Empowering Facility Managers: Multimodal Location-Based Visualization for Smart Sanitizer Dispensers Management

Victor-Adriel De-Jesus-Oliveira[1][a], Thomas Bigler[2], Florian Grassinger[1][b], Michael Zauchinger[1], Albert Treytl[2][c] and Wolfgang Aigner[1][d]

[1] *Sankt Poelten University of Applied Sciences, Austria*

[2] *University for Continuing Education Krems, Austria*

{*victor.oliveira, florian.grassinger, michael.zauchinger, wolfgang.aigner*}*@fhstp.ac.at,*

Keywords: Internet of Things, Data Visualization, Proof-of-Concept Application.

Abstract: Facility management employees are in charge of maintaining a safe and operational infrastructure. Even a seemingly simple task, such as maintaining disinfectant dispensers that need to be operational and constantly refilled, can become costly as the number of units and the distance between them increases. In this context, the deployment of wireless sensor networks allows not only scaling data collection but also for optimizing otherwise mundane tasks and improving response times. Location-based and situated data representations are then presented as powerful tools to visualize and assess data in relation to its physical referent. In this paper, we report a proof-of-concept study on the implementation of sensor-powered disinfectant dispensers deployed on a university campus. We present the design of different location-based visualization dashboards to explore and monitor dispenser status including a traditional web dashboard with list and map views, as well as an augmented reality (AR) app displaying embedded data representations. Interviews with facility management employees are conducted to review their impressions, discuss how such dashboards could be incorporated into their workflow, and explore potential improvements to better support their work.

1 INTRODUCTION

Internet of Things (IoT) allows for smart solutions that speed up data collection and problem resolution. In the context of facility management, IoT devices can be used to monitor and control various systems. Sensors can, for instance, detect occupancy levels and adjust heating or cooling accordingly, saving energy and reducing costs. Using data and information visualization tools is reported to significantly improve the decision-making process (Golparvar-Fard et al., 2013). In addition, augmented reality (AR) technology can further improve information sharing and decision-making regarding the worksite (Chung et al., 2021). However, previous literature does not address how such technologies can be incorporated into the facility manager's workflows, especially the integration of location-based visualizations.

[a] https://orcid.org/0000-0002-8477-0453
[b] https://orcid.org/0000-0003-4409-788X
[c] https://orcid.org/0000-0001-5383-0348
[d] https://orcid.org/0000-0001-5762-1869

This paper reports on a use case that comes from a demand to manage over 70 disinfection dispensers at the facilities of the Danube University Krems, in Austria, during the COVID pandemic. These dispensers are battery-operated and contain a bag of 1000 ml holding the disinfectant liquid. Constantly checking and refilling these devices means a significant additional effort for facility management. Therefore, the devices were powered by wireless sensors to give them more intelligence to reduce administrative effort and allow them to have quick reaction times in case of empty batteries or liquid containers. For that, different visualization alternatives are presented, including list and map views on a conventional dashboard and embedded visualizations rendered in an Augmented Reality (AR) app (see Figure 1).

The main contributions of this paper are:

- The demonstration of a smart solution to support facility managers.
- The design of location-based visualizations.
- The insights of how such visualizations can be incorporated into facility managers' workflow.

De-Jesus-Oliveira, V.-A., Bigler, T., Grassinger, F., Zauchinger, M., Treytl, A. and Aigner, W.
Empowering Facility Managers: Multimodal Location-Based Visualization for Smart Sanitizer Dispensers Management.
DOI: 10.5220/0013105200003912

In *Proceedings of the 20th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications (VISIGRAPP 2025) - Volume 1: GRAPP, HUCAPP and IVAPP*, pages 815-822
ISBN: 978-989-758-728-3; ISSN: 2184-4321

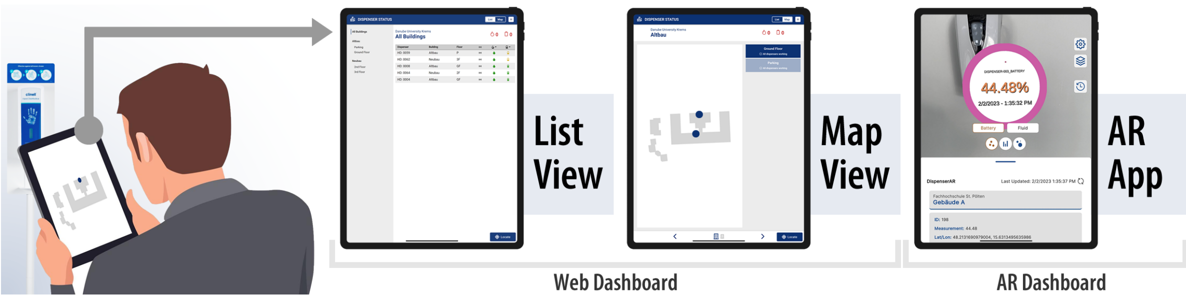

Figure 1: Visualization of location-based sensor data from disinfectant dispensers. A Web and an Augmented Reality (AR) dashboard provide a way for facility managers to inspect, monitor, and localize dispensers. Data from liquid and battery levels are displayed in a list view, map view, and in embedded visualizations using the AR app.

2 RELATED WORK

This work presents an IoT solution in which sensors are added to a non-smart device in order to facilitate data collection and monitoring by facility managers. To achieve such a solution, we took advantage of two main technical fields: the deployment of wireless sensor networks and data visualization.

2.1 IoT Solutions

Previous works are proposed to leverage the use of sensor technology to improve the efficiency of facility management. Udrea et al. (Udrea et al., 2021), for instance, describe how IoT solutions have been used to support facility management and propose a proof of concept using passive infrared sensors and ambient light sensors to collect data about the use of space in a building. Motivated by new pandemic restrictions, Seghezzi et al. (Seghezzi et al., 2021) also proposed a system to collect data about the use of space using cameras. More complex solutions (Kazado et al., 2019; Moreno et al., 2022) deploy environmental sensors to feed otherwise static building information models (BIM). Such models represent a virtual equivalent of the actual building in order to better support data exchange, management, and communication. Such studies demonstrate how BIM-sensor integration can lead to more responsive building management and operation. In our application, however, we focus on a more simple solution with just one type of sensor related to objects located inside the facility.

When it comes to the development of smart dispensers, a few similar works are also proposed. Loong et al. (Wen Loong et al., 2020) present a hand-hygiene monitoring and reminder system designed to improve hand hygiene compliance among healthcare workers. The system consists of a dispenser equipped with low-energy Bluetooth technology and a mobile application that provides location awareness to track the proximity of healthcare workers to the dispenser. Abubeker and Baskar (Abubeker and Baskar, 2023) present an alcohol-based hand hygiene system in hospitals, where communication is achieved using a combination of Bluetooth and LoRaWAN technology. A wearable Bluetooth Low Energy device used by hospital personnel and patients then monitored and tracked the hygiene activities in ICUs, elevators, patient rooms, and other hospital facilities. O'Brien et al. (OBrien et al., 2021) researched the deployment of hand sanitizer stations across a university campus. In that study, the strategic deployment of hand sanitizer stations across Clemson University was modeled to help determine the optimal number of stations to be placed while also minimizing the total cost. However, in this case, no sensors were deployed to support the maintenance of the devices. In our solution, we additionally provide dashboards to support visual analysis of the collected data.

2.2 Location-Based Visualizations

For decision-makers, it is essential to rapidly extract relevant information from the flood of data promoted by IoT solutions (Keim et al., 2008). Visual analytics is described as the science of analytical reasoning facilitated by interactive visual interfaces (Thomas and Cook, 2006). It aids users to obtain insights that directly support situation assessment, planning, and decision-making. Understanding and monitoring the context and situations related to the assessed data are fundamental to the analytical process.

Situated visualizations further allow users to make sense of data by displaying data representations in coordination with the physical environment and meaningful spatial referents. White and Feiner (White and Feiner, 2009) showed how to leverage Augmented Reality (AR) and spatial interaction to support in-situ analytic tasks by registering multidimensional information with the surrounding environment. Later on,

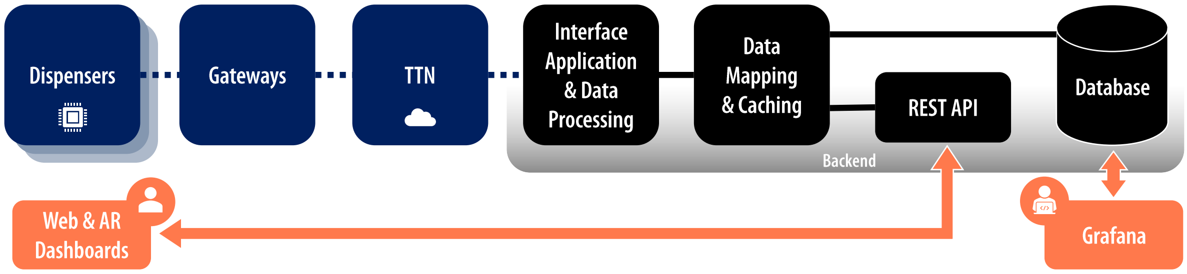

Figure 2: Simplified architectural representation of how the data is transmitted from the dispensers via LoRaWAN and the The Things Network (TTN) server to the back end. In the back end, data is processed and made available to various applications. In addition, a data mapping block is responsible for translating data structures between the services. On the front end, Grafana is used by developers to see the data saved in the database, while end users can navigate data through the Web and AR applications.

ElSayed et al. (ElSayed et al., 2015) proposed to use AR to provide the user with contextual information in real-time, and proposed *Situated Analytics* as an area at the intersection of visual analytics and AR. Building upon their work, Willett et al. (Willett et al., 2017) further introduced embedded data representations as visual and physical representations of data that are not only located near their physical referent but deeply integrated with the physical spaces, objects, and entities which the data refers to. This paper uses Willett et al.'s definition to differentiate between situated and embedded data representations.

There have been numerous attempts to visualize data generated by IoT. Dashboards are the most commonly utilized to monitor IoT deployments on desktop environments (Shrestha and Drozdenko, 2019). For in situ visualization, both AR headsets (Jakl et al., 2018) and handheld AR technology have been employed (Veas et al., 2013; Whitlock et al., 2019). The most common visualization techniques used in such applications are maps and billboards showing glyphs, texts, and 2D representations such as line and bar charts. In our study, we also implement both a conventional dashboard and an AR app for in-situ data analysis. However, we implement conventional 2D representations for our dashboard and explore non-conventional 2D and 3D representations in our AR application.

3 SENSOR IMPLEMENTATION

The installed dispensers originally only had an LED to indicate unit states, such as low battery or empty fluid. To utilize the existing floating magnet in the liquid container as a measure of liquid level, we mounted an additional Hall effect sensor (which detects magnetic fields) on the exterior of the housing. A printed circuit board (PCB) was tailored to the housing. A split adapter was connected to the battery pack to power the PCB and monitor the voltage. Since all dispensers were indoors or near buildings, LoRaWAN was chosen for connectivity. For collecting and transmitting measurement data, an ESP32-based module with an integrated LoRaWAN transceiver was used.

A simplified illustration of the backend architecture is shown in Figure 2, outlining the communication path from the dispensers to the backend.

To enable low-power operation, we actively poll the status of the sensors at regular intervals. Data transmitted from the dispenser is received by the LoRaWAN gateways, which then forward valid messages to The Things Network (TTN) server. The interface application on the backend subscribes to the specific backend application via the Message Queuing Telemetry Transport (MQTT) protocol, receiving valid messages with additional metadata, such as LoRaWAN-specific transmission parameters. These messages are processed and inserted into the database through a data mapping and caching layer.

The mapping and caching layer serve two purposes: 1) adapting parameter names and values (e.g., converting from string format to value types like integers or floats) from the LoRaWAN messages and formatting them appropriately for the database engine protocol, and 2) caching the most recent data and requests in memory, reducing the computational expense of database access.

The backend server offers a REST Application Programming Interface (API) for requesting current and historical dispenser statuses, as well as other metadata like network and connectivity parameters. This interface is directly utilized by the web application (refer to Section 4.1), which is also hosted on the backend servers. Grafana also permits data analysis directly on the raw database content, while end users can access the data via our proposed dashboards (as shown in Figure 2).

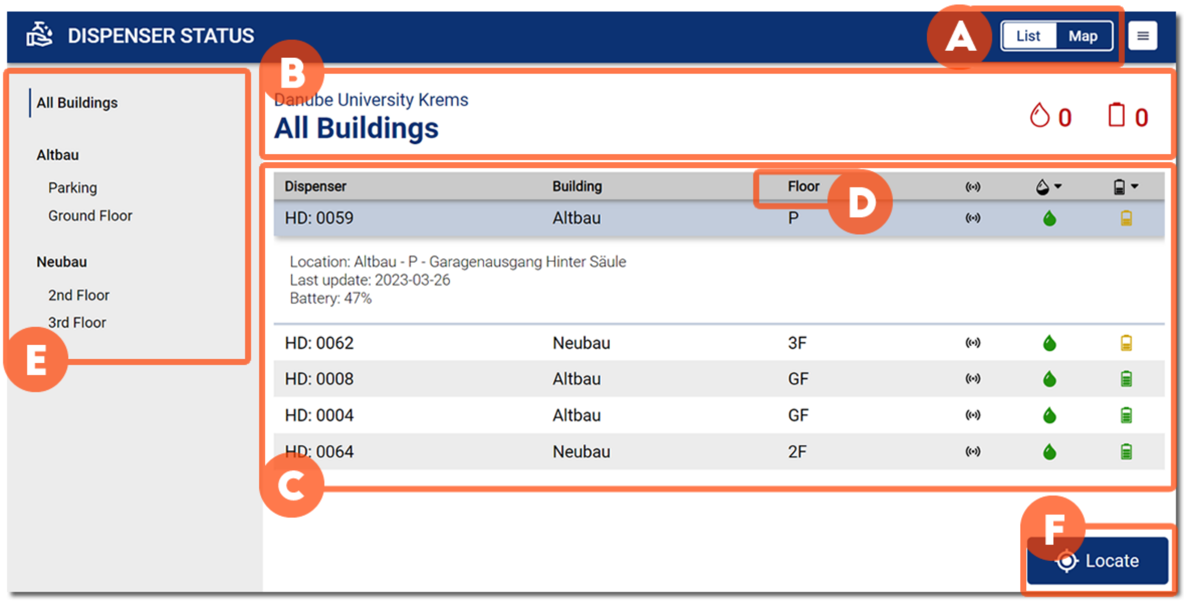

Figure 3: The Web dashboard's *List View* includes a switch (A) to navigate between map and list, a heading (B) with information about the current location and the devices on that location in need of maintenance. It also shows a tabular representation of the devices (C), with their identification, location, and status. The tabular representation could be reordered through their heading (D), and details from a device could be opened through a double click. The view also includes a navigation bar (E) to select buildings and a location button (F) to select the building corresponding to the user's current position.

4 VISUALIZATION DASHBOARDS

Once the smart dispensers were implemented, we worked on how to navigate the collected data, which includes the status of the device (battery and liquid levels), the status of the sensor (time of measurement and connection status), the location of the device (coordinates, building, and floor), and its identifier.

We first performed a structured interview with facility management employees to address their needs. We interviewed two employees of the Danube University Krems, Austria, who are responsible for facility management. The interviewed employees reported that issues with the dispensers are mostly done by chance. One of them explained that "every dispenser has a visible ID, and people can report by phone or e-mail that a dispenser has a fault. In the best case, these people state the ID of the dispenser. Otherwise, we have to ask where the dispenser is located". He continues by saying, "the dispenser also emits light signals that indicate a possible malfunction. Sometimes people from our department see this, then we can prevent a malfunction ahead of time".

To avoid those malfunctioning units going unnoticed, we designed different views to provide alternative data representations to convey:

- **R1.** Overview of dispenser status (e.g., through color-coded glyphs), showing which devices need immediate attention based on their status.
- **R2.** Details on demand about each unit (e.g., as additional pop-ups to avoid context switch).
- **R3.** Location of devices in the building (e.g., on a list, on a map, and in first-person by embedding the information on the scene with AR).
- **R4.** Location of devices around the user's current location (e.g., situated through GPS).

The different views focus on various aspects of the data and include non-situated visualizations (Web Dashboard) and a situated solution (AR app). The Web dashboard offers a *List View* (Figure 3) to focus on information about the devices and a *Map View* (Figure 4) with a focus on their location. The *AR app* (Figure 5) provides a situated view in which the data representation is embedded into the scene and rendered close to the actual dispensers.

4.1 Location-Based Web Dashboard

The web application that serves as a dashboard for monitoring the dispenser status was written in React (Platforms, 2023) and D3.js (Bostock, 2023). The first view, which the user sees immediately when the page

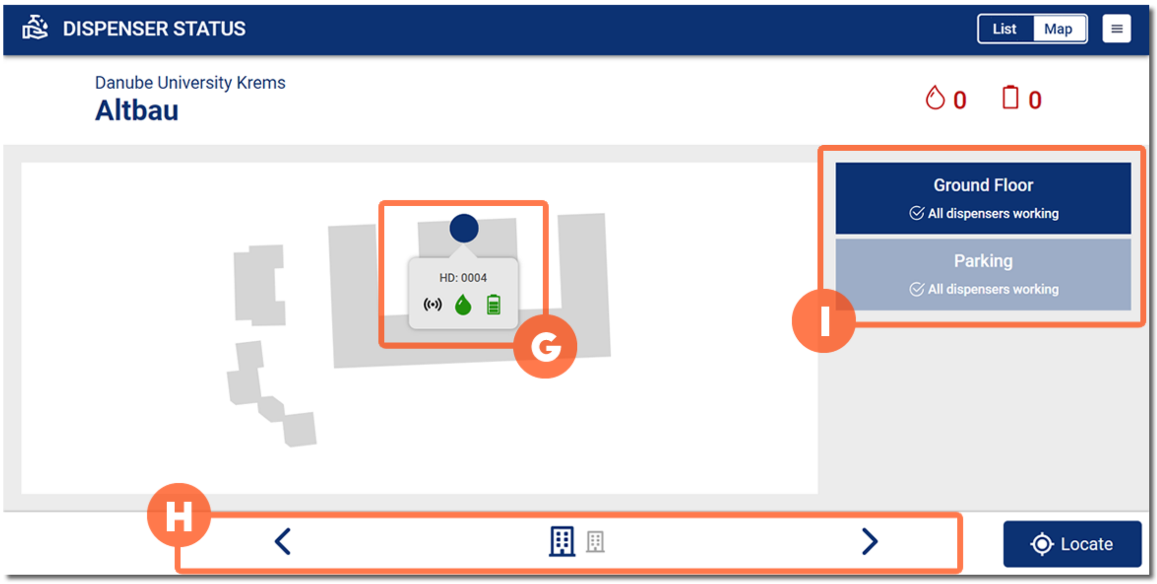

Figure 4: The *Map View* includes many of the same elements as the list view. However, the focus here is on the location of the devices, which are represented by dots over the outline of the building they are located (G). Hovering over them reveals a tooltip with detailed information. The navigation is now moved to the bottom (H) and includes the selection of the corresponding floor level (I).

is opened, is the *List View* for an overview of the sensor status (**R1**) and the second is the *Map View*. In both views, there is the possibility to hover a data point to see more detailed information, such as for the battery the exact percentage of charge (**R2**). The buildings where the sensors are deployed are listed in both views with their respective floors and the dispensers located there (**R3**). Finally, both views can be updated depending on the user's position with the "Locate" button (**R4**).

4.2 Situated Augmented Reality App

Although the Web dashboard could provide information about the devices and their location, situated visualization could provide an alternative for data monitoring and analysis by displaying embedded data representations where the sensor-based devices are deployed. Therefore, we created another view through an AR app. Unity Engine (Unity Technologies, 2023) was used to create a situated AR application for mobile devices. With such an app, users can view data collected in their surroundings, currently visualized in the form of dots, bubbles, or bars. The application is written in C# and AR functionality is provided by Unity's AR Foundation and Mapbox' Maps SDK (Mapbox, 2023).

With the AR app (see Figure 5), data points are placed in the scene based on their latitude and longitude (**R1**,**R3**,**R4**). Controls are always visible on the camera portion to interact with the data, to further calibrate the AR scene, or to load other projects. To select different data attributes and visualization types, a user interface is provided below the camera portion. A collapsible information card at the bottom displays details about a data point once the user taps on the point or swipes up the card (**R2**). This data can also be made temporarily visible by hovering over a data point with a small reticle on the screen.

4.2.1 Visualization Alternatives

Data representations are created from scratch instead of using a library or framework. Each one of the available visualizations can be configured beforehand to a certain degree through the backend. One or more of the available data representations can be enabled for a given data attribute. Therefore, different attributes may have different visualizations. For the tested use case, three visualizations were available:

- **Dots.** Each data point is represented by a flat circle facing the camera. The value of the selected attribute (or measurement) is displayed, including its identifier and timestamp. The circle is displayed at the eye level. A border is color-coded to represent the circle state, whether it is currently selected. When a data point is selected, the card portion of the app displays information about that point. That visualization works as an immersive scatter plot, in which points are rendered at their corresponding geographical position.

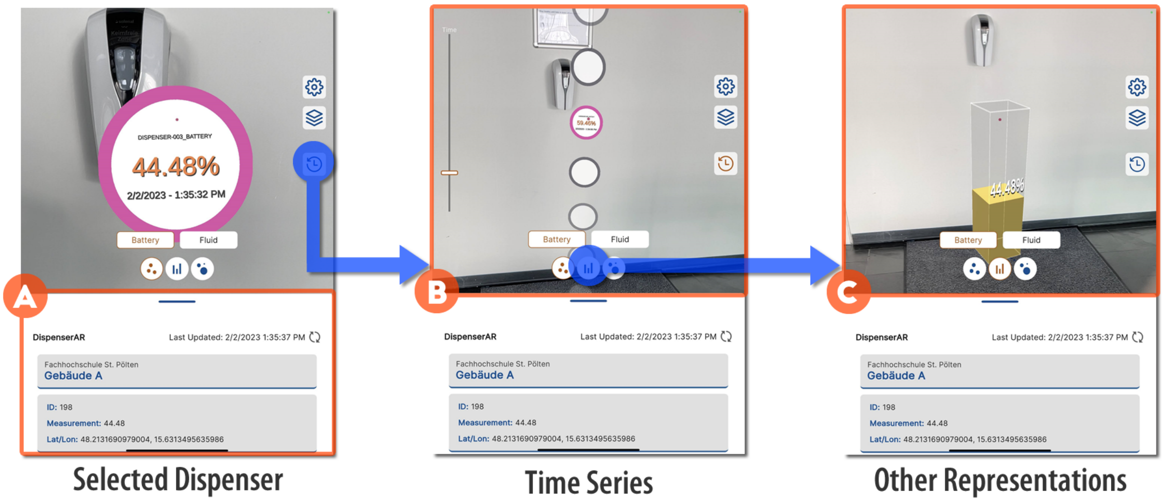

Figure 5: The AR app provides embedded visualizations in which data representations are rendered near its data source. In the camera portion of the screen, the user can find controls for the app and data. Further information about the data point as well as metadata is placed on the card portion of the screen (A). The card can be collapsed to provide more space for the camera. Once a data point is selected through gaze or by directly tapping on it, the card is automatically expanded to display information about the corresponding data point. History can also be toggled to display time series (B). The data can be explored by swiping along the y-axis, which encodes time. Multivariate data representations are not available. Data representations for each attribute include dots, bubbles, and bars (C).

- **Bubbles.** Each data point is also represented by a flat circle facing the camera. Differently from the dot visualization, the size of the bubble also encodes the value of the measurement. The bigger the value, the bigger the size of the circle, which is parametrized according to the range of the current selected data points.
- **Bars.** Each data point is represented by a rectangular column. Columns are then displayed from the floor up to eye level.

Additionally, a time series visualization is included based on the Space-Time-Cube proposed by Hägerstrand (Fisher et al., 2005) in which time represents the third dimension vertically.

5 USER STUDY AND RESULTS

Once again, we interviewed the same employees of the Danube University Krems who are responsible for facility management. E1 is employed at the Facility Management with E2, the latter is also responsible for Occupational health and safety at the Campus. The session was planned as a semi-structured interview, in which a few tasks were planned, but with space for new questions to be made.

We conducted the interview at their office, beginning by opening the *List View* of the Web dashboard on their computer and asking E1 to locate the status of the dispensers and identify any devices requiring maintenance. Following this initial question, E1 emphasized that crucial information for them should include the device's location, encompassing device identification, building name, and room number. Regarding identifying devices in need of maintenance, they suggested that integrating our application into their ticket system would be more effective. Based on this feedback, we delved deeper into E1's workflow. Our findings are summarized in Figure 6.

We identified five main steps followed by them:

1. **Identify Problem.** An issue can be casually discovered by a facility manager or other employees.
2. **Register Ticket.** When an issue is identified, the person needs to email the Facility Management department to automatically generate an entry in their ticket system.
3. **Assign to Responsible.** When a ticket arrives, it goes to the top of their backlog, to be categorized. Categorization implies defining the type of the reported issue as well as who is the person responsible for dealing with it.
4. **Resolve Problem.** Once a responsible person is assigned to a ticket, the person tries to understand the problem and follow the appropriate measures to solve it.
5. **Document and Report.** Before, during, and after solving an issue, the relevant data about the procedure is documented directly in the ticket system. That documentation supports reporting to

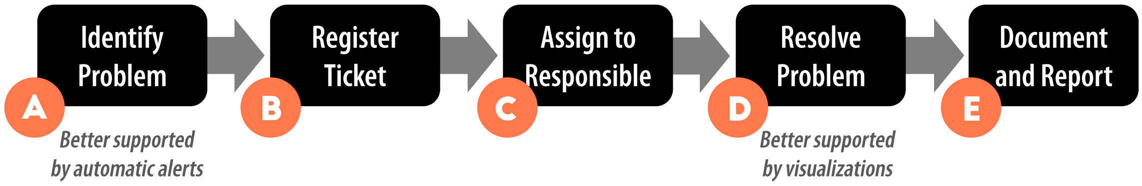

Figure 6: Facility management workflow derived from interviews. After identifying a problem (A), a ticket is created manually or by email (B). Such tickets represent a new entry on the backlog, which is classified and assigned to a responsible person (C). This person will then understand and resolve the problem (D). Finally, the process and results are documented and reported (E). Results show that although the visualization dashboards were created to support identifying problems (A), they were actually mentioned to better support understanding and locating the problem (D).

other interested stakeholders. In addition, before, during, and after solving an issue, other departments are communicated about the issue, such as other facility management sectors, the Campus spokesperson, fire workers, etc.

Not being able to identify an issue in time can be costly. E1 and E2 reported that an undetected water leakage during the weekend caused serious flood damage, which was expensive to fix. They also report that an undetected malfunction on a fridge can make them lose vaccines. Although the maintenance of the disinfectant dispensers does not impose the same urgency, IoT solutions can prevent issues from going unnoticed. However, E1 said a dashboard is not the best way to achieve that. He reported that being warned automatically by the device is more important than the visualization of the device's status. For that step in their workflow, the sensor-based device could trigger an SMS, a mobile notification, or a ticket entry reporting any issue as soon as they occur. In addition, it could provide a summary every morning about the status of all sensors. It could also include information about not working or offline sensors.

E2 mentioned that, even with an automatic connection between devices and their ticket system, the dashboard, with the information of all sensors, would make sense as a next step after receiving a notification about a malfunctioning device. A person could then monitor the status of the sensors with the dashboard and check where to find them. E2 then mentioned that the dashboard becomes particularly important when the number of sensors is big. "Depend on how many sensors are in a room".

Concerning the *Map View*, E1 noted that as long as the textual description is available on the list, the map is only a nice feature that is not needed. In our Web dashboard, the room number was missing, which was relevant to finding the device. That information would make the *List View* enough to navigate the list of devices and find the reported issue. Regarding the color coding and the semaphore metaphor (i.e., colored points according to their detected status), they argued that it would not make sense for more urgent issues that need to be dealt with as soon as possible.

Lastly, they tested the *AR View*. We exited their office and approached one of the dispensers. Using a tablet, we launched the AR app and aimed it at a QR code linked to the dispenser, promptly displaying data about its battery and liquid status. The QR code also facilitates calibrating coordinates, enhancing AR registration indoors. Upon seeing the dispenser data, E1 exclaimed it was "genius" and very cool. Being a visual person, he recognized the benefit of visualizing data directly over the device. He expressed a desire for the AR view to be seamlessly integrated with the Web views. E2 agreed that using the AR view to inspect devices on-site would be practical. We acknowledged that while the visualization options we presented might not be as useful as automatic warnings for identifying new issues (Figure 6.A), our interviewees found the visualizations valuable during problem resolution (Figure 6.D), enabling them to search for additional device information and accurately locate them.

6 CONCLUSION

Overall, data visualization provides facility managers with a powerful tool for understanding the performance of devices and equipment in real time. By using these techniques, managers should be able to quickly locate malfunctioning devices, prioritize maintenance and repairs, and optimize the performance of the facility. However, by interviewing facility management workers, new needs were identified. When it comes to locating malfunctioning devices, this task is mostly distributed in a way that anyone can actually report a problem. Only when a problem is identified, and registered, then analytical tools help solve the problem.

A list view was reported to be already used to get information about devices and their location and preferred over a map view. On the other hand, there was explicit excitement from the users towards the AR solution, which also displays data points near their physical location, this time from an egocentric frame of reference. Reasons for the acceptance of the AR solution over the map representation could include the novelty of the technology or the fact that the AR app reveals on-demand data measured by a device right in front of the user. The potential it created when directly inspecting the data source can play a factor in the received feedback.

This study addresses one use case, in which a device was adapted to attend to the needs of workers from a specific location. Cultural factors related to the context of use and internal protocols should be considered. Yet, the description of their processes should support creating visualizations that are better integrated into the workflow of facility management workers. The next steps include the assessment of the AR app, which is available as an open-source platform for situated visualization of sensor data (St. Pölten University of Applied Sciences, 2024).

ACKNOWLEDGEMENTS

This paper is the result of the research project DATASKOP funded by Amt der NÖ Landesregierung, FTI program.

REFERENCES

St. Pölten University of Applied Sciences (2024). Dataskop. Accessed: 2024-12-20.

Abubeker, K. M. and Baskar, S. (2023). A Hand Hygiene Tracking System with LoRaWAN Network for the Abolition of Hospital-Acquired Infections. *IEEE Sensors Journal*, pages 1–1.

Bostock, M. (2023). D3.js. Accessed: 2023-03-22.

Chung, S., Cho, C.-S., Song, J., Lee, K., Lee, S., and Kwon, S. (2021). Smart facility management system based on open BIM and augmented reality technology. *Applied Sciences*, 11(21):10283.

ElSayed, N. A., Thomas, B. H., Smith, R. T., Marriott, K., and Piantadosi, J. (2015). Using augmented reality to support situated analytics. In *2015 IEEE Virtual Reality (VR)*, pages 175–176. IEEE.

Fisher, P. F., Kraak, M.-J., and Koussoulakou, A. (2005). A visualization environment for the space-time-cube. In *Developments in Spatial Data Handling: 11 th International Symposium on Spatial Data Handling*, pages 189–200. Springer.

Golparvar-Fard, M., Tang, P., Cho, Y. K., and Siddiqui, M. K. (2013). Grand challenges in data and information visualization for the architecture, engineering, construction, and facility management industries. In *Computing in Civil Engineering (2013)*, pages 849–856.

Jakl, A., Schöffer, L., Husinsky, M., and Wagner, M. (2018). Augmented reality for industry 4.0: Architecture and user experience. In *FMT*, pages 38–42.

Kazado, D., Kavgic, M., and Eskicioglu, R. (2019). Integrating building information modeling (BIM) and sensor technology for facility management. *Journal of Information Technology in Construction (ITcon)*, 24(23):440–458.

Keim, D. A., Mansmann, F., Schneidewind, J., Thomas, J., and Ziegler, H. (2008). Visual analytics: Scope and challenges. In *Visual data mining*, pages 76–90. Springer.

Mapbox (2023). Mapbox Maps SDK. Accessed: 2023-03-22.

Moreno, J. V., Machete, R., Falcão, A. P., Gonçalves, A. B., and Bento, R. (2022). Dynamic data feeding into bim for facility management: A prototype application to a university building. *Buildings*, 12(5):645.

OBrien, T., Foster, S., Tucker, E. L., and Hegde, S. (2021). COVID Response: A Blended Approach to Studying Sanitizer Station Deployment at a Large Public University. In *2021 Resilience Week (RWS)*, pages 1–7.

Platforms, M. (2023). React. Accessed: 2023-03-22.

Seghezzi, E., Locatelli, M., Pellegrini, L., Pattini, G., Di Giuda, G. M., Tagliabue, L. C., and Boella, G. (2021). Towards an occupancy-oriented digital twin for facility management: Test campaign and sensors assessment. *Applied Sciences*, 11(7):3108.

Shrestha, S. and Drozdenko, B. (2019). Smart rural framework using IoT devices and cloud computing. In *2019 IEEE Green Technologies Conference (GreenTech)*, pages 1–4. IEEE.

Thomas, J. J. and Cook, K. A. (2006). A visual analytics agenda. *IEEE computer graphics and applications*, 26(1):10–13.

Udrea, I., Kraus, V. F., and Popescu-Cuta, A. (2021). Improving workplace services using a facility management platform sensors monitoring. *Journal of Human Resources Management Research*, Volume 2021:15.

Unity Technologies (2023). Unity Engine. Accessed: 2023-03-22.

Veas, E., Grasset, R., Ferencik, I., Grünewald, T., and Schmalstieg, D. (2013). Mobile augmented reality for environmental monitoring. *Personal and ubiquitous computing*, 17:1515–1531.

Wen Loong, J., Leong Chan, C., Venkatarayalu, N., and Lee, J. S. (2020). A Smart Location-Aware Hand Sanitizer Dispenser System. In *2020 IEEE Region 10 Conference (TENCON)*, pages 642–646.

White, S. and Feiner, S. (2009). SiteLens: situated visualization techniques for urban site visits. In *Proceedings of the 27th international conference on Human factors in computing systems - CHI 09*, page 1117, Boston, MA, USA. ACM Press.

Whitlock, M., Wu, K., and Szafir, D. A. (2019). Designing for mobile and immersive visual analytics in the field. *IEEE transactions on visualization and computer graphics*, 26(1):503–513.

Willett, W., Jansen, Y., and Dragicevic, P. (2017). Embedded Data Representations. *IEEE Transactions on Visualization and Computer Graphics*, 23(1):461–470. Conference Name: IEEE Transactions on Visualization and Computer Graphics.