Environmental Monitoring of Archival Collections: An Exploratory Study of Professionals' Data Monitoring Dashboard Needs and Related Challenges

Monica Maceli(✉), Elena Villaespesa, and Sarah Ann Adams

Pratt Institute School of Information, 144 W. 14th Street, 6th Floor, New York, NY 10011, USA
{mmaceli,evillaes}@pratt.edu,
s.ann.adams576l@gmail.com

Abstract. This work explores the data dashboard monitoring needs and challenges encountered by archives professionals engaged in environmental monitoring, such as collection of temperature and humidity data, across a variety of cultural heritage domains. The results of a practitioner focus group and data dashboard feature ideation session are presented. Findings suggest that practitioners' environmental monitoring struggles include a variety of factors ranging from little budget or staff buy-in, to struggles with environmental monitoring device features, data collection, and interpretation. Suggested revisions to popular data dashboard tools in use included integrating multiple sensors' data into a single, remotely-accessible real-time control interface. Participants' required features in a data dashboard included: charts, export options, value ranges and exceeded alerts, web and mobile access, real-time data, and a date range selector. An initial data dashboard mockup based on the expressed end user needs and challenges is presented.

Keywords: Archives · Environmental monitoring · Data dashboard · End users

1 Introduction

In the cultural heritage domain, archivists and other professionals seek to effectively preserve archives and collections consisting of a variety of types of materials, through monitoring and controlling of environmental conditions. A great deal of existing literature guides professionals in assessing the conditions that materials are being subjected to, and advocates for the use of environmental data (most commonly - temperature and humidity, but also light exposure and air quality) in identifying and correcting poor conditions [1, 2]. Building design and HVACs (heating, ventilation and air conditioning) systems can be constructed and configured to achieve the desired environmental conditions, but best practices advise archivists to operate independent devices that can monitor the actual conditions achieved and any problem areas [3, 4].

N. G. Taylor et al. (Eds.): iConference 2019, LNCS 11420, pp. 777–784, 2019.
https://doi.org/10.1007/978-3-030-15742-5_73

Digital environmental monitoring devices and data dashboard interfaces are increasingly being deployed to verify that HVAC readings are accurate [3] and are produced by companies such as the Image Permanence Institute (who provide the popular eClimateNotebook® data dashboard tool), OnSet, Vaisala, and Dickson. Such devices and services take a variety of forms, from non-networked stand-alone data-loggers to more complex wireless systems [5], and are available at a variety of price points. In contrast to the available commercial devices, research work has explored new approaches to wireless sensor networks designed to overcome limitations in building layout and manage technical tradeoffs, while ensuring high accuracy and ease-of-use [6–9]. Studies largely focused on temperature and humidity, often in the micro-climates that may develop around artworks, with some addressing light, such as Zhang and Ye [7], particularly in the museums context. Most solutions were designed for indoor environments, though some designed for outdoor context include both light and rain sensors [10]. Notably, much of this research emphasizes remote monitoring and utilizing common protocols and techniques borrowed from the Internet-of-things and open source hardware realms [9, 11]. Many of the products at the lower end of the commercial offerings lack such features entirely. Dashboards are a common visualization tool for monitoring a set of indicators in a single screen and highlight those that require immediate attention [12]. Using dashboards brings efficiencies in the data collection and reporting process due to automation and low staff training needs [13, 14]. In the preservation area, the eClimateNotebook tool, developed by the Image Permanence Institute, generates an overview report to monitor environmental data uploaded after collection [15].

Though there is a great deal of research and practical focus on what the desired conditions should be, what tools to employ to monitor such systems, and general best practices, less work directly seeks to understand the end users of such systems, their data dashboard needs, and their challenges encountered in environmental monitoring. Some of the existing research on novel wireless monitoring systems conducted small-scale user tests on the prototype device, such as the Peralta et al. 2013 study of a monitoring mobile application [16], motivating small iterative design improvements. Few recent works explored end user requirements in greater depth from the beginning of the design process and outside of the context of an already-developed system.

To close this gap in research, this exploratory study seeks to understand: (1) *what are the data monitoring dashboard needs of archives professionals engaged in environmental monitoring?* and (2) *what challenges do they encounter in their monitoring activities?* This paper reports on the findings of a practitioner focus group, comprised of professionals from a variety of types of cultural heritage domains, all engaged in environmental monitoring work. The data are analyzed using qualitative methods, and a proposed solution of integrating multiple sensors' data into a single, remotely-accessible data dashboard control interface is developed.

2 Research Methods

A focus group of participants involved in environmental monitoring, within cultural heritage organizations, was conducted in August 2018. A total of 4 participants were recruited from listservs relevant to archival practices in the New York City area. The focus group consisted of the following activities: (1) a series of initial questions drawn from related literature, (2) a dot voting activity, and (3) a data dashboard sketching exercise, all described in more detail below. All activities were guided by the researchers (authors one and two), with a graduate assistant taking notes, audio-recording the discussion, and photographing the designs created. Participants were asked to read and sign a consent form, introduce themselves, then respond to an initial series of questions aimed at understanding: what environmental data is tracked and how, who accesses the data within the organization and to what ends, as well as any challenges they had encountered in these activities.

Next, the participants of the focus group were asked to do a dot voting exercise based on a predefined list of data and dashboard features. The goal of the exercise was to get a full list of features prioritized by the potential future users. The exercise was undertaken in two rounds. During the first round, participants were provided with five green dots to mark the "must have" features; the second-round dots had a different color (yellow) to select an additional five "nice to have" features. The list of desired features was created based on common dashboard features as well as specific data points and functionalities identified in the literature review and existing reporting tools in the market. The list included a total of sixteen potential features and provided a space for participants to add other requirements.

Finally, participants carried out a drawing activity in groups of two, where the task was to sketch in a poster size sheet the visual look of the dashboard. The drawings were presented by each group and a discussion about the results followed. The goal of this task was to understand the key components of the visual elements required for the user interface as well as a confirmation of what the most valuable features would be.

The final anonymized session transcript was analyzed using inductive qualitative analysis to code the transcript, in pursuit of identifying themes and concepts of interest to the stated research question - namely the users' data dashboard needs and challenges in environmental monitoring. A final coding scheme was then developed and the findings were integrated into a preliminary data dashboard mockup by the researchers.

3 Results and Discussion

During the initial background questions, participants described their environmental monitoring work in a variety of cultural heritage organizations, including: one participant from an art gallery, two from museums, and one from an archive. All participants were engaged in some level of environmental monitoring activities, ranging from just beginning to monitor conditions with generic consumer devices, to operating dozens of commercial environmental monitoring devices. Participants reported using or having used devices and web-based data dashboards from a variety of popular manufacturers in this area, including dataloggers from the Image Permanence Institute and

OnSet. All participants reported similar needs in assessing and reporting environmental monitoring data. Participants' organizational data is used on an ongoing basis to monitor different metrics, primarily about temperature and relative humidity, but some of the organizations were also collecting data about air quality, light exposure, and water presence. The data are used to detect any critical situation that needs be addressed quickly and also gradually improve the collection environmental conditions. Reports based on this data are distributed to managers and partners to advocate for better conditions for the collection objects. For those organizations with current or upcoming construction work, data is also used for building planning, as well as fundraising and artwork loan requests.

Many challenges were reported by participants in conducting environmental monitoring activities within their organizations (summarized in Table 1, below). Difficulties were experienced in a wide range of environmental monitoring activities, including: lack of resources ("*I don't have a line item for my department, so I just have to wait until grant money comes in or write a special request*." [P1]), interpersonal ("*There has been a lot of resistance from other staff members about keeping doors closed, about keeping the temperature ranger where we want it*" [P3]), and, for those organizations that could afford environmental monitoring devices, technical issues with the devices themselves. One participant noted difficulty in interpreting the data provided:

> "*I'm still learning how to use the Onset data logging reporting. It gave me this really complicated graph, and I just couldn't zoom in or understand the data on the granular level in the way I was hoping to… I wanted to know, "What time was this happening? What's going on?" Was it because the door's opening a bunch during the day? Or is the humidity bumping up in the middle of the night, and why?"* [P3]

Table 1. Participants' environmental monitoring challenges, ordered by frequency of mention

Technical & sociotechnical	Difficulty monitoring conditions of remote locations (3) Unaware of technical possibilities, e.g. monitoring air quality (2) Device alerts (audible) useless in remote/unstaffed locations (1) Intimidated by novel technology (1) Sensors failing over time (1)
Resources	Lack of environmental monitoring budget (3) Lack of time to learn a new device (2) Lone advocate for monitoring activities (2) Excessive staff time consumed by data gathering (1)
Physical Space	Difficulty placing and securing sensors in ideal locations (3) Dealing with changing physical conditions, e.g. construction (1) Obscuring devices too large or prominent for public spaces (1)
Data Context	Difficulty understanding fluctuation of conditions (2) Difficulty assessing value of existing monitoring systems (1) Difficulty interpreting device data (1)
Communication	Need for executive summaries for stakeholders (2) Difficulty explaining complex preservation concepts (1)
Organizational	Staff resistance to environmental monitoring policies (2) Balancing professional guidelines vs sustainability practices (1)

Other participants reported that the perceived difficulty of operating the devices, and lacking the time to dedicate to learning a new system, were also barriers to use.

To explore the feature needs of practitioners in environmental monitoring, the results of the dot voting activity and dashboard drawing exercise were analyzed. First, the results of the dot voting activity are shown in Fig. 1 (below) with green bars denoting required features and yellow bars identifying nice-to-have features. The most popular features, required by half or more of participants, included: charts, export options, value ranges and exceeded alerts, web and mobile access, real-time data, and a date range selector.

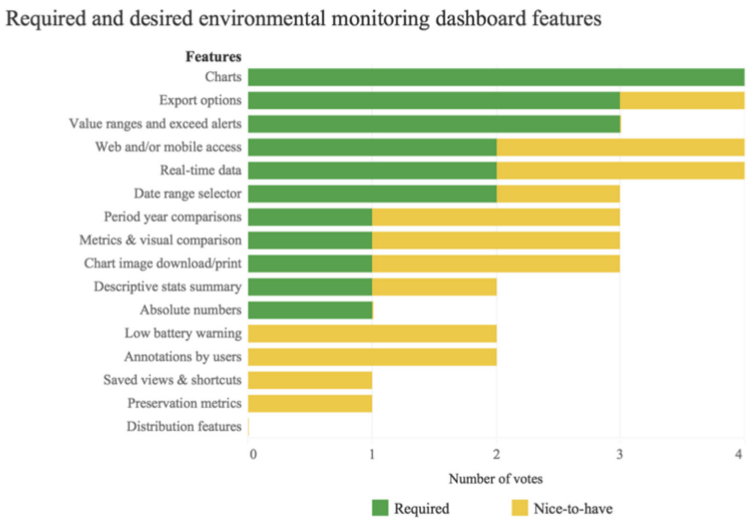

Fig. 1. Focus group participants required and nice-to-have features for a data dashboard (n = 4) (Color figure online)

In terms of the features needed and how those are presented visually, clear priorities emerged in the dashboard drawing exercise, which were aligned well with the findings from the previous dot voting exercise. Participants' drawings emphasized the need to monitor trends and detect areas of improvement, with charts prominently featured in all the sketches. Related to the chart other features were considered key: a date range selector and the ability to compare metrics with previous year or periods. In the list of highly desired features in the list, participants also highlighted export options as a PDF or the raw data as a CSV file to distribute the reports or carry out further data analysis.

One of the main purposes of environmental control is to quickly detect anomalies to avoid any risks of damage in the collection objects. This brings a major requirement of the reporting tool, the possibility to receive alerts and notifications when the data goes

outside the established normal parameters. This was mentioned by all the participants, and is nicely summarized in this comment:

> "*It would be beneficial to have an alert system or even something that would just make it easier so that I wouldn't have to think about getting up and going and collecting the data*" [P1].

This need brings another essential requirement mentioned by all participants as either a required or nice-to-have feature: remote access via mobile and/or web. There were several comments about this necessity to access the data on real time due to the daily tasks of the participants at work which involve moving in the storage areas or working remotely from the different locations of the organization: "*I am not frequently at a desk over the course of a day…a way to access that information when I'm moving around in the warehouse is really helpful*" [P3].

Based on the results of the dot voting and the drawing activities, an initial mockup of the data dashboard, as a proposed solution for monitoring multiple sensors remotely, was developed to capture the expressed user needs (Fig. 2, below). Features include: a main chart with a date range selector with options to compare to previous periods, filters to view the data by device, an alerts area if values have exceeded the predefined value ranges, export options, and real-time data for each of the devices.

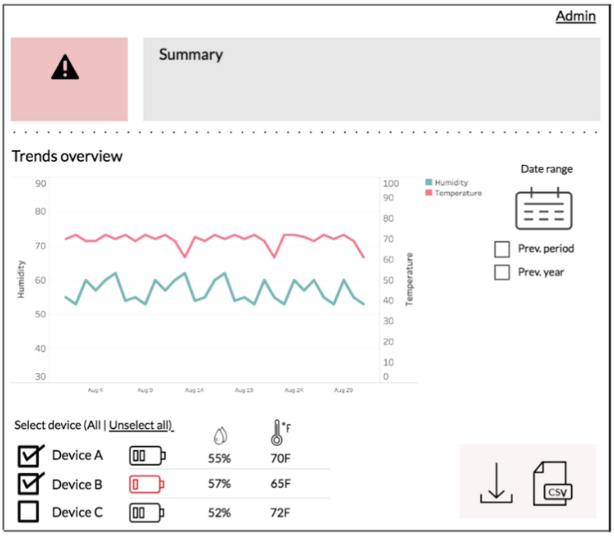

Fig. 2. Data dashboard mockup of web-based desktop

Though many of the features suggested by participants were well-supported by existing systems, such as charts and remote access, the focus group elicited additional requirements. Participants emphasized their need to constantly be advocating for greater budget, seeking buy-in from other staff, and regularly needing to produce executive summaries for various stakeholders. This deeper organizational context is difficult to observe from a hardware-focused user study, as was typically the user-centered emphasis of prior work. To address these problems, the mockup (Fig. 2, above)

included an admin view and a read-only view, as well as a summary of findings, to assist in creating an executive report for other stakeholders.

4 Conclusion

This research study details the findings of a focus group of archival practitioners involved in environmental monitoring work, exploring their data dashboard needs and challenges in monitoring activities. Technical and resources-related challenges dominated, that have not been the focus of existing research literature. An initial mockup of a data dashboard supporting these unmet needs was developed; future work will explore integrating this work into environmental monitoring systems and practice.

References

1. Harvey, R., Mahard, M.R.: The Preservation Management Handbook: A 21st-Century Guide for Libraries, Archives and Museums. Rowman & Littlefield, Lanham (2014)
2. Temperature, relative humidity, light, and air quality: Basic guidelines for preservation. https://www.nedcc.org/free-resources/preservation-leaflets/2.-the-environment/2.1-temperature,-relative-humidity,-light,-and-air-quality-basic-guidelines-for-preservation
3. Wilsted, T.P.: Planning New and Remodeled Archival Facilities. Society of American Archivists, Chicago (2007)
4. Pacifico, M.E., Wilsted, T.P. (eds.): Archival and Special Collections Facilities: Guidelines for Archivists, Librarians, Architects, and Engineers. Society of American Archivists, Chicago (2009)
5. Morris, P.: Achieving a preservation environment with data logging technology and microclimates. Coll. Undergrad. Libr. **16**(1), 83–104 (2009). https://doi.org/10.1080/10691310902754247
6. Bacci, M., Cucci, C., Mencaglia, A.A., Mignani, A.G.: Innovative sensors for environmental monitoring in museums. Sensors **8**(3), 1984–2005 (2008). https://doi.org/10.3390/s8031984
7. Zhang, Y., Ye, W.: Design and placement of light monitoring system in museums based on wireless sensor networks. In: Proceedings of 2011 International Symposium on Advanced Control of Industrial Processes (ADCONIP), Piscataway, N.J., pp. 512–517. IEEE (2011)
8. D'Amato, F., Gamba, P., Goldoni, E.: Monitoring heritage buildings and artworks with wireless sensor networks. In: Proceedings of 2012 IEEE Workshop on Environmental Energy and Structural Monitoring Systems (EESMS), Perugia, Italy, pp. 1–6. IEEE (2012)
9. Londero, P., Fairbanks-Harris, T., Whitmore, P.M.: An open-source, internet-of-things approach for remote sensing in museums. J. Am. Inst. Conserv. **55**(3), 1–10 (2016). https://doi.org/10.1080/01971360.2016.1217671
10. Mecocci, A., Abrardo, A.: Monitoring architectural heritage by wireless sensors networks: San Gimignano—a case study. Sensors **14**(1), 770–778 (2014). https://doi.org/10.3390/s140100770
11. Mesas-Carrascosa, F.J., Santano, D.V., Meroño de Larriva, J.E., Cordero, R.O., Fernández, R.E.H., García-Ferrer, A.: Monitoring heritage buildings with open source hardware sensors: a case study of the Mosque-Cathedral of Córdoba. Sensors **16**(10) (2016). https://doi.org/10.3390/s16101620

12. Few, S.: Information Dashboard Design: The Effective Visual Communication of Data. O'Reilly, Sebastopol (2006)
13. Eckerson, W.W.: Performance Dashboards: Measuring, Monitoring, and Managing Your Business. Wiley, Hoboken (2011)
14. Chen, C.Y., Rasmussen, N.H., Bansal, M.: Business Dashboards: A Visual Catalog for Design and Deployment. Wiley, Hoboken (2013)
15. About eClimate Notebook. https://www.eclimatenotebook.com/about.php
16. Peralta, L.M.R., Abreu, A.M.M., Brito, L.M.P.L.: Environmental monitoring based on wireless sensor network via mobile phone. In: Proceedings of 7th International Conference on Sensor Technologies and Applications, Wilmington, D.E., pp. 25–31. IARIA (2013)