Towards a Pattern Language for Scalable Interaction Design in Control Rooms as Human-Centered Pervasive Computing Environments

Nadine Flegel[1(✉)], Jonas Pöhler[2], Kristof Van Laerhoven[2], and Tilo Mentler[1]

[1] Trier University of Applied Sciences, Schneidershof, 54293 Trier, Germany
{n.flegel,mentler}@hochschule-trier.de
[2] University of Siegen, Adolf-Reichwein-Straße 2a, 57076 Siegen, Germany

Abstract. Control rooms are central for well-being and safety of people in many domains (e.g., emergency response, ship bridge, public utilities). In most of these domains, demands on operators are increasing. At the same time tasks, goals and well-being of the operators is rarely proactively supported. New technology solutions are often domain-specific and focus on specific functionalities. What is urgently needed to meet the increasing demands are reusable solutions. We develop a cross-domain pattern language for control rooms as pervasive computing environments within a human-centered design process. The pattern language consists of eight hierarchical levels, which combine the perspectives of human computer interaction (HCI) and pervasive computing environments. It will be made available for the public through a web-based pattern platform with feedback and comment functions. This research will contribute to a better understanding of suitable interaction paradigms for control rooms and safety-critical pervasive computing environments.

Keywords: Pattern Language · Design Patterns · Safety-Critical Systems · Control Rooms · Interaction Design · Pervasive Computing Environments

1 Introduction

Control rooms are central to the well-being and safety of people. Whether it's everyday things like electricity, water and gas supply, the transport of people or goods (aircraft cockpit, ship bridge, etc.) or emergencies and accidents where immediate medical help is needed, control room operators bear major responsibility for monitoring and controlling such processes under extremely stressful conditions (e.g., decision-making in short time periods). While pervasive technologies (e.g., wearables, smart home solutions) are increasingly becoming part of private and professional life, where "people and devices are mobile and

Published by Springer Nature Switzerland AG 2024
A. Bramwell-Dicks et al. (Eds.): INTERACT 2023 Workshops, LNCS 14535, pp. 279–291, 2024.
https://doi.org/10.1007/978-3-031-61688-4_27

use various wireless networking technologies to discover and access services and devices in their vicinity" [24], state of the art control rooms are still characterized by stationary work on single-user workstations with several screens [13,23]. The different types of control rooms (see Sect. 2) mentioned in the beginning, appear different at first, but from a socio-technical perspective, generic problems can be identified that occur in most domains (e.g., limited cooperation activities, information overload) (see Sect. 4). As demands on operators are increasing (e.g., private photo-voltaic systems influence energy grids, number of emergencies increase due to demographic and climate change) reusable approaches are needed so that it is not necessary to start from scratch in each domain. So far, only a few approaches exist that deal with "smart control rooms" [20,23] or "control rooms as pervasive computing environments" from a holistic perspective [14]. New insights in the design of scalable interaction paradigms where safety critical operation processes are not only pivotal on the systems level integration (e.g., in the control rooms' digital processes), but extended to the human operators and their interaction are required.

The aim of our research is to develop a cross-domain pattern language for scalable interaction design in control rooms as pervasive computing environments following a human-centered design process. A strict methodology is followed to gather and select candidate design patterns, following an evolution process with feedback loops [28]. The patterns are based on tasks, workflows and operators' needs in a variety of control room domains with respect to daily routine and critical situations, different levels of automation as well as individual and cooperative work. The pattern language is structured hierarchically on eight levels and will be made available for the public within a web-based platform with feedback functions for evaluation, development and discussion. This research will contribute to a better understanding of suitable interaction paradigms for control rooms and safety-critical pervasive computing environments in general (e.g., intensive care units or operating rooms).

The paper is structured as follows: In Sect. 2 we take a look on control rooms and pattern languages in safety-critical domains and pervasive computing environments. In Sect. 3 we provide details on the development process of the pattern language. Results (see Sect. 4) are presented focusing on the structure of the pattern language and example patterns. This is followed by a discussion in Sect. 5. Finally, plans for future work are presented (see Sect. 6).

2 Related Work

The taxonomy of Mentler et al. [22] provides a differentiation of control room types focusing on location and number of operators acting in parallel (see Fig. 1). It points out a key difference between control rooms at "fixed" locations (e.g., emergency response, public utilities) and "mobile" control rooms (e.g., ship bridges, aircraft cockpits). In all types generic HCI-related issues can be found (e.g., monitoring of process states, decision making, etc.).

Pattern languages, in terms of collections of related patterns, have been defined for different purposes (e.g. website development; cf. [17]). With respect

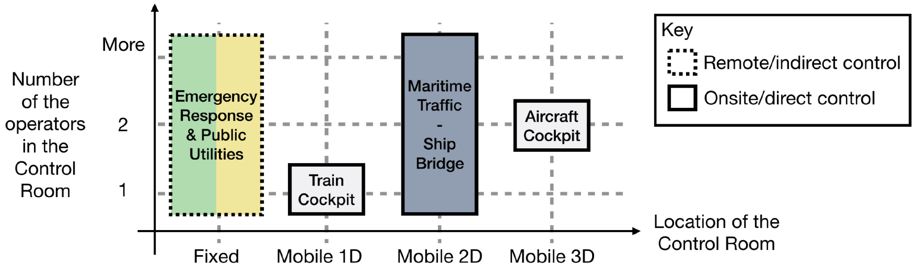

Fig. 1. Types of control rooms according to location and number of operators (Illustration based on [22]. Highlighted areas (green, yellow, dark grey) indicate the 3 domains considered in this study. (Color figure online)

to control rooms up to the authors' knowledge, there exists no specific pattern language for interaction design in control rooms from a holistic viewpoint. Romero-Gómez and Díaz [29] developed a pattern language to assist the design of alarm visualizations for operating control systems with 29 design patterns.

With respect to pervasive computing environments or ubiquitous computing research, there have been several suggestions and studies. For example, Chung et al. [5] developed a ubiquitous computing pattern language consisting of 45 patterns and addressing 4 topics (application domains, physical-virtual spaces, privacy management, fluid interaction). One of the few safety-specific pattern languages, in this case for frontline firefighters, has been presented by Denef and Keyson [9]. Wilde et al. [31] argue that long-range acceptance of design patterns it might be difficult but are convinced that developers of pervasive computing environments will require and refer to them in the future to a greater degree. Knote et al. [19] state that research on this topic is focussed rather on aspects like adaptivity or context-awareness than on "transparency, trust, privacy and informational self-determination". Using the example of personal data collection, one of the design pattern they describe is called "emergency button": "After pressing the [easily accessible] button, the system stops immediately collecting and using personal data" [19].

With respect to safety-critical domains, research on design pattern is mainly devoted to hardware- or software-related technical reliability [3]. Pap and Petri [27] describe one design pattern for safety-critical user interfaces based on the software engineering pattern Model-View-Controller (MVC). Therefore, it is related rather to software architecture than to interaction design. Grill und Blauhut [18] mention a pattern repository for user interfaces in safety-critical environments but no further information or public access has been provided since then. One of the more fine-grained approaches is presented by Mahemoff et al. [21] and Connelly et al. [6]. Their pattern language consists of 19 design patterns in 4 categories (task management, task execution, information, machine control). So far, design patterns with special consideration of scalability have been primarily related to software engineering issues like real-time applications or specific programming frameworks [11,25]. As Kaplan and Crawford [7] state:

"The important thing to know is that design patterns can improve performance in all four areas [extensibility, scalability, reliability, and timeliness]".

3 Methods

Within the framework of the research project PervaSafe Computing, which is dedicated to the topic of control rooms as human-centered pervasive computing environments, a pattern language for scalable interaction design in control rooms as pervasive computing environments, as described in the introduction (see Sect. 1), is under development. Subsequently, the development of the design patterns and the authoring process of the pattern language are presented.

3.1 Development of the Design Patterns

The collection of single design patterns is composed following the pattern evolution process by Reiners et al. [28] in which the patterns pass different states (just created, under consideration, pattern candidate, approved). According to Reiners et al. [28] the design patterns are derived from three sources:

- **Derived from project:** Patterns are directly derived from results of several studies conducted in the project as well as literature on control rooms focusing on HCI-related problems. In order to gain a common understanding of control rooms as future pervasive computing environments as well as to identify patterns (behaviours, needs, tasks, workflows) and individual variations, workshops at three different control rooms (emergency response, public utilities and ship bridge simulator) from two different types of control rooms (see Sect. 2) were conducted, in which challenges in the daily life of the operators according to the components of an interactive system [26] were analyzed and conceivable scenarios for future control rooms (e.g., autonomously carries out identified tasks, filters messages and forwards them to other operators if an operator is busy or stressed at the time, ensures that a message reaches the operator, suggests actions to maintain the operator's health) were discussed. In addition, 9 control room operators were asked about their opinion about the ideal control room using an interaction vocabulary and a free description [15] and an online-survey on digitalization in control rooms with 155 control room operators of the three aforementioned different control room domains [16].
- **Adapted to project:** Well-known patterns in the field of software engineering and software development [1,2] are explored by the project team, because so far, design patterns with special consideration of scalability have been primarily related to software engineering issues (see Sect. 2). The patterns are reviewed whether these are related to scalability and if they could be transferred to the context.
- **Project-external:** As some approaches to interaction design addressing parts of the described challenges (see Sect. 1) already exists for future pervasive computing environments (see Sect. 2), patterns from related pattern

collections (e.g., smart spaces, ubiquitous computing, pervasive computing) are adopted after reviewing whether these are related to the topic. The extent to which the patterns are suitable for safety-critical domains must be examined.

The pattern structure is based on the pattern language model by Borchers [4]. The pattern layout contains a name, an illustration showing the current problem, a context, problem, examples, a solution and a diagram which explains the solution. The patterns and the pattern language are developed within a human-centered design process in close cooperation with experts, therefore tools and formats for online and in-person evaluations, such as workshops, surveys, etc., are necessary. Pattern cards were chosen as a form of presentation reminiscent of playing cards, which makes it possible to present graphic and textual elements coherently. These pattern cards will be specifically designed for the control room domain. They are created for presenting, discussing and structuring design patterns within interdisciplinary workgroups.

3.2 Authoring Process of the Pattern Language

The collection of single design patterns needs to be organized in terms of relationships, purposes, scopes, levels or even contradictions in order to be comprehensible and an efficient aid for designers. The design patterns form the basis for the development of a pattern language. The authoring process consists of the following methods:

- **Pattern Hierarchy:** The design patterns are arranged hierarchically at different abstraction levels, which are derived from the concept of "control rooms as human-centered pervasive computing environments". The patterns are collected and organised in an online whiteboard.
- **Pattern Management Tool:** The design patterns, cards and pattern language will be made available to the public via an web-based interactive design pattern platform with tools for pattern management [10]. On the one hand, the platform should enable the authors of the patterns to manage them, on the other hand, it should be a living platform that is used throughout the entire development process in order to obtain feedback from experts in control room domains through appropriate feedback functions.

4 Results

In the following, first results of the development process are presented with selected design patterns as examples.

4.1 Development of the Design Patterns

In the following, two patterns of the aforementioned sources in Sect. 3.1 are introduced as well as two pattern cards.

The pattern “Ensure that a message/alarm reaches the operator.” (see Table 1) is a guideline which is derived from interviews with control room operators and literature describing the problem of alarm and information management in control rooms (e.g., [8,32]).

Table 1. Design pattern derived from project: Ensure that a message/alarm reaches the operator

Ensure that a message/alarm reaches the operator.	
Context	During a work shift, the operator has to deal with a large number of messages and alarms
Problem	In most control rooms, the visualization of messages and alarms is tied to stationary workstations. If the operator moves away from the workstation or does not have the screens in focus, messages and alarms can be lost. This can cost valuable time and, in the worst case, lead to accidents and disasters
Examples	When an operator goes to the coffee kitchen, messages and alarms are no longer in view or the person can only see from a distance if something is flashing on the workstation/public screen. In some cases, this is currently solved by placing another stationary screen for important messages and alarms in the coffee kitchen
Solution	It should be ensured and verified that operators perceive relevant information. The targeted presentation of messages and alarms should be made dependent on various factors related to the operator: location, focus, activity, status, resources. A check whether the person addressed has perceived the alarm and not just “blindly” acknowledged it should be automatically derived from these factors

The pattern “Load and State Balancer” described in Table 2 and Fig. 2 has been derived from software engineering patterns for scalability in terms of performance and technical reliability. In this context, scalable interaction design means that, on the one hand, users must be able to use a variety of possible interaction options with wearable, mobile, and stationary devices efficiently and securely. On the other hand, it means that users must still be able to cope with the increasing number of alarms and other messages by filtering, summarizing and automated processing.

The design pattern cards (see Fig. 2) contain the name and a graphical representation on the “front” side of the design pattern. The “reverse” side shows further information (problem and solution description). The graphical representation is developed systematically. A basic layout was developed for all design patterns. It depicts a control room with three control room operators on duty. Although the analysis of the context of use showed that the number of operators

Table 2. Design pattern adapted to project from the field of software engineering: Load and State Balancer.

Load and State Balancer	
Context	The flow of information is independent of the activities and states of the operator
Problem	Information is provided to many control room operators in different ways at the same time ignoring their individual current workload or affective state
Examples	While a human operator is for instance highly concentrated on solving an urgent problem in the control room, less relevant alarms that cannot be dealt with at the moment are still demanding attention through audio messages or via screen flashing
Solution	Control room operators' cognitive load and affective state (stress in particular) are modelled on a operator-worn computer. A dispatcher determines which operator will handle the request based on different policies

varies both within a control room, due to different shift staffing, and between control rooms, due to different tasks and responsibilities, this simplified representation can address both individual and cooperative aspects of the work.

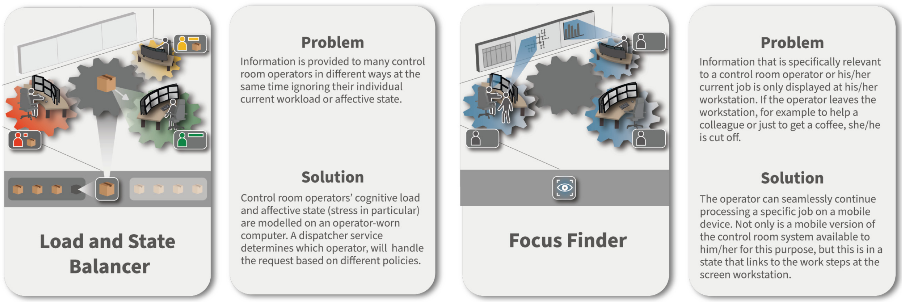

Fig. 2. Excerpt of the pattern language showing the patterns "Load and State Balancer" and "Focus Finder" in the format of design pattern cards.

4.2 Authoring Process of the Pattern Language

In the following, the results of the hierarchical structuring of the pattern language and the development of the web-based design pattern platform are presented.

The structure of the pattern language is based on the hierarchy concept of patterns by Reiners et al. [28]. The structure contains eight levels of abstraction (see Fig. 3). The four highest levels build the foundation of the pattern language. The Vision-Level contains the concept of "control rooms as human-centered pervasive computing environments" [14], which contains that the control room is "aware of operators' activities, cognitive load, and affective state as well as workflows and modes of operation." The challenge of this concept is to combine the research perspectives of the fields human computer interaction and pervasive computing. Therefore, the next level is devided in the perspectives on control rooms as human-centered environments as well as pervasive computing environments. The next two levels contain components of the two sub-visions. For human computer interaction the components are according to frameworks for the deisgn of interactive systems (e.g., [26]) tasks, operators, interactive system, organization and environment. Components of the pervasive computing environment are according to Satyanarayanan [12,30], e.g., mobility support, invisibility, localized scalability, context-awareness and user intent.

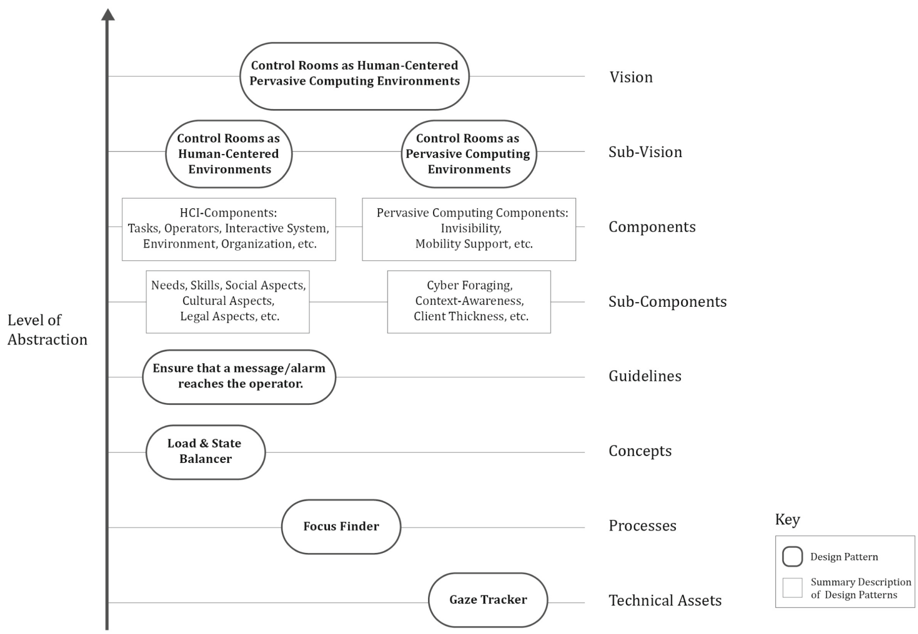

Fig. 3. Draft of a hierarchy scheme of the pattern language for scalable interaction design in control rooms with example patterns (based on the scheme of Reiners et al. [28]).

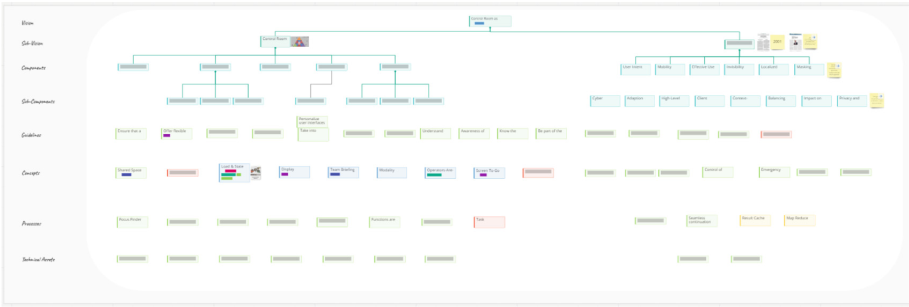

Fig. 4. Collection and hierarchical structure of the pattern language for scalable interaction design in control rooms in an online-whiteboard.

The next level contains guidelines for wide-ranging problems. One example is presented in Table 1, others are for instance that the control room should support the cooperation between operators, the operators' health and well-being and take into account the skills and states of the operators. The following level is about concepts like the "Load and State Balancer" introduced in Table 2. An example of the next level about processes, the "Focus Finder" is illustrated in the pattern card format in Fig. 2. The last level are technical asstes, important for pervasive computing environments, like the "Gaze Tracker", which is neccessary for patterns in the higher levels, for instance the "Focus Finder". At the current stage of development the pattern language consists of 80 patterns, organized in the online-whiteboard (see Fig. 4).

The web-based design pattern platform contains all patterns in the compact card format for a quick view (see Fig. 5) as well as a detailed view of the entire pattern layout. It is possible to rate a pattern and add comments. The rating is based on two questions: (1) How understandable is the pattern? (2) How relevant is the pattern?.

5 Discussion

Several discussion points arise regarding the vision of the control room as a human-centered pervasive computing environment, the different control room types, the development of a living pattern language and the transferability to related domains.

Is it Possible to Combine the Perspectives of HCI and Pervasive Computing Completely? In the development process, it is important to explore the relationships between patterns, with particular attention to patterns associated with the different perspectives. It is conceivable that some patterns contradict each other in their solutions.

Is the Pattern Language the Same for all Control Room Types? More specifically, it needs to be investigated whether the pattern language also differs in the mobile control room types (see Sect. 2) and to what extent the pattern language can be transferred to other safety-critical domains (e.g. surgeons in the operating room)?

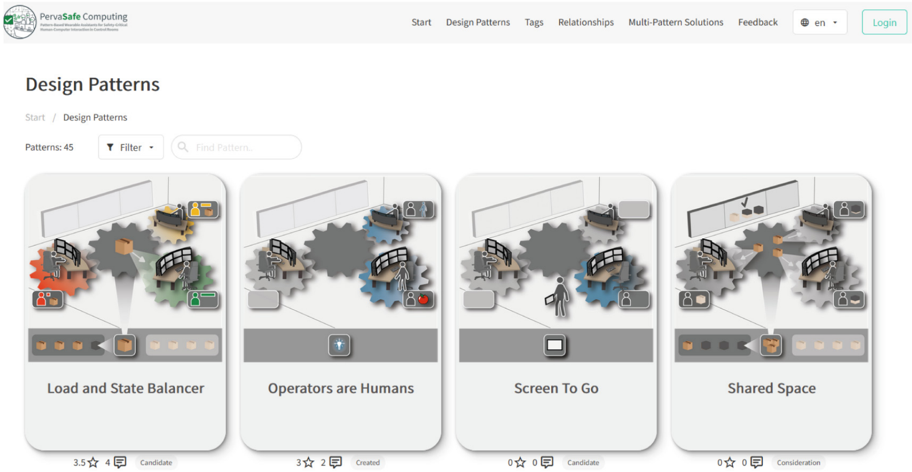

Fig. 5. Screenshot of the web-based design pattern library.

How can the Pattern Language be Designed in a Living Way? The question is whether the web-based platform and its functions to collect feedback can be used for evaluations and whether experts use it to give feedback.

6 Future Work

Within the framework of the project PervaSafe Computing, a wearable control room assistance system is under development, which serves as a central component of the vision of a control room as a "human-centered pervasive computing environment". The assistance system models the control room operators' cognitive load and affective state to influence information flow to the operator, which is guided by the work-related design patterns [14].

Future work on the pattern language includes the evaluation of individual design patterns with the help of the design pattern cards as well as the overall structuring of the entire pattern language (e.g., hierarchy, levels, relationships). For this purpose, expert interviews are planned with experts in the field of pattern languages, safety-critical HCI, pervasive computing environments and control rooms.

Acknowledgements. This project is funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) - 425868829 and is part of Priority Program SPP2199 Scalable Interaction Paradigms for Pervasive Computing Environments.

References

1. Ahluwalia, K.S.: Scalability design patterns. In: Proceedings of the 14th Conference on Pattern Languages of Programs, PLOP '07. Association for Computing Machinery, New York (2007). https://doi.org/10.1145/1772070.1772073
2. Ardagna, C.A., Damiani, E., Frati, F., Rebeccani, D., Ughetti, M.: Scalability patterns for platform-as-a-service. In: 2012 IEEE Fifth International Conference on Cloud Computing, pp. 718–725 (2012). https://doi.org/10.1109/CLOUD.2012.41
3. Armoush, A., Kowalewski, S.: Safety recommendations for safety-critical design patterns (2009)
4. Borchers, J.O.: A pattern approach to interaction design. In: Proceedings of the 3rd Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS '00, pp. 369-378. Association for Computing Machinery, New York (2000). https://doi.org/10.1145/347642.347795
5. Chung, E.S., Hong, J.I., Lin, J., Prabaker, M.K., Landay, J.A., Liu, A.L.: Development and evaluation of emerging design patterns for ubiquitous computing. In: Proceedings of the 5th Conference on Designing Interactive Systems: Processes, Practices, Methods, and Techniques, DIS '04, pp. 233-242. Association for Computing Machinery, New York (2004). https://doi.org/10.1145/1013115.1013148
6. Connelly, S., Burmeister, J., MacDonald, A., Hussey, A.: Extending and evaluating a pattern language for safety-critical user interfaces. In: Proceedings of the Sixth Australian Workshop on Safety Critical Systems and Software - Volume 3, SCS '01, pp. 39-49. Australian Computer Society, Inc., AUS (2001)
7. Crawford, W., Kaplan, J.: J2EE Design Patterns: Patterns in the Real World. O'Reilly Media Inc., Sebastopol (2003)
8. Dadashi, N., Golightly, D., Sharples, S.: Seeing the woods for the trees: the problem of information inefficiency and information overload on operator performance. Cogn. Technol. Work **19**(4), 561–570 (2017). https://doi.org/10.1007/s10111-017-0451-1
9. Denef, S., Keyson, D.: Talking about implications for design in pattern language. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '12, pp. 2509-2518. Association for Computing Machinery, New York (2012). https://doi.org/10.1145/2207676.2208418
10. Deng, J., Kemp, E., Todd, E.G.: Managing UI pattern collections. In: Proceedings of the 6th ACM SIGCHI New Zealand Chapter's International Conference on Computer-Human Interaction: Making CHI Natural, CHINZ '05, pp. 31-38. Association for Computing Machinery, New York (2005). https://doi.org/10.1145/1073943.1073951
11. Douglass, B.P.: Real-Time Design Patterns: Robust Scalable Architecture for Real-time Systems. Addison-Wesley Professional, Boston (2003)
12. Ebling, M.R., Want, R.: Satya revisits "pervasive computing: Vision and challenges". IEEE Pervasive Comput. **16**(3), 20–23 (2017). https://doi.org/10.1109/MPRV.2017.2940965
13. Flegel, N., Pick, C., Mentler, T.: A gaze-supported mouse interaction design concept for state-of-the-art control rooms. In: Ahram, T., Taiar, R., Groff, F. (eds.) Human Interaction, Emerging Technologies and Future Applications IV, pp. 208–216. Springer, Cham (2021). https://doi.org/10.1007/978-3-030-74009-2_26
14. Flegel, N., Poehler, J., Van Laerhoven, K., Mentler, T.: Towards control rooms as human-centered pervasive computing environments. In: Sense, Feel, Design:

INTERACT 2021 IFIP TC 13 Workshops, Bari, Italy, August 30 - September 3, 2021, Revised Selected Papers, pp. 329-344. Springer-Verlag, Berlin, Heidelberg (2021). https://doi.org/10.1007/978-3-030-98388-8_29
15. Flegel, N., Pöhler, J., Van Laerhoven, K., Mentler, T.: “i want my control room to be...”: on the aesthetics of interaction in a safety-critical working environment. In: Proceedings of Mensch Und Computer 2022, MuC ’22, pp. 488-492. Association for Computing Machinery, New York (2022). https://doi.org/10.1145/3543758.3547562
16. Flegel, N., Wessel, D., Pöhler, J., Van Laerhoven, K., Mentler, T.: Autonomy and safety: a quantitative study with control room operators on affinity for technology interaction and wish for pervasive computing solutions. In: Extended Abstracts of the 2023 CHI Conference on Human Factors in Computing Systems, CHI EA ’23. Association for Computing Machinery, New York (2023). https://doi.org/10.1145/3544549.3585822
17. Graham, I.: A Pattern Language for Web Usability. Addison-Wesley Longman Publishing Co., Inc., USA (2002)
18. Grill, T., Blauhut, M.: Design patterns applied in a user interface design (UID) process for safety critical environments (SCEs). In: Holzinger, A. (ed.) HCI and Usability for Education and Work, pp. 459–474. Springer, Berlin Heidelberg, Berlin, Heidelberg (2008). https://doi.org/10.1007/978-3-540-89350-9_32
19. Knote, R., Baraki, H., Söllner, M., Geihs, K., Leimeister, J.M.: From requirement to design patterns for ubiquitous computing applications. In: Proceedings of the 21st European Conference on Pattern Languages of Programs, EuroPlop ’16. Association for Computing Machinery, New York (2016). https://doi.org/10.1145/3011784.3011812
20. Koskinen, H., Laarni, J., Norros, L.: Activity-driven design approach to the novel control room environments. In: European Conference on Cognitive Ergonomics: Designing beyond the Product — Understanding Activity and User Experience in Ubiquitous Environments, ECCE ’09, VTT Technical Research Centre of Finland, FI-02044 VTT, FIN (2009)
21. Mahemoff, M., Hussey, A., Johnston, L.: Pattern-based reuse of successful designs: usability of safety-critical systems. In: Proceedings 2001 Australian Software Engineering Conference, pp. 31–39 (2001). https://doi.org/10.1109/ASWEC.2001.948495
22. Mentler, T., Palanque, P., Harrison, M.D., van Laerhoven, K., Masci, P.: Control rooms from a human-computer interaction perspective. In: Ardito, C., et al. (eds.) Sense, Feel, Design, pp. 281–289. Springer International Publishing, Cham (2022). https://doi.org/10.1007/978-3-030-98388-8_25
23. Mentler, T., Rasim, T., Müßiggang, M., Herczeg, M.: Ensuring usability of future smart energy control room systems. Energy Inform. **1**(1), 167–182 (2018)
24. Mezgár, I., Grabner-Kräuter, S.: Role of privacy and trust in mobile business social networks. In: Handbook of Research on Business Social Networking: Organizational, Managerial, and Technological Dimensions, pp. 287–313. IGI Global, USA (2012)
25. Nikolov, I.: Scala Design Patterns: Design Modular, Clean, and Scalable Applications by Applying Proven Design Patterns in Scala. Packt Publishing Ltd., Birmingham (2018)
26. Palanque, P.: POISE: a framework for designing perfect interactive systems with and for imperfect people. In: Ardito, C., et al. (eds.) Human-Computer Interaction - INTERACT 2021, pp. 39–59. Springer International Publishing, Cham (2021). https://doi.org/10.1007/978-3-030-85623-6_5

27. Pap, Z., Petri, D.: A design pattern of the user interface of safety-critical systems. In: International PhD Students' Workshop Control & Information Technology (2001)
28. Reiners, R., Halvorsrud, R., Eide, A.W., Pohl, D.: An approach to evolutionary design pattern engineering. In: Proceedings of the 19th Conference on Pattern Languages of Programs, PLoP '12. The Hillside Group, USA (2012)
29. Romero-Gómez, R., Díaz, P.: Towards a design pattern language to assist the design of alarm visualizations for operating control systems. In: Caporarello, L., Cesaroni, F., Giesecke, R., Missikoff, M. (eds.) Digitally Supported Innovation, pp. 249–264. Springer International Publishing, Cham (2016). https://doi.org/10.1007/978-3-319-40265-9_18
30. Satyanarayanan, M.: Pervasive computing: vision and challenges. IEEE Pers. Commun. **8**(4), 10–17 (2001)
31. Wilde, A.G., Bruegger, P., Hirsbrunner, B.: An overview of human-computer interaction patterns in pervasive systems. In: 2010 International Conference on User Science and Engineering (i-USEr), pp. 145–150 (2010). https://doi.org/10.1109/IUSER.2010.5716740
32. Wilkinson, J., Lucas, D.: Better alarm handling-a practical application of human factors. Meas. Control **35**(2), 52–54 (2002)