Government Open Data and Sensing Data Integration Framework for Smart Construction Site Management

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Abstract –

This paper proposes a cloud-based data management framework that integrates open data from the government and monitoring data from construction site sensors. The integrated data can be consumed by artificial intelligence for smart construction project management, e.g. schedule control, resource arrangement and workers' safety. The framework includes two major parts: one is the IoT (Internet of Things) sensors and edge computing devices for collecting data from a construction site; the other one is a cloud database with Autodesk Forge for managing 3D Building Information Modeling (BIM) model information and government open data. In addition, web-based management interface and information dashboard for desktop computers and App software for hand held devices are provided for users to easily manage, query, and visualize the integrated data. Because weather and environmental conditions often affect management of a construction site, the proposed framework is prototyped for a feasibility test to see how the integration of Taiwan government open weather/environmental data and construction site monitoring data can be implemented and helpful for construction site management.

Keywords –

BIM; Construction; Data Integration; Internet of Things; Edge computing; Data distribution Service

1 Introduction

In recent years, through popular application of Building Information Modeling (BIM), a good foundation has been laid for construction management to integrate digital construction and sensor technology for achieving lean construction with better efficiency [1]. The potential applications include site design, material inventory control, transportation vehicles scheduling, construction machinery and equipment management, remote structural health monitoring and progress checking [2], especially for risk control of large scale construction projects [3]. To monitor real-time construction progress and avoid construction hazards, the use of various kinds of sensors to collect data for management analysis in the construction sites is getting popular and even become necessary [4]. Furthermore, Taiwan's labor law always concerns the construction workers' health and safety and has increasing restrictions for the workers to be exposed to extreme weather conditions and hazard environmental conditions, e.g. PM2.5 air pollution. In India, excessive PM10 concentration produced during construction was studied and it was found that the health condition of workers is related the air pollution Index. Workers at sites with less precautionary measures suffer more with respiratory illness than those at sites with more safety measures against air pollution [5]. Besides the labor law issues, the everyday weather and environmental conditions on the construction site can affect working productivity of workers and indirectly impact the construction schedule. Although project managers can always refer to the national weather report to get the measured and predicted data for the city or the district where the site is located, they may need more precise and higher resolution data on the site for better decision making on project scheduling or resources arrangement. With some monitoring systems implemented, when the system detects an abnormal situation based on the comparison between real-time data from the site sensors and historical data accumulated in the database, the project managers will receive an alert message through their hand held devices for them to quickly adjust the resources accordingly to avoid extra cost due to law violation or schedule delay. On the other hand, government open data may be very useful for construction site management. For example, for those sites in the seismic zone, early earthquake warning messages published by the government agency can help to reduce disasters due to strong earthquake. For those construction sites beside the ocean areas, the project managers may benefit from the information provided by an early-alert ocean wave system for optimal resources utilization and risk control [6].

To assist construction project managers for smart site management, this paper proposes a cloud-based data management framework to facilitate integration of government open data and construction site monitoring data.

Based on the framework, a prototype BIM-based Smart Site Assistant (called BSSA) platform was implemented and tested for proof of concept. The prototype BSSA platform used Autodesk Forge as 3D BIM cloud database to manage digital construction site and integrated weather open data from Civil IoT Taiwan services (https://ci.taiwan.gov.tw/index_ne.aspx) as a testing and demonstration example for integrated application of government open data. The data collected by the various kinds of IoT sensors, such as vibration, PM10/2.5, and temperature sensors, installed in the construction site are gathered by edge computing control boxes through the DDS (Data Distribution Service) network protocol and stored into MariaDB database on a web-based server.[7] To ease the real-time management and access of needed data for the project manager, a web-based data management Graphical User Interface (GUI) and information dashboard are designed for desktop computers and an App software is designed for mobile hand-held devices. The rest of this paper will discuss the design of the framework and the implementation of the platform in more details.

2 The Framework

Figure 1 illustrates the system framework for the BSSA platform, which can be divided into three main parts, including data collection hardware devices in construction site, web-server for data management and applications for data visualization. First, different type of IoT sensors are needed at construction site for collecting site conditions, such as temperature, humidity, wind speed, air quality (PM10/PM2.5), ground water level, etc. These sensors data are collected and sent to edge computing devices (e.g. one per one floor) via Bluetooth, RS485 or RS232 interface. The edge computing devices communicate to each other using the DDS protocol to achieve low-latency, high-throughput data communications and one selected device is responsible for uploading collected data to the web server through network.

The second part is a web server for data management which uses Autodesk Forge for 3D BIM model data management (including basic project information) and MariaDB database to store the construction site sensing data and government open data from the Civil IoT Taiwan services. To compliment open data provided by the Civil IoT Taiwan services, which provide broad range but low resolution data, various kinds of sensors are needed to collect weather and environmental status data for the construction site.

The final part is data management GUI and APP software for users to effectively manage and access contents from the web server using desktop computers or hand-held devices.

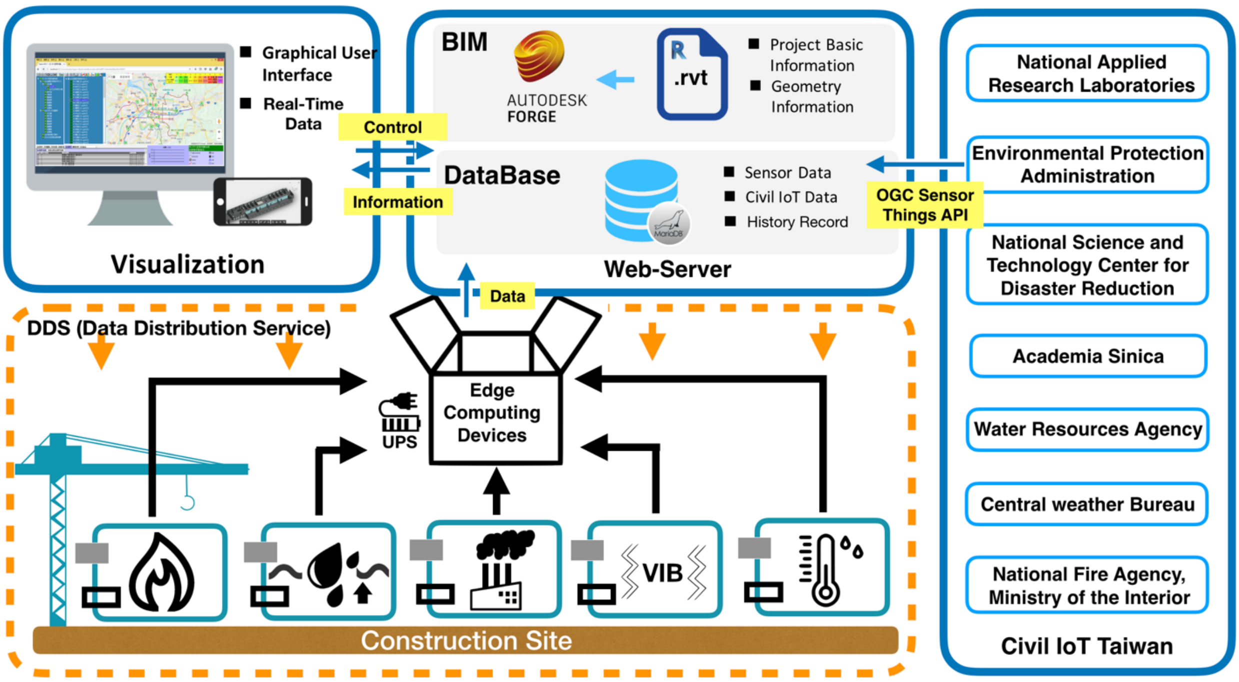


Figure 1. System Framework of the BIM-based Smart Site Assistant (BSSA) Platform

3 Prototype and Demonstration

With the rapid development and application of IoT and big data technologies, more and more government agencies have published their data as open data for public goods, especially environmental monitoring data, including temperature, humidity, air quality, precipitation, wind speed, river and ground water levels data and so on. In this work, the BSSA platform collects real-time environmental data from Civil IoT Taiwan services using OGC Sensor Things API (http://www.opengeospatial.org/ogc/markets-technologies/swe). However, the data in Civil IoT Taiwan database not only are multifarious but also come from various sources. Data filtering and integration are needed to increase their usability and reliability for construction management. Also, there are data collected through sensors installed on the construction site for a project manager to monitor the progress and various conditions of the construction, e.g. structural safety, air quality, etc. In the BSSA platform, a data management GUI is designed with the use of MariaDB, an open-source relational database management system, to help users to select and integrate data. Also, Autodesk Forge is employed for managing 3D BIM model data of the construction site. The BIM model is often built by Revit, one of the most popular building modelers, and uploaded by the user to the Forge cloud. The platform connects the model to the related environmental data and provides a viewer on the website for data visualization. In addition, mobile app software is designed for on-site project managers to easily retrieve and visualize data for decision making.

3.1 Data management GUI and information dashboard

Figure 2 illustrates the three-level data management scheme designed in the BSSA platform. The first level includes basic functions for users, such as historical data query, real time data and event alert and getting government open data. The second level includes operations for users to manipulate data in the database. The database in the third level integrates two types of data, open data (such as Civil IoT Taiwan) and local data (Edge Computing data). The central data management GUI includes six blocks, namely A, B, C, D, E, F (see Fig.3). Block A shows environmental data from the Civil IoT Taiwan database which orders contents by government administrative areas (i.e. cities, provinces, counties, etc.). There are construction sites under each area and users may connect to those sites to quickly access the surrounding environmental information. Block B provides links to all governmental sensors' data with a scroll down menu. Block C uses Google Map API to lay down different sensors' locations on map by transforming the coordinate system from WGS84 to TWD97 to help users understand better the sensor

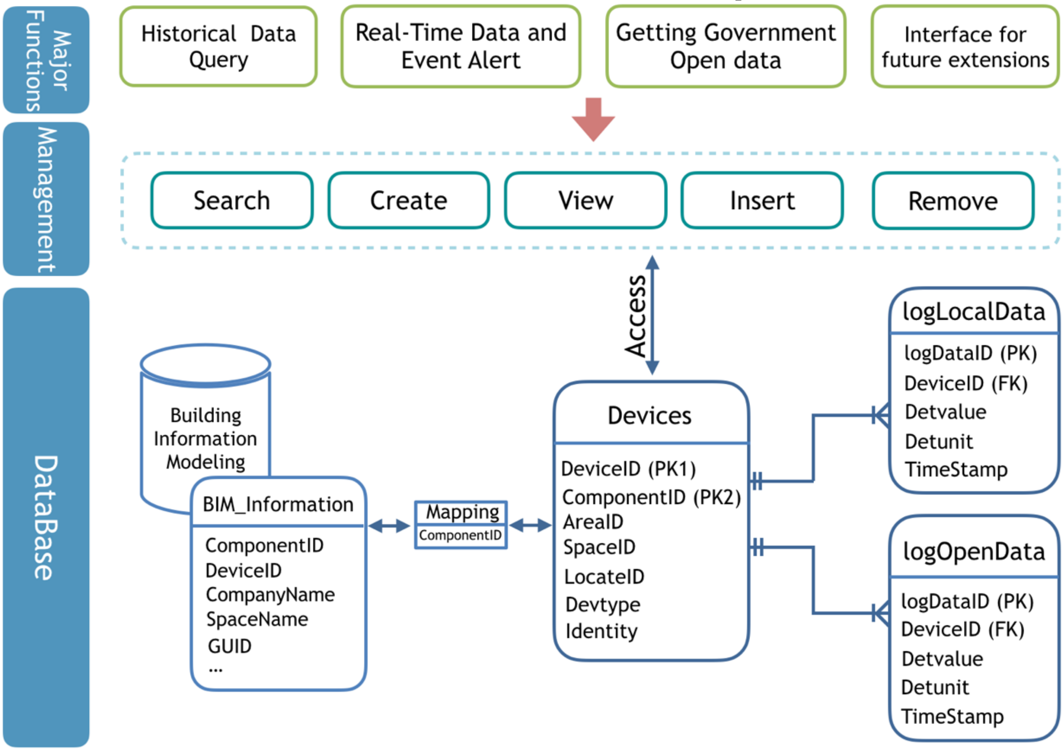


Figure 2. Data Management

locations and improve data readability. Block D records the logs of all system activities for system and data security. Block E shows the real-time data plots from the selected data source so that the user can monitor if the data remain within the normal range. This block provided the capability functions of prediction or historical data review. Block F reports the current overall status of the construction site based on all of the available data.

The dashboard interface for construction site status is shown in Fig.4, which has three blocks. Block "a" is an online building model viewer allowing users to query information about building objects and check the construction schedule. Also, the user can easily visualize the locations of the sensors in the model. Block "b" plots history data for the selected sensor, shows the location of the construction site on Google Earth, and the overall index of site conditions for construction tasks. Block "c" shows the navigation tools for viewing the model and its attributes, and users can use them to modify, explore and query more information from the model.

3.2 App software for information query

The design of an App software for the platform is for helping site managers to quickly find and visualize needed information. The App connects to the web server built by Forge and put the building model on the frontpage (see the block a in Fig.5(a)). Moreover, the block b on the frontpage is associated with environmental data. When any abnormal value of the monitoring data is detected, the user is alarmed (see the block b in Fig. 5(a)) and the level of impact by different environmental properties is visualized by colors. If the users need more detailed information, they can use the menu provided (see Fig.5(b)) to get the information. In addition, Fig. 6 shows the page displaying detailed information on some environmental aspects.

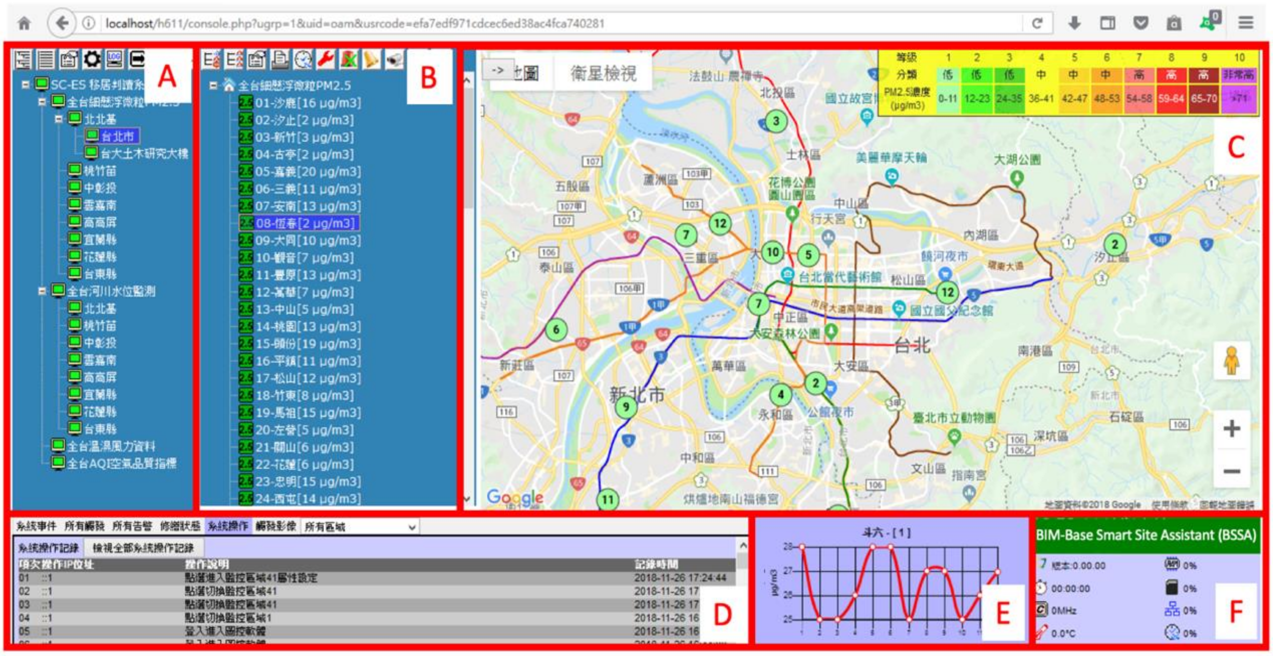


Figure 3. GUI for Central Control Management

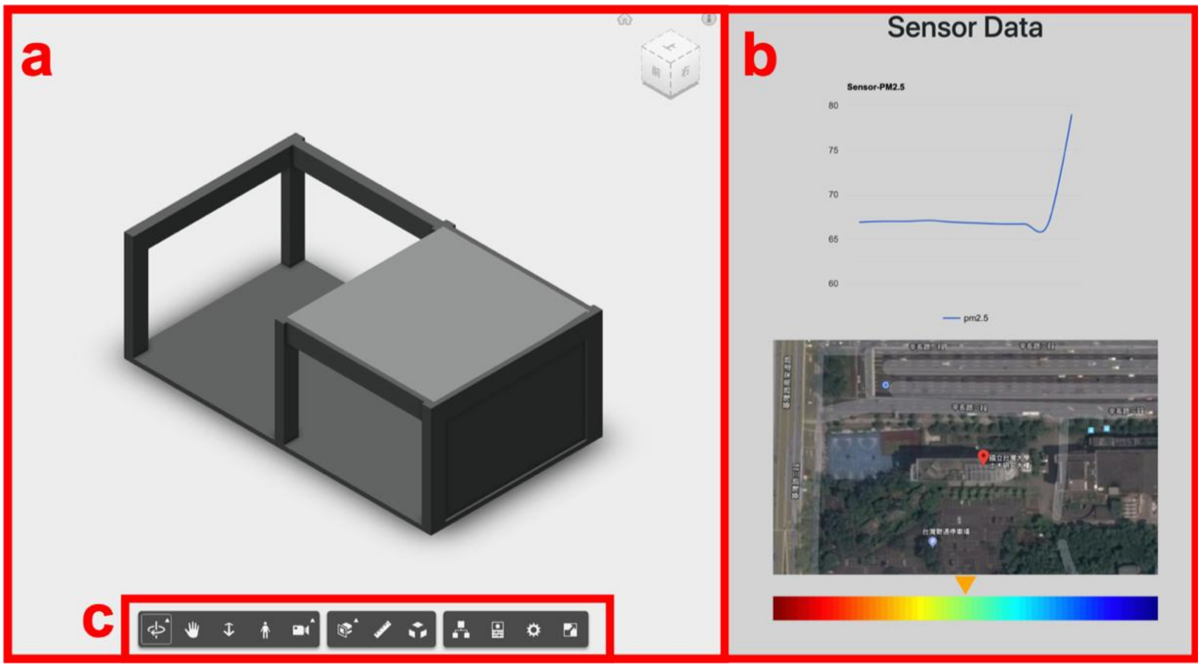
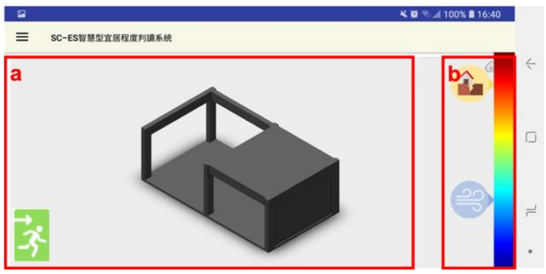
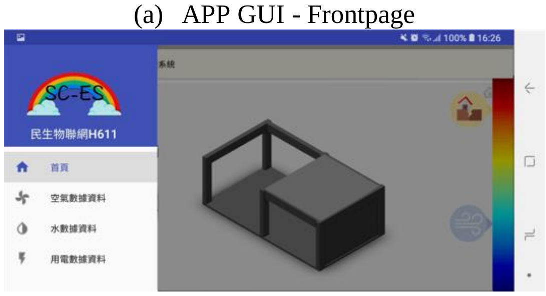


Figure 4. Construction Site Status Dashboard



(a) APP GUI - Frontpage



(b) APP Menu Interface

Figure 5. App User Interfaces

Figure 6. Data Screen

3.3 Platform Demonstration

The demonstration of the platform can be summarized by 6 steps (see Fig. 7):

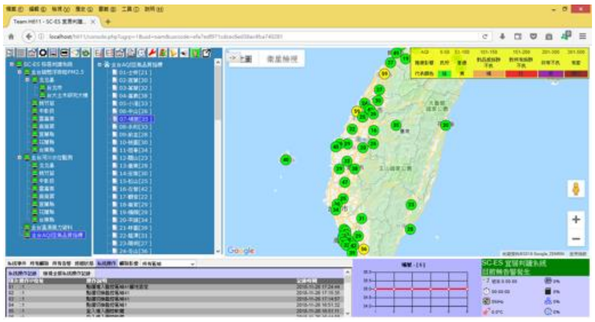
Step 1: From the GUI provided by the central control page, the user can select first the construction site from the map and its nearby sensor data from the catalogue of government open data (e.g.

those from Civil IoT Taiwan database). Then, the system will display the data retrieved on screen using a data synchronization engine. The user may use the Google map interface to interactively examine the sensors and retrieve their monitoring data with colour indicators for easy identification of the conditions detected by the sensors.

Step 2: The user may zoom in and out the location of a construction site and examine the sensors around the site and their data.If the user selects the location icon of the construction site from the map, the platform displays the BIM model of the site on the screen.

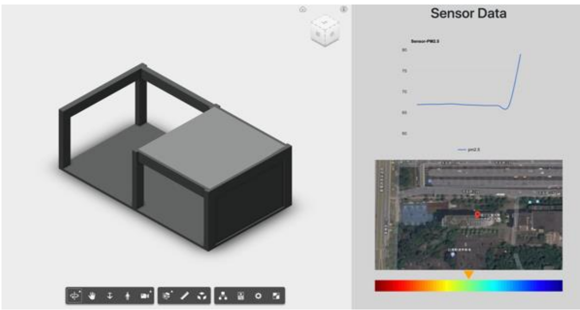
Step 3: The user may select a specific data source (e.g. monitoring sensors) for detailed examination of its data. The source can be either from the Civil IoT Taiwan services or one of those sensors installed on the construction site. With the data from all related sources and sensors, the data-analysis engine of the platform provides analyzed data for the site manager to make decision on construction management tasks.

Step 4: When the platform detects abnormal data, it alerts the user to take proper actions.

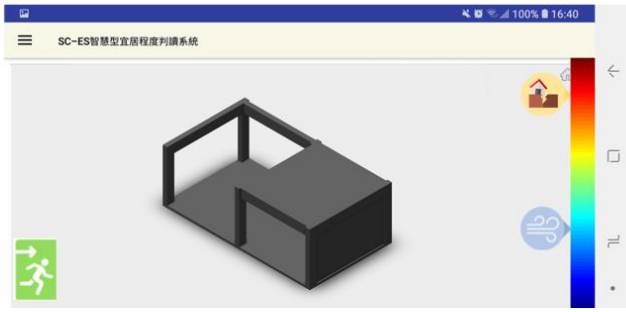


Step 1. Central Control Page

Step 2. Zoom Into the Construction Site



Step 3. Sensors’ Data



Step 4. APP GUI - Alarm

Figure 7. Prototype System Demonstration

4 Conclusion

This paper presents an effort on designing a cloud-based data management framework for integrating government open data and local monitoring sensor data for construction site management. The framework consists of two major parts: one for managing local sensing data with IoT sensors and edge computing devices; while the other one for managing 3D BIM model information and government open data with a cloud database and a web server. A BIM-based platform for facilitating smart site management has been prototyped based on the framework. Although the present effort is just a preliminary one and requires more work on the development and testing of the prototype platform, the preliminary results have shown promising feasibility of the proposed framework for assisting smart construction site management.

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