Ambient Reflection: Towards self-explaining devices

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ABSTRACT
In the course of ubiquitous and pervasive computing a variety of smart devices are developed and entering our everyday life. These devices increasingly rely on novel interaction modalities from the field of Natural Interaction, such as gesture control. Common concepts to explain and illustrate devices' interaction possibilities can't be applied to these interaction techniques due to embedding of devices and as a consequence disappearing interfaces as well as distribution of functionalities among device ensembles in terms of IoT, AAL and Smart Home. These emerging and currently existing problems in accessing devices' interaction possibilities present users with new challenges. In addition, current possibilities for device documentation provide only a limited viable option to learn devices. Hence, a general documentation for interconnected devices and thus functionality can not be created manually. In order to counteract these problems we present an approach for in-situ generation of an ambient manual for interconnected smart devices.

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Ambient Computing; Human Computer Interaction
Guidance

ACM Classification Keywords
H.5.2. User Interfaces: Training, help, and documentation

INTRODUCTION
As a result of the ongoing research and development in the areas of ubiquitous and pervasive computing the variety of heterogenous commercial devices with rich functionalities and novel interaction techniques arise. Particularly with regard to the fields of Ambient Assisted Living (AAL), Internet of Things (IoT) and Smart Home, users are increasingly faced with natural interaction. While bulk of HCI research strives to create interaction techniques that are easy to learn, natural, self-explaining, and novel, documentation of interaction techniques is generally an underestimated and ignored issue or simply considered luxury and unnecessary. Considering the progressive complexity in ambient scenarios containing heterogenous devices and interaction techniques, this results into an increasing gap between the users' ability to learn and remember these techniques and the provided functionality.

Currently, documentation of smart devices' interaction techniques in ambient space scenarios is usually spatial distributed and highly eco-centric, if accessible at all. Concerning the ongoing interconnection of devices and interaction behavior in terms of IoT, such documentation can't be realized manually. In total, the variety of current Smart Objects challenge users in accessing and operating. It is reasonably assumed, that these interaction challenges will increase significantly caused by complexity and unpredictable interconnections in ambient spaces.

SMART AMBIENT SPACES
Ambient spaces are manifested by an expanding world of interconnected Smart Objects full of rich interaction capabilities driven by ubiquitous and pervasive technologies. Research and industrial development in this area have resulted into vast increase in the number of smart commodity devices and objects (thereafter, called Smart Objects) seamlessly interweaving in a wide range of inhabited environments (e.g., households). A recent study conducted by BITKOM (Federal Association for Information Technology, Telecommunications and New Media) revealed that every household in Germany owns at least 50 electrical devices with an increasing tendency towards more devices [4] and half of all household devices are expected to be connected as part of a network by 2018 as reported by RWE Effizienz GmbH [25].

While users are currently familiar with handling normal physical objects and with interacting with simple and often limited number of electrical devices [25], the variety and diversity of functions and handlings of Smart Objects pose new challenges, especially to enable and familiarize users with interaction possibilities in ambient spaces [5, 28].

The increasing number of devices as well as the increasing diversity of offered functions imposes serious learning issues for the user according to Poppe et al. [20]. In one of his articles, Norman argued that this may easily lead to long-term usability obstacles and inflate problematic and irrational use of devices [16]. For instance, in case of a time change, different clocks in households offer inconsistent ways and interaction modalities for modifying the time. Hence, even this simple operation normally challenges the user [11]. Such challenges easily evolve with more emphasis on the required implicit knowledge of users and the lack of adequate documentation [30]. Sometimes devices can't even be controlled without the use of additional material [27].

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The interaction challenges and difficulties with current and future smart devices and artifacts were also the subject of Norman's book, titled Living with Complexity [17]. In this book, Norman drew a clear distinction between *complexity* and *complication*. While complexity refers to the form of presentation of possible interaction states and transitions, complication donates the psychological state of a person who tries to learn an interaction with an object. Hence, complex objects and artifacts are not necessarily complicated to interact with. Complication barriers can appear due to different reasons including changing the environment and simultaneously changing artifacts. We believe that ambient spaces may result into various complication barriers due to three inherited characteristics reported by Pruvost et al. [23], namely, the heterogeneity and distributivity (containing a variety of devices with various capabilities); dynamic media mobility (interaction capabilities are highly dynamic as interaction devices may join and leave the ambient space at any time), and user mobility (challenging users to attend to interaction needs). This leads, very commonly, to missing the natural mapping of offered functionality and adequate interaction modalities [15, p. 12], as well as to hindering the user from building the correct mental model of the system.

OPPORTUNITIES AND CHALLENGES OF NATURAL USER INTERFACES

Recent advancements in HCI research have revealed new and novel interaction techniques to operate and control devices in ambient spaces by using Natural User Interfaces (NUIs) as in multi-touch gestures, motion-gestures, gaze-interactions, etc. [8]. In literature, different definitions of interactions with NUIs were elaborated and most of them refer to the user's natural abilities, practices, and activities to control interactive systems. Many of those interactions are mostly caused and characterized by motion and movement activities, ranging from pointing, clicking, grasping, walking, balancing, dancing, etc. as discussed in [1].

In the last 10 years, NUIs, using touch and motion enabled technologies, found their way commercially and became widely accessible to the end user. Moreover, users are becoming more acquainted with using different body parts to interact with applications such as gaming (e.g., motion-controlled active play by Microsoft Kinect or the Wii system), data browsing, navigation scenarios (e.g., tilting for scrolling photos as in iOS and Android devices), and many more. This has encouraged the HCI community to continuously expand towards the NUI paradigm and currently various new calls have been arisen to explore new potential in designing for the whole body in motion [7, 9]. Despite the efforts towards intuitive and simple interfaces, the NUI paradigm is challenged by an expanding user population and diversity with respect to age and physical abilities, as discussed in [1]. On the one hand, the naturalness of NUI does not imply the simplicity to recall and use interaction techniques [18]. On the other hand, utilizing the human body and its parts for interaction comes with its own set of complexities. Simple commands, like "raise your arm", may have very different interpretations. Different aspects are important to consider for correctly executing such a simple command, for instance movement direction, involved body parts, timing information, etc.

GUIDANCE IN AMBIENT SPACES

In order to correctly use simple or complex technologies, the availability and accessibility of relevant information are essential for the user. Therefore, Norman [14] coined the term *affordances* in respect of objects' self-revealing interaction possibilities to easily enable users interacting with them. The same applies for the interaction in ambient spaces, however the current concept of affordances does not apply to the ongoing embedding of devices and accordingly their interaction possibilities [26, 22]. The dynamic nature of ambient spaces imposes different learning and affordance challenges on users. In this regard, relaying solely on visual appearance and affordances of a smart object to explain its logic and function are not enough [26]. Hence, adequate documentation and presentation of interaction possibilities and the utility of an object are essential part for learning ambient spaces, which aim at correct usage of devices and optimized user mental models.

In ambient spaces, documentation is not only vital for the use of objects but also for the design process itself and for a successful share and exchange of components and knowledge. Although different device manufacturers pay attention to the consistency of interaction patterns and product descriptions, there are currently no consistent and unified standards for describing smart objects and their offered interaction possibilities in ambient spaces. Based on this, users have to repeatedly remember how to interact with such devices [24]. This recurring state of knowledge between beginner and expert in interacting with a device is called perpetual intermediate [6, p. 42].

Our previous work on reviewing existing documentation-related tools for NUIs revealed four general observations or shortcomings, namely the lack of widely adopted tools by NUI designers, the absence of dedicated NUI documentation tools, the lack of end-user support, and the lack of support and considerations of body movements and postures as part of the interaction descriptions (if at all found). Furthermore, the review revealed that there is a lack of formalized languages and notations of generic motion documentation [1, 3]. For the previously mentioned reasons and potentially more, people turn to rely on other learning approaches and methods. Trial-and-Error is a very common practice to unveil adequate system interactions used by users. However, it is not necessarily the most effective approach in many cases. This was the subject of many research studies in the area of safety and critical environments. A study has revealed that 70% of surgeons and 50% of nurses demonstrated problems dealing with medical devices in operating theaters [12], where 40% of the respondents indicated that the ignorance of adequate operation guidelines of medical devices have resulted into repeatedly occurring hazards. In a previous study [1], the majority of reported respondents of a questionnaire (more than 90%) rely on try and error to learn interactive techniques of personal interactive devices (e.g., smart phones, interactive TVs, handhelds, and game consoles). This can be due to the limited range and simplicity of interaction features currently available in the users' commodity devices (e.g., swipe, shake, and pan). Nonetheless, there is a strong evidence that learning and memorizing interaction techniques will become more complex due to the vast growth of multi-touch- and motion-based interactions in terms of, but not limited to, the number of interactions proposed, the increasing complexity of interaction techniques, expanding diversity of interaction types, involved body parts, involved actions, and runtime ensembles of interaction techniques [7, 9, 13, 2]. This clearly advocates the need for reference documentation of interaction techniques as a necessity and an aid tool for users [19]. In fact, interactivity in ambient spaces is becoming even increasingly dynamic (interaction environments are becoming increasingly heterogeneous and dynamic and no longer static and closed [23]), adaptive (required for sustainable utility and usability), and multi-modal. Hence, interactive ambient spaces are created in an ad-hoc manner, where multiple interaction techniques grouped together to adapt the available interaction resources and possibilities to the user's physical context and abilities. This shift towards an evolving world of interactivity (smart spaces, user mobility, anthropomorphic abilities and disabilities, preferences, etc.) requires new dissemination, deployment, and adaptation mechanisms for NUI. For these reasons, documentation for training, demonstration, and reference purposes plays a major role to set the limits and boundaries for NUI deployment and adoption in interactive ambient spaces.

A FRAMEWORK FOR AMBIENT REFLECTION

In order to offer a possibility to compensate the previously mentioned emerging problems in interaction and documentation, we strive for developing a three-divided framework for Ambient Reflection as an integral component of reflective systems self-x properties [21, p. 322 et seq.]. By providing this framework as a feasible solution, we foster the multimodal self-description of (interconnected) devices regarding interaction possibilities. In total, our envisioned framework consists of three building blocks, namely an *Ambient Reflective Documentation Language*, *Documentation Fusion* and *Presentation Oriented Publishing*. In the following paragraphs, these components are described in detail.

Ambient Reflective Documentation Language

Current possibilities for technical documentation are limited to unstandardized media entities, i.e., each device is described in different modalities using different types of media in various formats. Hence, caused by this diversity an automated processing is not possible. In order to achieve this property a unified extensible documentation language for ambient spaces should be provided, covering a structured description about devices specification and interaction possibilities on a high granularity (further referred as micro-level). Moreover, a documentations content should be decoupled from its presentation in order to achieve more flexibility for further processing, which already has successfully been done (e.g. by [29]). This approach of presentation-neutral describing of Smart Objects may guarantee distributivity, extensibility and further presentation oriented processing.

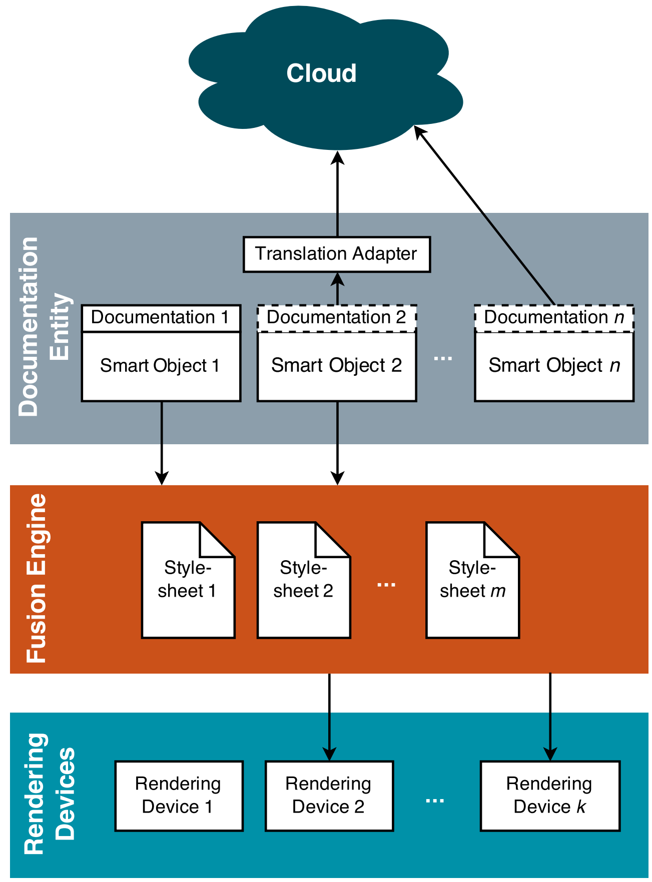

Figure 1. Ambient Reflection Framework

Documentation Fusion

Given the assumption, that relevant devices in an ambient space scenario were described by an ambient reflective documentation, the documentation fusion will take place. In the following, a device with access to its remote located or attached documentation is called documentation entity. Including the current context and environmental state, the fusion step performs in-situ processing and merging of distributed documentation entities. As result it generates a presentation-neutral adaptive ambient space manual for interconnected ensembles of Smart Objects in ubiquitous and pervasive environments, considering just involved devices and interaction possibilities.

Distributing the generated material to a dedicated coordinating engine will enable a guidance system to offer further instructions regarding interaction of device ensembles at the time the user needs or asks for support. Nonetheless, the fusion step might be skipped to provide even single device interaction guidance as well.

Presentation Oriented Publishing

Using concepts of presentation oriented publishing for markup languages [10] adds an additional abstraction layer between the generated manual and the final presentation of instructions to the user. The formerly mentioned decoupling properties of presentation-neutral documentation facilitates the documentation language translation into other renderable languages. Furthermore, the inclusion of a standardized style description to the translated language concerning presentational aspects will offer a possible solution for adaptivity in presentation. Finally, the fused documentation should be deployed to appropriate rendering devices. E.g. a fused documentation might be translated into the Scalable Vector Graphics format using different color sets for color-blind users and visualized by an internet browser's rendering engine.

EXEMPLARY SCENARIO

In order to further illustrate the frameworks' working-process the following scenario is assumed (see figure 1): A user resides in an environment containing of *n* Smart Objects. Since a device ensemble, consisting of Smart Object 1 and 2, was built, the user needs guidance in usage. Object 1 is already described by using the Ambient Reflective Documentation Language, where Object 2 still needs to be described. Therefore, an adapter is used to translate existing documentation, written by the manufacturer, into the documentation language. It is likewise conceivable, that an ambient reflective documentation is remote located, whereas the device just provides the destination (as done by Smart Object *n*). The Fusion Engine fetches and merges the documentation of the involved Objects as well as applying a stylesheet based on the users preferences. Finally, the generated manual is deployed to rendering devices 2 and *k* and by association delivered to the user. It should be noted, that a rendering device might be equal to a Smart Object in the environment and thus might also be documented. Hence, a set of documented rendering devices might form a device ensemble with other Smart Objects and thus are by definition documentation entities.

CONCLUSION

Considering the current development in the areas of IoT, AAL and Smart Home face users with new challenges in terms of Human Computer Interaction. Devices' and their functionality are progressively interconnected, embedded and new interaction techniques within the scope of Natural Interaction arise. As a result of the ongoing disappearing of user interfaces as well as the emerging usage of gesture control, the current concept of affordances may not apply to current developments. Existing difficulties in HCI will increase in the areas of ubiquitous and pervasive computing, caused by the environments high complexity, heterogeneity and dynamic. Beyond this, present technical documentation does not follow a common pattern or is adapted to the user's needs. As a possible solution to tackle these problems, we presented the approach of a conceptual ambient reflection framework, consisting of three major components: An Ambient Reflection Documentation Language for describing interaction possibilities of Smart Objects on a micro-level, documentation fusion using the description language to merge documentation entities of interconnected devices for generating an ambient manual tailored to the users' context and needs as well as the presentation oriented publishing for multi-modal rendering the manual in-situ. In total, we strongly believe to counteract emerging interaction problems in ambient space scenarios by further investigating this framework.

FUTURE WORK

Next, we take to carry out a study to identify different contexts and therefore needs of users with respect of documentation and guidance in interaction. Including these findings and further research regarding description languages, we will develop a unified Ambient Reflective Description Language for Smart Objects and apply it to a representative set of Smart devices, composed of different device categories. In addition, we try to determine a set of generic rules and processes in order to achieve a consistent manual generated by the fusion engine. Upon this, the development of interweaving style description and documentation and the delivery to rendering devices should enable Smart Objects to describe themselves. Finally, we plan to evaluate our framework by carrying out a scenario-based evaluation to determine the precision of the fusion itself as well as the usefulness of our provided guidance for the user.

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