Real-Time Data Visualisation for the IoT Application in Industrial Motor using Digital Twin Technology

[1]*Dr. Pravin Latane*
[1]Professor and Dean Academics, Dr. D. Y. Patil College of Engineering and Innovation,
Department of Computer Engineering, Varale, Talegaon, Pune., Lincoln University College, Malaysia
pclatane@gmail.com , pdf.pravin@lincoln.edu.my ,

Abstract: The world of IoT services offers extensive opportunities to connect devices and upload data to the cloud, enabling data-driven decisions, AI model processing, and dynamic visualizations through powerful dashboards. Simultaneously, the ease of use of data visualization tools has been a driving force behind the widespread adoption of tools like Tableau, which leads the market in this domain. This paper presents a comprehensive account of creating interactive visualizations for real-time data from IoT applications, utilizing Tableau as a business intelligence tool. It highlights the significance of real-time data analytics in the IoT context and showcases how interactive visualizations can provide valuable insights and facilitate prompt decision-making. By leveraging the capabilities of IoT services, cloud connectivity, Digital Twin Technology can unlock the potential of their data, leading to better performance and a competitive edge in today's fast-paced business environment. A digital twin is a virtual representation or digital replica of a physical object, process, or system. It is designed to accurately mirror its real-world counterpart, enabling real-time monitoring, simulation, and analysis. Digital twins can be used in various industries to improve operations, optimize performance, and predict future outcomes.

Keywords: Digital Twin, Business Intelligence, REST API, Data Visualization, Interactive Dashboards, Predictive models.

Introduction

In this decade, there has been a growing demand for self-service analysis tools and skills across various business domains. These tools enable organizations to maintain data records and perform data analysis tasks to make informed decisions and improve business operations. Particularly in the realm of Internet of Things (IoT), gathering sensor data has become essential for measuring performance. To store IoT sensor records efficiently, many businesses rely on Excel sheets due to their speed and reliability. However, to gain deeper insights and flexibility in representing results, Real time analysis of these is crucial for corporations. Analyzing and visualizing this data is essential for identifying business trends, preventing diseases, forecasting future paradigms, combating crime, and more. Data visualization tools, like Digital Twin Technology provide accessible and insightful views of data patterns and outliers [1].

Digital twins of factory machines help in monitoring wear and tear, improving maintenance schedules, and optimizing production lines. It can be created for human organs to assist in personalized treatment planning or surgical simulations. Cities use digital twins to optimize infrastructure, energy consumption, traffic flow, and urban planning. Digital twins simulate vehicle performance, allowing for safer designs, faster testing, and ongoing operational efficiency. They are used in power grids, wind farms, and oil rigs to monitor and manage energy production and consumption. General Electric (GE) uses digital twins for its industrial equipment (e.g., gas turbines) to monitor performance and predict maintenance needs. Tesla leverages digital twins for its cars, enabling them to improve vehicle performance through over-the-air updates based on real-world driving data.

DATA COLLECTION

The data utilized for visualization in this demonstration is secondary data originating from an IoT device, specifically the DHT11 sensor. The primary parameters measured by this device are temperature and humidity. The main goal was to measure and visualize industrial data using this IoT device. Due to the substantial amount of data, the preference is to view it on cloud server. One practical application of this data is in digital agriculture, where temperature sensors can calculate growing degree days or soil moisture sensors, in combination with relays and pumps, can monitor and water plants automatically when needed.

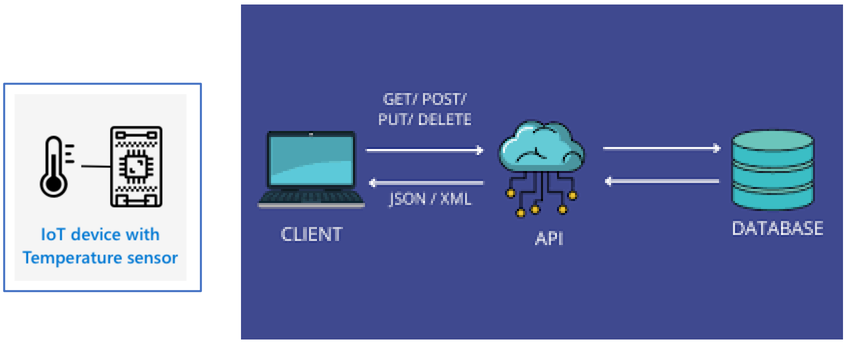

Figure 1: Architecture of REST API over HTTPS for real time data collection.

To achieve this, NodeMcU 8266, and DHT11 sensor is utilized. However, the challenge lies in transmitting data from these devices to XAMPP server. To address this, a relatively straightforward architecture can be employed. As long as the IoT device is equipped with WiFi capabilities, it can expose to REST API over HTTPS. This API can then be accessed by an Apache server, allowing seamless communication with the device. Through this API, sensor data can be read, actuators controlled, and data visualized efficiently.

IoT device with a REST API

The Excel add-in JavaScript API has the capability to make calls to REST endpoints, including those running on your local network. To leverage this feature for IoT applications, you can expose a REST API on your IoT device, enabling data retrieval from sensors or control of actuators. For instance, let's consider a scenario where you have a Raspberry Pi equipped with a soil moisture sensor and a relay. You can create a Python/Flask app on the Raspberry Pi and set up a REST API with two endpoints:

- temperature/ - Making a GET request to this endpoint will provide the current reading for the temperature sensor.
- relay/ - Making a POST request to this endpoint with a boolean value in a JSON request body will allow you to turn the relay on or off, effectively controlling it.

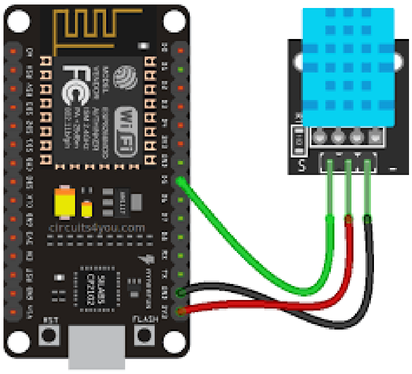

Figure 2: Interfacing of DHT11 with NodeMcU for real time data collection.

The real-time data for temperature and humidity measured using DHT11 is stored in mysql database in table form, and the intention was to visualize this data using digital twin technology. The interfacing of DHT11 with NodeMcU is as shown in figure 2 to upload temperature and humidity data on XAMPP server.

Environment Setup in XAMPP

XAMPP is a free and open-source cross-platform web server solution stack package developed by Apache Friends, primarily for PHP-based applications. It provides a development environment for local web applications, especially for those that will be deployed on the LAMP stack (Linux, Apache, MySQL, PHP). Creating a REST API over HTTPS for real-time data collection using XAMPP (Apache, MySQL, PHP, and Perl stack) involves several key architectural components and considerations. Below is an outline of architecture.

- **Web Server:** XAMPP comes with Apache, which serves as the web server to handle incoming HTTP/HTTPS requests.
- **Database:** Use MySQL (or MariaDB) for storing collected data, with tables structured to store real-time data logs.
- **PHP for API Endpoints:** PHP scripts will handle the API logic, processing incoming requests, and interacting with the database.

XAMPP also includes other tools and utilities, such as phpMyAdmin for database management, and FileZilla FTP Server for handling FTP connections. This powerful feature enables users to interact using Apache server with database and also perform additional tasks using standard SQL quiry to fetch table value.

Data Visualization using Digital Twin Technology

Data visualization with digital twin technology involves creating dynamic, interactive representations of physical objects or systems using real-time data. Digital twins are virtual replicas of physical entities, and they enable engineers, operators, and other stakeholders to monitor and simulate performance, detect issues, and optimize processes in real-time. Here’s a breakdown of how digital twin technology is leveraged for data visualization**:**

1. Physical Entity: The real-world object or system that is being represented digitally. This can be anything from a machine, vehicle, or building to entire ecosystems like factories or even cities.

2. Digital Model: The digital twin itself—a virtual model that mimics the physical entity's characteristics, behaviour, and performance in real-time or near real-time.

3. Data: The continuous flow of data from sensors, IoT devices, and other sources that monitor the physical entity. This data is fed into the digital twin to ensure the virtual model remains synchronized with the real world.

4. Analytics and Algorithms: The digital twin uses data analytics, artificial intelligence (AI), machine learning (ML), and simulations to understand, predict, and optimize the behaviour of the physical entity.

DATA PREPARATION AND CONNECTION

Data preparation and connection are critical steps in visualizing data using digital twin technology. Ensuring high-quality data and seamless data flow from physical assets to the digital twin model helps in creating accurate, real-time, and predictive insights. Here’s a breakdown of the data preparation and connection process for visualizing a digital twin effectively.

Data Collection from Physical Assets

- **IoT Sensors and Devices**: Digital twins require data from physical assets, which is typically gathered through IoT sensors. These sensors measure relevant parameters like temperature, pressure, speed, and location, providing real-time data that updates the digital twin.
- **Data Types**: Collected data can include time-series data, metadata, transactional records, logs, and sensor readings, depending on the asset being mirrored.
- **Connectivity**: Data is transmitted from sensors to a central system via connectivity protocols like MQTT, HTTP, or CoAP. The choice of protocol often depends on factors like data transfer rate, energy consumption, and network reliability.
- **Time-Series Databases**: Store continuous sensor data streams in time-series databases. Use relational databases (e.g., MySQL, PostgreSQL) for structured data like asset metadata, configurations, and transactional records using XAMPP server.
- **APIs for Data Connections**: Use REST or MQTT APIs to connect real-time data feeds from IoT devices to the digital twin platform, ensuring data flow between the physical system and digital twin.
- **Real-Time Synchronization**: Synchronize data continuously between the physical system and the digital twin, especially for applications that require real-time visualization or predictive updates.

Following these steps ensures a robust data preparation and connection process for digital twins, leading to a reliable, dynamic visualization that accurately mirrors the physical asset. This setup enables organizations to gain deep insights, improve operations, and optimize performance based on the digital twin's visualized data insights [3].

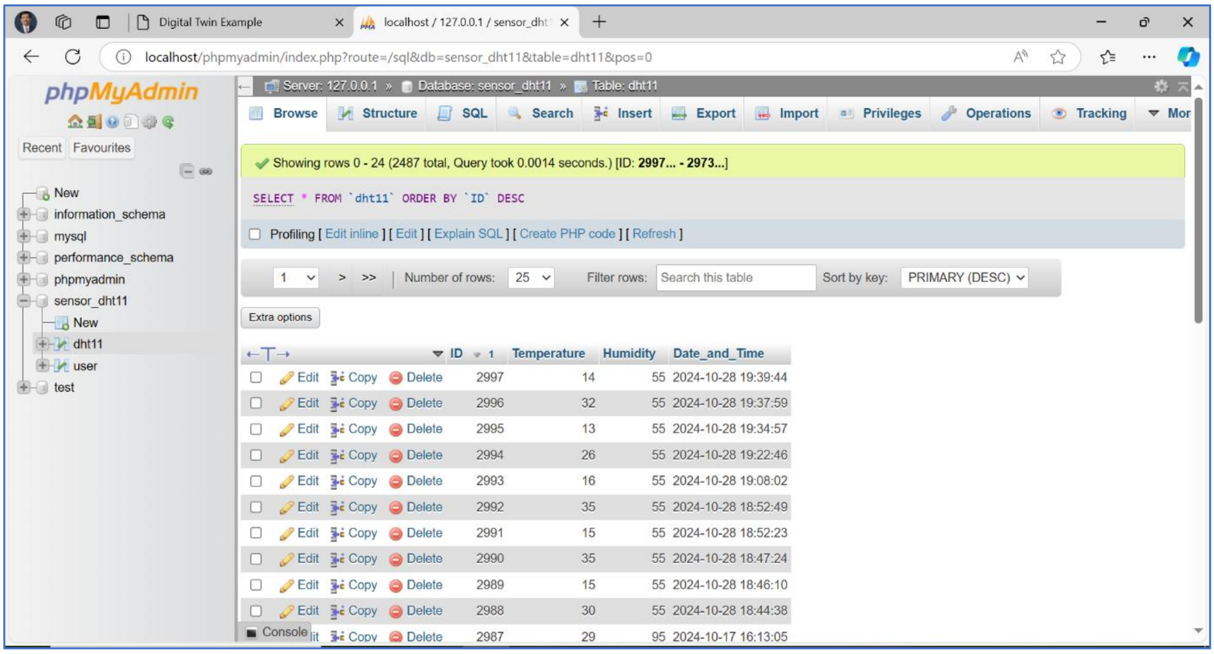

Figure 3: phpMyAdmin dashboard of XAMPP server

If logged into XAMPP Server, users may also have access to saved data sources stored in the server's repository. Figure 3 displays the phpMyAdmin window, with the data source being table file that is being accessed using SQL query such as: "SELECT Temperature FROM `dht11` ORDER BY `id` DESC LIMIT 1" [4].

After selecting and customizing the data connection, users will be directed to the second data connection window. Here, they must decide whether to create an mirror of the data using Motor.glb 3D model can enhance performance and improve data visualisation efficiency.

HTML script calls JAVA script and PHP script to generate Digital Twins model. HTML script set up the scene, camera, and renderer. PHP script connect with database, "sensor_dht11/dht11" and fetch current temperature from the database using sql query and generate output in the form of JSON format. PHP script confirm the model is loaded and respond its behaviour along with real time temperature. Here animation is designed such that temperature threshold will decide the body colour of 3D motor model.

VISUALIZATION USING DIGITAL TWIN TECHNOLOGY

In this section, we will explore how 3D model of motor allows users to add trend lines, reference lines, and control data sorting and filtering to enhance their data analysis. Its primary mission is to facilitate self-service visual analytics, enabling non-technical users to see and understand their data effectively [5,6]. Visualisation of 3D motor model is figure 4 and figure 5. Near to 3D motor model on consol window real time reading of temperature is shown which is fetched from XAMPP server database using SQL query. Here threshold value is set to be 20^{o}C. Figure 7 shows 3D motor model colour is changed to red as real time temperature is greater than 20^{o}C and Figure 8 shows 3D motor model colour is changed to original as real time temperature is below 20^{o}C.

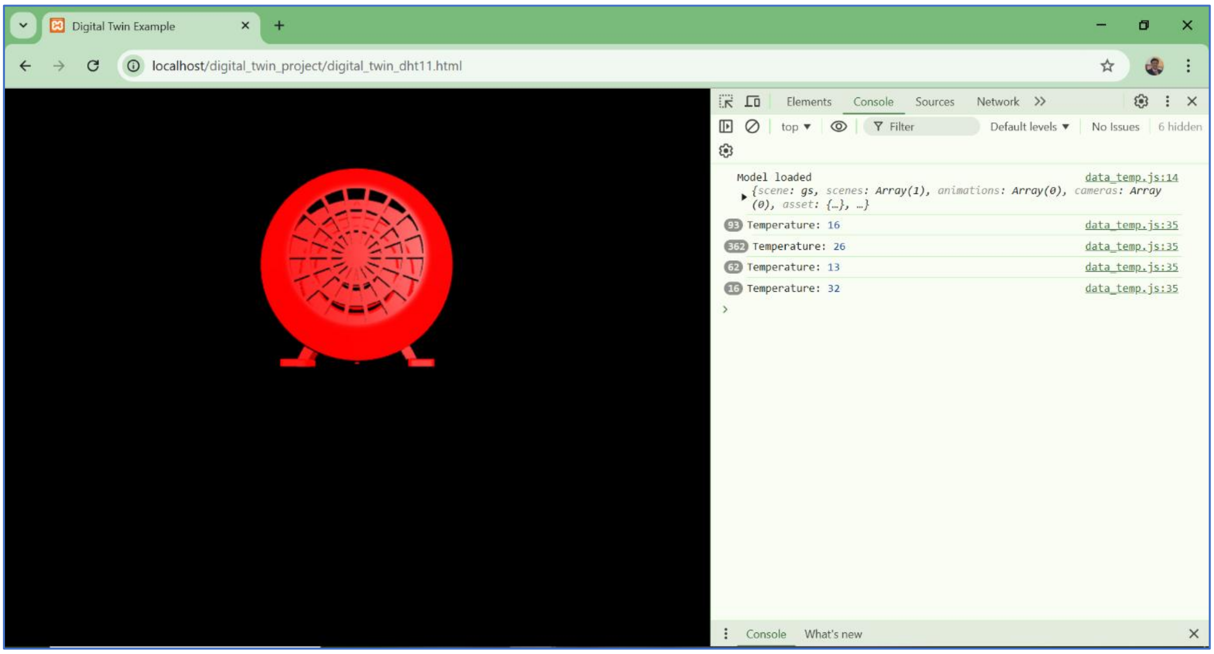

Figure 4: Real time visualization of Motor 3D model changing colour above threshold value of temperature.

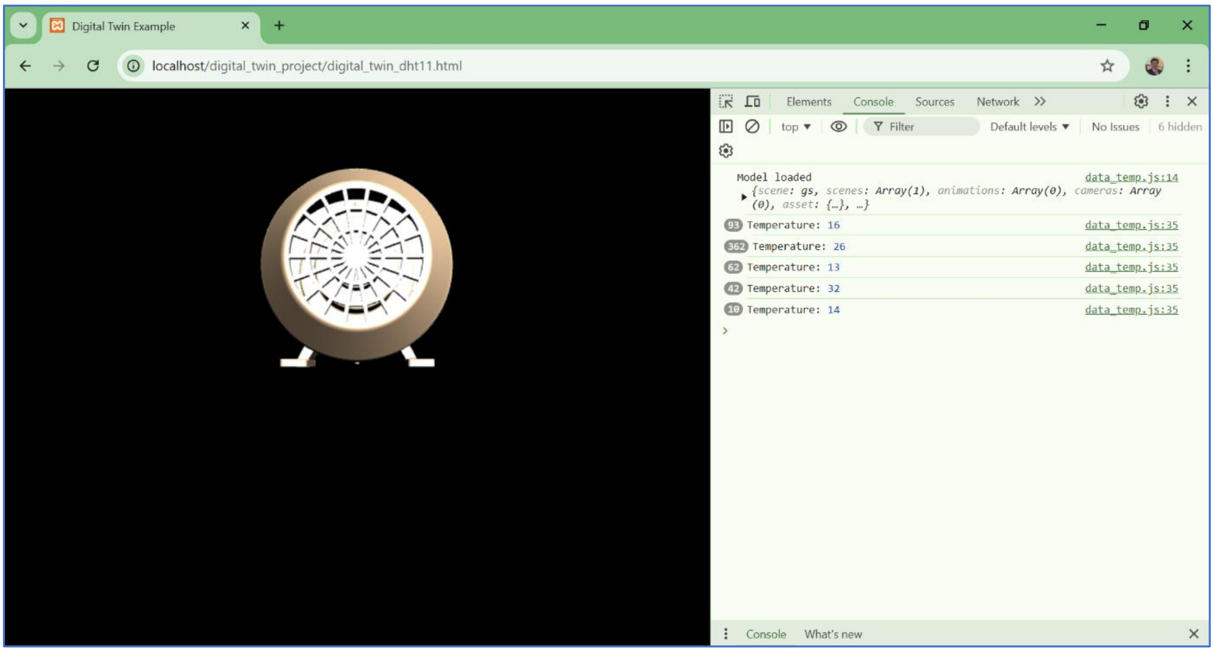

Figure 5: Real time visualization of Motor 3D model changing colour below threshold value of temperature

The application of digital twin technology varies significantly across industries, each with tailored requirements, benefits, and challenges. The choice of platform, data management approach, and visualization capabilities depend on the specific goals and constraints of the industry. By continually evolving to integrate advanced analytics, machine learning, and enhanced 3D modelling, digital twins are rapidly expanding their role in optimizing operations, enhancing decision-making, and ensuring sustainable practices across sectors [7].

CONCLUSION

Digital twin technology allows us to connect with almost any database, visualize our data, and derive meaningful insights for better understanding. We can create interactive visualizations, enabling us to thoroughly analyse our data and construct compelling data-driven narratives. Digital twin technology proves to be an invaluable tool for generating data stories that are easily understandable by key decision-makers. Furthermore, Digital twin technology facilitates the discovery of data patterns, complementing the results obtained through machine learning algorithms with its visualizations. One of the primary tasks is to efficiently connect with and extract information stored in diverse locations. It effortlessly collects data from XAMPP server databases. In essence, Digital twin technology's capabilities extend to connecting and extracting information from multiple sources, thereby providing organizations with a powerful platform to make data-driven decisions and uncover valuable insights that contribute to their growth and success. A digital twin acts as a bridge between the physical and digital worlds, providing insights that allow for more effective management, optimization, and maintenance of physical systems. It's increasingly becoming a cornerstone of Industry 4.0, smart manufacturing, and IoT-enabled innovation.

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