Does Automation Scale? Notes From an HCI Perspective

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Abstract
Computer-based interactive systems increasingly shape all areas of life. Scalability with respect to human computer interaction (HCI) is an umbrella term under which various developments in this regard are discussed (e.g., growing numbers of users, variety of devices). However, scalability relates not only to user interface and interaction design but to automation. Whether and how automation scales or can be scaled regarding HCI has hardly been addressed by previous research. By introducing a one-day user journey focusing on automation experience, we discuss characteristics and research directions for safe and satisfying scaled automation experiences.

Keywords
Scalability, Automation Experience, User Journey

1. Introduction

Computer-based interactive systems increasingly shape all areas of life, and many people's everyday lives [1, 2]. The associated challenges to designing interactive systems and interaction concepts, such as using applications by numerous users or under various environmental conditions, are discussed in human computer interaction (HCI) research under the umbrella term scalability [3, 4]. This discussion is still relatively young compared to scaling debates in other computer science disciplines, e.g., distributed systems or database management [5, 6].

However, scalability does not only mean that users must master different devices and interaction concepts. They will also increasingly come into contact with automation solutions at home, at work, and on the road [7, 8]. Some even argue that "automation comes to dominate interaction" [9].

However, whether and how automation scales or can be scaled regarding HCI has hardly been addressed by previous research. This appears necessary because the interaction between users and single automation solutions is already characterized by numerous challenges (e.g., mode confusion, loss of competence) [10]. How these phenomena develop in connection with the experience of different automation solutions, or to what extent others occur, needs to be explored. It is at least conceivable that the mode confusion problem occurs not only with respect to a specific level within one automation scheme but that users are confused by different automation concepts.

AutomationXP23: Intervening, Teaming, Delegating - Creating Engaging Automation Experiences, April 23rd, Hamburg, Germany
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In the following, we first summarize which scaling aspects have been considered so far in the context of HCI research (see section 2). A fictitious user journey focuses on the automation experience in section 3. Based on this, characteristics and research directions for safe and satisfying scaled automation experiences are discussed in section 4. Conclusions are drawn in section 5.

2. Scaling in HCI Research

As indicated in the introduction, the concept of scaling, which is considered "a key challenge" [9] in general, is used in the context of HCI with respect to different perspectives. Essentially, three of them stand out [9, 4, 11]:

- number, abilities and needs of users of computer-based solutions;
- number, variety and computing power of technical solutions;
- diversity of contexts of use.

The scale of users ranges, on the one hand, from individual users, groups and families to the population of an entire city, etc. (see Figure 1). On the other hand, a wide range of diversities (e.g., age, computer literacy, affinity for technology interaction, mental and physical abilities) must be considered [12, 13].

Figure 1: Scale from single-user to multiple-users

The scale of devices can be viewed from different perspectives: the number of devices from single-device to multiple devices support (e.g., gestural text entry on multiple devices [14], multimodal information access across multiple devices [15]) and the size and complexity of devices as shown in Figure 2.

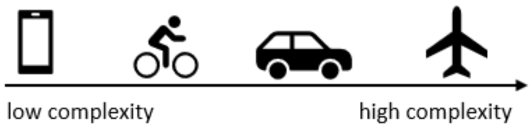

Figure 2: Scale of technologies from low to high complexity

Streitz and Wichert [16] describe the dimension of contexts also as spaces and places "where the interaction happens, where services are provided or being used and their operating range in terms of proximity, being close or distant." The contexts range from private to public spaces such as the bathroom, the office to the smart home, factory, market place, train station, neighbourhood and entire countries [16] (see Figure 3).

Figure 3: Scale of contexts from private spaces to public spaces

In addition, scalability was also associated with visualizations [17], safety-critical human computer interaction [18], design patterns for multi-platform user interfaces [19], moving from smartphone to tablet applications [19], small- and large-scale interactions (finger, body) [20], and scope, duration and realism of evaluation of interactive systems [3].

With respect to scaling and automation, only a few HCI-related works have been identified by the authors, e.g., scalability of formal verification analyses with the aid of task-analytic models [21] or task planning [22]. In addition, automation concepts with different stages/levels [23] can also be understood in terms of scalability. However, as illustrated below, they do not address the individual user perspective of scaling automation experiences.

3. An One-Day Automation Experience Journey

In Figure 4, a fictitious, but in principle indeed not absurd, working day is depicted from the morning routine in one's own smart home to the end of the day on a business trip in a hotel. Note that the adjective "smart" should also represent concepts like pervasive computing environments [24] or industry 4.0/50 [25].

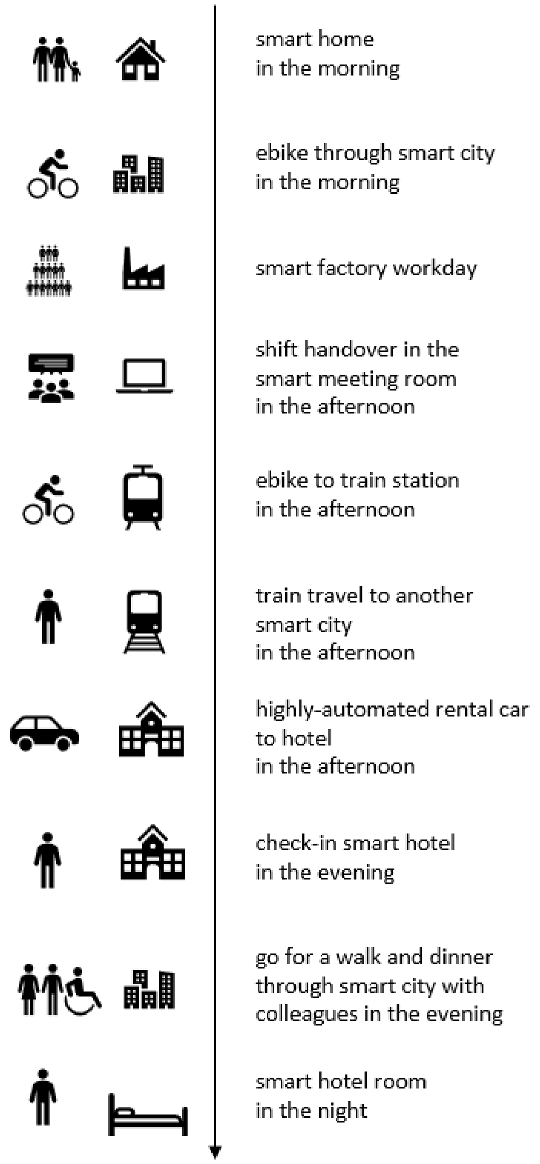

Figure 4: An exemplary one-day automation experience with different scales of users, technologies, and contexts

As can be understood, the user encounters several automation solutions on an ordinary day in various private and public situations. mobile and wearable devices are integrated in the technical infrastructures differently. The user and other family members can monitor and control lighting and heating at home with their private smartphones [26]. On the way to work, navigation system of the ebike receives information about closed bike paths, construction sites and accident blackspots and adjusts the route accordingly [27]. Although direct use of the private smartphone for work purposes is not permitted, the user also receives status messages from his home during this period and can respond remotely if necessary. At work, sensor data of the private smartwatch are used to detect stress situations and locations [28]. While the user is familiar with these automation solutions, there is initial contact with those in the highly-automated rental car and the hotel room equipment later that day [29].

In this context, it can be assumed that the automation solutions at different "stages" of the journey also come from different manufacturers, at least in part. Furthermore, it can be assumed at this point that the organizational and legal framework conditions, which can also impact the respective automation experience (e.g., occupational health and safety, data protection), are adhered to and resolved in the users' interests. These aspects will not be discussed further below.

4. HCI-related Automation Scaling

Subsequently, characteristics and research questions for scaling automation from an HCI perspective are described.

4.1. Characteristics

From the previous "automation experience journey" in private and professional life, characteristic features can be derived that are relevant beyond this specific example.

- Users will encounter several automation concepts in everyday life, which will differ in number and meaning of stages/levels.
- Users' mobile and wearable devices will be integrated differently in the automation solutions, from not at all to data suppliers (e.g., sensor data) to comprehensive interaction components (e.g., remote controls, dashboards). In addition, other stationary and mobile devices will be used on a context-specific basis.
- Users will make automation experiences individually, in teams and in larger groups of people. In the process, it will not always be clear to them which actors are still involved.
- Users will make automation experiences in private and public settings. With regard to technical solutions, the definition of private and public is not bound to physical spatial boundaries or other directly perceptible characteristics.

The previous example does not describe the actual dynamics and diversity of a person's automation experience: Daily routines are different, software and hardware components may be faulty or updated, and user needs and capabilities may vary. These circumstances complicate matters more than they facilitate them. However, the validity of the aforementioned characteristics remains essentially unaffected.

4.2. Research Questions

The awareness that a seamless automation experience does not necessarily have to grow out of the experience of individually matching automation solutions strung together raises questions for further research:

- How can automation concepts be explained in a way that is appropriate to the user and the situation, assuming that users experience multiple forms of automation?
- How can existing automation concepts be systematically transferred to new contexts, thus avoiding unnecessary new developments?
- How can different automation concepts be compared with respect to different socio-technical settings, e.g., private home environment, public workspace?
- How can best practices and lessons learned regarding scaling automation with respect to users, devices, and contexts be documented and shared?
- What could be learned from scalability-related research in others fields of research and practice, e.g., software engineering or database systems?

Parts of these questions have already been addressed in previous research, be it on the question of automation in collaborative teamwork (scaling the number of users) [30] or application of existing automation concepts in domains different from the one that the concept evolved from (scaling contexts of use) [31]. Design patterns and pattern languages have been developed with respect to scalability in general [32] and human-computer interaction in particular [33]. For scalable human-centered automation, such an approach is missing so far. The following scaling issue has not been addressed: There is always more than one automation for users in their life.

5. Conclusion

Questions about the scalability of automation approaches have been discussed primarily concerning technical aspects, e.g., resource requirements, and with respect to number of users, variety of devices, and different contexts of use. As can be seen here based on an exemplary user journey, challenges related to individual and scaled automation experiences will also have to be mastered to an increasing extent in the future. They concern the safe switching between different automation concepts, the use of mobile and wearable devices in different automation contexts, and the use of automation solutions with varying numbers of co-users.

Therefore, an answer to the question posed at the beginning, "Does automation scale?" can be as follows. First, it must, since users increasingly have to deal with different automation solutions. Second, if research and development is carried out with this awareness and on the research questions mentioned, it can.

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