MeUI - Machine Learning Enhanced Adaptive User Interaction

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***Abstract*—This position/vision paper describes the idea of a novel approach/research agenda of interacting with mobile devices. Usually, users have to learn how to interact with a mobile device adhering to rules that need to be learned. We intend to challenge and question this approach – we rather want the device to adapt to the needs and the behavior of the user. Thus, the idea is to use machine learning and artificial intelligence technologies to reverse the core principal of device utilization by providing a distinct, personalized and dynamically self-adaptive foundation towards modern human computer interaction. This position paper summarizes the core idea, provides an overview of related work and identifies and discusses research challenges.**

***Index Terms*—Mobile device interaction; human computer interaction; machine learning, adaptive user interfaces**

I. INTRODUCTION

Machine-Learning (ML) [1] and more generally Artificial Intelligence (AI) [2] are ever more present in different disciplines and industries. Disruptive innovations [3] change established technologies and markets, whereas - very often - ML and AI play a vital role in this phenomenon. Examples for such disruptive innovations are *Uber* [4], *Spotify* [5] or *Netflix* [6]. All of them build upon a strong fundament of massive data that is being processed with different AI/ML approaches in order to maximize the user experience and comfort. This allows for the advent of new technological innovations opening new markets and business models.

The core idea of this position paper entitled *MeUI – Machine-Learning Enhanced Adaptive User Interaction* intends to challenge the classic approach of interacting with mobile devices [7], [8]. Usually, users have to determine how to interact with a device adhering to rules that need to be learned. Following the trend of maximizing user experience and user comfort by radical new technological approaches, the idea is to use ML/AI technologies to reverse the core principal of device utilization by providing a distinct, personalized and dynamically self-adaptive foundation towards modern human computer interaction [9]–[11].

The rest of the paper further discusses this idea and provides an overview of conceivable use-cases that would allow for reversing this traditional approach of interacting with mobile devices. Furthermore, research challenges are defined consisting of hypotheses and questions that build the base for this novel approach. Since this is meant to be a position/vision paper, the authors strongly believe that this is a novel approach and has potential to radically transform the field of research of mobile device interaction by reversing the classic one-size-fits all approach to a personalized experience and that the discussed interaction aspect could build a fundamental new scientific field in the broader area of human machine/mobile interaction.

The rest of the paper is structured as follows. Section II discusses relevant use-cases, section III identifies the core research challenges and formulates research questions. In section IV potential methodological approaches are discussed and section V closes the paper with a conclusion and outlook.

II. SPECIFIC CONCEIVABLE USE-CASES

Although interface design and user experience are both important and long-standing branches [12]–[14] within product design on a broad scale, the elemental concept of such interfaces remains to reflect a learning task for the users with varying learning curves. Individual needs and requirements, such as disabilities or impairments [15], but also custom usage habits are hardly taken into account. Moreover, situational factors like body posture during certain activities, general body physique, location and more generally the context of the users [16] and the form factor of different devices may dramatically alter the requirements towards design, composition and organization of user interfaces.

With those non-ideal conditional factors in mind, modern machine-learning methodologies can help to acquire an understanding of how a user actually uses a device, including the detection and adaption to erratic behaviour and the repeated inversion of particular tasks or steps (e.g., repeatedly typing a particular character, while immediately afterwards deleting it again in order to type the correct one). Furthermore, the general adaptation of the keyboard on different mobile devices for specific users constitute the first relevant use-case: **UC1: Self-Learning Keyboard Adaptation**. The keyboard for textual input is adapted to the specific needs of the users - whereas this adaptation could range from simply highlighting specific characters (e.g., by resizing or colouring) to a different keyboard layout optimized for the user's habits.

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Among other use-cases, certain interface elements, such as buttons and sliders may not be placed and scaled in the optimal and most efficient way possible for the behavioural characteristics of the utilizing person. For example, certain clickable elements may be out of reach for single-handed use, or sliders may be placed along the entire width of the available screen-space which may result in particular areas not being reachable in a comfortable way. On the other hand, slider elements which provide a horizontal scale being too narrow can undermine the precision required in order to set desired values. Interface configuration parameters like scrolling speed and, if supported by the respective device, touch sensitivity resemble adjustable values whose configuration may also be subject to being configured autonomously after a machine-learning algorithm has learned how the user likes to handle a device. This recomposition of interface components according to a specific user is the second relevant use-case: **UC2: Adaptive Interface Component Recomposition**.

Another specific use case worth mentioning tackles the ordering and grouping of applications on mobile devices. Recent studies show that users in Germany usually have around 90 apps installed on their smart phones but use only around 30 of them [17]. Furthermore, specific apps are only used on dedicated occasions (e.g., when travelling) - thus, besides other personal data, the context of the user could be an important factor regarding preferences for specific applications. If an intelligent component built from AI/ML technologies would manage to order and group applications autonomously according to the user's behaviour and context, user experience could increase dramatically. This aspect constitutes the third specific use-case: **UC3: Personalized and Context-Aware App Arrangement**.

Generally, the traditional one-size-fits-all approach of the past decades which aims to treat all users the same regardless of their needs has shown to coerce users to adapt their behaviour according to device expectations, while we believe that machine learning and AI approaches may in fact reverse this procedure and allow devices to adapt to their users.

Summarized, within the idea we intend to focus on the following specific use-cases that have been described above (whereas of course further relevant use-cases are imaginable and thus are not excluded from being investigated):

- **UC1:** Self-Learning Keyboard Adaptation
- **UC2:** Adaptive Interface Component Recomposition
- **UC3:** Personalized and Context-Aware App Arrangement

III. Research Challenges

Generally, the following hypothesis and research questions build the foundation for the approach of reversing the traditional way of interacting with mobile devices, whereas the three use-cases described above build the core baseline for these challenges:

- **Hypothesis**: ML/AI technologies allow for a significant change in the (mobile) device interaction in terms of usability. The classic approach of one-size-fits-all approach can be reversed towards a personalized experienced and a self-learning adaptation of interaction increasing the user experience.
- **RQ I**: which ML/AI technologies are suited for enhancing mobile device interaction?
- **RQ II**: to what extent can the user experience be improved focusing on the three described use-cases?
- **RQ III**: which differences concerning different mobile devices (e.g., smart phones and tablets) are relevant when improving the customer interaction with ML/AI technologies?
- **RQ IV**: which data and contextual information of the user is relevant for improving the customer interaction based on a self-learning ML/AI approach?

More and more people tend to use their mobile phone on a daily basis, which transforms the device into a constant companion [18]. With the advent of global interconnected mobile-devices, which offer significant computational power, applications running on mobile phones could gather huge information about the user. Thus, we believe that it is possible to turn the device into a self-adaptable, user-specific device that is constantly adapting to the user's needs and also the user's context [19] in order to maximize the customer experience and device-interaction. To the best of our knowledge this is a novel approach and has potential to radically transform the field of research of mobile device interaction by reversing the classic one-size-fits all approach to a personalized experience. We believe that the combination of ML/AI technologies with the discipline of human-computer interaction opens a new research field and has potential to (i) raise new research questions, (ii) to radically change the paradigm of interacting with mobile devices, and (iii) to build the foundation for a new era of technological inventions. The following paragraph summarizes the transformative potential of the idea.

A. *Transformative potential*

Long-established research concerning user interfaces and experiences primarily focused on the static and global layout structure as well as element selection, placement and feedback characteristics in order to create efficiently utilizable UIs, without taking the individual user needs into account. Longing for major progress within this field of research may consequently create an entire new niche of research questions and applications relevant to UX researchers as well as software development and manufacturing companies on a global scale. The currently predominant understanding of having to learn and adapt to predefined interfaces rather than smart devices getting used to how users actually employ, avail and devote to interfaces not only needs to be questioned but may also see a paradigm-shifting amendment in terms of how the interaction between humans and computers can be shifted towards a cooperative, device-reactive accommodation in the near future.

As an example, whereas some major manufacturers of smart mobile devices have gone through a development during the last decade, where they started to present their users a personalized user experience in terms of what information will be displayed when certain actions are performed. These advancements, however, merely represent a contentual and data-driven personalization rather than changing the elemental opportunities of device usage to the user's benefits and needs. A novel modal approach, restructuring and renewing the prototypical concept of the actual interfaces by allowing them to change and adapt dynamically allows us to move post the archetypical one-size-fits-all approaches regarding human-computer interaction in general, and user interfaces in particular by making software learn from and adapt to needs, adjust to and correct input errors and provide a meaningful and assisting individualization for every user. Using ML/AI technologies, the device has to gain knowledge of how it is used, rather than to dictate it.

IV. Research Methodology

In order to investigate the hypothesis as well as the intended research questions as stated in the previous section, the following methodological approach seem to be applicable. First and foremost, relevant mobile devices of different kinds and manufacturers (e.g., smart phones, tablets) have to be identified and their suitability for the different use-cases needs to be secured. For example, it needs to be clarified, if the keyboard layout can be easily changed - in case this is not necessary, a self-implemented keyboard mockup for evaluation can be developed. In detail, the most prevalent devices seem to be relevant, like (i) Apples iPhone, (ii) Android phones (e.g., Google Pixel 3, Samsung Galaxy S10), (iii) Apples iPad, (iv) Samsung Galaxy Tab.

Fundamental implementations on the intended different devices need to be done in order to enable the planned use-cases. Furthermore, ML/AI technologies need to be researched for investigating the suitability of the intended use-cases. In detail, *classical* approaches (e.g., Support Vector Machines (SVM), Naive Bayes, k-Nearest Neighbors (KNN) and Random Forest) [20] will be considered, as well as neural networks, deep learning [21] and long-short-term memory [22]. This is closely related to the identification of relevant user- and contextual-data that is of high value for the intended approach. Prototypical implementations of the use cases will be subject for user-studies and evaluations. The following Figure 1 illustrates the targeted steps for the research approach.

Summarized, the following methodological fragments need to be considered and constitute the base for the proposed research plan:

(i) Mobile device eligibility evaluation
(ii) User data identification and ML/AI technological qualification
(iii) Prototypical realization of the three identified use-cases
(iv) Conducting experiments and user-studies
(v) Evaluation of hypothesis and research questions
(vi) Identification of future potential and use cases

As it can be seen in 1 we intend to identify future potentials and also novel UX research paradigms by following the idea of reversing the traditional approach of mobile user interaction.

A. Risks and Challenges

The landscape of modern smartphone operating systems is rather limited, with only two major systems running on 98% of all such devices. As such, the applicability of dynamically adaptive interfaces may not be able to function on its full extent due to the fact of backend services and frameworks limiting the degree of freedom towards running applications (*apps*) when changing essential elements like GUI widgets at runtime. In such cases, the desired adaptability has to be either integrated through a transparent virtualized UI emulation layer, or by using technological capabilities beyond regular apps in order to acquire the desired results.

One such possibility would be to chose web-applications, whose UI elements consist largely of locally rendered HTML output which can elegantly be manipulated at runtime, even when the user is currently using the application – so-called *Progressive Web Apps*. While showing several major advantages compared to regular apps, progressive web-apps do not provide the capabilities of mobile operating systems in its entirety, by, e.g., not being allowed to access various hardware elements like I/O devices and sensors.

Another risk regarding technological feasibility is the possibility to manipulate tightly integrated and security-relevant core components like software keyboards. These are, at least in the case of Apple's iOS, not easily interchange- or manipulatable. Such limitations could be bypassed easily by creating dedicated applications for testing and evaluation purposes only, while not directly conveniently and efficiently suitable to be used by either third party applications, or any other native applications at all. Despite the fact that this may represent a potential outcome, the subsequent learning potential regarding the insights gained during research would unequivocally be of intrinsic significance, like described below.

B. Learning potential in case of failure

Failures within this research approach can be twofold, either technically or regarding the conceptual methodology of our main hypothesis.

If the technical evaluation proves that our approach provides benefit to users, but is not applicable to the current technical opportunities and status of mobile operating systems, having gained the expected knowledge advancements about ML-enhanced interfaces will hopefully start a discussion about how programmers and manufacturers can remove these limitations and barriers in order to allow more individualized device handling. If the prototypes manage to effectively show a major benefit towards user experience, a measurable decrease of erratic usage and an increased degree of contentment among device users, leading to a heightened awareness within both, the research community as well as commercial providers of frameworks and operating systems, the latter are expected to realize and appreciate the potential augmentation of market value and customer satisfaction and eventually begin to include the technical foundations needed to proceed.

If, however, our principal hypothesis along with the research questions proves to be incorrect, we gain insight into the

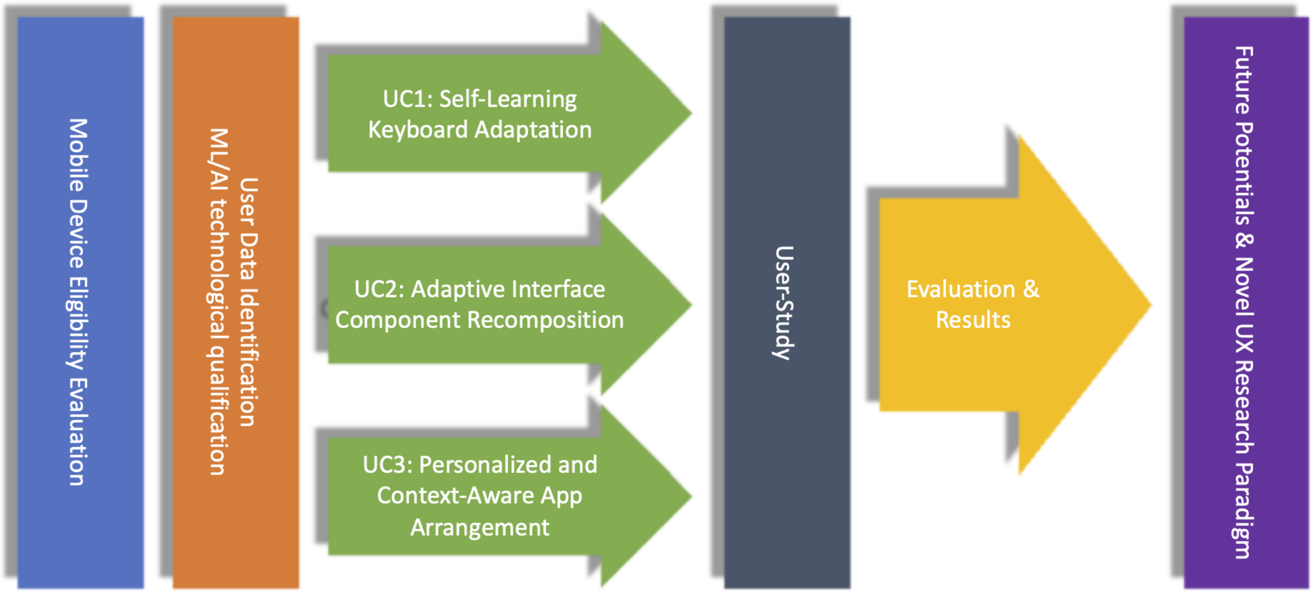

Fig. 1. The methodological aspects constituting the research agenda.

particular reasons thereof using the data and evaluation results generated during the pathway of our research and can hence help to steer further community efforts into different directions which may nevertheless incorporate various findings.

V. Conclusion

In our position/vision paper we presented the idea of reversing the classic approach of mobile user interaction. Instead having users to learn interaction and thus adapt to the mobile device, we envision systems that instead adapt to the user in an intelligent way, allowing to interact in the most possible intuitive way. Mobile device technology nowadays is able to deliver a variety of relevant user and context data - with machine learning and artificial intelligence mechanism it is our believe that smart devices can become really "smart" by adapting to the user. This aspect is perfectly summarized in our postulated hypothesis:

ML/AI technologies allow for a significant change in the (mobile) device interaction in terms of usability. The classic approach of one-size-fits-all approach can be reversed towards a personalized experienced and a self-learning adaptation of interaction increasing the user experience.

We have presented a research agenda constructed around identified use-cases. We intend to investigate our hypothesis in order to identify future potentials and also to put novel UX research paradigms on the table.

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