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Design Systems for Intelligent Technology

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ABSTRACT

Intelligent technology seems poised to emerge with unprecedented force across many domains of human activity. Advanced technologies (e.g., artificial intelligence (AI)–based applications and services) hold great promise to enhance work processes such as industrial operations and process control. However, the promise of intelligent technologies will not be realised unless their use is properly grounded in terms of their advantages to human action, operational safety, and the efficiency of the controlled system. Therefore, the novelty associated with what can be done with intelligent technology and how it should be integrated into human action and thought presents key design problems and questions to be answered in the design of future systems. Design systems (DSs) have become standard product design and development tools for creating consistent and well-functioning software applications and industry products by providing standard and reusable design patterns, components, and language. Currently, the industrial application of DSs mainly focuses on aspects of technology design such as visual identity, design principles, user interface elements, traditional engineering design, and interaction patterns. In the present paper, we propose to investigate and open a discussion on the concept of DSs for intelligent technology. This concept extends and builds upon current ideas and industrial practices regarding DSs. This paper is based on case studies of Finnish industrial companies seeking to implement and develop intelligent technology solutions for process control and design processes. Based on our research, we offer preliminary ideas on how DSs should be expanded to better address, identify, and solve challenges relevant to the design of intelligent technologies. Furthermore, we see that these extensions to the present industrial applications of DSs represent an important – even indispensable – step towards realising the vision of Industry 5.0, in which people and intelligent technologies collaborate.

Keywords: Design systems, Intelligent technologies, Artificial intelligence, Design

INTRODUCTION

Intelligent technology seems poised to emerge with unprecedented force across many domains of human activity. Intelligent technologies (e.g., AI-based applications and services) hold great promise to enhance industrial operations and process control. New industrial and societal paradigms (Industry 5.0 and Society 5.0, i.e., a superintelligent society) are characterised by their human-centric objective of creating an environment in which people work in balanced and synergistic cooperation with intelligent technologies to increase the sustainability, well-being, and resilience of human individuals, societies, and the entire planet (Huang et al. 2022). In these visions, humans and 'human-aware AI partners' (Korteling et al. 2021, p. 1) can collaborate to support each other's activities and strengths in the best possible way (Rožanec et al. 2022). The development and implementation of advanced digital technologies also play an important role in the green transition towards a sustainable and fair future, or 'twin transitions' (European Commission et al. 2022).

These advanced technological developments are starting to transform important aspects of both industrial process–control work and its design. In the context of industrial operations and manufacturing processes, intelligent technologies can be used, for instance, to automate repetitive tasks in quality control and to generate data syntheses and simulations to improve both effectiveness and worker well-being and safety (Rožanec et al. 2022) while 'ensuring that production respects the boundaries of our planet' (Huang et al. 2022, p. 425).

However, the promise of intelligent technologies will not be realised unless their use is properly grounded in terms of their advantages to human action, operational safety, and the efficiency of the controlled system, which requires practical design work. Thus, the novelty associated with what can be done with intelligent technology and how it should be integrated into human action and thought presents key design problems and questions to be answered in the design of future systems. It is critical to determine the right questions to be asked, the directions in which the answers can be sought, and the ways in which the patterns of solutions can be organised. One way to address these issues is through design systems (DSs), which ideally provide a coherent and systematic repository of design-relevant knowledge and assets.

Design Systems and Intelligent Technology

DSs have become standard product design and development tools for creating consistent and well-functioning software applications. By providing 'one source of truth' for standards and reusable design patterns, components, and language, DSs assist in reaching more consistent end results efficiently (Chandrasegaran et al. 2013; Dearden and Finlay, 2006; Lamine and Cheng, 2022; Vesselov and Davis, 2019). Currently, industrial applications of DSs mainly focus on aspects of technology design such as visual and brand identity, user experience, organisation-specific design principles and guidelines, cross-platform user interface elements, traditional engineering design, and interaction patterns (Fessenden, 2021; Lamine and Cheng, 2022; Vesselov and Davis, 2019).

Nielsen Norman Group defines a DS as 'a complete set of standards intended to manage design at scale using reusable components and patterns' (Fessenden, 2021). Academic research on the concept of DSs is scarce, but their origins can be traced to the idea of design patterns and pattern languages proposed by Alexander (1977, 1979) in the context of architectural design. These ideas later found their way into software engineering and human–computer interaction (see Dearden and Finlay, 2006), although similar notions can already be found in earlier studies, such as Freeman and Newell's (1971) functional DS for operating systems and Gayretli and Abdalla's (1999) DS for concurrent engineering and manufacturing processes.

Similar to the ontologies of knowledge management (Chandrasegaran et al. 2013), DS can also be understood as an ontology of central concepts and their definitions; objects and attributes; structures; functions and patterns; and their relations in a particular domain. Finally, DSs as 'umbrellas' of information repositories can have both abstract knowledge content (such as user experience models, process descriptions, and high-level design goals), but they can also entail concrete design objects such as code snippets, visual icons, and interaction patterns.

Although using DSs has many perks, they can be difficult to quantify. Various calculations on the value and return-on-investment (ROI) of a DS are available in non-peer-reviewed sources online (see Speicher and Baena Wehrmann, 2022, and the links therein). This logic converges with the idea that value for companies comes from faster and higher-quality outcomes of software development projects (Vesselov and Davis, 2019), which are often late and over budget (Brooks, 1995). Thus, it makes sense that introducing standards and shared tools for development will increase productivity and quality while reducing costs (Lamine and Cheng, 2022). DSs can also decrease designers' frustration, improve collaboration and communication within an organisation, and ensure that the design follows the product vision (Lamine and Cheng, 2022; Vesselov and Davis, 2019).

Intelligent technology design, being by nature more complex and novel than 'ordinary' software development, is apt to introduce new problems for design and development processes while exacerbating the existing 'normal' problems in software development. Forms of intelligent technology such as AI systems have been found to be notoriously difficult to design (Yang et al. 2020). Thus, the very idea of intelligent technology design seems to not only make the case for having some DS in place but also suggests that extensions to ordinary aspects of DSs in accordance with the novel problems of intelligent technology and related AI technologies are necessary.

Therefore, it is logical to ask what would a DS that incorporates solutions to address some of the key problems of intelligent technology design look like – what are some of the features and dimensions it would add to DSs as traditionally conceived? The main idea of this study is to explicate the basic concept and the critical aspects such DSs should address as they emerge through the case studies that form the empirical background of this work. This leaves much room for further research and discussion.

METHODS AND MATERIALS

The research presented in this paper was conducted under the auspices of the Intelligent Human–Technology Co-Agency in Process Control (COACH) project, funded by Business Finland, which investigates optimal human–technology interaction in an industrial context. COACH is a research-oriented project that builds on a practical industrial challenge: how to develop and implement intelligent technology solutions in companies' day-to-day operations.

Empirical Case Studies. Three specific case studies within the COACH project have contributed to the content of this paper: 1) a case study in which the industry's product development practices, particularly around DSs, are investigated, 2) a case study concentrating on the introduction of predictive (AI-based) services into one Finnish paper mill's wastewater treatment process control, particularly from a design perspective, and 3) a case study about one Finnish automation system provider's performance service centre concept, through which expert support is delivered to optimise and solve its customers' process-control problems. While each of these cases is different, they all contribute important perspectives from a DS standpoint, as each case explores different facets of the problem space. These aspects are not exhaustive, but they provide an empirical premise for discussion and future research.

Participants and Procedures. To collect the data, we conducted eight semi-structured interviews with people who either work in remote operations and process control in the paper and pulp industry or design tools and processes for remote operations and process control in this industry. The interviews were conducted in 2023. Three of the interviews were conducted on-site, and four were conducted remotely. Before the interviews, the participants gave their consent to be interviewed. The interviews were recorded in audio format and then transcribed using Microsoft Word and analysed.

Methods. The analysis of the interview data was conducted using a mixed-methods approach combining core-task analysis (Norros, 2004; Norros, Savioja, and Koskinen, 2015) and content-based analysis (Myllylä and Saariluoma, 2022; Saariluoma, 1995).

RESULTS

Our interviews revealed many practical situations in which operators or designers need to, for example, analyse and manipulate data, identify, and solve problems, anticipate the development of situations, and communicate and share information and experiences with other experts or customers. In other words, under different situations, various central information contents, typical intelligent processes, and regular, repetitive practices and ways of interacting can be identified.

Study One: Current Use and State of Design Systems

Summary: For the company studied, elements of the DS have been around for almost a decade, but they were not organised systematically in a single place ('a single source of truth'). One reason for implementing a DS was to relieve the design team from some of the mundane pressure it faced (e.g., repeated questions about UX elements, colours, etc.). Another was to achieve a 'level playing field' so that new product teams could get their design work off the ground smoothly and without avoidable reinventions of the wheel. The DS was still being developed, but the focus was on the visual aspects of design, user interface elements, and general design guidelines. Therefore, currently, the DS is neither intelligent in itself nor targeted at intelligent technology design problems. This makes our basic premise novel and, according to the interview, important and interesting.

Takeaways: The DS contained a number of UX principles. These were general goals for any system design, such as *meaningful human control* and *situational awareness*. This prompted two considerations. First, how do these goals play out with intelligent technology? For example, both of these objectives may be jeopardized by increasing automation and the inherent obscurity of machine-learning systems. Recognising and solving these tensions in practice will result in *solution patterns*, which would benefit from being made explicit (within a DS). Second, what would be similar principles for intelligent technology? Here, we propose that *seamless and natural human–technology co-agency* could be added to the list. Another takeaway was the question of the extent of the service that comes with a product in the context of intelligent technology. As intelligent technology has more potential agency, it changes (or should change) work processes and interfaces with people in ways different from conventional passive technology. Should a company therefore offer, for example, operational research and development services as a corollary to a core product offering and training, specifically from the perspective changes in e.g., operations wrought by the introduction of intelligent technology? If that is the case, attention to *methods and practices* – some of which could be embedded in the DS – would be beneficial.

Study Two: Predictive Systems

Summary: In a predictive system interface designed for wastewater treatment process operators, the system presents the user with a status update and automatically generated recommendations for actions based on the system's predictions. The user should then press a button marked 'Start' to indicate that they have noted (and acted on) these recommendations. However, this feature was underused. As the designer interviewed noted, 'You can carelessly press […] that Start [button] – (it does not actually activate anything) but perhaps some junior operator might wonder [about it]'. Thus, the text on the button does not clearly indicate the consequences of pressing it. A user might become confused about its intended purpose or feel hesitant to use that feature.

Takeaways: Design may need to solve problems on different levels. If basic HCI challenges are not solved well enough, this can also prevent the efficient use of more intelligent functions. We were able to identify several similar cases of *rudimentary problems* from the interview data (manual and repetitive work that could be automatised, dispersed data and systems, etc.), which should be fixed by, for example, following basic design standards and methods. Therefore, intelligent design methods should be integrated with standard and existing methods, making the case for having and *extending* DSs rather than replacing them.

Study Three: Remote Work and Decentralised Expert Networks

Summary: Managing processes requires collecting and merging a vast amount of data to get the big picture. However, issues arise in doing so – for instance, one operator described how inadequately labelled data sources often generate extra work. Interviewees also noted how they must pre-process and combine data manually and look for tips on analysis from colleagues and online, as 'someone has probably already thought about it in some industry'.

Takeaways: Here too, we find some basic HCI problems. The interviewees also described several manual and unorganised *patterns of actions* related to data management that could benefit from support by intelligent technology and the extended pattern libraries stored in DSs. Designers should try to better understand the *holistic contexts* in which human activities happen to ideate how to support operators' work in recurring issues.

DISCUSSION: PRELIMINARY IDEAS ON HOW THE DESIGN SYSTEM SHOULD BE EXPANDED

Niiniluoto, applying G. H. von Wright's idea of a *technical norm,* captured something essential (of the nature of applied and design sciences): 'If you wish to achieve A, and you believe you are in a situation B, then you should do X' (Niiniluoto, 1993, p. 1). A vast number of such norms will emerge for intelligent technology in the coming years and decades. Capturing and embedding such patterns in DSs is our main idea for this paper.

Based on our investigations, we identified six important aspects that need to be considered when developing DSs for intelligent technologies. This list of recommendations is illustrative, not an exhaustive list of all potential issues:

1) Formulate general design goals that focus on achieving seamless and natural human–technology co-agency (e.g., 'the system always keeps the operator informed of its intentions').
2) Recognise how existing UX principles may be in tension with common intelligent technology properties (e.g., badly designed autonomous 'black box' technology may decrease the operator's feeling of control, situational awareness, and trust). Create solution patterns in DSs in which these design tensions are made explicit and solved.
3) Include in DSs descriptions of methods and practices for how intelligent technology should be implemented as an active agent in work processes and interfaces and how it should affect them, as well as how a company should further develop these methods and practices.
4) Integrate – do not replace or separate. Intelligent technology design issues extend standard design problems, and they should not be mistaken for novel issues. Make sure that standard HCI questions are addressed in DSs and continue from there.
5) Make it possible to capture and communicate different types of action and solution patterns that can be used to anticipate, avoid, and solve common issues. Make them searchable and linked with, for example, general design goals and UX principles, as well as recurring tasks and problems.
6) Know the context: intelligent technology supports, replaces, and changes patterns of work and activities when deployed. Find out where the most value can be derived and what it means for future work. Have methods

to comprehensively investigate and operationalise knowledge and practices. How methods and procedures are supported or embedded in a DS presents an important question.

The trajectory from concepts to concrete systems is the process of posing design questions, identifying needs, and solving and identifying problems from different perspectives. One of the reasons for using DSs is that this avoids needing to find things out or do things repeatedly. This is not only good for consistency but also helps answer a designer's practical design problem. One of the most pragmatic use cases for DSs is to act as an external memory or repository for reusable elements; for example, in recognising a situation, the designer recalls the pattern used to address the specific problem. Alternatively, when faced with an almost identical task, such as the design of an interactive element like a button, the designer can simply copy and paste the solution from a library. Intelligent technology only expands the questions, even if many of the problems it generates have essentially the same solution as they do in a 'normal' technology context. Over time, interaction patterns and other patterns for intelligent technology will emerge, but the essential point is to enable a system for capturing them as they occur today and to describe ways to balance possible tensions in collaborative human–technology systems (Norros and Salo, 2009).

One important class of patterns is *patterns of human action*. On the one hand, intelligent technology changes patterns of human action in important ways and, on the other hand, it should be designed to accord with and support them (Norros and Salo, 2009; Saariluoma, Cañas, and Leikas, 2016). This aspect of a DS relates to the 'design-for-human-action' aspect of technology.

A second important class can be referred to as the *recurring problems* at the intersection of intelligent technology and human action, perception, and thought (Dearden and Finlay 2006). This class refers to, for example, the so-called black-box effect (Wahlström et al. 2023) relating to the transparency of modern AI systems. In this class, the inherent properties of technology meet and conflict with human mental processes and actions. A DS should facilitate solving these problems, regardless of whether the problems are related to the use of the technology itself (user perspective) or to the design of the use of technology (designer perspective). A problem needs to be identified before it can be solved (and a pattern generated for the problem–solution pair). These problems are not necessarily solely due to the characteristics of intelligent technologies but can also be caused by people's erroneous thinking (Korteling et al. 2021; Saariluoma, Cañas, and Leikas, 2016). In these situations, human mental contents and intelligent processes are a 'black box' – something that may be corrected, possibly, with the help of AI (Korteling et al. 2021).

When designing intelligent technologies, information about a) tasks and the nature of work and the environment is needed, as well as of b) task-specific activities and interactions (e.g., objectives, cues/prompts), intelligent processes, information gaps, and data sources (e.g., databases, guidebooks, or other experts). To gain a correct situational awareness and the ability to act efficiently also requires, for example, c) technical know-how and specialisation gained through learning and previous experiences (Korteling et al. 2021; Saariluoma, Cañas, and Leikas, 2016).

The modelling of human activity in some contexts requires that information about it can be obtained in some way. This can be done with core-task analysis (Norros, 2004; Norros, Savioja, and Koskinen, 2015), content-based analysis (Myllylä and Saariluoma, 2023), and other cognitive methods (Oulasvirta, Jokinen, and Howes, 2022; Saariluoma, Cañas, and Leikas, 2016). Analysing activity patterns in a human–technology joint system helps reveal what kinds of technology should be designed and how technology potentially changes things (Norros and Salo, 2009). Human–technology collaboration in the context of intelligent systems should be based on some universal characteristics, but at the same time, some issues are highly context specific. No two situations or solutions are ever identical, even if a repeating pattern can be observed in the background. Thus, both universal and situational empirical knowledge is needed.

DSs for intelligent technology should not replace or be kept separate from existing DSs: insofar as a DS already contains standards, guidelines, and reusable elements for general human–technology interaction, the main point from an intelligent technology–human co-agency perspective is to recognise and expand towards these novel issues, while building on tradition. Technologically mediated human action can break down for many reasons, some of which are 'elementary'. For instance, a button with an unclear description makes users reluctant to push it because its consequences are unknown. These types of basic mistakes in HCI can lead to deteriorating co-agency, as frustration is known to still be a common problem faced by users (Hertzum and Hornbæk 2023; Vesselov and Davis, 2019). For this reason, new technological matters must always be tied to existing knowledge and resources (Oulasvirta and Hornbaek, 2022), albeit on a case-by-case basis.

CONCLUSION

As future technological systems need to be designed in a consistent and systematic manner, it is crucial to investigate and explicate the concept of a DS for intelligent technology. We mapped out some of the critical aspects that it should address, based on three empirical case studies conducted within the COACH project.

The guiding principle in designing sociotechnical systems should be that the co-agency between intelligent technology and human operators is seamless, natural, and well-functioning. This means that intelligent technology should feel reliable and trustworthy and be transparent, adaptive, communicative, and responsive to human goals and actions. It should also be ethical and responsible. Making these principles explicit as part of a DS makes them a standard part of design processes.

Principles do not prescribe how they should be achieved. This translates into questions of methods: understanding the psychology and cognition of joint action, as well as ways of making systems of regular human action explicit, such as core-task analysis (Hollnagel and Woods, 2005; Norros, 2004; Oulasvirta, Jokinen, and Howes, 2022; Saariluoma, Cañas, and Leikas, 2016). Recurring problematic issues can be addressed through solution-suggesting patterns.

Sometimes a core technology may advance to a high degree of sophistication, with rudimentary issues on the application level lagging behind. For instance, functionally excellent software can become un- or under-utilised simply because the basic tenets of usability are not recognised. This means that DSs for intelligent technology should start from the basics and build upon existing DS ideas rather than trying to replace them.

Finally, before even entering the process of coming up with – or fixating on – a design concept and solution, one should start with the context and determine where (intelligent) technology can provide most value (Saariluoma, Cañas, and Leikas, 2016). Knowing the context and comprehending the structure of the larger human–technology system requires methods such as those explicated above to observe the context and talk with people to find out what they actually do and how they do it.

Future Design Systems

In this study, we have deliberately not attempted to address many of the other issues that are current in the context of AI discussions. Future research might consider, for example, how AI can help design work or build and develop DSs, or whether DS itself should be intelligent. The important question is: What types of questions should the DS of intelligent technology answer in the first place? How does it help realise the vision of Industry 5.0, in which people and intelligent technologies collaborate? First, the main principles and features of a DS for intelligent technology need to be defined.

Intelligent technology will place new demands on design processes. Thus, on the one hand, the field of design methods for intelligent technology will develop over the coming years and decades. Tackling the design problems related to intelligent technology and accumulating design knowledge will place new demands on companies. Design systems can be used as a technical system that provides a focal point through which the development of design, both cultural and practical, can proceed. The remarks above should provide some empirically based seeds for future development.

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