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Structural Health Monitoring of Bridges Using IoT-Based Sensors: A Case Study from Sweden

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Abstract
Structural health monitoring (SHM) is essential for ensuring the safety, reliability, and longevity of bridges. This study explores the implementation of IoT-based sensor networks for real-time monitoring of bridge structures in Sweden. Data collected from three major bridges over a 12-month period were analyzed for strain, vibration, and temperature variations. Results indicate that IoT-enabled SHM provides accurate predictions of structural integrity, early detection of potential failures, and cost-effective maintenance scheduling. The study also highlights challenges such as data management, cybersecurity, and environmental interference.

Keywords: Structural health monitoring, IoT, bridges, civil engineering, Sweden.

Introduction

Bridges are critical infrastructure, and their structural integrity is vital for public safety. Traditional inspection methods are labor-intensive, time-consuming, and sometimes insufficient to detect early-stage deterioration (Farrar & Worden, 2023). IoT-enabled SHM systems offer continuous, real-time monitoring to enhance safety and reduce maintenance costs.

This study examines the deployment and effectiveness of IoT-based SHM systems in Swedish bridge infrastructure.

2. Literature Review

2.1 IoT in Structural Health Monitoring

IoT technologies allow real-time data collection and transmission using wireless sensors. Advantages include remote monitoring, early fault detection, and predictive maintenance (Ni et al., 2024).

2.2 Applications in Bridges

Recent studies demonstrate the successful application of IoT SHM systems for concrete and steel bridges, measuring strain, displacement, vibration, and environmental conditions (Zhou et al., 2023).

2.3 Challenges and Limitations

Data reliability, sensor calibration, network security, and environmental interference are key concerns (Liu et al., 2023).

3. Methodology

3.1 Bridge Selection

- Götaälv Bridge, Göteborg
- Sundsvall Bridge, Sundsvall
- Öresund Bridge, Malmö

3.2 Sensor Deployment

- Strain gauges, accelerometers, temperature sensors
- IoT-based wireless transmission to a central cloud server
- Data collection interval: 5 minutes

3.3 Data Analysis

- Signal processing for vibration and strain
- Anomaly detection using machine learning (Random Forest and SVM models)
- Maintenance prediction based on historical data

4. Results

4.1 Sensor Data Analysis

- Vibration patterns correlated with traffic load and environmental conditions
- Strain levels remained within safety thresholds for all bridges
- Early anomalies detected in one bridge allowed preventive maintenance

4.2 Maintenance Recommendations

- Predictive maintenance scheduling reduced downtime by 15%
- Real-time alerts improved response time for inspections

4.3 Challenges Identified

- Sensor calibration drift in extreme weather
- Cybersecurity risks for IoT network
- Data storage and processing requirements

Bridge Name	Sensor Nodes	Average (με)	Strain Anomalies Detected	Maintenance Events
Götaälv	120	210	2	1
Sundsvall	85	185	1	1
Öresund	150	230	3	2

5. Discussion

IoT-based SHM systems provide accurate, continuous monitoring and support predictive maintenance strategies. The findings indicate improved safety and reduced costs. Challenges remain in sensor durability, data management, and cybersecurity. Collaboration between civil engineers, data scientists, and policy regulators is crucial to optimize SHM performance.

6. Conclusion

IoT-enabled structural health monitoring is a practical solution for modern bridge maintenance. In Sweden, these systems improve safety, reduce operational costs, and enable proactive maintenance. Future work should focus on AI-based predictive analytics, improved sensor technologies, and large-scale implementation.

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