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DESIGN RESEARCH IN THE DIGITAL ERA

Opportunities and implications Notes on Doctoral Research in Design 2020

edited by Lucia Rampino and Ilaria Mariani



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Human-centered Design Practice

Designing for Ambient UX: Design Framework for Managing User Experience within Cyber-Physical Systems

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Abstract

The research aims to contribute towards the field of User Interaction and Experience Design by proposing a design strategy and toolset to be applied within emerging projects for spaces enhanced by digitized services, based on an Ambient UX design approach. This particular design field deals with highly complex projects focused on user experience, which does not seem to be addressed appropriately with current tools employed in practices. Therefore, the research identified the need to expand current practices in the UX field by supporting them with the set of upgraded tools to be used as a backbone for structured design processes. In this context, design tools facilitate the creation of a common language between all parties and stakeholders involved in the design project for identifying and communicating user values.

The main overview of the tailored research methodology will be provided in this chapter, along with the main results derived from the research presented and discussed. The methodology comprises three main research areas: (1) hypothesis for a design strategy for Ambient UX, deriving from literature review; (2) verification of the Ambient UX framework hypothesis through practical design projects; and (3) analysis of UX value alignment tools and proposal for their upgrade.

Introduction

This doctoral thesis is developed in collaboration with TIM S.p.A., Services Innovation Department, through Joint Open Lab Digital Life in Milan. The telecommunications company is looking into designing meaningful services supported by the new stream for the 5G network that will be guiding the company's business application fields in the current and following years (Notiziario Tecnico TIM, 2017, 2018). The network promises to have significant higher speed and reliability, thus easily enabling the employment of complex connected services, which rely on the diversity of sensor and actuator systems implemented within the physical space (Li *et al.*, 2014; Gupta and Jha, 2015). This comprehension of an emerging application field helped to shape the main research field of the doctoral thesis. The research aims at responding to observed emerging needs of novel design systems, which are becoming ever more complex in terms of connected elements supported by AI algorithms.

From the stream for development of meaningful application areas for connected spaces and the Internet of Things (IoT) systems (Atzori, Iera and Morabito, 2010; Gubbi et al, 2013), the research refers to a vision of Ambient Intelligence (AmI) (Aarts and Marzano, 2003; Augusto and McCullagh, 2007; Mukherjee, Aarts and Doyle, 2009; Carneiro and Novais, 2014) and Cyber-Physical Systems (CPS) (Rajkumar et al. 2010; Yang 2014; Bier et al., 2018). This vision and the application area find their connections within diverse fields that finally merge towards the same practices. The fields are Artificial Intelligence (AI) (Ferber and Weiss, 1999; Russell and Norvig, 2016; Gams et al., 2019), Pervasive and Ubiquitous Computing (Lyytinen and Yoo, 2002; Chen et al., 2004), and Interactive Architecture (Fox, 2016; Dalton et al., 2016). CPSes imply interactive spatial systems where human activities are enhanced by digitized services. The study addresses this application field with an approach of designing for user/customer experiences (UX) (Hassenzahl and Tractinsky, 2006; Meyer and Schwager, 2007; Hassenzahl, 2008), as such an approach looks into sustainability and durability of design systems in terms of user engagement over time. Furthermore, as the application field represents a convergence, the design approach is observed through convergences as well, positioning itself on the merge between Service and Interaction Design, and AI and Spatial Design.

Research questions arose from the identified research area of design practice, targeting the identification of an Ambient UX approach. It is to note that Ambient UX is not a currently existent and defined field of practice, as this thesis is shaping the notion of a novel emerging design field.

Research Objective and Methodology

Specific research questions are shaped, and an objective is posed to define an Ambient UX strategy as a possible suitable approach to respond to the focus application field. The aim is to develop a framework for a design process that emphasizes user experience values, and a toolset that would support such processes within a multi-stakeholder work environment.

Research questions are shaped as following:

- What might be the suitable design strategy for Ambient UX?
- How to map the user experience and how to represent its values within Cyber-Physical Systems?
- Are the currently practiced UX design tools enough to address projects of Ambient UX? Is an update needed?

To respond to the above questions, the selected research methodology comprised three main areas of inquiry (fig. 1): (1) hypothesis of a design strategy for Ambient UX; (2) verification of the Ambient UX framework hypothesis; and (3) design tools for the Ambient UX framework.

The needs of novel design practices are shaped around the imposed complexity of CPS, where a holistic UX approach is a necessity. Facing the imposed complexity, as well as its implications on the user's experience, is a challenging quest. In this context, the aim is to propose a strategy for a holistic UX approach, while building up a common language among practitioners in the field. Common language for novel design practices would bridge the communication gaps between the diversity of professional backgrounds regarding project stakeholders gathered around a cyber-physical project with a focus on UX.

The research contributes to translate the very fuzzy moments of shifting from user research to design hints within a design process by proposing a conceptual framework for a design strategy, and design tools that help to implement the framework within a process in a tangible manner. The outcome provides industry practitioners with a solid comprehension of designing for a holistic UX in CPSes through the proposed conceptual framework. Moreover, with design tools it provides a tangible introduction to the framework in practices, while nurturing the development of a common language. In this context, industry practitioners range from companies offering differentiated services, also including digitized ones, as well as hardware product development, for architects and governing organizations and institutions. Establishing a strategic design framework based on user values can support the process of building sustainable systems comprising pre-thoughts regarding societal impact and long-term usage.



Fig. 1 – Research methodology plan with areas of inquiry, applied methods and main findings.

Main research methods employed throughout diverse inquiry phases include: literature reviews, gathering and comparative analysis of case studies deriving from practice, research-through-design employed using practical design projects that participated, analytical confrontation between the defined Ambient UX framework and practical design projects that participated, gathering and critical analysis of design tools deriving from practice, analytical confrontation between the defined Ambient UX method and gathered UX design tools.

An initial case study of a dynamic lighting system for a workspace is presented to verify the overall Ambient UX framework by confirming the Design Domains (DDs) and User Values (UVs) during the designing process. Furthermore, three case studies of participating projects were taken as research samples to verify the framework through an analysis of dominant UVs and their relations with DDs (Humanitas, MEMoSa, and Connected Lighting for a Caring City). Precisely, user experience was shaped within diverse environments (hospital, automotive, city) in these projects to enable observations based on a broad range of Ambient UX applications. The three projects also reflect on one of the three architectures (i.e., Design Domains), which appears as the dominant one in each of them. UX values emerging during the research phases in case studies showed the importance of identified UV levels, thus confirming their importance for the Ambient UX framework. During the design practices developed through three case studies, UX design tools had to be modified according to the needs of the CPS and adapted to the complexity encountered within UX.

Providing a tangible form to the Ambient UX framework, explorations on design tools were made with the intent of shaping a backbone for the design strategy. Currently employed design tools were analysed, focused on value alignment between user values and stakeholders developing the project. A comparison of tools gathered with the Ambient UX framework detected mismatches that were further highlighted by six thematic issues. The issues are proposed as an upgrade of currently employed tools in the UX field to address the complexity of CPS projects. The analysis of tools and the conceptual framework are a base and/or a starting point for the development of a novel design toolkit.

The research contributes towards both design practices and design education files. The originality of this contribution lies in its close relations with fast-paced changes in design practices, and its translation into an upgrade proposal for a common language shared through design tools.

Design Strategy for Ambient UX

During all the steps within a design process workflow, various design tools can be employed to support the diversity of needs of the ongoing work, from ideation to prototyping and testing. It can, therefore, be said that ideation and evaluation are always present and iterate constantly within a design process. The two phases, **ideation and evaluation**, respond to the questions concerning what is/can be designed and why it should/will be deigned in a specific manner.

With regard to the design process, a UX practitioner (UXer) is positioned between the individuals, i.e., users and customers, and the organization providing an interactive system, i.e., one or group of stakeholders involved (fig. 2). The in-between space reflects the interactions between the two sides, where the UXer empathizes with the individuals and evaluates these interactions from both sides to define and/or reshape interaction touchpoints. For the envisioning phase, the UXer comes up with a set of guidelines and requirements that are shaped into final design outcomes with a team of diverse design profiles (from architects to UI designers), developers and makers.



Fig. 2 – *Diagram to position a UX practitioner within the design process, taking into account relations with project stakeholders.*

Ambient UX Framework

Ambient UX is a conceptual framework, which provides a strategy for structured design processes that target CPSes. Dealing with abstract and intangible concepts like experience is challenging for practitioners in the field, as well as for design educators within the same theme area. Indeed, another layer of complexity is added to these efforts, when it comes to designing systems of intelligent interactive spaces. A shared comprehension of peculiar UX practices within these complex projects is required.

The Ambient UX framework consists of a definition of Design Domains (what is to be designed) and of User Values (why it is designed) observed within Ambient UX and CPS.

Design Domains are analysed through possible outcomes of complex systems of enhanced spaces, in terms of what a designer can manipulate and shape in a certain sense. Precisely, what domains and elements a designer can manipulate to create enablers and constraints for certain activities, thus influencing the user's experience. The observations provide grouping options for design outcomes, such as physical products, information flows and triggers for social relations. In this context, the Design Domains are interpreted through three architectures within targeted design systems: Spatial, Informational and Relational. Besides the architectures, the element of Time is also considered, presented as a variable between the architectures which impact on activities and experience has the same significance.

Defined Design Domains are directly related to the user's experience and, therefore, to the User's Values, perceived as such regarding the interaction with a designed system. Experience is, thus, influenced on diverse levels, scaling from personal to social perceptions and acceptability. The levels are herein discussed as: Usability, Meanings & Motivations, and Social Consensus. This is to say that architectures and time are acknowledged as a variable influence on comfort and well-being, creation of meanings and motivations over time, and social relations within the interactive system.

Usability concerns the modalities of user interaction, which are natural and multimodal. This level implies comprehension of functions and usability, and it includes ergonomics of material solutions as well as their pleasantness in direct interaction (Gibson, 1977; ISO, 2015; Nielsen, 2013). Creation of Meanings & Motivations over time entails analysing and understanding motivations and goals, acceptability and desirability, as well as context-aware interaction (Desmet and Hekkert, 2002; Blythe *et al.*, 2005; Hassenzahl, 2006; Verganti, 2008). The level of Social Consensus is referred to as the level, which deals with acceptability on a social scale (Battarbee and Koskinen, 2005; Bevan, Carter and Harker, 2015; Steen, 2016; Pavlovic *et al.*, 2019). It concerns data usage (data privacy and security), as well as stimulated behavioural changes.

Verification of the Ambient UX Framework Hypothesis

The Ambient UX framework hypothesis is verified by comparing the proposed design strategy with research projects that satisfy the Ambient UX concept and involve studies on user experience. This is done by identifying what is perceived as User Values in all of them, and what is the relationship between DDs and UVs.

Initially, first testing was carried out to verify the framework hypothesis with a case study of a dynamic connected lighting system within an office working environment (Pavlovic *et al.*, 2018). The verification consisted in identifying the DDs as such, as well as their influence on the hypothesized UV levels. After running this first holistic check of the framework, i.e., the existence and suitability of hypothesized DDs within the project and the suitability and existence of influenced UVs within the same, three case studies took part to further verify the hypothesis and observe the connections between DDs and UVs within a project, also considering their mutual influence. The three projects are selected according to their diversity in terms of different dominant architectures, diverse product complexity and nature, and diverse levels of user or automated input (through sensors). Moreover, they are all placed in different environments, namely: hospital, automotive and city (outdoor and indoor) environment. The projects are:

- 1. Humanitas (hospital environment; green colour in fig. 3),
- 2. MEMoSa (automotive environment; pink colour in fig. 3),
- Connected Lighting for a Caring City (city environment; purple colour in fig. 3).

Project Humanitas refers to a holistic overview and evaluation of UX, where users are influenced by the sensitive ambient context, the interaction with digitized kiosks that support hospital administrative services, as well as interactions with hospital staff. Project MEMoSa considers an approach of de-



Fig. 3 – Radar diagrams showing the diversity between the three projects, according to: architectures as Design Domains (above), system input modalities (below).

signing for user's experiences within a car interior environment, having as a core concept an IoT system that supports safer driving behaviours. Connected Lighting for a Caring City project considers an approach of designing for user's experiences within an urban environment, following user's daily activities within diverse outdoor and indoor ambient contexts that are being enhanced by digitized services, using lights as a medium of communication and interaction.

For each of the projects the conducted UX research led to a discussion on User Values and their fluidity, and the projects contributed to provide an overall Ambient UX framework verification.

Design Tools for Ambient UX

This section aims to identify design tools that could support a design process for an Ambient UX strategy. Hence, the research methodology comprises two macro steps: (1) Overall analysis of current UX tools employed in practice to understand User Values and Design Domains they refer to; (2) Comparative analysis of the tools with the proposed framework for Ambient UX Design Domains and User Values.

During the first research step, tool samples were collected with a majority of them deriving from practices in industry as well as from design consultancies. The search focused on tools that support design processes targeting value alignment (Kalbach, 2016; Pavlovic and Pillan, 2018). Such tools are: Customer Journey Maps, Experience Maps, Mental Model Diagrams, Service Blueprints, Spatial Maps, Ecosystem Models, Stakeholder Maps, Storyboards, Touchpoint Matrix, Business Model Canvases, Value Proposition Canvases, and Empathy Maps. The analysis discussed structures for each of the tools to identify Design Domains and User Values. Finally, all the tools were compared, and possible emerging grouping patterns were observed.

During the second research step, tool samples were compared against the proposed framework for Ambient UX, in terms of DDs and UVs it considers. The framework is based on a design strategy deriving from literature review; therefore, this comparison is between the theoretical methods presented in literature and tools employed in design practices. Discussion is shaped according to encountered mismatches between the gathered tools and the method, and proposals to upgrade tools that could support a designing process for Ambient UX were made accordingly.

Six Issues on Tool Upgrades

This research relates to experience mapping in order to create a common language for physical/digital ambient design. The discussion is supported by case studies of tools that are suitable for a conversation on drawing principles for experience design. These tools are discussed as the foundation to establish an emergent design language.

Three case studies showed that UVs vary depending of the context and design outcome, and that particular values appear to be more dominant than others in certain projects. Comparing the dominant UVs derived from the projects, it is noticeable that they are matching with gaps identified in the current UX design tools. Namely, the values reflect, through concrete examples, a correspondence and overlap with the gaps encountered in the tools when confronting them with the Ambient UX design framework. Main observations are based on the following theme elements:

- All three architectures should be considered simultaneously within the tools,
- Tools should enable an analysis of alternative user journey paths,
- Tools should enable a zooming in and out perspectives in regard to design outcomes,
- Tools should support analysis and discussion on social acceptability of the design outcome,
- Tools should enable observations on different time spans of user engagement and their analysis,
- System intelligence levels should be taken into consideration within the tools.

First five, out of the six, theme elements are the issues recognized as gaps within the overlap between the Ambient UX framework and tools currently employed in practices. Through analysed project case studies the five gaps have been observed and verified and a new one emerged that did not appear before, referring to intelligence levels (Pavlovic *et al.*, 2019).

All the presented projects contain the recognized Design Domains, i.e., architectures. When some architectures are more dominant than others in certain projects, they all still require a holistic comprehension of the design system. Furthermore, all the projects presented have possible alternative pathways. It is hardly possible to have only one determined path within a design system. Paths depend on many DDs and variables, and thus should be faced as such. Comparing and analysing alternative pathways helps to identify desirable ones as well as to anticipate potential problems a design system might cause. It is necessary to change perspective and scales in all the observed projects, as the design process is a constant iteration, which faces refinement of the concept and outcome in various moments. The UX design process supported by research is never a linear process; rather, it requires the ability to constantly zoom in and out of social impact of the design solution on interface features and usability issues. Therefore, design tools should respond to this need by enabling a change of perspective at any moment, providing a holistic overview of the system, scaling from very broad strategical levels and impact to very small detailed considerations for a design artefact.

Dealing with design concepts that shape user values through complex data flows, also involving sensitive personal data, raises many considerations in terms of data treatment, privacy and transparency. This consideration is observed as a need to establish a social consensus for data processing, which touches one's experience levels beyond personal perceptions and expands on ethical levels of a society. Since this particular consideration is interwoven with the design process, an evident need to shape design tools that support its implementation arises.

We must take into account the different time spans to plan design system implementation within a timeline, as well as to analyse any impact the system might have on users within diverse timelines of use. The design tools collected consider the diversity of time spans, but usually only one of the possible scales, without reflecting on shorter and longer terms of combined use within one holistic representation. Design tools should enable planning and analysis across various time spans to envision and develop design concepts of changes they might cause in user perceptions over time, and the creation of meanings.

Considering the emerging systems of AI applied to design practices, we notice that the design field for these applications is still young, though AI is not a novel research area at all. Novel systems supported by AI require reasoning on intelligence levels that influence the user's experience and, therefore, novel design processes require design tools to be shaped accordingly.

These six conceptual issues are a proposal for an update and expansion of tools currently employed in UX practices that regard design strategies supporting the Ambient UX framework.

Conclusions

The research provides strategic support to bridge the fuzzy phase from user research to design hints. This strategy is translated into a conceptual framework to design for Ambient UX, while targeting CPSes. The framework can be used both to analyse and plan novel design systems supporting the design process. The research contributes to this context by providing a base to support design processes focused on user experiences, which enable to build CPSes that are sustainable in terms of user values and, thus, acceptability over a certain time period of use and engagement.

Facing the complexity imposed by CPS, the research proposes a holistic approach to UX. This approach is embodied through an additional proposal for design tools to be used during a design process. Tools are also the backbone to build a common language among all stakeholders involved in a project who represent professionals from diverse backgrounds. Hence, the common language can be observed as common understanding of the process of translation and interpretation from user research to design hints.

The UX tools currently employed in practices do not seem sufficient to cover all aspects of the Ambient UX framework; for this reason, the research proposes updating tools and/or developing a novel toolkit for the framework. The main six conceptual issues were identified as mismatches between the framework and the tools gathered and, as such, are proposed as issues for an upgrade to a novel toolkit. Recommendations on including novel conceptual issues imply having: (1) all 3 architectures considered simultaneously; (2) analysis of alternative pathways; (3) zooming in and out; (4) social acceptability; (5) different time spans; (6) intelligence levels.

Being deeply grounded within a design practice, the research provides contributions on two levels, namely the academic theoretical research body on design, and the emerging design practices within industry. The contribution to the academic research body on design is reflected in the manner of reasoning about building the conceptual hybrid framework. The manner of reasoning could be repeated for similar research scenarios that need to establish a strategy to support design processes with regard to Design Domains and User Values. The contribution to design practices within industry is the concrete strategy proposed, which can be re-used during design processes for Cyber-Physical Systems. By making the strategy more tangible, design tools are also another research outcome that provides support to design practices.

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