Real-Time Data Visualisation on the Adaptive City Platform

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ABSTRACT

In smart buildings research, the integration of Building Information Models (BIM), Building Management Systems (BMS), and Internet of Things (IoT) is of paramount importance. However, such integration often overlooks real-time building data visualisation. In this demo, we examine challenges related to spatiotemporal data representation and novel visualisation methods in smart environments. Following this, we present the front-end design of our Adaptive City Platform (ACP), a system for collecting, processing and visualising building information and sensor data in real-time.

CCS CONCEPTS

• **Human-centered computing** → **Heat maps**; *Information visualization*; • **Computer systems organization** → Real-time systems.

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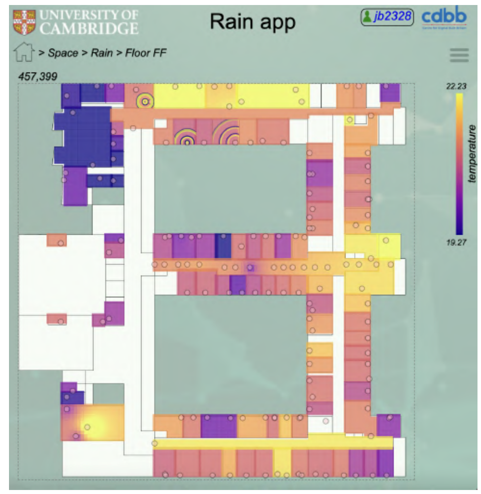

Figure 1: An example application used to visualise current temperature levels in every office. The radiating circles, called *ripples*, show the real-time data coming in.

1 INTRODUCTION

The next generation of smart environments will be driven by BIM, BMS and IoT fusion. Such fusion will give rise to digital twins with real-time asset monitoring capabilities. In such environments, spatiotemporal real-time data flow (or *flux*) from IoT sensors and BMS will combine with contextual BIM data to facilitate energy monitoring, accident prevention, increase comfort and resilience.

While creating such integrated smart building management systems comes with challenges like crafting efficient APIs and flexible ontology schemas [5], contextually meaningful spatiotemporal data visualisation often recedes to the background despite being a key interaction aspect that enables assessment of the created platforms.

To tackle this, we have crafted the Adaptive City Platform, a real-time building monitoring system capable of asynchronously handling spatiotemporal data from BIM and IoT sources with low latency and high throughput. Here, we showcase the ACP's front-end interface and describe how data visualisations enable capturing spatiotemporally contextual data flux from BIM-IoT fusion[1].

1.1 Challenges

Related literature [1–4] highlights three major issues with smart building platforms and their spatiotemporal data representation.

Facilitating building expandability: Any smart building platform should have expansion capabilities so that the system could either be ported to other buildings or have new buildings be added to it. Such capabilities imply that the platform should use an easily accessible and modifiable building database containing contextual and spatial information, such as floorplans.

Capturing high granularity data flux: In contrast to ageing BMS, a high number of deployed IoT sensor devices create the need for high-bandwidth, low-latency data management platforms. With sensors being set up to either send messages periodically or after interrupts, capturing the incoming data flux is crucial for any real-time building monitoring system.

Hierarchical data representation layers: A hierarchical template structure with an increasing granularity of data allows scale-specific information to be displayed at necessary moments. In return, this leads to contextually relevant applications for every spatial scale, as well as privacy-preserving measures.

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[1]Supplementary video showcase of the platform: www.vimeo.com/593360345

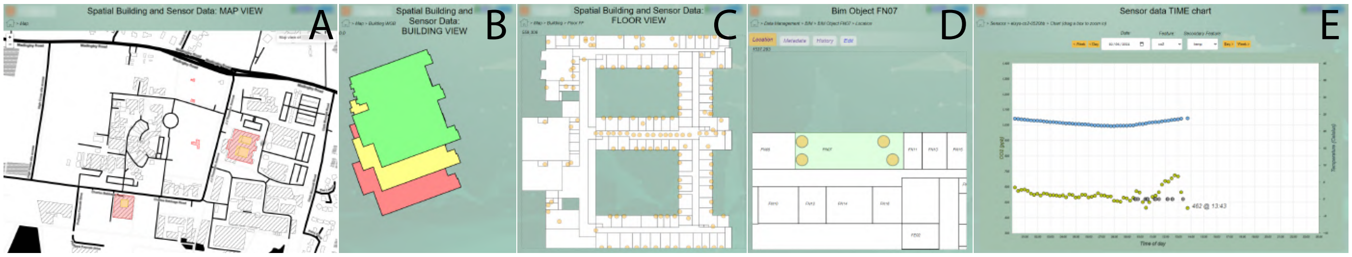

Figure 2: The five templates used to show BIM and IoT data on different scales: (A) Site, (B) Building, (C) Floor, (D) Floorspace, and (E) Sensor. In (E) scatter plots feature two zoomable Y-axes, allowing comparison of CO_2 and temperature readings.

2 DESIGN

For the ACP, we first create different hierarchical templates, each capturing spatiotemporal building data at different granularities. These templates are presented in Figure 2, where moving from a high-level overview of the site, we eventually enter floor and room level views, ultimately reaching scatter plots for individual sensors.

The platform is designed to accommodate multiple buildings easily. Rather than relying on manually crafted SVGs for floorplan representation, our platform either parses existing BIM files or generates SVG files from a list of coordinate data. We then manipulate the SVG on screen as well as draw sensor icons using the visualisation library *D3.js*.

2.1 Sample Applications

To illustrate how high granularity and low latency data can be effectively utilised in a smart building context, we develop two sample applications. One is a heatmap overlay over a floorplan called *Rain* (Figure 1), the second, called *Splash*, is used as a maintenance tool to monitor the state of the deployed sensors.

Our primary goal was to meaningfully and contextually demonstrate the flux of spatiotemporal data. To do so, we use a rain metaphor to facilitate the design process. Next, we aim to portray the real-time high-granularity data using room-bound heatmaps that show intricate differences even in room-scale environments.

Data as Water Droplets: We envision the data flux to be similar to a torrent of rain pouring on a puddle surface, where the sensors' messages were akin to splashes of water on the floorplan.

The analogy enables us to both make use of the size of the ripple effect over the floorplan or individual rooms to illustrate the magnitude of the reading, as well as give a clear visual indication to the observer that new data has arrived. Furthermore, as multiple ripples appear in the same space, the observer can perceive more complex events happening, such as a meeting.

Room-bound heatmaps: Existing smart building platforms use floorplan-wide heatmaps or choropleth maps [1, 2, 4] to colour parts of the floorplan or rooms with single colour values to represent the sensor readings. These solutions are not ideal in our research context due to the inherent inability to maintain high granularity sensor data. To tackle this, we generate room-constrained heatmaps with a dense resolution for every floor.

We first draw a dense cell network in our heatmap to show fine differences in sensor values. For example, in long corridors, sensor readings might be affected by the sensor being positioned close to windows or hidden away in corners. ACP is capable of displaying such differences with sub-metre accuracy, as shown in Figure 1.

Second, our solution prevents data leaking from one room to another, e.g. server rooms might have significantly different temperatures than surrounding offices. The lack of hard boundaries between rooms with different temperatures renders such floor-scale heatmaps unusable. We create individual heatmaps for every room on the floorplan with surrounding walls. Hence, we can display room-level differences without data *spilling* to surrounding spaces.

Finally, low-latency and high-throughput enable instantaneous building monitoring, where we can detect people walking across a corridor in real-time, as the ripples propagate through the visualisation, immediately catching an observer's attention.

3 CONCLUSION

In this paper, we argue the importance of efficient and clear data visualisation methods for such platforms. The presented Adaptive City Platform showcases our novel visualisation tools such as room-bound heatmaps, and through the use of a splash metaphor, can capture the arriving data flux in an immediately obvious and spatiotemporally meaningful way.

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