Ad-hoc Action Adaptation through Spontaneous Context

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Abstract

Typical everyday physical interactors, such as switches, perform a *specific static action* upon actuation by a user. For such simple components, this action is independent of the immediate user situation; consideration of this situation typically involves the augmentation of the interactor with specific added interface features (e.g., long-press of a button for dimming). We introduce the "spontaneous context" interaction pattern for everyday interactors where the concrete action is spontaneously adapted based on information about the user situation that the interactors gather and interpret ad hoc. In our approach, the interactor and user hence share no prior relationship and no user data is stored, yet the interactor adapts the action at interaction time. To demonstrate the spontaneous context pattern, we implemented a "plot door": this is an automatic door that differs from classical infrared motion sensor-activated doors by opening only when it is *likely* that an individual wants to enter. Our plot door uses an infrared sensor that is augmented with our proposed interaction pattern and thereby spontaneously gathers and interprets accelerometer and gyroscope data from the individual to determine whether it should open or not.

CCS Concepts

• **Human-centered computing → Contextual design**; **Ambient intelligence**; **Ubiquitous computing**.

Keywords

Adaptation, User Context, User Situation, Ad-Hoc Interpretation, Sensor, Interactor

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1 Introduction

"Today's automatic doors are maximally stupid"[1]. It is a common observation among fans of the science fiction media franchise *Star Trek* that ordinary automatic doors do not consider user intention when *deciding* whether or not to open, typically followed by admiration for the TV series' "magical" doors that know when to open, seemingly accurately predicting actors' intentions or being operated by "plot sensors".

Also researchers have noted this challenge, defining a *smart door* as a "system that predicts the intention of people near the door based on the social context of the surrounding environment and then makes rational decisions about whether or not to open" [3, p.670]. That interactors are often permanently tied to static actions is hence nicely illustrated in the case of motion-sensor-activated automatic doors that incur energy wastage (think of malls and passers-by), annoyance (think of small waiting rooms where every twitch activates the door), and manual work (think of bus drivers manually opening doors in winter). However, the practice is ubiquitous: typical light switches, for instance, do not consider what type of on/off behavior (e.g., rapid maximum illumination vs. slow dimming) would fit the user's current situation, or automatic water faucets in public restrooms do not adapt to user intent, shutting off too soon or staying on unnecessarily.

Making user interfaces (UIs) like these simple interactors more context-aware is a heavily researched field for several decades, stretching dynamically adapting UIs—in software (e.g., [12]) and hardware (e.g., [10])—, intelligent UIs, smart homes, and context-aware computing in general. However, many of the proposals in these fields commonly take an infrastructure-heavy approach (cf. [15]), emphasizing the collection of user data, creation and storage of user profiles, reasoning components that decide the ideal action to take, and generally tightly coupling infrastructure and user devices (e.g., smartphones). However, especially for sporadic interactions with interfaces in the public—think again about automatic doors in a shopping mall—such tight coupling is not desired.

In this paper, we introduce a concept for ad-hoc, spontaneous, situational action adaptation that extends the context awareness of such interactors while keeping infrastructure-user coupling at a minimum; we refer to the interaction pattern that derives from this concept as "spontaneous context". After a brief discussion of related work that situates our proposal with communication and HCI research, we present the proposed interaction pattern. We then illustrate the pattern with a demonstrator of a "plot door" that follows our approach to create a spontaneously adapting automatic door sensor and discuss its implementation and limitations. We conclude with proposed directions for future research.

2 Related Work

Traditional physical and virtual UI elements—referred to as atomic interactors by Mayer et al. [11]—trigger a system action upon a user interaction. The user interaction might be deliberate (as when pressing a button) or inadvertent (as when approaching a motion sensor). To illustrate this with a simple example, consider a binary

[1]All direct quotes in this paragraph are comments by users ~~Timo~~ and Bry_Sinclair on https://www.trekbbs.com/threads/ds9-defiant-doors-know-only-to-open-when-people-want-to-go-through.293225/. Last accessed August 1, 2025.

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light switch. When users toggle this switch, the system turns on or off the light. The system might implement further logic *after* the switch toggle, such as decreasing the intensity of the light at night, which is a basic form of context awareness. The same principled logic—a (modulated) system action based on a user interaction—applies to sensor-activated lights, automatic doors, water faucets, etc.; we illustrate it in Fig. 1(a). Importantly, this logic does not depend on the user interaction modality: the types of atomic interactors we consider here may also be activated by (deliberate or inadvertent) gaze, voice, or gesture commands and are aligned with Mayer et al.'s atomic interactors [11].

Atomic interactors across all these modalities in principle could include further situational adaptation by taking into account the user's current situation—an idea at the core of *context-aware computing* [5], *adaptive interfaces*, and *smart homes*. Such contextual adaptation of an interface may also be viewed with consideration of communication models among humans. Interaction among humans encompasses multiple dimensions, which are captured in human communication models such as the four-sides model [14]. According to this model, a message between a sender and a receiver encompasses four dimensions: the *factual* aspect is the data and facts that are conveyed in the message; the *self-revealing* aspect refers to the implicit information about the speaker's personal state, such as emotions, values, or beliefs; the *relationship* aspect addresses the connection between the sender and the receiver, considering their interpersonal dynamics; and the *appeal* aspect reflects the speaker's intention regarding what they wish the listener to do or how they expect the listener to respond. When receiving a message, humans hence gather context information beyond the factual content of the message and along the self-revealing, relationship, and appeal dimensions; and they integrate and interpret this information to decide on the action to take in response.

With context-aware computing, HCI research has enabled *machines* to also consider the context of a message they receive—from voice assistants that consider context to assist cooking [6], smart environments that interpret the current situation and respond to user queries while considering this interpretation [7], and context-aware wearables that aim to improve well-being [13]. And just like for humans who communicate verbally and non-verbally, HCI has integrated multimodal context approaches (e.g., that consider different interaction modes like gaze, voice, gesture, and haptics [8, 9, 17]). Relating this to human communication, consideration of the multiple dimensions of a message is hence today ubiquitous in communications research that focuses on interactive context [4] and provides a stimulating perspective on context-aware computing. Through the lens of the four-sides model, context-aware systems hence gradually integrate more dimensions of the communication: in this sense, a simple button press might be interpreted beyond the factual information ("botton pressed") while considering *how* the button was pressed: was the user running towards the button (self-revealing dimension), was the button pressed gently (appeal dimension), and is the user even authorized to press the button (relationship dimension)? However, since the early days of context-aware computing, the gathering of context data has been performed in a rather tightly-coupled, infrastructure-oriented way [1]. This is illustrated well with "context-aware middlewares" [1] that represent infrastructure components which handle context, often centrally.

We argue that, especially given more and more pervasively deployed environmental sensors (including batteryless wireless *information fountains* [2]) that support spontaneous peer-to-peer interaction (e.g., through Bluetooth Low Energy, BLE), the possibility to *spontaneously* consider context information should be explored in greater depth to complement sophisticated, infrastructure-oriented, tightly-coupled context-aware environments.

3 Method

We propose an interaction pattern where an interactable component, upon actuation by a user, *spontaneously* gathers context data from its environment and interprets this data towards adapting the triggered system action (see Figure 1(b)). The novelty of our contribution lies in the spontaneous triggering of the context gathering and interpretation, i.e., that the relationship between the interactable component and the environment information source is established ad hoc and remains purely sporadic; this avoids tight coupling and has positive implications (e.g., in terms of privacy).

We emphasize the sporadic, ad-hoc nature of this interaction pattern. In our proposal, the UI's atomic interactors have no prior relationship with the source of the context data. Rather, the usage of an atomic interactor by a user triggers the establishment of a connection to a context source, the gathering of context data from this source, and the interpretation of this data towards a suitable system action. While we require that all steps of this process are performed within a timespan small enough for the user not to notice the context data gathering and interpretation, we put no further constraints with respect to the level of sophistication of the data interpretation: if fast enough, this may range from a simple if-else (e.g., `if (walkingSpeed > 15) { switchOn(); setIntensity(100); }`) to the usage of machine learning (e.g., `setIntensity(model.predict(gyroscopeData));`).

To perform this interpretation, the atomic interactor requires specific information from the context data source (e.g., `walkingSpeed` and `gyroscopeData`). This requirement may be specified towards the context source with respect to the type and timespan of the data, which means that the context data source *remains autonomous* with respect to its decision to provide this data in full (e.g., because of privacy considerations). In this sense, we note that our concept does not dictate that the interpretation of the context data needs to be performed by the atomic interactor. Rather, context data sources with sufficient energy and processing power may *themselves* select the most suitable system action—after receiving possible action suggestions from the interactor.[2] While this mode of operation incurs an additional transmission between the two components, it further increases data privacy, as the context data never leaves the context source. This is illustrated well by considering that, following a *mobile code* pattern, the selection algorithm itself could be shipped to the context source as well.

With respect to the context data source, our only constraint is that it must be spontaneously available (e.g., through a peer-to-peer communication protocol such as BLE) and that it exposes context data in a readily interpretable way—syntactically as well as semantically. Since the format and meaning of the context data need

[2]This consideration aligns—conceptually as well as formally—with the formal model of signifiers and affordances proposed in [16].

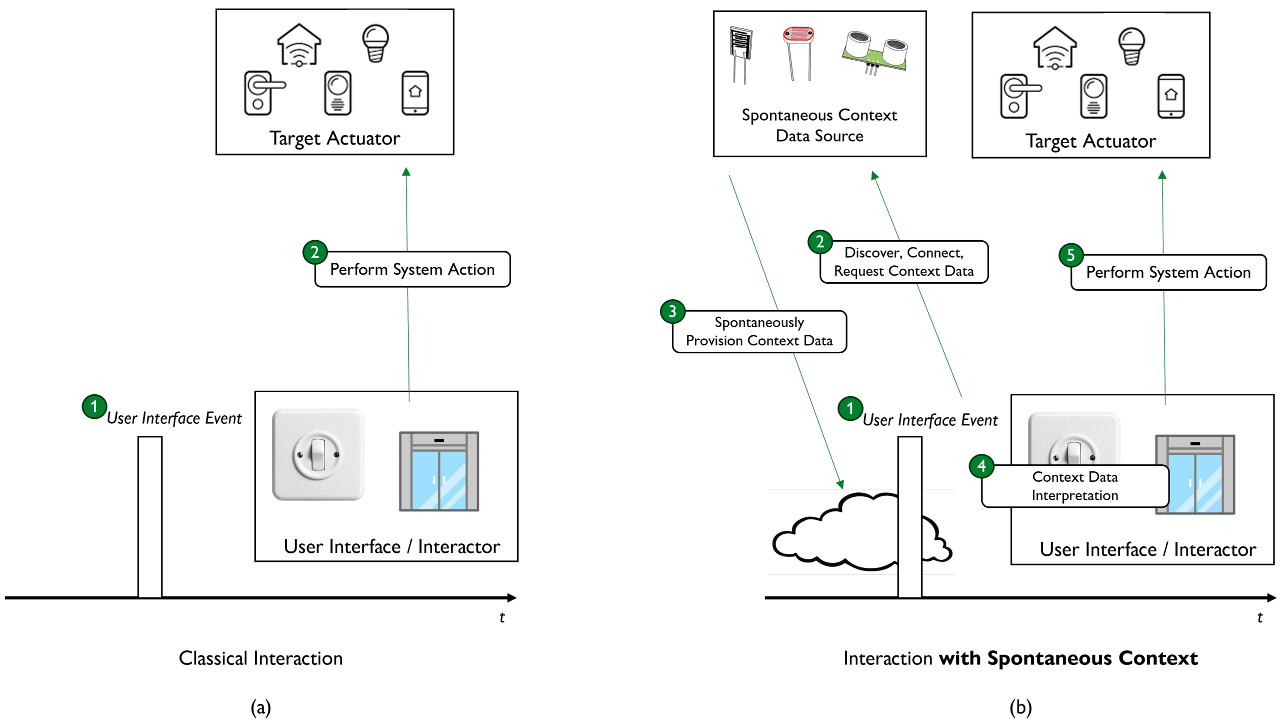


Figure 1: In traditional UIs, the atomic interactor triggers a static, possibly context-modulated system action. In our proposed interaction pattern, the atomic interactor spontaneously gathers and interprets context data before selecting a more appropriate, possibly context-modulated, system action. Symbols from imlab.cn/whale and vectorportal.com.

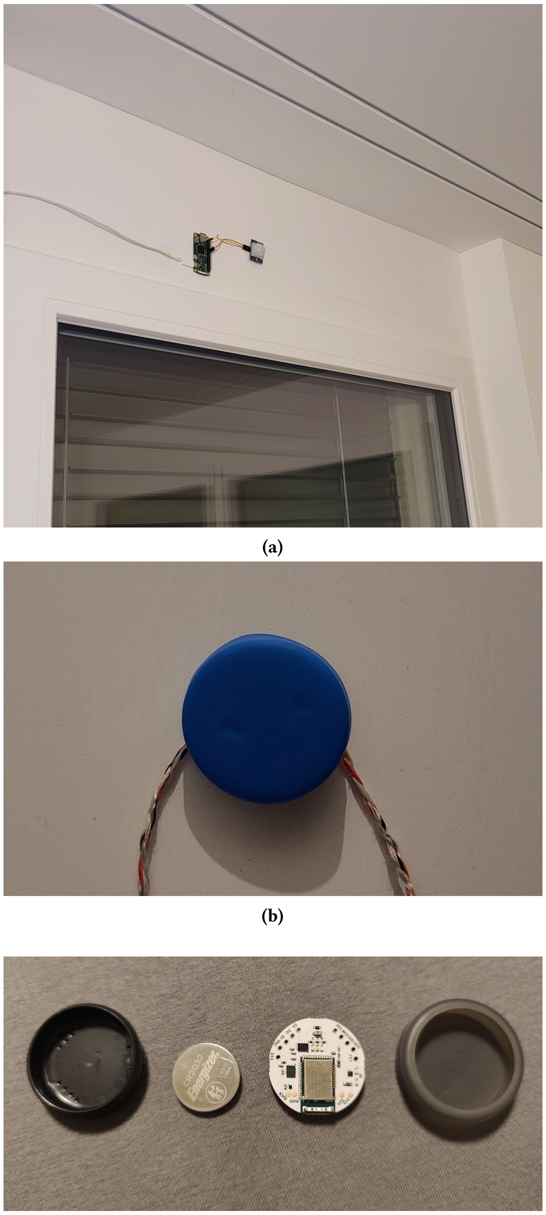
to be synchronized across the atomic interactor and the context data source while keeping coupling to a minimum, we propose the usage of well-known and widespread ontologies such as SSN/SOSA[3] in combination with compatible serializations such as JSON-LD[4]. In this way, the system components are interoperable with respect to the transmitted data while still remaining decoupled; the proposed interaction pattern is furthermore compatible with decentralized data stores, e.g. through Solid[5]—in this case, no context data is transmitted but, rather, the source spontaneously configures the access rights to context data that is stored in its Solid pod to permit the interactor to access and interpret this information. Finally, our concept supports graceful degradation in case there is no context data source or if the spontaneous connection to this data source fails. In this case, the interactable component executes its default, non-contextual, system action.

Viewed from the perspective of the four-sides model introduced above, interaction according to our proposed pattern already starts before the trigger event occurs: the context data source is already collecting data before the user interaction. Upon the UI event, the system spontaneously requests specific context data from the context data source to select the appropriate action. Hence, the *factual* dimension of the communication between the user and the system encompasses the transmitted facts (e.g., that the switch was pressed; that there is walking speed data; that the walking speed is 16 km/h); the *self-revealing*, *relationship*, and *appeal* dimensions—that they are in a hurry; that they are authorized to use the UI element; and that they want to switch on the lights at maximum intensity—are not explicit but can be found by interpreting this data.

[3]See https://www.w3.org/TR/vocab-ssn
[4]See https://json-ld.org/
[5]https://solidproject.org/

4 Illustration and Demonstrator: Plot Doors

As an illustration and demonstration of the "spontaneous context" interaction pattern, we implemented a “plot-driven” door, or “plot door”. In our scenario, user *Alice* is wearing a battery-powered wireless sensor around her neck (this will become the context data source). The sensor continuously collects accelerometer and gyroscope data and stores it locally. Alice approaches the plot door from the side, as if walking along an aisle or along a shopping mall. Just before reaching the door—in expectation of the door opening—she starts turning towards the door. As soon as the door's motion sensor detects Alice, it connects to the context data source, gathers accelerometer and gyroscope data of the five seconds just before the trigger, and uses a random forest classifier to estimate whether the motion pattern indeed indicates a turn towards the door. Based on the classification, the appropriate system action—opening the door or leaving it closed—is determined: the door either opens if the Alice turned towards it, or remains closed otherwise. We implemented this concept in a laboratory demonstrator. The context



(a)

(b)

(c)

Figure 2: (a) Our system's PIR motion sensor triggers the spontaneously adapted user interaction. (b) A Puck.js is attached to a string and worn by the user. (c) A disassembled Puck.js.

data source was implemented using a Puck.js device[6] and the door motion sensor was created by attaching a passive infrared (PIR) motion sensor to a Raspberry Pi Zero W device (see Fig. 2).

While our plot door demonstrator is based only on accelerometer and gyroscope data, the concept is not limited to these (or to any specific kind of information) in principle. Indeed, the plot door may integrate multiple heterogeneous context data sources that it contacts and connects to spontaneously. For instance, it may contact an ambient microphone, where the interpretation software could be extended to not open the door when someone calls Alice's name and asks her to stay (admittedly, this would yield a rather overbearing door). The interpretation hence might integrate various types of inputs, and it might also consider past, current, and (predicted) future development of the observed situation.

[6] https://www.espruino.com/Puck.js

5 Limitations and Future Work

The system we presented in this work is not without limitations. With the plot door, our prototype uses a simple real-world example inspired by Star Trek, and a straightforward random forest machine learning model is used for classification. While the demonstrator serves well to illustrate and demonstrate our fundamental concept and the core aspect of spontaneity, its current accuracy would not permit the public deployment of the system due to misclassifications (and, hence, user annoyance). Upgrades to the classification model as well as the inclusion of further context data sources are likely to overcome this limitation. The interpretation process itself may also be implemented in non-traditional ways such as through combinations of different machine learning approaches, with integrated language models that might add common-sense interpretative aspects to enhance the system's combined reasoning strength. Yet, such modifications are naturally constrained by the computing power of the system's devices and the latency requirements of our concept, to preserve spontaneity.

6 Conclusion

In this paper, we introduced a concept for the ad-hoc action adaptation of situational actions that extends the context-awareness of everyday UIs while keeping coupling between the interactive system and context data sources at a minimum. We illustrated this "spontaneous context" pattern with a demonstrator of a "plot door" that follows our approach to create a spontaneously adapting automatic door sensor, discussed its implementation, and briefly discussed limitations. Drawing on the four-sides model of communication, we propose an alternative view on context-awareness that is inspired by human communication and illustrates the usefulness of considering an interaction between a human and a device beyond the factual information that is transmitted. By additionally considering *how* a human's interaction is performed, our concept enables the ad-hoc adaptation of peer-to-peer interaction between user and systems, without the need for sophisticated, infrastructure-oriented, tightly-coupled context-aware environments. In a world with an increasing number of smart devices offering interaction possibilities, the introduced concept opens the door for the employment of low-cost solutions that allow the adaptation of these interactions spontaneously in a privacy-respecting way.

References

[1] Matthias Baldauf, Schahram Dustdar, and Florian Rosenberg. 2007. A Survey on Context-Aware Systems. *International Journal of Ad Hoc and Ubiquitous Computing* 2, 4 (2007), 263. https://doi.org/10.1504/IJAHUC.2007.014070

[2] Christoph Borchert, Jochen Streicher, Alexander Lochmann, Olaf Spinczyk, Mojtaba Masoudinejad, Markus Buschhoff, Andres Gomez, Lars Suter, and Simon Mayer. 2023. *Data Gathering and Resource Measuring*. De Gruyter, Berlin, Boston, 15–70. https://doi.org/10.1515/9783110785944-002

[3] Luigi Capogrosso, Geri Skenderi, Federico Girella, Franco Fummi, and Marco Cristani. 2023. Toward Smart Doors: A Position Paper. In *Pattern Recognition, Computer Vision, and Image Processing. ICPR 2022 International Workshops and Challenges*, Jean-Jacques Rousseau and Bill Kapralos (Eds.). Springer Nature Switzerland, Cham, 660–673.

[4] Rick Dale, Riccardo Fusaroli, Nicholas D. Duran, and Daniel C. Richardson. 2013. *Chapter Two - The Self-Organization of Human Interaction.* Psychology of Learning and Motivation, Vol. 59. Academic Press. 43–95 pages. https://doi.org/10.1016/B978-0-12-407187-2.00002-2

[5] Anind K. Dey. 2001. Understanding and Using Context. *Personal and Ubiquitous Computing* 5, 1 (Feb. 2001), 4–7. https://doi.org/10.1007/s007790170019

[6] Razan Jaber, Sabrina Zhong, Sanna Kuoppamäki, Aida Hosseini, Iona Gessinger, Duncan P Brumby, Benjamin R. Cowan, and Donald Mcmillan. 2024. Cooking With Agents: Designing Context-aware Voice Interaction. In *Proceedings of the 2024 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI '24)*. Association for Computing Machinery, New York, NY, USA, Article 551, 13 pages. https://doi.org/10.1145/3613904.3642183

[7] Sanjiv Jha, Kimberly Garcia, Yasmine Antille, Marc Solèr, Simon Padua, Nicolò Ghielmini, and Simon Mayer. 2024. Temporal Scene Understanding using Contextually Unique Identification. In *Proceedings of the 36th IEEE International Conference on Tools with Artificial Intelligence (ICTAI)*.

[8] Naveen Kumar and Seul Chan Lee. 2022. Human-machine interface in smart factory: A systematic literature review. *Technological Forecasting and Social Change* 174 (2022), 121284. https://doi.org/10.1016/j.techfore.2021.121284

[9] Jinchao Li, Shuai Wang, Yang Chao, Xunying Liu, and Helen Meng. 2022. Context-Aware Multimodal Fusion for Emotion Recognition. In *Proc. Interspeech 2022*. 2013–2017. https://doi.org/10.21437/Interspeech.2022-10592

[10] Xin Li, Martina Eckert, José-Fernán Martinez, and Gregorio Rubio. 2015. Context Aware Middleware Architectures: Survey and Challenges. *Sensors* 15, 8 (2015), 20570–20607. https://doi.org/10.3390/s150820570

[11] Simon Mayer, Andreas Tschofen, Anind K. Dey, and Friedemann Mattern. 2014. User interfaces for smart things – A generative approach with semantic interaction descriptions. *ACM Trans. Comput.-Hum. Interact.* 21, 2 (Feb. 2014), 25. https://doi.org/10.1145/2584670

[12] Mahdi H. Miraz, Maaruf Ali, and Peter S. Excell. 2021. Adaptive User Interfaces and Universal Usability through Plasticity of User Interface Design. *Computer Science Review* 40 (May 2021), 100363. https://doi.org/10.1016/j.cosrev.2021.100363

[13] Kim Olivia Snooks, Joseph Lindley, Daniel Richards, and Roger Whitham. 2021. Context-Aware Wearables: The Last Thing We Need is a Pandemic of Stray Cats. In *Extended Abstracts of the 2021 CHI Conference on Human Factors in Computing Systems* (Yokohama, Japan) *(CHI EA '21)*. Association for Computing Machinery, New York, NY, USA, Article 25, 9 pages. https://doi.org/10.1145/3411763.3450367

[14] Friedemann Schulz von Thun. 1981. *Miteinander Reden: Störungen Und Klärungen: Psychologie Der Zwischenmenschlichen Kommunikation* (originalausg ed.). Rowohlt, Reinbek bei Hamburg.

[15] Zinovia Stefanidi, George Margetis, Stavroula Ntoa, and George Papagiannakis. 2022. Real-Time Adaptation of Context-Aware Intelligent User Interfaces, for Enhanced Situational Awareness. *IEEE Access* 10 (2022), 23367–23393. https://doi.org/10.1109/ACCESS.2022.3152743

[16] Danai Vachtsevanou, Andrei Ciortea, Simon Mayer, and Jérémy Lemée. 2023. Signifiers as a First-class Abstraction in Hypermedia Multi-Agent Systems. In *Proceedings of the 2023 International Conference on Autonomous Agents and Multiagent Systems*. 1200–1208.

[17] Jialu Yang, Ying Liu, and Phillip L. Morgan. 2024. Human–machine interaction towards Industry 5.0: Human-centric smart manufacturing. *Digital Engineering* 2 (2024), 100013. https://doi.org/10.1016/j.dte.2024.100013