Authors (2018): Title. In: Proceedings of the 16th European Conference on Computer-Supported Cooperative Work: The International Venue on Practice-centred Computing an the Design of Cooperation Technologies - Exploratory Papers, Reports of the European Society for Socially Embedded Technologies (ISSN XXX-XXXX), DOI: 10.18420/ecscw2018-to-be-added

Maintaining User's Agency in IIoT Settings– Supporting the Use of Systems of Systems

Martin Stein, Nico Castelli and Timo Jakobi
University of Siegen
{firstname.lastname}@uni-siegen.de

Abstract. Information and Communication Technology (ICT) is increasingly pervading everyday life of western societies. Systems collect, process, and distribute information for most various reasons, such as to save energy, to provide more comfort and security through home automation, to support transportation and mobility, and to take advantage of cyber physical systems in industrial plants. Based on data, systems may either make decisions and act themselves or inform users about their analysis for them to act. IN both cases, it is crucial for the administrative staff to maintain informational awareness and support coordination in different tasks and use cases. To provide users with a "systems-of-systems", we developed a user-centered visualization framework, which follows a dual approach by containing static visualizations as well as a tool for the creation of individual data views. The visualization tool provides flexibility, informational awareness and easy ways to access information behind complex data to maintain the user's agency.

Introduction

Information and Communication Technology (ICT) is being more and more imprinted into the everyday life of western societies (see e.g. [2]). Particularly with the advent of the "Internet of Things" (IoT), the vision of ubiquitous and pervasive computing is becoming a reality and has strong impacts on business as well: Jobs are advertised on LinkedIn, Facebook and Twitter, production planning is taken care of by advanced planning and scheduling systems, production machines automatically collect production process data and ERP systems not only automatically order materials but also assess and choose suppliers and prioritize clients to provide a more stable production setting. With the emergence of new cyber-physical systems in the context of the industrial internet of things (IIoT) all these infrastructures will interweave even more forming new “systems of systems”.

In this article, we want to discuss experiences from various research projects that focused on designing a system allowing users in different settings to assemble their personal information visualizations. The challenge we faced lies in the sources of data, which users were typically keen to use: Data was created within invisible, distributed systems including various IoT sensors, actors and devices, some of which were connected by shared middlewares, while other information stemmed from external services, such as weather, stock or news services.

In addition, taking the user’s point of view, identifying relevant data sources turned out to be highly context-dependent, e.g. depending on the role or task at hand [5]. Deciding which information is relevant and should be integrated with each other in order to gain relevant insights turned out not to be stable across companies or even within different departments of one company, which emphasized a non-neutrality of technology [6] or the need to reflect the heterogeneity of social practices in which technology is embedded [18].

Taking both into account – 1) an increasing number of data sources that need to be integrated into the IIoT and 2) the role or task dependent working processes, which are shaped by case-specific social practices – technology design needs to provide support for people to oversee (awareness) and steer (coordination) processes within companies. In contrast to a fully automated vision of the IIoT, we argue that ICT must support users to maintain their agency emphasizing their role in the innovation of processes and infrastructures.

Supporting Users to Make Use of Systems of Systems

Nowadays new tools arise and systems collect and forward information for various reasons, such as to save energy [5, 19]; to provide more comfort and security through home automation [4, 12]; to support transportation and mobility by sensors and new services [16, 23]; and to take advantage of cyber physical systems in industrial plants [14]. While many of these services are just the beginning in taking advantage of the newly available sensors or of interacting with each other, it becomes obvious that those services interact more and more with each other and form a new kind of system: “systems-of-systems” [21]. While, according to Stankovic [21] many issues regarding these new systems needs to be resolved, such as scalability, architectures, robustness, security and privacy, he also highlights how the “Humans in the Loop” need to be taken into account. Especially in situations where humans are responsible for controlling the systems (e.g. monitoring a manufacturing process) or in situations where the systems monitoring

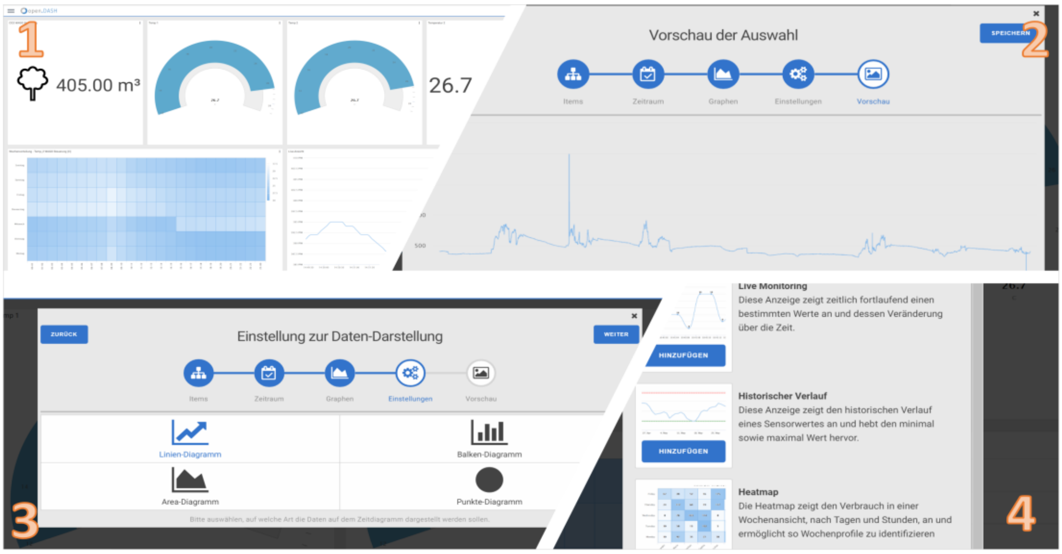

Figure 1: Core Features of open.DASH for providing informational awareness in IIoT

users to take appropriate actions (e.g. building automation or safety controls on machines) it is important to maintain the user's agency by creating information awareness and/or coordination support.

In CSCW and HCI research this question is concerned with the design of assistance and monitoring systems to support people in this analysis and the associated use of this data [1]. In the related work it becomes clear that the challenges in designing such systems is to take into account the different contexts of use as well as the individual abilities and mental models of users [5, 8, 15, 22], which may change over time through changing practices and data learning [4, 12, 17]. Due to the specificity of information, in the literature static solutions are typically developed and investigated in individual contexts [9, 15] and very individual user needs are not taken into account [10]. Particularly in the area of information visualization, therefore, flexible solutions such as Prefuse [11] or the InfoVis Toolkit [7] are being considered. These approaches aim to enable users to develop visualizations meet their needs or questions individually. These systems primarily aim at developers and require advanced IT and/or database knowledge in order to be used purposefully. There is often a lack of more far-reaching concepts for designing suitable human-machine interactions.

In the following, we present a solution that addresses regular users without programming experience and that allows to assemble personal, task specific dashboards.

The Example of 'open.DASH'

To create informational awareness and support coordination in different tasks and use cases, we have developed a user-centered visualization framework (figure

1-1)[4, 12]. The framework contains a dual approach (combining the two from literature), in that it contains static visualizations (figure 1-4) as well as a tool for the creation of own data views by the user (figure 1-2 and 1-3). The static predefined visualizations are developed context-specifically by empirical requirements analysis in a user-centered approach, the tool for designing own data views is based on an end-user development approach [13] to enable users without programming knowledge to extend and adapt the system.

We have implemented both concepts in order to provide flexibility for case-specific informational needs, as well as complex task-oriented visualizations that would require programming experience or at least an understanding of Extract, Transform, Load (ETL) operations. The main goals are twofold:

A **data overview** should provide a starting point by showing first possible data-based use-cases, a catalogue with pre-defined visualization, where the user can freely choose possibly suitable visualizations to add to the dashboard. The development of pre-defined visualizations is mostly steered by the Visual Information Seeking Mantra by Shneiderman [20], and first provides an overview of the related topics and subsequently offers filtering and details on demand. Next to visualizing numerical data, the system allows the user to analyze textual, logical (true/false), geo and custom generic formats (for specific use cases) by predefined widgets. Typically, these widgets serve highly specific task use cases, such as highlighting frequently visited locations on a map using a heatmap for geo data.

Secondly, open.DASH provides **individual visualizations** to support detailed data exploration and customization on demand [20], with an EUD environment. The visualization creation process consists of four steps (see Fig. 1), following the visualization pipeline by Card et al. [3]. Accordingly, in open.DASH, users select and customize data source visualization using following four steps;

a. select the time range to show data of;
b. select the type of chart (line, bar, area and spider charts as well as a heatmap visualization are available);
c. select additional options such as time based aggregation or options for comparing (such as mean, min or max value of selected data points);
d. can check a preview of the visualization including options, such as tooltips, zoom options or labels and colors of axis etc.

Discussion & Conclusion

Data and Information is central to many new services and is becoming more important to former “analog” tasks, such as manufacturing processes or commerce. While the increasing amount of information helps human users to perform their tasks, it is also a necessary to create so called “systems-of-systems”, that can provide complex, (semi-)autonomous services by exchanging relevant information.

Especially in IIoT settings, looking at these (semi-)autonomous, complex systems, there is a growing challenge to keep users in the loop, as expanding infrastructures and networks require them to maintain a broad understanding of cause-and-effect links across organizational departments or even across different organizations and markets.

For tackling this challenge, we argue, users need a toolset to make use of the "systems-of-systems" and thus a visualization tool that provides flexibility, informational awareness and easy ways to access information behind complex data to maintain the user's agency. By doing so, users can contribute their expertise and continue to iteratively enhance socio-technical infrastructures and processes.

References

[1] Bellotti, V. and Edwards, K. 2001. Intelligibility and Accountability: Human Considerations in Context-aware Systems. *Hum.-Comput. Interact.* 16, 2 (Dec. 2001), 193–212. DOI:https://doi.org/10.1207/S15327051HCI16234_05.

[2] Büscher, M., Liegl, M. and Thomas, V. 2014. Collective Intelligence in Crises. *Social Collective Intelligence*. D. Miorandi, V. Maltese, M. Rovatsos, A. Nijholt, and J. Stewart, eds. Springer International Publishing. 243–265.

[3] Card, S.K., Mackinlay, J.D. and Shneiderman, B. 1999. *Readings in Information Visualization: Using Vision to Think*. Morgan Kaufmann.

[4] Castelli, N., Ogonowski, C., Jakobi, T., Stein, M., Stevens, G. and Wulf, V. 2017. What Happened in My Home?: An End-User Development Approach for Smart Home Data Visualization. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2017), 853–866.

[5] Castelli, N., Schönau, N., Stevens, G., Schwartz, T. and Jakobi, T. 2015. Role-based Eco-info Systems: An Organizational Theoretical View of Sustainable HCI at Work. *ECIS 2015 Completed Research Papers*. (May 2015). DOI:https://doi.org/10.18151/7217284.

[6] Fallman, D. 2011. The New Good: Exploring the Potential of Philosophy of Technology to Contribute to Human-computer Interaction. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2011), 1051–1060.

[7] Fekete, J.-D. 2004. The InfoVis Toolkit. *Proceedings of the IEEE Symposium on Information Visualization* (Washington, DC, USA, 2004).

[8] Foster, D., Lawson, S., Wardman, J., Blythe, M. and Linehan, C. 2012. "Watts in It for Me?": Design Implications for Implementing Effective Energy Interventions in Organisations. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2012), 2357–2366.

[9] Froehlich, J. 2009. Promoting energy efficient behaviors in the home through feedback: The role of human-computer interaction. *Proc. HCIC Workshop* (2009).

[10] He, H.A., Greenberg, S. and Huang, E.M. 2010. One size does not fit all: applying the transtheoretical model to energy feedback technology design. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (2010), 927–936.

[11] Heer, J., Card, S.K. and Landay, J.A. 2005. Prefuse: A Toolkit for Interactive Information Visualization. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2005), 421–430.

[12] Jakobi, T., Ogonowski, C., Castelli, N., Stevens, G. and Wulf, V. 2017. The Catch(Es) with Smart Home: Experiences of a Living Lab Field Study. *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2017), 1620–1633.
[13] Lieberman, H., Paternò, F., Klann, M. and Wulf, V. 2006. End-User Development: An Emerging Paradigm. *End User Development*. H. Lieberman, F. Paternò, and V. Wulf, eds. Springer Netherlands. 1–8.
[14] Ludwig, T., Kotthaus, C., Stein, M., Pipek, V. and Wulf, V. 2018. Revive Old Discussions! Socio-technical Challenges for Small and Medium Enterprises within Industry 4.0. *Proceedings of 16th European Conference on Computer-Supported Cooperative Work - Exploratory Papers, Reports of the European Society for Socially Embedded Technologies* (Nancy, 2018).
[15] Mennicken, S., Kim, D. and Huang, E.M. 2016. Integrating the Smart Home into the Digital Calendar. *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2016), 5958–5969.
[16] Pakusch, C., Bossauer, P., Shakoor, M. and Stevens, G. 2016. Using, Sharing, and Owning Smart Cars. *Proceedings of the 13th International Joint Conference on e-Business and Telecommunications* (Portugal, 2016), 19–30.
[17] Rodgers, J. and Bartram, L. 2010. Residential Resource Use Feedback Technology: A Framework for Design. *Proceedings of the GRAND (Graphics, Animation, and New Media) Conference2010*. (2010).
[18] Rohde, M., Brödner, P., Stevens, G., Betz, M. and Wulf, V. 2016. Grounded design–A praxeological IS research perspective. *Journal of Information Technology*. (2016).
[19] Schwartz, T., Stevens, G., Ramirez, L. and Wulf, V. 2013. Uncovering Practices of Making Energy Consumption Accountable: A Phenomenological Inquiry. *ACM Trans. Comput.-Hum. Interact.* 20, 2 (May 2013), 12:1–12:30. DOI:https://doi.org/10.1145/2463579.2463583.
[20] Shneiderman, B. 1996. The eyes have it: a task by data type taxonomy for information visualizations. *, IEEE Symposium on Visual Languages, 1996. Proceedings* (Sep. 1996), 336–343.
[21] Stankovic, J.A. 2014. Research Directions for the Internet of Things. *IEEE Internet of Things Journal*. 1, 1 (Feb. 2014), 3–9..
[22] Stein, M., Boden, A., Hornung, D. and Wulf, V. 2016. Third Spaces in the Age of IoT: A Study on Participatory Design of Complex Systems. *Symposium on Challenges and experiences in designing for an ageing society, 12th International Conference on Designing Interactive Systems (COOP)* (Trento,Italia, 2016).
[23] Stein, M., Meurer, J., Boden, A. and Wulf, V. 2017. Mobility in Later Life – Appropriation of an Integrated Transportation Platform. *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (New York, NY, USA, 2017).