# Application Development of Real-time Structural Health Monitoring

*Report submitted to the Indian Institute of Information Technology Guwahati*

*for*

**Bachelor of Technology**

**by**

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## Project Overview:

The primary goal of this project is to address and solve challenges in research related to designing an early warning system for damage identification in large structures. The project aims to develop novel methodologies for user UI-based damage detection using machine learning approaches and real-time monitoring through the integration of IoT and Machine Learning.

### Importance of Real-time Structural Health Monitoring:

Traditional SHM systems relying on manual inspection and periodic sensor measurements can be expensive and time-consuming. The significance of real-time structural health monitoring lies in its ability to detect damages early, preventing failures. The project focuses on developing an UI-based alert system/app by implementing machine learning techniques, such as 1D CNN, and real-time monitoring with IoT to assess and identify structures at high risk of collapse.

### Requirements:

The application utilizes Raspberry Pi with trained ML model to analyze sensor data and provide the final output as: “Undamage”, “Damage_Type1”, “Damage_Type2”, “Damage_Type3”.

## Software Development Life Cycle (SDLC):

The Agile SDLC methodology has been selected for this project to facilitate iterative development and adaptability to evolving requirements.

### Management of Phases:

**Requirements:** Clear and detailed requirements have been established to guide the development process.
**Design:** The design phase involves creating a robust architecture for both the frontend and backend components.
**Implementation:** Development is carried out using Node.js for the backend and JavaScript for the frontend, with React as the framework.
**Testing:** Rigorous testing methodologies, including unit testing and integration testing, ensure the reliability and quality of the application.
**Deployment:** Deployment is planned to be seamless, with consideration for scalability and performance.
**Maintenance:** Ongoing maintenance and updates will be managed through regular monitoring and addressing feedback from users.

## System Architecture:

The architecture of the application involves the integration of IoT and machine learning for real-time structural health monitoring where the damage classes can be accessed through an application. Raspberry Pi acts as the edge device, running the trained model to test raw vibration sensor data and provide damage classification.

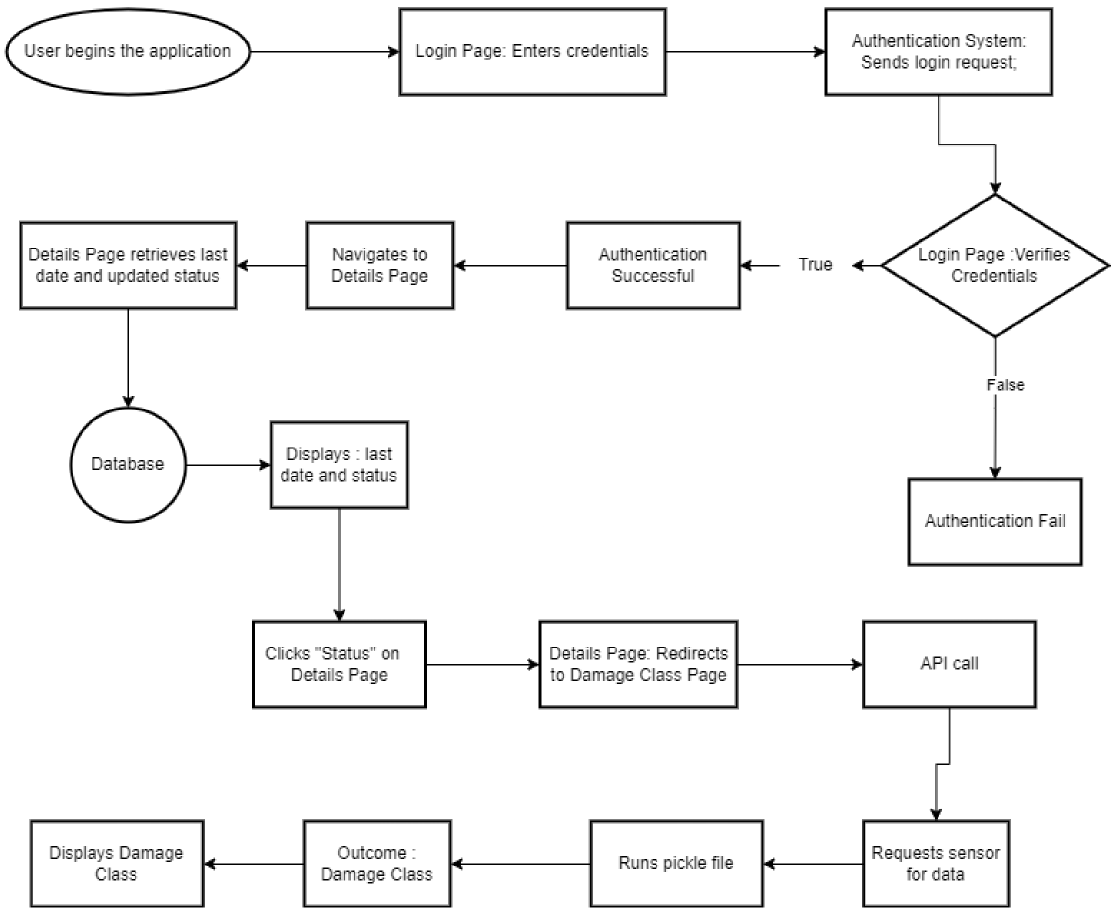


Figure 1: Sequence Diagram of BuildGuard

## Programming Languages and Technologies:

- Frontend: JavaScript
- Backend: Node.js
- Framework: React
- Tool: Figma

## User Interface (UI) and User Experience (UX):

The UI has been designed using Figma, with a focus on user-friendliness. Regular feedback has been incorporated to keep the interface simple and distraction-free, ensuring a positive user experience.

# Case Study - Detektia

**Detektia's EyeRADAR App: Revolutionizing Infrastructure Monitoring**

Detektia, a startup specializing in infrastructure monitoring from space, has launched the EyeRADAR Android App. Utilizing their DinSAR technology, the app provides continuous measurement of millimeter deformations in infrastructures, enabling early warnings and anomaly detection.

**Importance of Remote Sensing in Structural Health Monitoring (SHM):** Remote sensing technology reduces maintenance costs and allows for effective planning by providing early warnings and detection of anomalies in infrastructures.

**Advantages of EyeRADAR:** EyeRADAR offers an all-in-one SAAS solution for infrastructure deformation monitoring, including interactive analysis of deformation series and automated alerts based on custom metrics. It also allows seamless integration with third-party infrastructure management software through its API.

**Impact:** Detektia's EyeRADAR app revolutionizes infrastructure monitoring by harnessing remote sensing technology, cost-effectively providing continuous measurements, and enabling proactive maintenance and risk mitigation.


Figure 2: UI of Detektia's EyeRADAR App

## Comparison between Detektia and BuildGuard (Our IOT):

1. **Real-time Monitoring:**

Vibration-based sensing provides real-time data on structural health by directly measuring the dynamic response of structures to external forces. This enables immediate detection of changes and anomalies in structural behavior, allowing for rapid intervention and preventive measures.

2. **Localized Precision:**

Vibration-based sensing offers localized and precise data collection, focusing on specific points of interest within the structure. In contrast, satellite-based sensing, such as radar sensors, may encounter limitations in spatial resolution and acquisition frequency, potentially leading to less granular and delayed information about structural health.

## Considerations for UX:

The user experience is optimized for monitoring and interpreting structural health data efficiently, presenting relevant information without overwhelming the user.

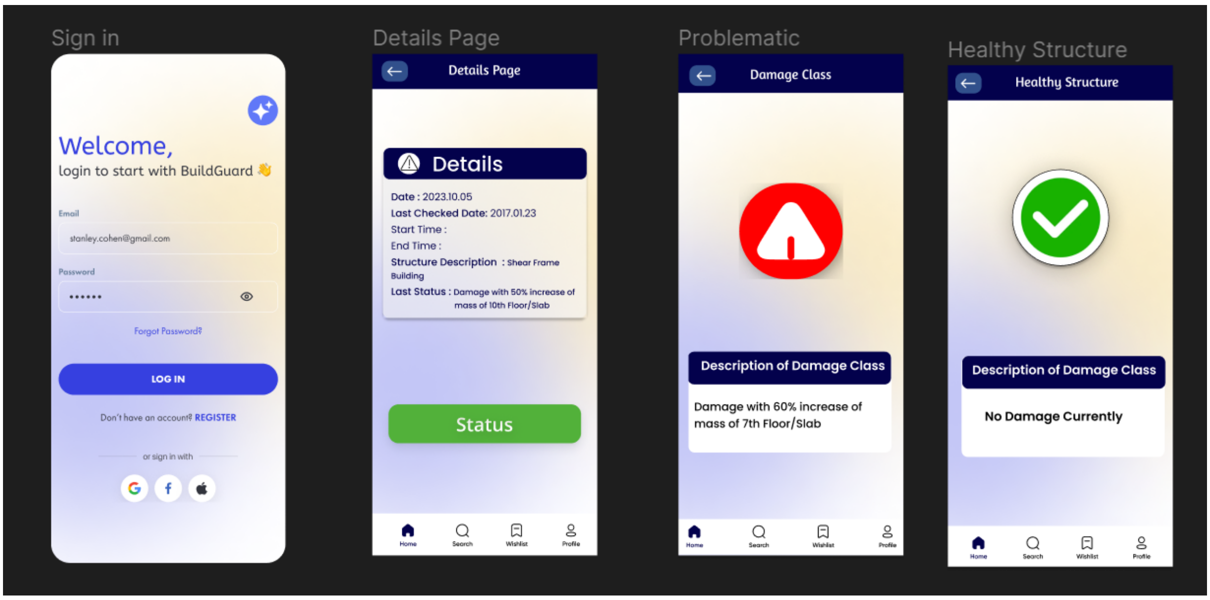


Figure 3: UI of BuildGuard

# Literature Review

Osama *et al.* [1] presented a novel approach for detecting damage of structure using a machine learning algorithm (1D CNN) for feature extraction and classification by using raw vibration signals from accelerometers. The experiment was implemented on a large grandstand simulator with 27 PCB model 393B04 accelerometers and 3 B&K model 8344 accelerometers placed at 30 joints. Each CNN detects damage at the respective joints independently from the other CNNs.

Sharma *et al.* [2] proposed an article for detecting damage at joints using 1D CNN. Feature extraction and classification from 2D signal was performed and the validation was performed on a 2D steel frame at different locations with damages.

H. Malik *et al.* [3] proposed a system where multiple sensors where used to monitor vibration, strain, temperature, humidity of a structure. The readings from the sensors were transmitted to ThingSpeak for analyzing and processing the data, where data was uploaded after 15 seconds because of its limitations. This system was successfully tested on an indoor pedestrian steel bridge.

V. Naraharisetty *et al.* [4] presented an architecture which enables monitoring of structures on AWS cloud using Xbee protocol. Data transmitted to Raspberry Pi through this protocol and then to AWS cloud to store and analyze the data. The main purpose is to demonstrate an architecture for analyzing and visualizing sensor data for live monitoring in AWS cloud as a standalone interface.

# Future Work

**Testing and Quality Assurance:** To ensure reliability and quality, the application will undergo rigorous testing, including unit testing and integration testing. This comprehensive approach aims to identify and address potential issues throughout the development process.

**Security and Privacy:** Measures will be implemented to ensure the security and privacy of collected data. Compliance with relevant standards is a priority to protect sensitive information.

**Deployment and Maintenance:** Deployment will be executed with scalability and performance considerations. Ongoing maintenance involves regular monitoring and addressing user feedback, ensuring the application remains up-to-date and effective.

| Project | Status | Notes |
|---|---|---|
| Ready to deploy IoT device completely on cloud | Not started | Store the raw vibration signal collected from the sensors on the cloud for future research purposes |
| Link the application with Raspberry Pi (IoT device) | In progress | Working prototype of the IoT |
| Update the application with real-time data | Launched | Currently damage class can be displayed on our application in real time |

## References


[1] Osama Abdeljaber, Onur Avci, Serkan Kiranyaz, Moncef Gabbouj, Daniel J. Inman, "*Real-time vibration-based structural damage detection using one-dimensional convolutional neural networks*", Journal of Sound and Vibration, Volume 388, 2017, Pages 154-170, ISSN 0022-460X.

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[3] H. Malik, K. S. Khattak, T. Wiqar, Z. H. Khan and A. B. Altamimi, "Low Cost Internet of Things Platform for Structural Health Monitoring," 2019 22nd International Multitopic Conference (INMIC), Islamabad, Pakistan, 2019, pp. 1-7, doi: 10.1109/INMIC48123.2019.9022801.

[4] V. Naraharisetty, V. S. Talari, S. Neridu, P. Kalapatapu and V. D. K. Pasupuleti, "Cloud Architecture For IOT Based Bridge Monitoring Applications," 2021 International Conference on Emerging Techniques in Computational Intelligence (ICETCI), Hyderabad, India, 2021, pp. 39-42, doi: 10.1109/ICETCI51973.2021.9574044.