:** 3-floor and 10-floor buildings
- **Rooms:** 20 rooms per floor (60 rooms & 200 rooms)

Experiment Results

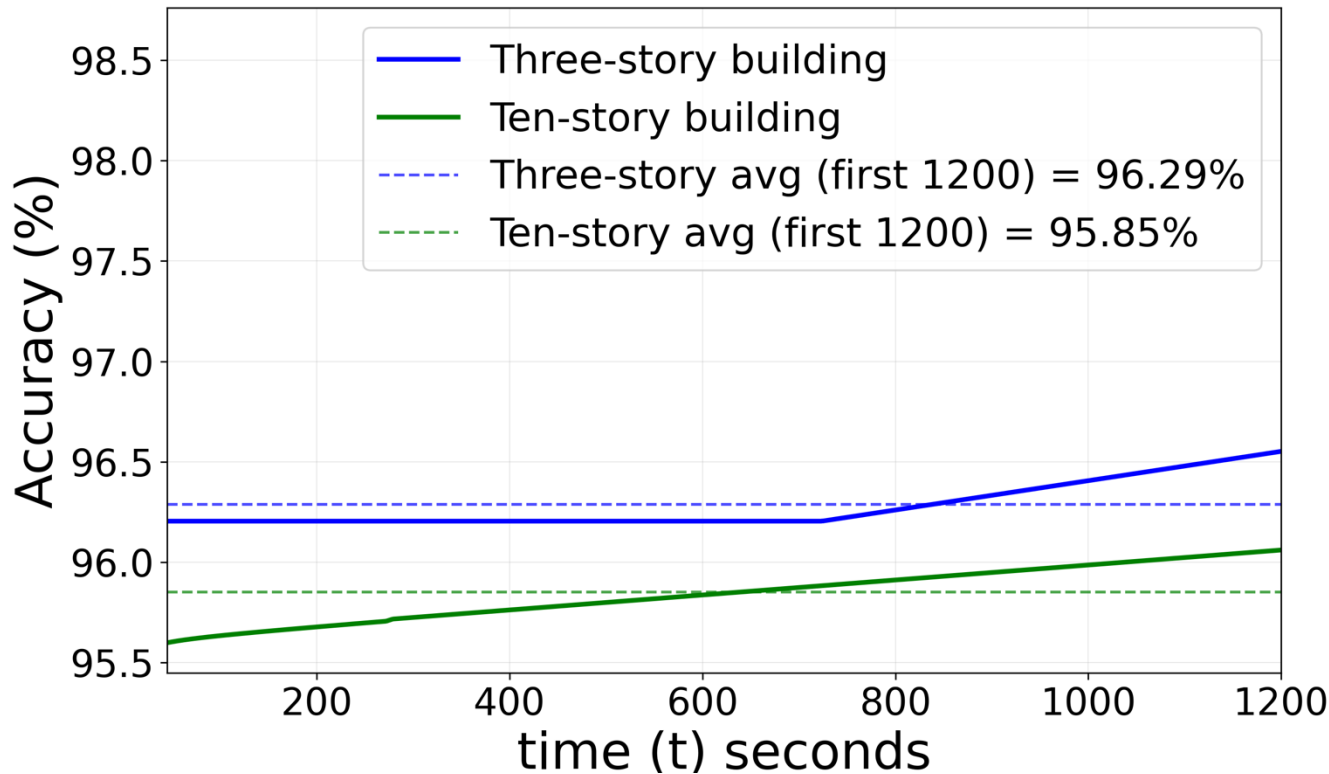


Figure: Prediction accuracy (%) of SPARK over time. Accuracy at epoch t is defined as the percentage of rooms correctly predicted for fire spread.

Experiment Results

Building	Static-Only	Dynamic-Only	Dynamic + Static
Three-floor	97.12	94.77	98.09
Ten-floor	95.31	91.67	97.06

Table: prediction accuracy (%) of SPARK under different sensor settings for three-story and ten-story buildings.

- **SPARK** : A fire-prediction system for smart buildings
- Incorporates:
 - Static, dynamic/mobile and human sensors
 - Room attributes (e.g., flammability)
- **≈96% accuracy** at identifying vulnerable rooms

Thank You

Slides are available online: <https://web.njit.edu/~ss797/>

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