An IoT Platform for Civil Infrastructure Monitoring

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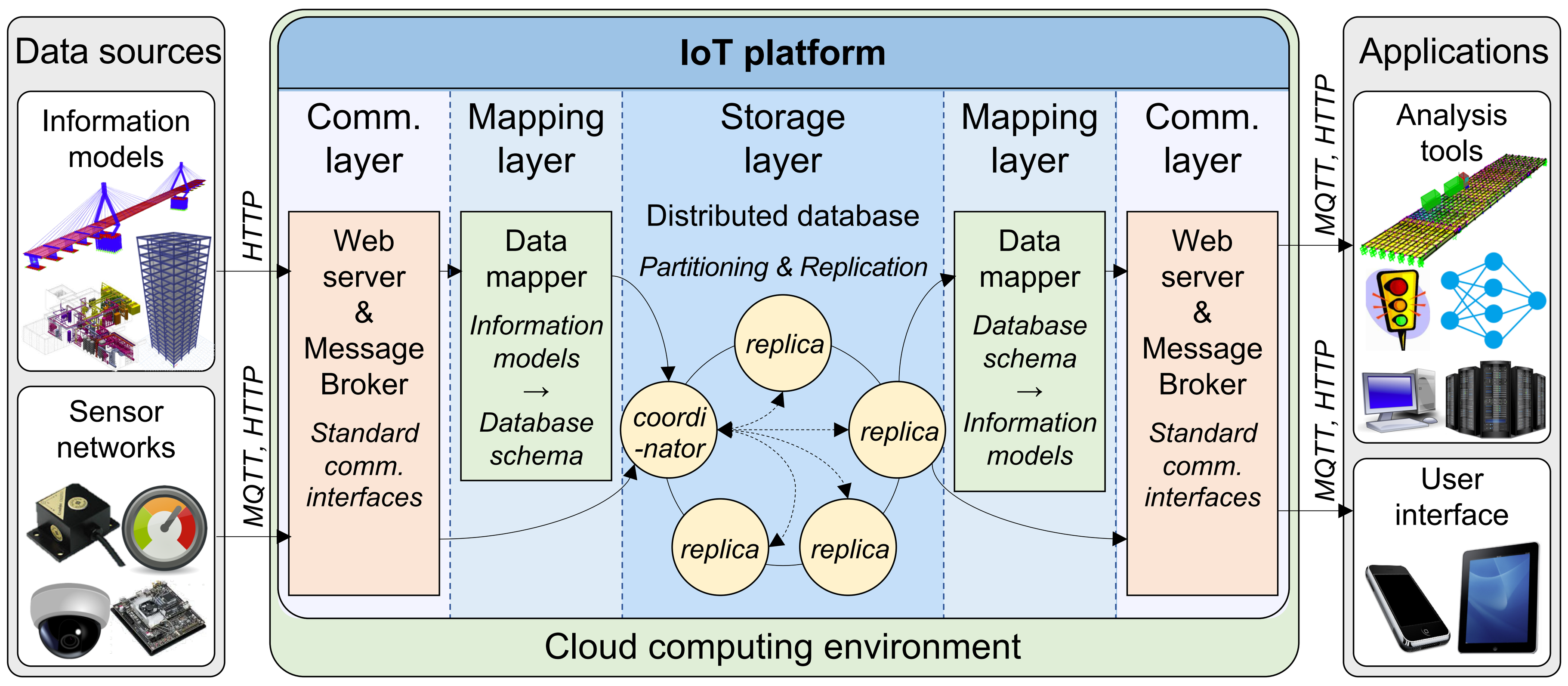
Background

Internet of Things (IoT) can have a huge impact in engineering by leveraging state-of-the-art information and communication technologies (ICT). In practice, however, deploying IoT platforms to handle domain-specific engineering information along with sensor data of different types remains to be a challenging problem. To effectively support data sharing and interoperability and facilitate access by engineering tools, engineering modeling information and sensor data of different types need to be managed properly. This study describes an IoT platform that is tailored to civil infrastructure monitoring applications and adopts an information modeling approach to facilitate data interoperability and to integrate engineering information with sensor data. The design goals of the IoT platform include:

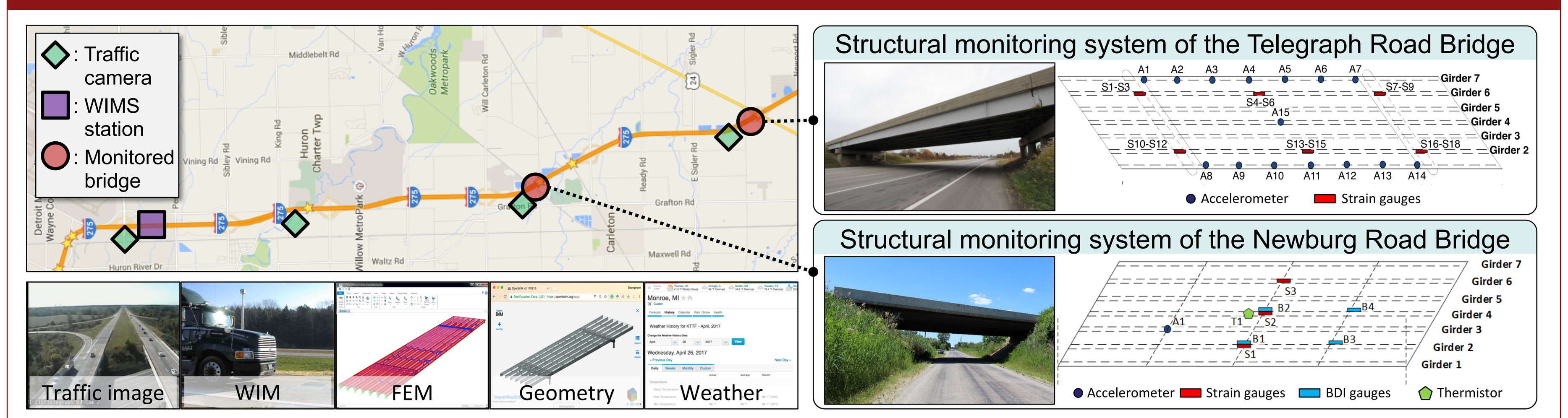
(1) Scalable data management to handle engineering and monitoring data,
(2) Standard interface to allow client applications to access the IoT platform, and
(3) Data integration & interoperability to facilitate sharing and utilization of data.

IoT Platform Overview

- The IoT platform consists of three basic layers to offer data management services:
  - **Communication layer** offers web services and pub/sub services available over the Internet and mobile devices. This layer supports standard communication protocols and standard data exchange formats to allow client applications to use the data services.
  - **Mapping layer** maps data between standard data exchange formats supported by communication layer and database schema defined in the storage layer.
  - **Storage layer** manages the data using a cloud-based distributed NoSQL database for flexible and scalable data management.
- The IoT platform is built upon cloud computing environment for high scalability, reliability, easy maintenance and optimal use of computing resources.
- Information managed by the platform can be retrieved in a platform-neural language based on information modeling standards. Therefore, the retrieved information can be easily parsed, converted and used by different application software tools.



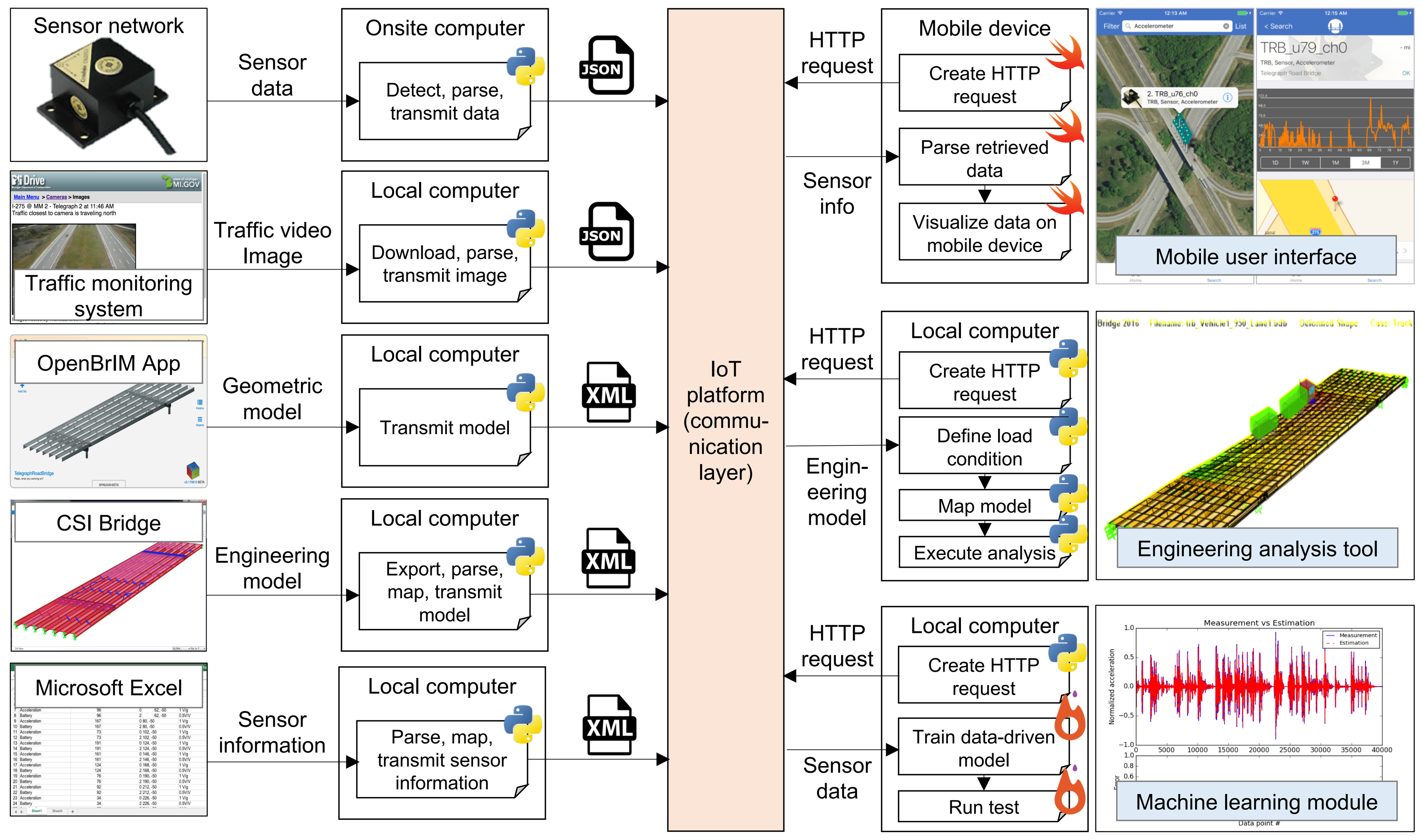
Testbed: I-275 Corridor, Michigan



- Structural monitoring systems collect data about the behavior of the bridges.
- Traffic videos & WIM data are collected to identify vehicles travelling on the bridges.
- Finite element models of the bridges are created for numerical simulations.
- Geometric models, weather data and sensor metadata are collected.

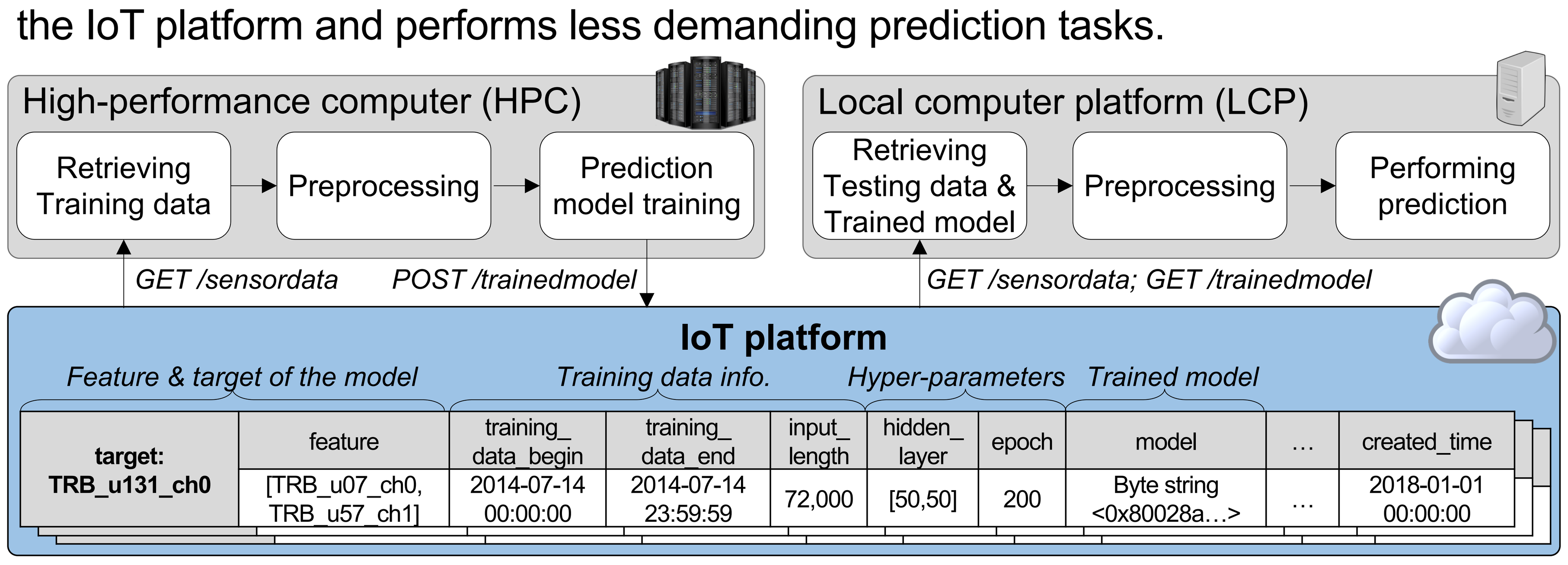
Data Management Services

- The IoT platform stores and manages comprehensive sets of data involved in civil infrastructure monitoring. Client systems can parse the data into data exchange formats (e.g., XML and JSON) and transmit the data by invoking data store services offered by the IoT platform over the Internet or other communications services.
- Applications and devices can retrieve data from the IoT platform via standard communication protocols. Data interoperability and integration are enabled based on information modeling standards and ontology.



Data Analysis Pipeline

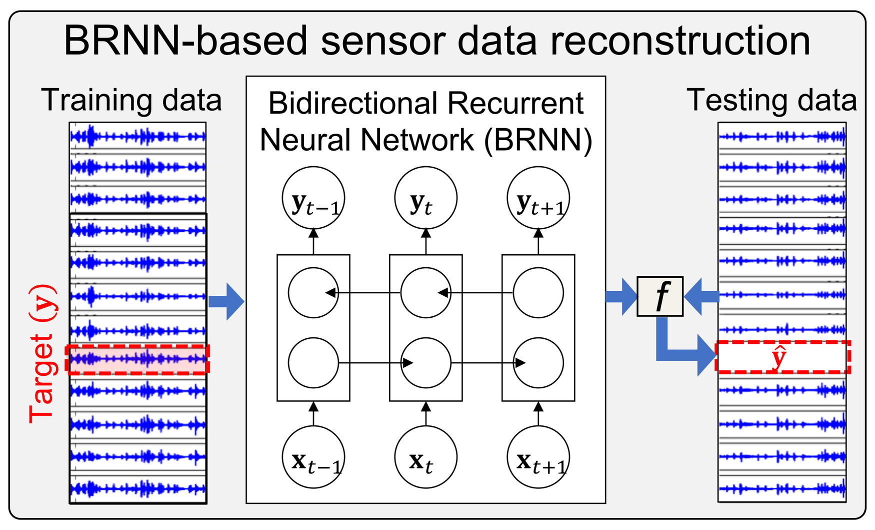
Data analysis pipeline is developed to facilitate efficient data analyses by using the data management services of the IoT platform. In this pipeline, HPC performs computationally demanding training tasks, while LCP retrieves trained models via the IoT platform and performs less demanding prediction tasks.



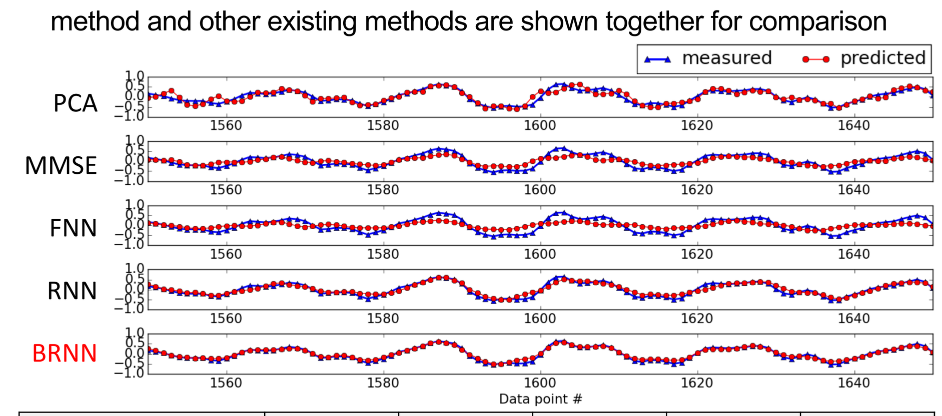
Example: Sensor data reconstruction using BRNN

Sensor data reconstruction is an important method that enables fault detection, fault isolation and fault recovery for ensuring a healthy sensor network of a monitoring system. Leveraging the data analysis pipeline, a bidirectional recurrent neural network (BRNN)-based sensor data reconstruction method is developed. Based on spatiotemporal correlation among sensors, the BRNN-based method reconstructs missing or faulty sensor data.

BRNN-based sensor data reconstruction



Reconstruction of vibration data collected from TRB. Results of BRNN-based method and other existing methods are shown together for comparison



	PCA	MMSE	FNN	RNN	BRNN
Testing RMSE	0.0852	0.0524	0.0561	0.0353	**0.0288**

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