The Collation and Use of Data from Remote Monitoring Systems

Tim Procter (1), Deanna Tomerini (2) and A.L. Brown (3)

(1) Griffith School of Environment, Griffith University, Brisbane, Australia

ABSTRACT

Over the last ten years there has been a significant increase in the number and type of remote monitoring systems used to measure a range of natural and man-made environmental parameters. Initially developed as stand-alone systems that required a field technician to down load the data, these monitoring units are now web enabled allowing for the centralised storage of data in repositories. The data is as diverse as it is detailed and the quantity of the data is both challenging to manage and challenging to interpret. The increase in the number of monitoring systems has coincided with an increase in the requirement for the timely notification of changes to environmental parameters. The current trend is to use 'dashboard' and 'traffic light' systems that incorporate alarms using email and SMS notifications which result in reactive management strategies. This paper provides an overview of the research behind Situation Awareness and Data Visualisation that can assist in the integration of monitoring data from a range of different data streams. The research indicates that the user's perception and awareness of the situation is enhanced when they are provided with appropriate data visualisation. Furthermore, the increased situation awareness results in decision-making that can be pre-emptive rather than reactive.

1 CONTEXT

Over the course of two weeks I met with each of the mines open cut examiners (OCE), the men and women responsible for the day-to-day operation of the mine. The roles of the OCE are dictated by statutory rules and laws that govern the safety and health of people working in and around the surface excavations during mining. Typical activities include the daily management of the workforce, the organisation of machines and manpower required to achieve the production schedule, and the implementation mine's environmental controls and safety requirements. Every meeting was accompanied by the incessant chatter from a two-way radio carried by the OCE. To me, the chatter from the radio was garbled and incoherent and I had to concentrate to make out even the simplest sentence. At each meeting I felt I had the OCE's full attention, but every now and then the OCE would reach for the radio and say something like "Joe, can you run that load around to the B12 RL 65 dump". I can only assume that someone else was talking on the radio about the load of rock Joe had on his truck and that the OCE could interpret the garbled static coming over the radio. Even while talking to me the OCEs were fully aware of what was happening in the mine and could respond to the situation in a timely fashion. I was there to talk to the OCEs about adding to their workload, or was it to simplify their workload? It seemed to me that they already had a really good understanding and awareness of what was happening within the mine. My objective was to streamline one aspect of their job; facilitate the interpretation of the monitoring data from their continuous noise monitoring network to enable them to better manage the noise emanating from the mine.

2 BACKGROUND

EU Directive 2002/49/EC defines environmental noise as unwanted or harmful outdoor sound created by human activities. Major sources of noise include road and rail traffic, aircraft, industrial activity and power generation. The challenge with measuring, assessing and reporting environmental noise has been the subject of numerous research articles over the millennia. In recent years the deployment of permanent monitoring networks (Vincent & Lambert 2005, Mioduszewski et al. 2011, Parnell 2015, Aumond et al. 2017) has resulted in the development of techniques for the dynamic interpolation (tuning) of noise maps using continuous noise monitoring data (Mioduszewski et al. 2011, Wei et al. 2016, Aumond et al. 2017), the development of pattern classification algorithms to separate target and interfering noise sources recorded by continuous noise monitors (Maijala et al. 2018), the assessment of uncertainty in monitoring data (Morillas & Gajardo 2014, Liguori et al. 2016, Ruggiero et al. 2016, Shilton 2017) and the development of innovative methods for communicating and presenting the monitoring data to the public in real time (Vincent et al. 2011, Kenny & Manvell 2014, Gasco et al. 2017).

Manvell (2015) proposes that environmental noise standards and legislation were typically structured around principles of noise monitoring (after the fact) rather than noise management. To wit, over the last 18 years the mining industry in New South Wales, Australia, has installed over 60 continuous noise monitors either individually or as part of a continuous noise monitoring network. The data from the different proprietary units is reported in a number of different formats using a range of different media and access protocols. In addition to this, the quantity of raw data recorded by a single noise monitor can be in excess of 330 Mbytes per day.

Our a priori is that the installation of continuous noise monitoring networks facilitates the move away from an operational framework based around monitoring to one that enables the strategic management of the noise source(s). However, to facilitate this, these systems need to collate, analyse and report on the real-time noise monitoring data, and the accompanying meteorological conditions and operational parameters associated with the noise source(s). To augment the OCE's awareness of their complex surroundings, this information needs to be presented in a format that enhances their perception of the current environment, improves their comprehension of the data in relation to the stated aim, objective or goal of their role, and enables them to identify potential future actions and outcomes. All these elements are encompassed by Endsley's 1995 theory on Situation Awareness (Endsley 1995) and the research into Data Visualisation (Aigner et al. 2008, Aigner et al. 2011, Franklin et al. 2017, O'Neill et al. 2017).

3 SITUATION AWARENESS, VISUALISATION AND DASHBOARDS

The theory of situation awareness has been described as comprising three levels: the perception of the environment, both element and event, with respect to time and space; the comprehension of the meaning of these elements and events as it relates to a specific goal; and the projection or anticipation of what is to occur (Endsley 2015, Franklin et al. 2017). Endsley (1995) states that situation awareness is distinguished as a state of knowledge as opposed to the process that is used to achieve that state, and that these processes vary widely among individuals and contexts. In a dynamic environment a person's situation awareness is being updated constantly through the meaningful integration of all the available information. However, maintaining situation awareness is challenging and, as Franklin et al. (2017) note, "it's not enough to simply thrust all the available data at an individual".

Technological developments, system automation, data overload, poor integration of information and the complexity of hard-to-spot patterns make developing a system to support situation awareness challenging (Franklin et al. 2017, O'Neill et al. 2017). When developing a system to support situation awareness Franklin et al. (2017) promotes that visualisations conceived with an understanding of the work environment and users requirements can improve the perception and comprehension of the available information. The development of such a system would also need to address factors including: the time criticality of making decisions in a complex and dynamic environment; an individual's experience and the cross-disciplinary nature of the users; and physical factors such as colour blindness (Randel et al. 1996, Sohn & Doane 2004, Pauwels et al. 2009). In addition to this, Pauwels et al. (2009) notes that when developing systems for data visualisation it is important to reduce comprehensive sets of metrics to a manageable number and even delete metrics that show little variation over time and metrics that are too volatile to be reliable or don't add to the situation awareness of the user.

As a tool, visualisations in the form of graphics, maps, charts and dashboards can identify trends and patterns that are not obvious from the raw data. Visualisations can screen out 'the noise', analyse from multiple perspectives and then display data that has greater relevance to the situation. Shneiderman (1996) notes that the visualisation of abstract information can reveal patterns, clusters, gaps and outliers that could go unnoticed. The resulting increase in awareness of the situation can then have a positive impact on decision-making (Franklin et al. 2017).

Choosing the appropriate techniques to analyse and present the data are essential to expressive and effective visualisations. The integration of analytical and visual methods requires firstly an understanding of the data type and associated data attributes such as the difference between time points and time intervals for temporal data. Techniques for integrating analytical and visual methods include: filtering the data to eliminate unwanted information; curve fitting to manage outliers and suppress noise; temporal data abstraction that can be used to derive qualitative values and patterns; clustering of data into subsets that exhibit similarities; dynamic queries using Boolean expressions; and the interaction of different data sources/sets (Shneiderman 1996, Aigner et al.

2008, Franklin et al. 2017, O'Neill et al. 2017). Shneiderman (1996) notes that the display of data visually enables relationships to be identified due to proximity, containment, connected lines and even colour.

As a warning: visualisations are open to manipulation and misinterpretation; and techniques developed for one type of data should not necessarily be applied to data that exhibits different attributes (Aigner, et al. 2008, O'Neill et al. 2017). In addition to this, Keys (2017) notes that expertise gained through experience facilitates the build-up of an accurate description of situational elements that are tactically important. Randal et al. (1996) reports that experts place a greater emphasis on correctly assessing the situation while the majority of novices are deciding on the course of action to take. In short, expressive and effective visualisations are not a substitute for experience but experts base their decision making on the situation assessment.

A well designed data visualisation system reduces the need to obtain information from others sources and enables the user to grasp, at a glance, the current status of the situation. To achieve this, the data visualisation system needs to reduce complexity but not at the expense of cohesion and context. Other features of a well designed data visualisation system include the differentiation between alerts, the aggregation and integration of disparate information, being visually salient, and maintaining an expression of the quantitative measures (Gröger et al 2013, Hugo & Germain 2016). The goal is to make the visualisation system simple without using simplistic indicators (Allio 2012).

Alarms are used to indicate a deviation from normal operating conditions and are the simplest form of indicator. Red-yellow-green traffic lights, while universally understood, are a form of alarm prioritisation that includes an intermediate indication of a quantitative measure. In both cases alarms or traffic lights promote reactive user intervention and generally require the users to obtain information from other sources before taking action (Mehta & Reddy 2014). Brazil et al (2013) found that information presented in a traffic light without any quantitative visualisation was the hardest to understand and least influential of the visualisation tools available to knowledgeable users.

On the other hand, a well designed data visualisation system can be monitored at a glance, where the most important information is easily and correctly interpreted by the user. The system should be based around a consistent visual vocabulary with succinct analytical text. In many cases the system would include temporal instances of the quantitative measure that provides context on what has happened in the past, enabling the user to infer what might happen in the future. The objective is to provide information in an uncluttered form, that is easy to comprehend and promotes understanding that leads to better, often pre-emptive, decision making (Few 2005, Allio 2012).

4 CONCLUSION

Based on the research outlined above, our goal was to develop a suitable visualisation of the noise monitoring and weather data to support the OCE's situation awareness of the noise impacts and associated management requirements for the mine. Ideally the resulting visualisation would provide the information in a way that could be "readily perceived, easily recognised and processed expeditiously into inferences" (Franklin et al. 2017). By enhancing situation awareness through appropriate data visualisation the inferences drawn from the information by the OCEs should result in decision-making that is pre-emptive rather than reactive.

5 ACKNOWLEDGMENT

The material contained in this paper was developed as part of a HDR project funded by the Australian Coal Association Research Program (ACARP).

6 REFERENCES

Aigner, W., Miksch, S., Müller, W., Schumann, H., & Tominski, C. (2008). *Visual methods for analyzing time-oriented data*. IEEE transactions on visualization and computer graphics, 14(1), 47-60.

Aigner, W., Miksch, S., Schumann, H., & Tominski, C. (2011). *Visualization of time-oriented data*. Springer Science & Business Media.

Allio, M. K. (2012). *Strategic dashboards: designing and deploying them to improve implementation*. Strategy & Leadership, 40(5), 24-31.

Aumond, P., Can, A., Mallet, V., De Coensel, B., Ribeiro, C., Botteldooren, D., & Lavandier, C. (2017*). Acoustic mapping based on measurements: space and time interpolation*. Paper presented at the INTER-NOISE and NOISE-CON Congress and Conference Proceedings.

Brazil, W., Caulfield, B., & Rieser-Schüssler, N. (2013). *Understanding carbon: making emissions information relevant*. Transportation Research Part D: Transport and Environment, 19, 28-33.

Department of Natural Resources and Mines Qld. (Accessed 2018). *Roles & Responsibilities of an OCE: Understanding the legislative requirements of an OCE / Supervisor*. Queensland Department of Natural Resources and Mines.

EU Directive 2002/49/EC of the European parliament and the Council of 25 June 2002 relating to the assessment and management of environmental noise. Official Journal of the European Communities, L, 189(18.07), 2002.

Endsley, M. R. (1995). *Toward a theory of situation awareness in dynamic systems Situational Awareness* (pp. 9-42): Routledge.

Endsley, M. R. (2015). *Situation awareness: operationally necessary and scientifically grounded*. Cognition, Technology & Work, 17(2), 163-167.

Few, S. (2005). *Dashboard design: Beyond meters, gauges, and traffic lights*. Business Intelligence Journal, 10(1), 18-24.

Franklin, A., Gantela, S., Shifarraw, S., Johnson, T. R., Robinson, D. J., King, B. R., Nguyen, V. (2017). *Dashboard visualizations: supporting real-time throughput decision-making*. Journal of biomedical informatics, 71, 211-221.

Gasco, L., Asensio, C., & de Arcas, G. (2017). *Communicating airport noise emission data to the general public*. Science of the total environment, 586, 836-848.

Gröger, C., Hillmann, M., Hahn, F., Mitschang, B., & Westkämper, E. (2013). *The operational process dashboard for manufacturing*. Procedia CIRP, 7, 205-210.

Hugo, J. V., & Germain, S. S. (2016). *Human Factors Principles in Information Dashboard Design*. Idaho National Lab.(INL), Idaho Falls, ID (United States).

Kenny, S., & Manvell, D. (2014). *Noise sentinel–a proactive approach to noise management in mining operations at BHP Billiton Worsley Alumina Pty Ltd*. Proceedings of Internoise 2014, Australia.

Key, C. (2016). *The comparative Situation Awareness performance of older (to younger) drivers*.

Liguori, C., Paolillo, A., Ruggiero, A., & Russo, D. (2016). *A preliminary study on the estimation of the uncertainty of traffic noise measurements*. Paper presented at the Instrumentation and Measurement Technology Conference Proceedings (I2MTC), 2016 IEEE International.

Maijala, P., Shuyang, Z., Heittola, T., & Virtanen, T. (2018). *Environmental noise monitoring using source classification in sensors*. Applied Acoustics, 129, 258-267.

Manvell, D. (2015). *From noise monitoring to noise management–a better way to deal with noise issues*. Paper presented at the INTER-NOISE and NOISE-CON Congress and Conference Proceedings.

Mehta, B. R., & Reddy, Y. J. (2014). *Industrial process automation systems: design and implementation*. Butterworth-Heinemann.

Mioduszewski, P., Ejsmont, J. A., Grabowski, J., & Karpiński, D. (2011). *Noise map validation by continuous noise monitoring*. Applied Acoustics, 72(8), 582-589.

Morillas, J. B., & Gajardo, C. P. (2014). *Uncertainty evaluation of continuous noise sampling*. Applied Acoustics, 75, 27-36.

O'Neill, K., Weinthal, E., & Hunnicutt, P. (2017). *Seeing complexity: visualization tools in global environmental politics and governance*. Journal of Environmental Studies and Sciences, 7(4), 490-506.

Parnell, J. (2015). *The Generation and Propagation of Noise from Large Coal Mines, and How it is Managed in NSW*. Paper presented at the Acoustics 2015.

Pauwels, K., Ambler, T., Clark, B. H., LaPointe, P., Reibstein, D., Skiera, B., Wiesel, T. (2009). *Dashboards as a service: why, what, how, and what research is needed?* Journal of Service Research, 12(2), 175-189.

Planning and Environment NSW. (2017). *Guide Certificate of Competence*. NSW Department of Planning and Environment, NSW Resources Regulator.

Randel, J. M., Pugh, H. L., & Reed, S. K. (1996). *Differences in expert and novice situation awareness in naturalistic decision making*. International Journal of Human-Computer Studies.

Ruggiero, A., Russo, D., & Sommella, P. (2016). *Determining environmental noise measurement uncertainty in the context of the Italian legislative framework*. Measurement, 93, 74-79.

Shilton, S. (2017). *Uncertainty in Noise Modelling*. Paper presented at the The 24th International Congress on Sound and Vibration (ICSV24), London: International Institute of Acoustics and Vibration (IIAV).

Shneiderman, B. (1996). *The eyes have it: A task by data type taxonomy for information visualizations*. Paper presented at the Visual Languages, 1996. Proceedings., IEEE Symposium on.

Sohn, Y. W., & Doane, S. M. (2004). *Memory processes of flight situation awareness: Interactive roles of working memory capacity, long-term working memory, and expertise*. Human factors, 46(3), 461-475.

Vincent, B., Cristini, A., Vallet, J., Sales, C., Poimboeuf, H., Sorrentini, C., & Anselme, C. (2011). *An urban noise observation: Scientific, technical, strategic and political challenges: A systemic complementary approach to the new requirements of the European directives*. Paper presented at the INTER-NOISE and NOISE-CON Congress and Conference Proceedings.

Vincent, B., & Lambert, J. (2005). *Assessing the quality of urban sound environment: complementarity between noise monitoring system, noise mapping and perception survey, the stakes for the information to the public*. Paper presented at the Congress and Exposition on Noise Control Engineering.

Wei, W., Van Renterghem, T., De Coensel, B., & Botteldooren, D. (2016). *Dynamic noise mapping: A map-based interpolation between noise measurements with high temporal resolution*. Applied Acoustics, 101, 127-140.