FAKULTÄT FÜR !NFORMATIK
Faculty of Informatics

UX in the AAL Field of Practice

Interaktiongestaltendes Framework, das die Langzeitbeziehung zwischen den BenutzerInnen und dem zu entwickelnden interaktiven System forciert

DISSERTATION

zur Erlangung des akademischen Grades

Doktor der Technischen Wissenschaften

eingereicht von

Dipl.-Ing. Miroslav Sili
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by

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Erklärung zur Verfassung der Arbeit

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Miroslav Sili

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Kurzfassung

Der Begriff "User Experience" wurde erstmals durch Don Norman formuliert, der im Jahr 1993 in das Unternehmen Apple eintrat und dort die Abteilung "User Experience Architect's Office" gründete. Seit über 25 Jahren entwickelte sich der Begriff "User Experience" stetig zu einer wichtigen Designdisziplin weiter und gewann damit zunehmend an Bedeutung.

Unter "User Experience" versteht man alle Aspekte auf welche Weise Menschen Produkte erforschen, benutzen, mit ihnen spielen, von ihnen lernen und auf sie reagieren. Diese Faktoren unterstreichen, dass der Begriff vielschichtig verwendet werden kann. Diese vielseitige Aussagekraft ist grundsätzlich positiv zu bewerten. Sie spiegelt die Bandbreite unserer Wahrnehmung wieder und sie unterstreicht, dass das HCI Feld diese Vielfalt adressieren muss. Anderseits bringt die Vielfalt einen wesentlichen Nachteil mit sich, nämlich sie erschwert die Adressierung dieser Eigenschaften in der Praxis.

Diese Arbeit setzt hier an und stellt einen praxis-orientierten Ansatz bereit um die erwähnten Aspekte der gezielten "User Experience" in etablierte Interaktions-Gestaltungs-Routinen einzubetten. Diese Dissertation präsentiert ein konzeptuelles Framework, das UI Designer und Interaktionsdesigner in ihren Design-Routinen unterstützt.

Das "Interaction Design Framework" ist in zwei Hauptkomponente strukturiert: In ein dynamisches Benutzermodell, das die "User Experience" Aspekte abdeckt und in ein praxis-orientiertes Forschungsnetz, das in der "Active and Assisted Living" Domain angesiedelt ist.

Die Arbeit illustriert ihre Nützlichkeit auf Basis eines Fallbeispiels, welches die kommutative, 15-jährige Erfahrung aus der bisherigen Arbeit in diesem Feld repräsentiert.

Schlüsselwörter: UX, UxD, User Experience Design, AAL, IxD, Interaction Design, UCD, User Centered Design, practice-oriented approach, AAL in practice

Abstract

The term User Experience was firstly shaped by Don Norman who joined Apple in the year 1993 and where he established the User Experience Architect's Office. This was now 25 years ago and since then the term has grown into an important design discipline. Moreover, the term continues to grow and to evolve.

By "User Experience" we mean all aspects of how people are exploring, using, playing with, learn from, and respond to products. These aspects highlight that the term User Experience can be used in a broad manner. The expression diversity of the term is, on the one hand, a positive factor since it reflects that users' perception is versatile and that the field of Human Computer Interaction is in need to address this versatility. On the other hand, the expression diversity carries the drawback that it is challenging to address its characteristics from the practical standpoint.

This work tackles this drawback and provides a practice-oriented approach that incorporates User Experience Design aspects into well-known and well elaborated interaction design routines. This dissertation thesis presents a conceptual interaction design framework that supports user interface designers and interaction designers during the design process of new interactive systems.

The conceptual framework, named "Interaction Design Framework", is structured in two core components: into a dynamic user model covering the user experience and the user experience design aspects and into an interaction design research grid covering the practical standpoint from the Active and Assisted Living domain.

This work illustrates the usefulness of the concept based on a scenario that reflects the commutative experience gained through the work in the field for more than one and a half decades.

Keywords: UX, UxD, User Experience Design, AAL, IxD, Interaction Design, UCD, User Centered Design, practice-oriented approach, AAL in practice

Contents

CHAPTER 1

Introduction

Human Computer Interaction (HCI) is a multidisciplinary field including computer science, cognitive and behavioral psychology, anthropology, sociology, ergonomics, industrial design, and more [WZS16]. HCI addresses a broad range of topics and has various forms of manifestations. This also applies to people that use these HCI techniques. They have different needs, different expectations, different preferences, and different habits. Unfortunately, these individual characteristics are usually considered only superficially during the design process of interactive systems. This results in dissatisfaction and frustration in latterly use of these systems. Even if the provided functionality is perceived as valuable, user might reduce the usage time or stop the using the offered systems because they leak to support individual aspects. Thus, interactive systems that target the long-standing engagement with the user are requested to address these individual aspects to reach this goal.

Lauralee Alben highlights the dominance of individual aspects in her work that defines eight criteria for effective interaction design [Alb96]. One of these criteria addresses the effectivity of the design process but the remaining seven addresses the understanding of the users that are supposed to use the product. This underlines that the resulting quality of the perceived user-product experience is significantly influenced by the user itself. Thus, in order to provide successful and satisfying experience, designers are asked not to focus only on the identification of the problem and on the problem-solving methodology but also on individual user aspects.

On the other side, it is understandable that the incorporation of individual user aspects increases the design and development efforts which consequently cause the increase of costs and the enlargement of infra-structural setting. On the other side, this seems to be a necessary burden for companies and designers in order to provide successful and satisfying user-product experience. The challenge is to find the right balance between the ecological design perspective and the potential user-specific perspective that, in an ideal case, generates profitable revenues by the long-standing engagement of the user with the designed product and consequently with the brand.

1.1 Motivation

Situated in the Active and Assisted Living (AAL)-field of practice for more than one and a half decades, I have been experienced the demand for diversity in building Information and Communication Technology (ICT)-based solutions. We have been asked to design and develop various applications, targeting numerous and complex goals, in different research projects. Guided by concrete user needs and project specific parameters, we have been created ICT prototypes ranging from traditional single device-based applications, over to multi device-based applications, over to adaptive and personal assistance-based applications to so called tangible applications. This variety illustrates that application design nowadays is not necessarily limited to one design style, e.g., manifested as a classical Graphical User Interface (GUI)-based application. Application designers can draw on different interaction design styles to realize the intended interactive system and its HCI artifacts.

This experience formed my curiosity about the question if a holistic view across all these different interaction design styles can maybe be useful for the design process of new interactive systems and their HCI artifacts? This was the starting point for the formulation of the research question and consequently the starting point of the deep investigation of the problem statement.

1.2 Problem statement

As pointed out before, user involvement is essentially for the design of interactive systems that targets the long-standing engagement of the user with the offered product. The question is how to involve the user into the design process? Luckily this is not a new question and researchers have been invented a good-practice standard that targets this goal and that is in rage use for more than three decades. The User Centered Design (UCD) process [AMKP04] addresses exactly this question. In UCD the user is placed into the center of the design process, inviting her or him to participate in several design activities starting from the identification of the need-phase till the evaluation of the results phase. Moreover, some UCD methods, e.g., the participatory design method, involve the user on such a deep level that users become co-designers during the design phase. This in fact can increase users' satisfaction about the final product. Consequently, this requires their deep involvement which also increases the needed efforts. Admittedly, this represents the extreme case of the user involvement. At the end of the day, it is up to the designer and the current setting to decide which UCD methods are necessary and in which depth they need to be applied.

However, even if the UCD process seems to be the right tool for the user involvement, we have been experienced that the utilization of the UCD does not always and per se leads to successful and satisfied user experience. As mentioned before, situated in the AAL field of practice, we had the opportunity to apply the UCD process in various project developments. User evaluation results, gained within these projects, high-lighted that there is a significant number of unsatisfied users which decreased the usage time of the designed prototype. In some cases, the users stopped the using of the offered prototype before the end of the project.

This represents a contradiction to the concept of the UCD approach since users have been involved from the early stage of the project. They have been involved in the user requirements analysis, in the mock-up testing, in the testing of the first functional prototype, and very often also into the testing of the second functional prototype before the release of the final prototype. Since users were involved from the early stage of the project and even in the identification process of their needs, it is precluded that the functionality of the offered product failed. Functional aspects have been explicitly requested by the users. Also, since users were involved in several design, evaluation and improvement cycles, it is precluded that the usability of the offered product failed. The improvement of the usability was one of the key elements of every iteration step. These two aspects highlight that the applied approach could address basic user needs (in terms of problem identification and problem-solving utilizing functionality and usability), but also that the applied approach did not reach the targeting user on an individual level, considering her or his inner and very often unconscious values, wishes, and needs.

Admittedly, the UCD process defines design activities. It does not define a direct methodology within these activities. It is understood that particular UCD methods, e.g., participatory design, provide the right design setting for the incorporation of individual desires. Nevertheless, from a practical and economical perspective, there is a need for a structured and shorthanded method for the capturing and the interpretation of inner values, wishes, and needs which in turn can draw conclusions about concrete interaction design styles.

1.3 Aim of the work

This work targets the problem statement and elaborates delighting aspects in user-product experience and a method for a stronger incorporation of these aspects into the design process.

The overall goal is to provide a structured and shorthanded method for the identification of individual inner values, wishes, and needs that are able to increase user's satisfaction and that in turn contribute towards the long-standing engagement of the user with the offered product. This work aims to address these aspects already on the conceptual level in order to provide a better understanding of users' expectations and to alleviate additional efforts during the design process.

This dissertation thesis discusses following research question: **How can the UCD process be enriched in order to provide a stronger user involvement on an individual level, considering their inner values, wishes, and needs?**

The list of objectives frames the aim of this dissertation thesis as follows:

- Identification of Interaction Design (IxD) patterns.
- Identification of relationships between IxD patterns.
- Elaboration of characteristics of IxD patterns.
- Identification aspects that make products delightful for the user.
- Identification of aspects that are able to reflect the user on an individual level.
- Fusion of the delightful product aspects with aspects that are able to reflect the user on an individual level.
- Incorporation of identified IxD patterns and their characteristics.
- Development of a conceptual framework that bounds all previously mentioned objectives to one practicable unit.

As an overall goal, this dissertation thesis aims the development of a conceptual Interaction Design Framework (IxD-FW) that supports user interface designers and interaction designers in addressing these inner values, wishes, and needs in a structured and short-handed manner.

1.4 Methodological approach

This work utilizes the evolutionary design approach as illustrated in Figure 1.1. The horizontal axis depicts the time line at the bottom and the milestones at the top. The vertical axis summarizes activities, components, and stakeholders clustered by aspects common in the waterfall methodology [Sch97]. Moreover, the figure highlights that this dissertation thesis has a well-defined foreground (including real interaction design tested on real users) and that the concept will be addressed, stressed, and evolved in future research projects. This will be described in more details in the future work Chapter 8.

This work is founded on the practice-theoretical approach in social science [Rec02]. It utilizes practices that represent collective patterns of interaction that are reproduced in specific contexts. The specific context of this work is the AAL domain and the collective patterns are based on a set of design case studies applied in this field. As one can see in Figure 1.1, the foreground represents the starting point for this dissertation thesis.

The literature research cluster is subdivided in three parts. The first part focuses on the specific field of practice with the strong focus on interaction design. This research analyses the stat-of-the-art and contributes towards the synthesis of interaction designs results gained from various design case studies. The second part focuses on the enhancement of the state-of-the-art. It utilizes concepts, methods, and tools from the Product Design (PD), IxD, and User Experience Design (UxD). The third part focuses on the identification of similar works that address the practical domain specific field as well as the general UxD field.

The user and expert involvement cluster highlights the involvement of different stakeholders before, during, and afterward the development of dissertation this thesis. The development of this work was supported and advised by my supervisor, expert in HCI and human-centered technology, by my colleagues, experts in the design of interactive technologies and scientific experts in the AAL domain and by one cross-domain scientist, expert in AAL and cardiovascular diagnostics. The involvement was performed in terms of regular presentations and discussions, review process and exchanges on daily basis. Moreover, the cluster also depicts the involvement of the end users and the involvement of the interaction designers since it is based on design cases studies involving my own participation and work in this field for more than one and a half decades (see also my publications).

The elaboration cluster highlights the sequential focus on different topics that aim the synthesis process and the enhancement process.

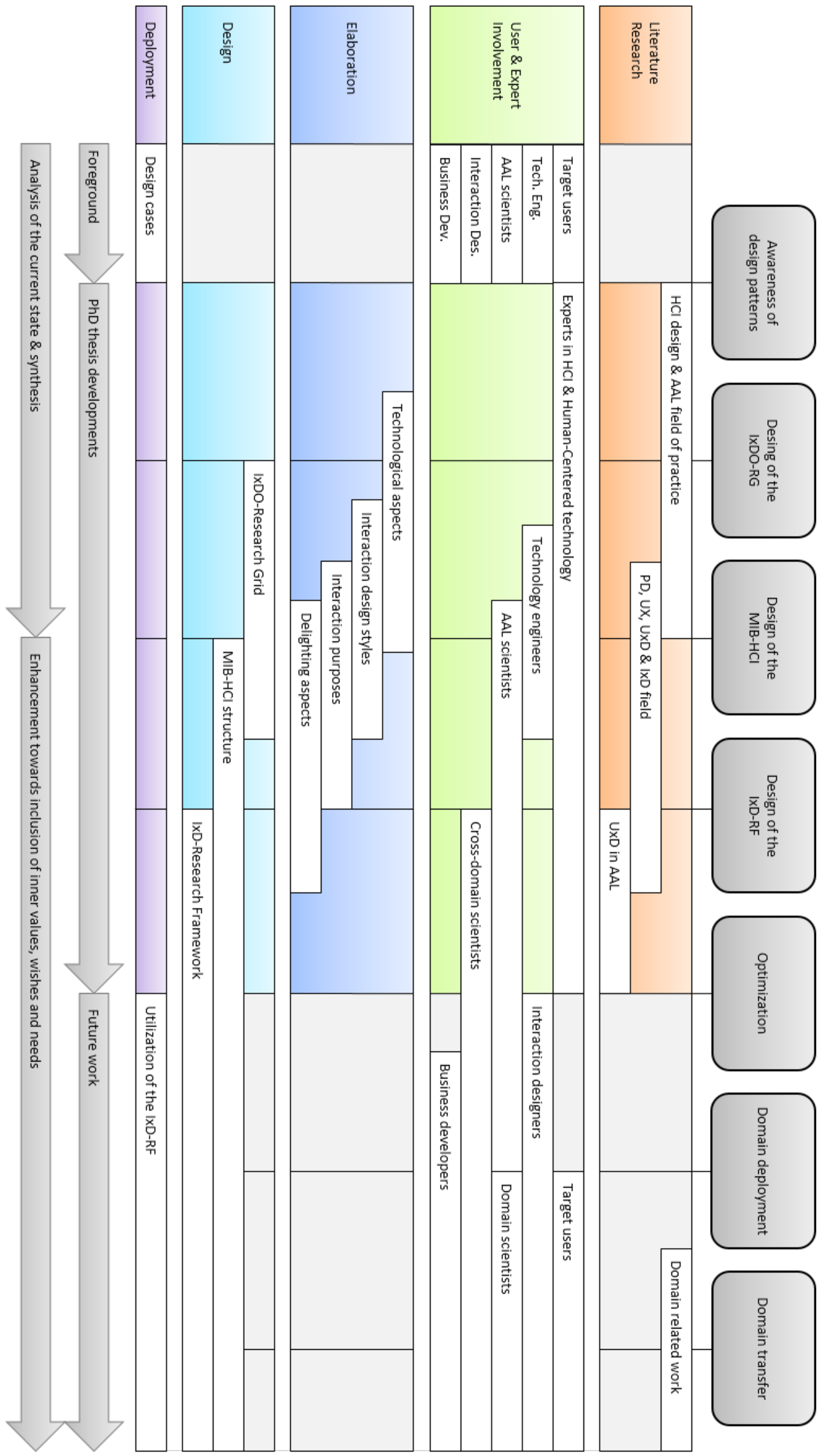


Figure 1.1: Methodological Approach of the dissertation thesis including the foreground and the future work.

The design cluster highlights the two-folded goal of this dissertation thesis. Firstly, the identification of current state and the synthesis of the current state with the goal to provide a comprehensive overview of considerable aspects in IxD process. And secondly, the enhancement of the current state towards interaction designs that are able to satisfy the targeting user and thus to provide a long-standing engagement with the product. The depicted IxD-FW combines these two goals to one practicable unit that represents the main output of this dissertation thesis.

The deployment cluster highlights the concrete utilization of this work in future research projects that will discussed in more details in Chapter 7.

1.5 Structure of the work

This thesis is structured as follows:

Chapter 2 focuses on related approaches and methods relevant to the objective of this dissertation thesis.

The first Section 2.1 lists relevant term definitions, their characteristics and their meaning with the aim to reflect the general research field of this dissertation thesis.

The second Section 2.2 elaborates relevant works and approaches from the AAL field of practice with the strong focus on interaction design techniques.

The third Section 2.3 focuses on concepts and methods that aim the identification and utilization of delighting aspects in user-product experience.

Chapter 3 elaborates the main topic of this dissertation thesis, namely the design of the IxD-FW. The initial part highlights that the IxD-FW is conducted of two research areas, namely the interaction design-related research area and the user-related research area.

Chapter 4 elaborates different interaction styles, their structural dependencies, their technical characteristics, design characteristics, and pleasure characteristics utilizing the Interaction Design Opportunity Research Grid (IxDO-RG) structure.

Chapter 5 focuses on the sequential development of the dynamic user model Model for Identification of Balanced HCI (MIB-HCI) utilizing concepts and methods from the product design, interaction design and user experience design. The model combines all relevant works that were presented in the state-of-the-art Section 2.3.

Chapter 6 presents the bound of the two research areas into one union, namely into the mentioned IxD-FW. The Chapter highlights additionally the interplay between these two research areas and depicts the work flow for the user of the framework.

Chapter 7 provides a critical reflection of the dissertation thesis. Section 7.1 focuses on the comparison of related works including both research areas and Section 7.2 discuss of open issues and enhancement possibilities.

Chapter 8 summarizes the dissertation thesis and highlights the future work.

CHAPTER 2

State-of-the-Art

2.1 Definition of Terms

Before we focus on the Interaction Design Framework (IxD-FW) and different interaction design styles it is necessary to provide a comprehensive list of term definitions used in the HCI field and in this work. The listing highlights basic differences between used terms and emphasizes their main characteristics and their relevance to this work.

2.1.1 HCI

The HCI field becomes popular in the late 1970s. Until then, mainly a small user group, such as technology professionals and hobbyists, used computers. This changed dramatically in the late 1970 as personal computing becomes more popular and suddenly made everyone in the world to a potential computer user. At that time researches started to investigate disadvantages of computers with respect to usability 2.1.6 for those who wanted to use computers as a tool [Car13].

Started from the usability perspective HCI evolved to a multidisciplinary field including computer science, computer graphics, artificial intelligence, information science, sociology, and psychology [WZS16]. This work utilizes well elaborated HCI methods and investigates them from the User Experience (UX), User Experience Design (UxD), Interaction Design (IxD), and Product Design (PD) perspective.

2.1.2 Interactive Applications / Systems

Interactive systems have two main characteristics, namely the bi-directional communication and timely response time. Albrecht Schmidt defines an interactive application as follow: "Interactive applications offer a timely bi-directional communication between the human user and the computer system. When using interactive applications, the user and the system are in a direct dialog. This dialog is a sequence of communication events between the user and the system" [Sch05, p. 160].

The first characteristic (bi-directional communication) might be clear but the second one (timely response time) might not be so obvious. Jakob Nielsen identified three important limits for response times: 0.0-0.1 seconds to provide the feeling that the system is reacting instantaneously, 0.1-1.0 seconds to keep user's flow on thought uninterrupted and 1.0-10.0 seconds to keep user's attention focused on the dialog [Gro93]. Thus, while designing interactive systems we need to keep these time limits in mind to provide an appropriate flow in the dialog sequence between the user and the system.

2.1.3 IxD

IxD is the basic element and an indispensable condition in the HCI design process. The Interaction Design Association defines IxD as follows: "Interaction Design (IxD) defines the structure and behavior of interactive systems. Interaction Designers strive to create meaningful relationships between people and the products and services that they use, from computers to mobile devices to appliances and beyond" [Ass18b, p. 1]. Following on from this, every User Interface (UI) design implies also IxD tasks, where designers determinate concrete interaction steps.

Traditional GUI designers do not see the IxD process as a separate task. In traditional GUI-based designs the IxD process is very often automatized and unconscious. Starting from the targeting users' and the UI perspective, designers very often think in terms of graphical screens and elements on this screen that might cause system events which in turn trigger the rendering of other graphical screens. Thus, the IxD process is primary perceived as UI design process and the final interaction model is consequently a set of all possible interaction steps which are deep interwoven into the business login of the interactive system.

However, as mentioned previously, IxD defines not only the behavior of an interactive system but also the structure. This includes, e.g., the architecture, used components, devices, modalities, or the context of use and its implications regarding the appearance. All these aspects belong to the IxD process and play a major role in upcoming sections of this work.

2.1.4 Explicit Human Computer Interaction (eHCI) vs. Implicit Human Computer Interaction (iHCI)

Previously, we defined interactive applications and systems and the dialog-forming character of such systems. Moreover, we highlighted that a dialog in an interactive system is a sequence of communication events, occurring between the user and the system. These events are generated alternately but explicitly by the user and the system. This basic procedure of interaction is known as eHCI [JS07] and represents the classical HCI design approach. Schmidt summarizes a user initiated explicit interaction by following steps:

- The user requests the system to carry out a certain action.
- The action is carried out by the computer, in modern interfaces providing feedback on this process.
- The system responds with an appropriate reply which in some cases may be empty. [Sch05, p. 161]

Schmidt argues further that in explicit HCI computers are inevitably in the center of the activity and that the user focus is on the interface or on the interaction activity. This contradicts the vision of ubiquitous and disappearing computing [SN05, WB97, Wei99]. In such environments, computers cannot be placed into the center of the action. Thus, it is necessary to include implicit elements into the communication in addition to the explicit dialog. Schmidt defines this new implicit interaction paradigm as follows:

- iHCI is the interaction of a human with the environment and with artifacts which is aimed to accomplish a goal. Within this process the system acquires implicit input from the user and may present implicit output to the user.
- Implicit inputs are actions and behavior of humans, which are done to achieve a goal and are not primarily regarded as interaction with a computer, but captured, recognized and interpret by a computer system as input.
- Implicit output of a computer that is not directly related to an explicit input and which is seamlessly integrated with the environment and the task of the user. [Sch05, p. 164]

This work addresses both HCI types. Some interaction design styles described in this work target the design of eHCI artifacts, whereas others target rather the design of iHCI artifacts.

2.1.5 Multimodal Human-Computer Interaction (MMHCI)

MMHCI focuses on interaction techniques that utilizes various input and output modalities. Unlike the early stage of computing, users are no longer forced to use only one input modality (e.g., the keyboard) and only one output modality (e.g., graphical visualization on the monitor device). Quite the opposite – since the mix of signals is essential for the understanding of communication and novel HCI techniques that target the goal to provide more effective and more natural HCIs, multimodality is crucial for the field [JS07].

This is also highlighted by Schmidt in the following statement: "Typical user interfaces (UIs) of interactive programs are text based (e.g. command line), graphical user interfaces, voice interfaces, gesture interfaces or a combination of those, often referred to as multimodal interfaces" [Sch05, p. 160].

In respect to the mentioned HCI vision of designing more effective and more natural HCIs, this work addresses the multimodality aspect in some interaction design styles more intensive, and in others less intensive. This is because some interaction design styles address rather the efficiency aspect (allowing users to finish the intended and already familiar task in a shorter period) as the learnability aspect (explaining what should be done). The former requires less natural interaction and thus less multimodal interaction elements, whereas the later focuses on understanding that can be transported more efficiently by using natural interaction and thus requires more multimodal interaction elements.

2.1.6 Usability

Usability plays a major role in IxD of interactive systems. According to Nielsen, usability is a multi-dimensional property of a UI and traditionally associated with following five attributes:

- Learnability: The system should be easy to learn so that the user can rapidly start getting some work done with the system.
- Efficiency: The system should be efficient to use, so that once the user has learned the system, a high level of productivity is possible.
- Memorability: The system should be easy to remember, so that the casual user is able to return to the system after some period of not having used it, without having to learn everything all over again.
- Errors: The system should have a low error rate, so that users make few errors during the use of the system, and so that if they do make errors they can easily recover from them. Further, catastrophic errors must not occur.
- Satisfaction: The system should be pleasant to use, so that users are subjectively satisfied when using it; they like it. [Nie94, p. 26]

IxD requires the consideration of all five aspects. As Bevan suggested in his article "International standards for HCI and usability" [Bev01], HCI and usability standards concern also areas like the process used to develop the product, the UI, the interaction itself and the capability of an organization to apply UCD process. The versatility of usability is also pointed out by Carroll as follows: "Usability now often subsumes qualities like fun, well-being, collective efficacy, aesthetic tension, enhanced creativity, flow, support for human development, and others. A more dynamic view of usability is one of a programmatic objective that should and will continue to develop as our ability to reach further toward it improves" [Car13, p. 1].

Nevertheless, from the targeting user perspective, this work tackles the "use of the product" usability area and focuses especially on the satisfaction factor. Thus, the satisfaction will play a major role in upcoming sections.

2.1.7 UCD

UCD is a broad term to describe design processes in which end-users influence how a design takes shape [AMKP04]. The International Organization for Standardization (ISO) 13407 standard [fS18a, JIMK03] provides a guidance on human-centered design activates throughout the life cycle of computer-based interactive systems. The activities include:

- The understanding and the specification of the context of use.
- The specification of the user and the organizational requirements.
- The production of the design solution.
- The evaluation of the design solution against the requirements [JIMK03, p. 55].

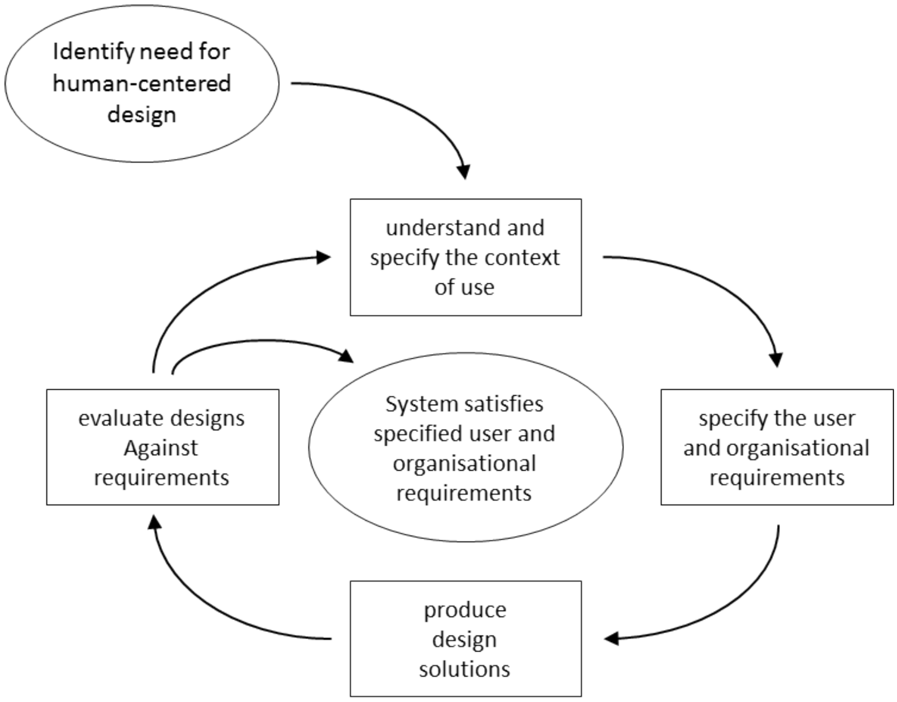


Figure 2.1: Visualization of activities and their relations in the UCD process [JIMK03, p. 55].

The first activity aims the understanding of the user and the environment of the use. The second activity determinates the success criteria of usability for the product in term of tasks. The third activity incorporates HCI knowledge into the design solutions, and finally the fourth activity evaluates the usability against user tasks. Figure 2.1 illustrates these activities and their relations in the UCD process. As one can see, the process is an interactive process and it is understood that these activities have to be performed several times in order to design a product which has the ability to satisfy the user.

2.1.8 UX

The ISO defines UX as follows: "Person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service" [fS18b, p. 1]. Although this definition provides a clear comprehension about the fundamental idea of UX, it is difficult to find universal valid metrics to measure and to quantize these subjective aspects. Law confirms this view in his work "Understanding, Scoping and Defining User eXperience: A Survey Approach" by the following statement: "**UX highlights non-utilitarian aspects of such interactions, shifting the focus to user affect, sensation, and the meaning as well as value of such interactions in everyday life. Hence, UX is seen as something desirable**, though what exactly something means remains open and debatable" [LRH+09, p. 719]. Hassenzahl underlines the desirable aspect in his work and points out that UX focuses on aspects beyond the functional, on the positive and that the experimental and emotional are no coincidence [HT06].

However, following this concept of "**UX is seen as something desirable**", UX can play an essential role in the IxD process. This work does not focus on various interpretations of UX nor on its possible measurement variables such emotion, affectivity, and aesthetic but rather on the functional whole of UX which targets the provision of pleasure for the user during the use of the interactive system. Thus, users' individual understanding of pleasure will play a major role in this work.

2.2 Interaction Design in the AAL Field of Practice

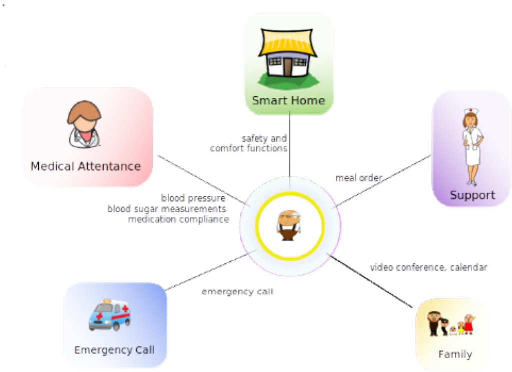
As outlined above, situated in the AAL field of practice, we have been asked to design and develop various applications, targeting numerous and complex goals in different research projects. Each of those projects has been accompanied by an IxD process that resulted in the development of an interactive system that can be assigned to a specific class of interaction design styles. Thus, it was obvious to investigate these interaction design style classes and their implication for the targeting user. For simplification purposes, I will call these interaction design styles hereinafter Interaction Design Opportunities (IxDOs). In this section we provide a state-of-the-art overview about eight identified IxDOs, their main characteristics and in relation to my publications in the AAL field of practice as well as published works out of this domain. Later, in Section 4.3 I will summarize the objectives of these eight identified IxDOs and frame them together into a so-called Interaction Design Opportunity Research Grid (IxDO-RG) which can be used by UI designers and interaction designers in order to identify possible, and from the targeting user perspective valuable, IxDOs during the the IxD process.

2.2.1 App Interaction Design Opportunity (App-IxDO)

App-IxDO focuses on IxD that targets the use of one primary interaction device. Smartphones or tablet devices represent, for instance, such primary interaction devices. In the App-IxDO users are requested to use mainly one such device to interact with the interactive system. However, it is not meant that App-IxDO limit the number of usable devices to one single device. The Interaction Design Opportunity (IxDO) rather characterizes the concept where the full functionality set, and thus all possible interaction steps, are provided and accessible by one single device. This small but very important distinction, includes also design styles that focus on the inclusion of multiple devices, e.g., the concept of responsive design. Responsive design pursues the main idea to create a single website that can adapt its layout and its content to viewing contexts across a spectrum of digital devices [Mar17, Gar11]. However, in such dynamic adaptivity setting the concept of App-IxDO remains valid since the whole functionality set of the application is available on every device regardless how many devices the system supports.

In our AAL field of practice, App-IxDO was utilized in the large scale pilot project *moduLAAr* [1] [SPAK+14]. The project was conducted between the years 2012 and 2015 in eastern Austria. The main objective was to equip up to 50 flats with an AAL solution that can be adapted to the individual needs of the residents in assisted living homes. Figure 2.2a illustrates the end user frontend of the *moduLAAr* prototype. It represents the classical App-IxDO, offering a GUI on an Android tablet device.

(a) The *moduLAAr* prototype rendering the end user frontend on an Android tablet device [Aus18, p. 5].



(b) The visualization of offered services within the project *moduLAAr* [Bar15, p. 5].

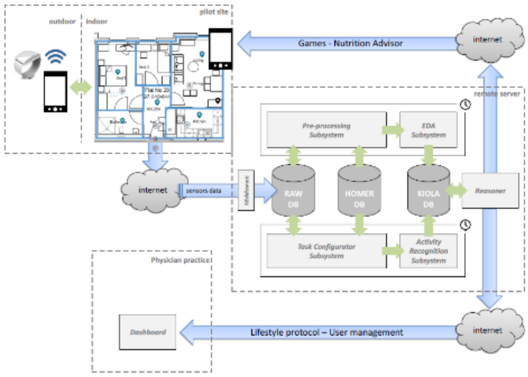
Figure 2.2: The GUI of the *moduLAAr* prototype and the visualization of provided services within the project.

Figure 2.2b illustrates the offered services ranging from emergency call, over to social inclusion and medical assistance to the control of the smart environment. It is remarkable that even if the system architecture can be classified as a multi-service, Ambient Intelligence (AmI) and Context-Aware System (CAS), the offered user frontend is classifiable as App-IxDO. This highlights that the system design of an interactive system does not necessary reflect the applied interaction design and that more complex IxDOs can utilize less complex IxDOs, but this will be described in Sections 4.4 and 4.5 in more details.

[1] My contributions within the project: system architecture co-design, backend co-development, rule-based reasoning development, service integration, reporting

The distinction between system design, on the one hand and the IxD, on the other hand, is also noticeable in the project *DOREMI* [SMH+17, Bac15]. The aim of the project was to devise ICT-based home care services for aging people to contrast cognitive decline, sedentariness and unhealthy dietary habits. Figure 2.3a illustrates the implemented end user frontend of the prototype and Figure 2.3b visualizes the high-level architecture. Here again, the frontend utilizes the classical App-IxDO (including Gamification aspects) whereas the backend system is more complex, including several subsystems such as smart environments and CAS modules.

(a) The final GUI of the *DOREMI* prototype [SMH+17, p. 353].



(b) The high-level architecture and deployment of a typical installation of the project *DOREMI* [Bac15, p. 61].

Figure 2.3: The project *DOREMI* highlighting the GUI and the developed architecture.

2.2.2 Multi App Interaction Design Opportunity (MApp-IxDO)

MApp-IxDO targets the design of seamless interactions between multiple devices. The primary goal is to exploit synergies between complementary modalities used on multiple devices and to offer an optimized interaction for the targeting user and the concrete use case. The seamless interaction aspect allows users to interrupt an existing interaction on one device and seamlessly to continue the same interaction on another device or even to use different modalities on different devices to accomplish the intended interaction step.

The positive effect of complementary modalities and the seamless interaction was experienced, for instance, in the project *ibi* [2] [HTSC15, SBS+15, SGMRM15]. The positive experience is remarked as follows: "Users appreciated the possibility to interact with the system using multiple devices. Hence, many users combined these devices, e.g., by starting the dialog on the tablet device and continuing the interaction by using the avatar-based TV output and the speech recognition" [SBS+15, p. 143].

[2] My contributions within the project: project management, system architecture design, model-based user interaction design, backend and fronted development, reporting

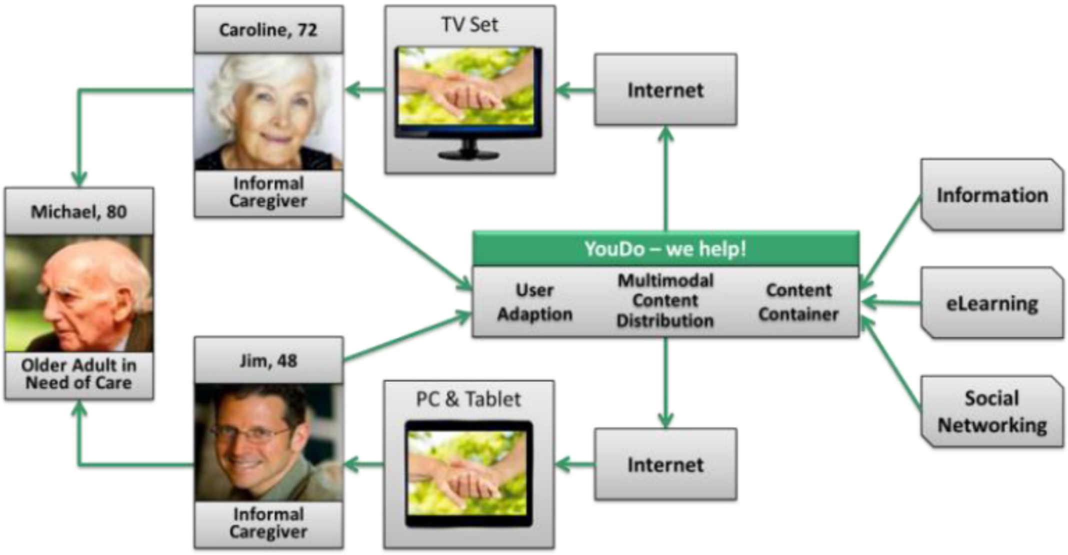


Figure 2.4: **YouDo** Platform conducted of three main module groups, the content container on the right, the multimodal content distribution in the middle and the user adaption on the left [SBM+15, p. 874].

MApp-IxDO was also utilized in the project *YouDo* [3] [SBM+15]. The goal was the development of a modular, extensible and user adaptable multimodal information and training platform. As depicted in Figure 2.4, the multimodal content distribution module represented the key component in the *YouDo* platform. Together with the distributed system architecture this module was responsible for the cross-device system interaction which reflects the main characteristic of the MApp-IxDO. In this context, multimodality was also used to increase the accessibility for the end users. Figure 2.4 illustrates the scenario based on two different end users, both informal caregivers but of different age. The persona Caroline, 72 years old, preferred the TV set as the main interaction device. Contrary to this persona, the persona Jim, 48 years old, preferred the PC or the tablet device as the main interaction device. MApp-IxDO was able to address both needs by offering an interactive system that supported both informal caregivers on their proffered interaction device.

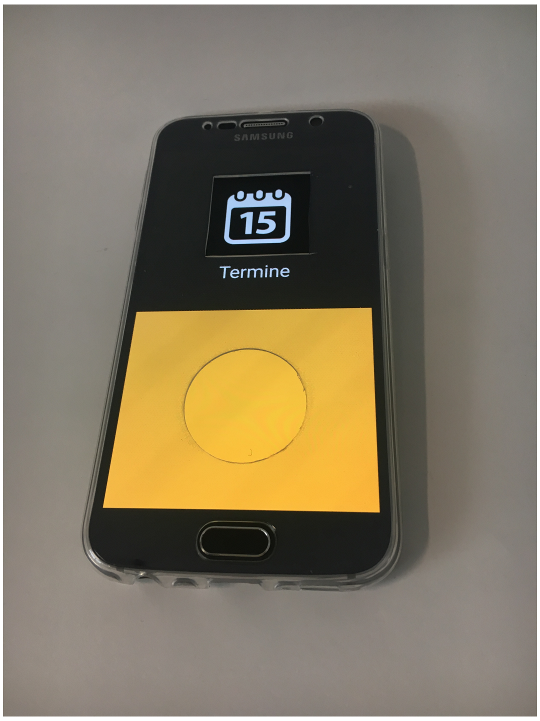
2.2.3 User Group Tailored Interaction Design Opportunity (UGT-IxDO)

UGT-IxDO focuses on optimization of traditional and eHCI techniques. The primary goal is to fulfill users' wishes and meet their needs by increasing accessibility and usability. The former is related to aspects that provide equivalent user experience for people with

[3] My contributions within the project: project management, system architecture design, testing and user involvement, reporting

disabilities, including people with age-related impairments and the latter is related to the design process towards effective, efficient, and satisfying products (see also Section 2.1.6). UGT-IxDO utilizes App-IxDO or MApp-IxDO and modifies either existing interaction techniques or generates new interaction techniques according users' needs. The main characteristic of UGT-IxDO is that tailoring process takes place during the design time, considering the anticipated use, and not during the operational and rendering time. Schmidt describes this as follows: "When designing a conventional information appliance the context of use is taken into account at design time. Assumptions about potential users and usage scenarios are made in the design process. Based on this analysis the user interface is created to support the anticipated use in an optimal way" [Sch05, p. 168].

Thus, UGT-IxDO relays on a deep understanding of the targeting user group in beforehand since this information is main driving force for the design and tailoring process.



(a) *ION4II* prototype highlighting the combination of haptic smartphone case and the rendered GUI [oTG18, p. 3].

(b) *ION4II* prototype highlighting the haptic smartphone case that supports the fining of touch-sensitive GUI elements [oTG18, p. 3].

Figure 2.5: The *ION4II* prototype rendered on an Android smartphone for the target group of visual impaired and blind people.

In our AAL field of practice, UGT-IxDO was utilized in the project *ION4II* [4] [SGM17]. The aim of the project was to develop an assistive system for visually impaired or blind

[4] My contributions within the project: project management, Android frontend development, system architecture design, service integration, reporting

older adults living in a care and residential facility. The developed interactive system offered next to the indoor and outdoor navigation also several assistive services such as the daily meal plan reminder or the user specific appointment management. Figure 2.5 illustrates the final prototype that was tested during the period of eight weeks in the care and residential facility. The depicted prototype demonstrates the characteristics of UGT-IxDO.

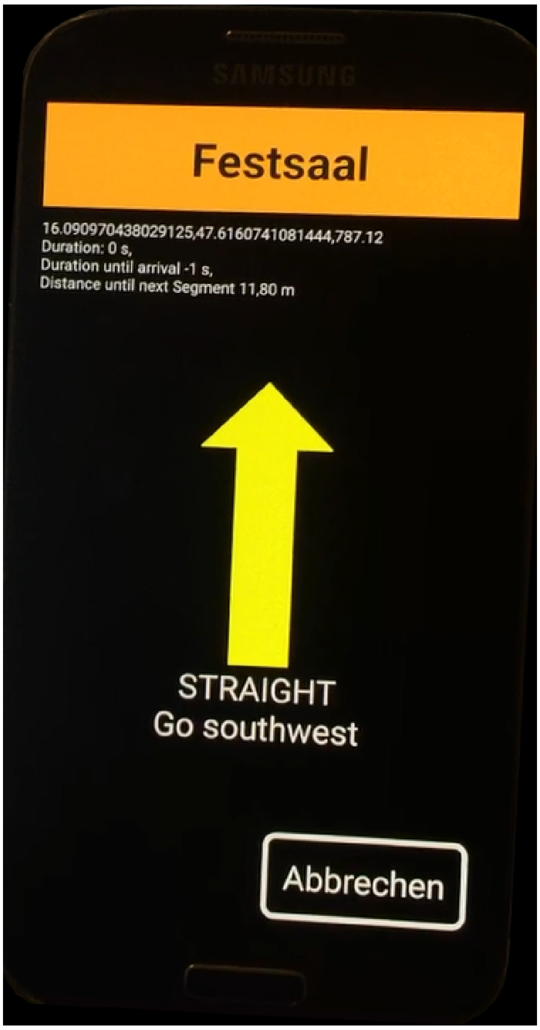
The prototype utilized an App-IxDO (a classical smartphone application) and modified the preexisting interaction technique (the graphical and touch-based UI) towards user needs. The tailoring process was conducted by the functionality reduction and by the provision of the tactile feedback for visual impaired and blind people. Figure 2.6 illustrates the software tailoring results of the *ION4II* prototype. Figure 2.6a depicts the original and plain GUI-based indoor-navigation software and Figure 2.6b the tailored, simplified, high contrasted and speech output modality-supported version of the indoor navigation.

The *ION4II* prototype underlines that the IxD process is not limited only to the tailoring process of software and digital interaction patterns. Within this project, a significant amount of design efforts have been spent on the investigation of users' tactile perception, capabilities to distinct different shapes and the finale tactile hardware design as illustrated in Figure 2.5.

The project outlines the need for a deep understanding of targeting user needs. The solution was developed with a strong involvement of end users clarifying their problems, wishes and needs. From a more general point of view, UGT-IxDO represents the preliminary stage of personalization and the Adaptive Interaction Design Opportunity (Adaptive-IxDO) which will be described in the following Section 2.2.4 in more details. This preliminary status is justified by the fact that UGT-IxDO aims to fulfill users' wishes and meet their needs, but it does not act on the individual user level nor does the adaption takes place during the operational and rendering time and thus the system cannot act accordantly on changing conditions and external circumstances.

However, even if the tailoring process takes place during the design time and not during the operational and rendering time, interaction elements designed for the UGT-IxDO can also be combined with an adaptive system as introduced in this work [MZG+16]. In this study a comparison of three systems for the design of flexible user interfaces is presented. The Universal Remote Console (URC) and Global Public Inclusive Infrastructure (GPII) approach described in this work utilize the concept of UGT-IxDO to design so called "pluggable user interfaces" which are stored on a resource server. During the operational time, as the target end user and his or her needs are identified, the corresponding pluggable user interface is selected and presented to the user. In this setting, the design process of pluggable UIs utilizes the concept of the UGT-IxDO since each pre-designed UI targets not only one but rather a group of users.

(a) Original GUI of the preexisting indoor navigation solution [SGM17, p. 392].



(b) The target group tailored GUI of the indoor navigation [SGM17, p. 392].

Figure 2.6: The software tailoring process within the project *ION4II* highlighting the preexisting indoor navigation and the target group tailored representation

2.2.4 Adaptive-IxDO

Adaptive-IxDO has an analogy to the UGT-IxDO with the focus on optimization of traditional and eHCI techniques. In contrary to the UGT-IxDO, the Adaptive-IxDO can act on users' individual level and reacts timely since the adaption process takes place during the operational and rendering time. From this point of view, the Adaptive-IxDO can be used for personalization purposes as indicated by the following statement: "personalization aims to adapt a system (the adaption process) according to concrete decisions (adaption decision) that are influenced by users' wishes, needs, requirements and external circumstances (the acquisition and preprocessing of applicable information)" [SGM+16, p. 201].

These personalization steps are also used in CAS. Matthias Baldauf defines in his work "A survey on context-aware systems" CAS as follows: "context-aware systems are able to adapt their operations to the current context without explicit user intervention and thus aim at increasing usability and effectiveness by taking environmental context into account" [BDR07, p. 263]. This definition highlights the close relation between CAS and adaptive systems. Moreover, it highlights that there is almost no difference regarding personalization steps, except the stronger focus on the environmental context in CAS. However, adaptive systems are, in a broader view, not limited to environmental context. They can also react on other contextual information, e.g., to the spatio-temporal context, the personal context, the social context, or even the task context [BM07, AK12].

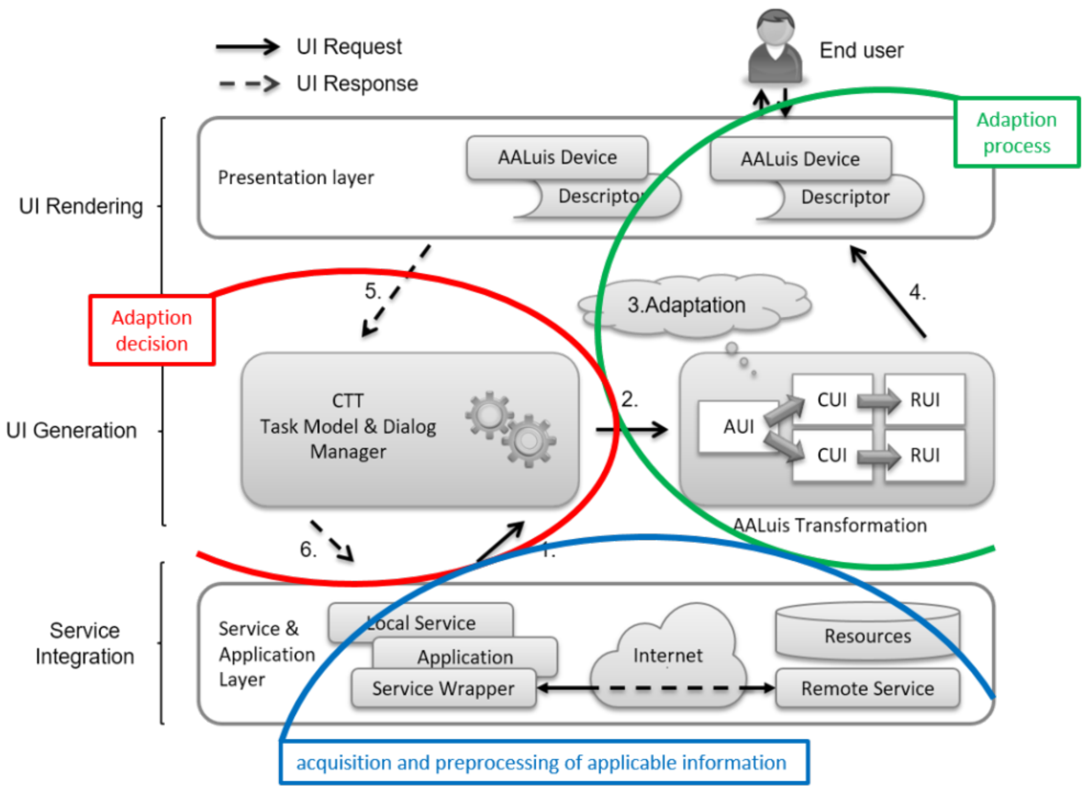


Figure 2.7: UI generation process of the *AALuis* framework illustrating the personalization steps of (a) acquisition and preprocessing of applicable information at the bottom in blue, (b) the adaption decision on the left in red, and (c) the adaption process on the right side in green [MZG+16, p. 131].

In our AAL field of practice, Adaptive-IxDO was firstly utilized in the project *AALuis* [5]

[5] My contributions within the project: system architecture co-design, model-based user interaction

[May13b, May13a, MMC+13, SMM+14]. The aim of the project was to develop a middleware UI generation layer that can automatically adapt the user interface according users' wishes and needs. The prototype addressed all three previously described personalization aspects. One of the key factors in Adaptive-IxDO is that adaptive systems require an explicit interaction model. These abstract models serve as basis for the runtime development of the final UI that is presented to the end user.

Figure 2.7 illustrates the adaptive UI generation process of the *AALuis* framework including the mentioned personalization steps emphasized by the colored circle segments. As one can see, the work flow begins at the bottom in the "service and application layer". This layer represents the business logic in the conventional application design paradigm. Moreover, in the *AALuis* framework this layer is responsible for the personalization steps, namely the acquisition and preprocessing of applicable information. The UI generation layer, located in the middle part of the illustration, is responsible for the adaption decision (on the left) using the explicit interaction model (Concur Task Trees (CTT) Model & Dialog Manager) and partly for the adaption process (on the right) that generates the final user interface using a three-step approach (starting from an abstract UI, over a concrete UI towards the final renderable UI). Finally, the presentation layer on the top of the illustration is responsible for the second part of the adaption process addressing different Input/Output (IO) devices in order to serve different interaction modalities. More technical details regarding interaction models and adaption steps can be found in following works [MZG+16, MMC+13, PWJ16, SMM+14].

In respect to this section about the Adaptive-IxDO, it needs to be mentioned that the presented technological concepts are not exclusively reserved for one particular IxDO but rather can be used in several IxDO. If we consider, for instance, the previously mentioned prototype developed in the project *ibi*. This prototype was used as the stereotypic example for the MApp-IxDO. In fact, the *ibi* prototype used also an interaction model that served as basis for the generation of concrete user interfaces. However, the focus in the project *ibi* was not on the automatic adaption according single user needs but rather on the multimodal interaction type, as described earlier in this section. Regarding interaction models, a detailed comparison between the two applied interaction models in the *AALuis* and *ibi* project can be found in these works [SGMRM15, SMP16]. The works highlight the advantages of interaction models, but at the same time they highlight also disadvantages of explicit interaction models and presents a possible approach to alleviate these disadvantages.

2.2.5 Ambient Intelligence Interaction Design Opportunity (AmI-IxDO)

AmI-IxDO focuses on interactions that are supported by, and embedded in, digital equipped environmental settings. As indicated by Juan Carlos Augusto Wrede, AmI is a concept that refers to a digital environment that pro-actively, but sensibly, supports

design, CTT interpreter engine, service integration, reporting, testing people in their daily lives [AM07]. From this point of view, AmI-IxDO represents a specialization of the previously mentioned Adaptive-IxDO, with the stronger focus on the environmental setting. The importance of contextual information in AmI systems is also highlighted by Albrecht Schmidt as follows: "Context and context-awareness are central issues to ambient intelligence. The availability of context and the use of context in interactive applications offer new possibilities to tailor applications and systems on-the-fly to the current situation" [Sch05, p. 160]. The "on-the-fly" adjustment according the current situation is also a central element in the Adaptive-IxDO. AmI-IxDO goes a step further and utilizes the Adaptive-IxDO in digital equipped environmental settings.

One remarkable work that addresses AmI-IxDO was presented by Norbert Streitz in the paper "Situated Interaction with Ambient Information: Facilitating Awareness and Communication in Ubiquitous Work Environments" [SRP+03]. The paper introduces an approach as well as examples of the AmI-IxDO realization for situated interaction in the context of future work environments. The work highlights how AmI can be used to provide context-dependent information based on the user's position and its distance to the interaction device. The work introduces three different interaction zones, namely (a) the interactive zone directly in front of the interaction device, (b) the notification zone, near by the interaction device, and (c) the ambient zone, outside the range of the interaction device.

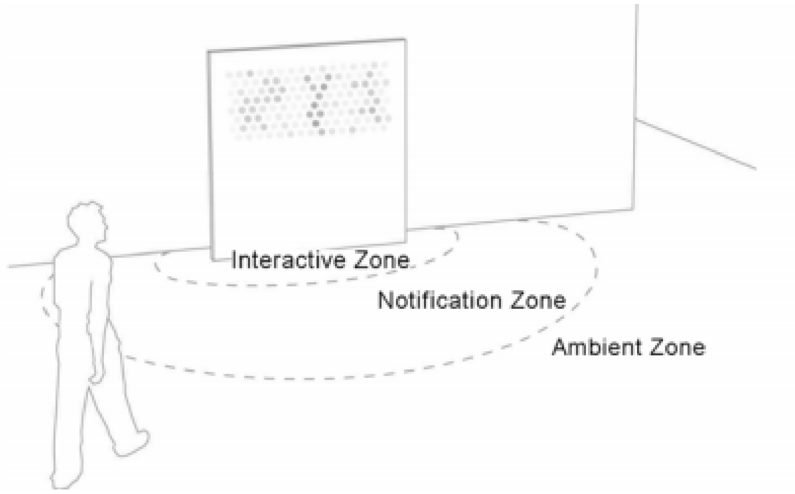
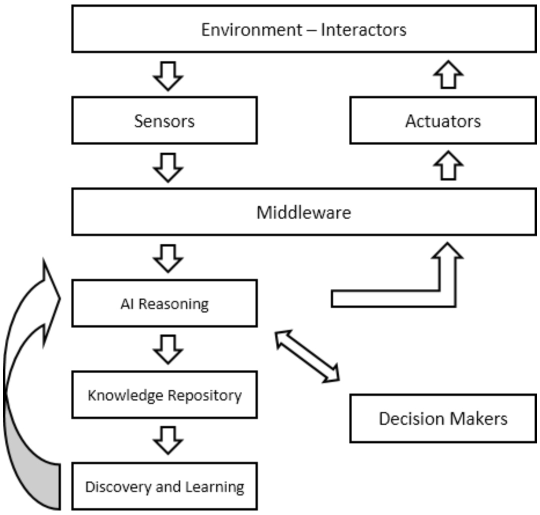


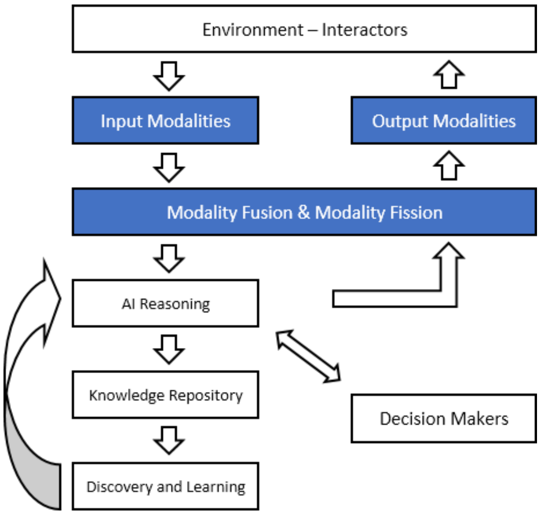
Figure 2.8: Three zones of interactions utilizing users' distance relatively to the interaction device in order to provide different kind of information [SRP+03, p. 3].

This example illustrates that AmI-environments utilize not only interaction devices but also devices (such as sensors and actuators) to provide context-awareness that is can be used to provide situated interactions.

In our AAL field of practice we have been confronted with AmI setting in several projects. This lead to the development of a cross-project platform *HOMER* [FMH+10] that implements the core components of an AmI system. Figure 2.9a depicts these core components based on a general AmI architecture [AM07]. As one can see, the central middleware element, aggregates and harmonizes sensor data and delegates actions towards different actuators installed in the environmental setting.



(a) General AmI system architecture and the flow of information [AM07, p. 10].



(b) The modification AmI interaction architecture with the focus on modality fusion and fission.

Figure 2.9: General AmI system architecture and the flow of information and the modification AmI interaction architecture.

The *HOMER* platform is capable to cover all relevant components of an AmI system architecture as illustrated in Figure 2.9a. Some parts, such as the intercommunication with environmental sensors and actuators, a basic reasoning and the decision maker represent core components of the *HOMER* system. Advanced components such as the Artificial Intelligence (AI) reasoning, the knowledge repository or the discovery and learning module are either embedded modularly or integrated using cloud and network services.

However, the system architecture, as depicted in Figure 2.9a, considers sensor data reasoning and actuator control, but it neglects the user-system interaction which is crucial for the AmI-IxDO. However, the interaction flow reflects the presented flow of information within an AmI system. Thus, the architecture can also be applied on modality handling as depicted in Figure 2.9b. In this concept sensors and actuators have been replaced by input and output interaction modalities. The middleware layer was enriched by an additional task, namely the fusion and fission of modalities. The other components remain the same, except that they now also support the interaction data which is provided by the used input and output modalities.

Figure 2.10: The idea of the project *RelaxedCare* illustrating an AmI environment at the person in need of care (upper part of the image) and various communication and interaction channels providing information for informal caregivers about the overall well-being status of the person in need of care [MDK+16, p. 385].

In our AAL field of practice, AmI-IxDO was utilized in the project *RelaxedCare* [6] [Mor16, MDK+16]. The aim of the project was to develop a solution for informal caregiver which can reduce the necessity of regularly checking the status of a bellowed person, in need of care, living at home. Figure 2.10 illustrates the basic idea of the project. As one can see, the solution includes an AmI environment installed in the living environment of the person in need of care (upper part of the figure) and various interaction devices such as a smartphone, picture frame, ambient light lamp (bottom part of the figure) installed and usable at both sides, in the living environment of the

[6] My contributions within the project: system architecture design, backend co-development, reporting

person in need of care as well as in the living environment of the informal caregiver. The figure illustrates the need for the mentioned middleware layer in order to merge sensor data and to control actuators on the person in need of care's side but also the need for modality fusion and fission for the coordination of the illustrated interaction devices and their modalities.

2.2.6 Personal Assisted Interaction Design Opportunity (PA-IxDO)

PA-IxDO focuses on the design of computer generated personal assistants, or at least on designs that imitate the presence of such an assistant. The personal assistant requires two main characteristics, namely (a) it needs to provide timely, direct, and personalized support for the targeting user, and (b) it requires a representation of an independent and personal entity. PA-IxDO encourages a level of personality that can be unique named and that people can become familiar with. Especially this characteristic, namely the aim to establish a trustful relationship with the user, shapes the PA-IxDO and differs it from others, previously mentioned, IxDO.

Personal assistance systems are very versatile, they can range from small, single-task oriented systems (e.g., an personal appointment remainder) to very broad and complex systems, capable to fulfill multiple and independent tasks such as modern assistant systems such as the Google Assistant, Amazon's Alexa, or Apple's Siri. However, all these systems have one in common, they can be identified as a unique entity. Some of them caries the perception of a unique entity on the cognitive level, e.g., by aspects like "my assistant knows what I need at a certain situation" and some utilize meta-level elements such as the voice, the assistance's appearance to provide the perception of a unique entity. The ideal solution represents the combination of both levels.

In our AAL field of practice, PA-IxDO was utilized in the project *CogniWin* [7] [Por16, Han15]. The aim of the project was to develop an integrated framework which provides personalized support to overcome eventual age-related memory degradation and gradual decrease of other cognitive capabilities. The solution assists users to increase their learning abilities by using an innovative cognitive-based user model, embracing various cognitive characteristics. Moreover, *CogniWin* provides to older adults personalized tips to avoid unwanted age-related health situations at their work using an intelligent computer mouse and an eye tracking device. Figure 2.11 illustrates the overall architecture of the prototype with the hardware layer at the bottom, the higher software layer in the middle and the UI layer at the top. Figure 2.11 highlights that PA-IxDO relies on the interplay of various components and software modules. The project *CogniWin* carried the perception of a unique entity on the cognitive level. Especially the components "well-being advisor" and "personal learning assistant" address this goal.

The PA-IxDO was also utilized in the mentioned project *ibi* [SGMRM15, SBS$^+$15, HTSC15]. The independent entity was realized as an avatar, an audio-visual representation of a virtual 3D character. Figure 2.12 illustrates the end user frontend of the

[7] My contributions within the project: project support, system architecture co-design, testing, reporting

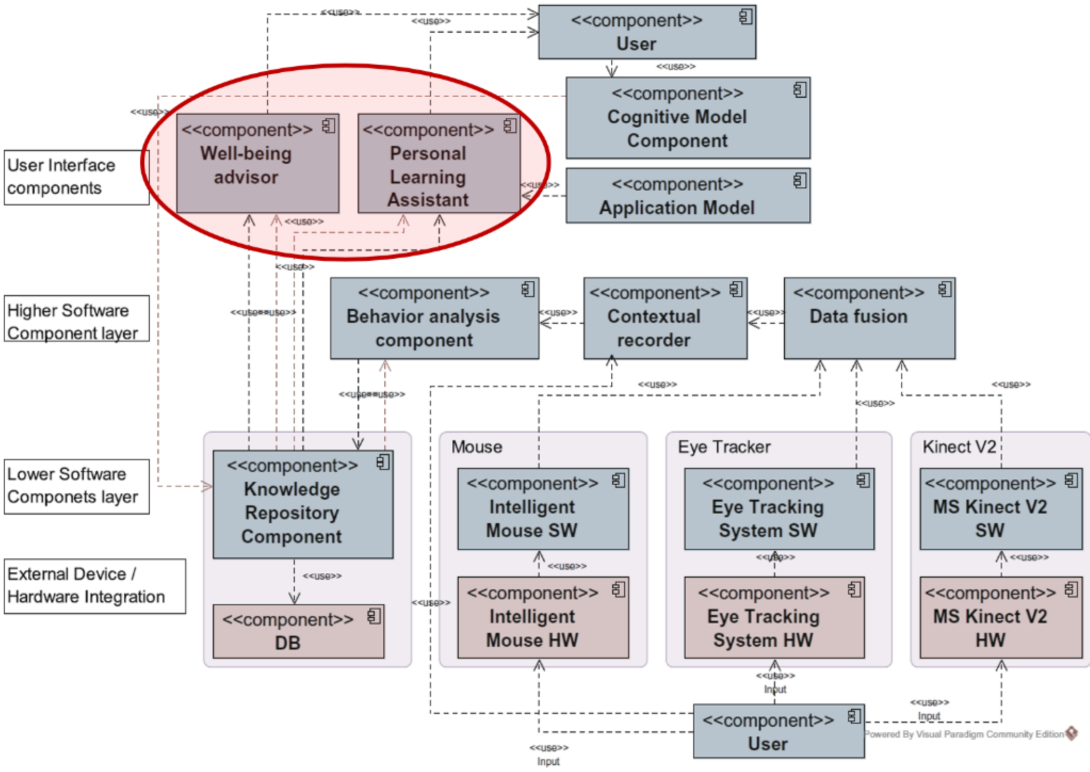


Figure 2.11: The overall *CogniWin* architecture highlighting two components that characterize the solution as PA-IxDO [Han15, p. 260].

ibi solution. In contrary to the project *CogniWin*, the *ibi* prototype was developed as a lightweight solution serving just a few static user services such as messaging service, personal reminder, and time scheduler. Thus, the architecture is simplified and does not incorporate high level software components compared to the *CogniWin* solution. For instance, the "behavior analysis component" or the "cognitive model component" was not used in the *ibi* solution. The project carried the perception of a unique entity via the mentioned meta-level, the avatar representation.

2.2.7 Companion Interaction Design Opportunity (Companion-IxDO)

Companion-IxDO utilizes PA-IxDO techniques and enhances the previously mentioned independent entity towards a so-called companion. The primary focus is on designing virtual beings, able to support the user but also able to bear company to the user. A complex Companion-IxDO requires a certain amount of AI skills to interpret the current situation, to weight up the need to start a user dialog and to utilize the right interaction channels and interaction mediums. Companion-IxDO employs activating and pleasant core affects such as curiosity, eagerness, desire, joyfulness, satisfaction to engage the user with the system, and to establish a kind of companionship with the user.

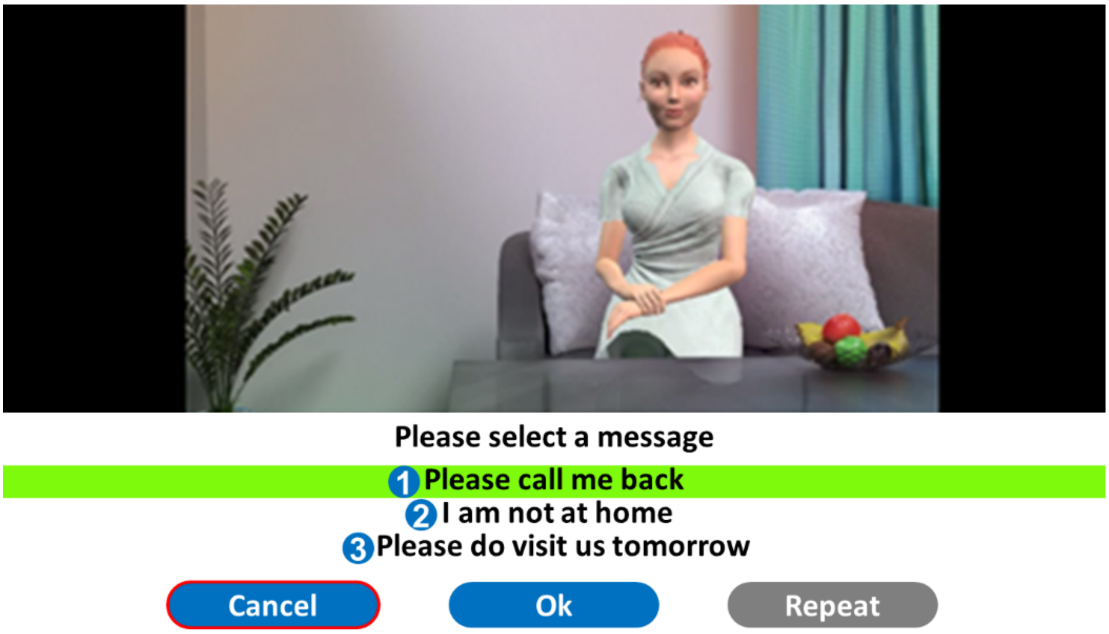


Figure 2.12: The *ibi* frontend representing a personal assistant which was visualized on a tabled device as well as on the TV [HTSC15, p. 78].

In our AAL field of practice, Companion-IxDO was utilized in the project *CompanionAble* [RPG10, Bad09]. The aim of the project was to provide a new AAL solution through the combination of a service robot that is perceived as a companion and that is seamlessly integrated into the smart home environment. Figure 2.13 illustrates the final prototype of the project *CompanionAble* interacting with the user.

Figure 2.13: User interacting with the *CompanionAble* prototype robot [dR18, p. 1].

The public project delivery D9.2 Evaluation Trial Results of the Integrated *CompanionAble* Prototype [Bad12] emphasizes that the final set of user trials has provided a valuable usability information for the *CompanionAble* Consortium. Moreover, they had a positive input and people indicated that they got used to such a thing the home that drives around. They unconsciously started talking to the robot almost like to a human or pet. During the trials researches observed that people attribute human characteristics to the robot very quickly, even when things went wrong. The participants described this misbehavior using words like "it's not his day", "he is not in the mood", or "that is not really friendly, is it. . . ".

Other research groups have been working on similar projects with the aim to support older adults in their daily life. The *SocialRobot* [PSA+15], for instance, involves a practice-oriented home care mobile robot platform that targets people with light physical or cognitive disabilities who can find pleasure and relief in getting help or stimulation to carry out their daily routine.

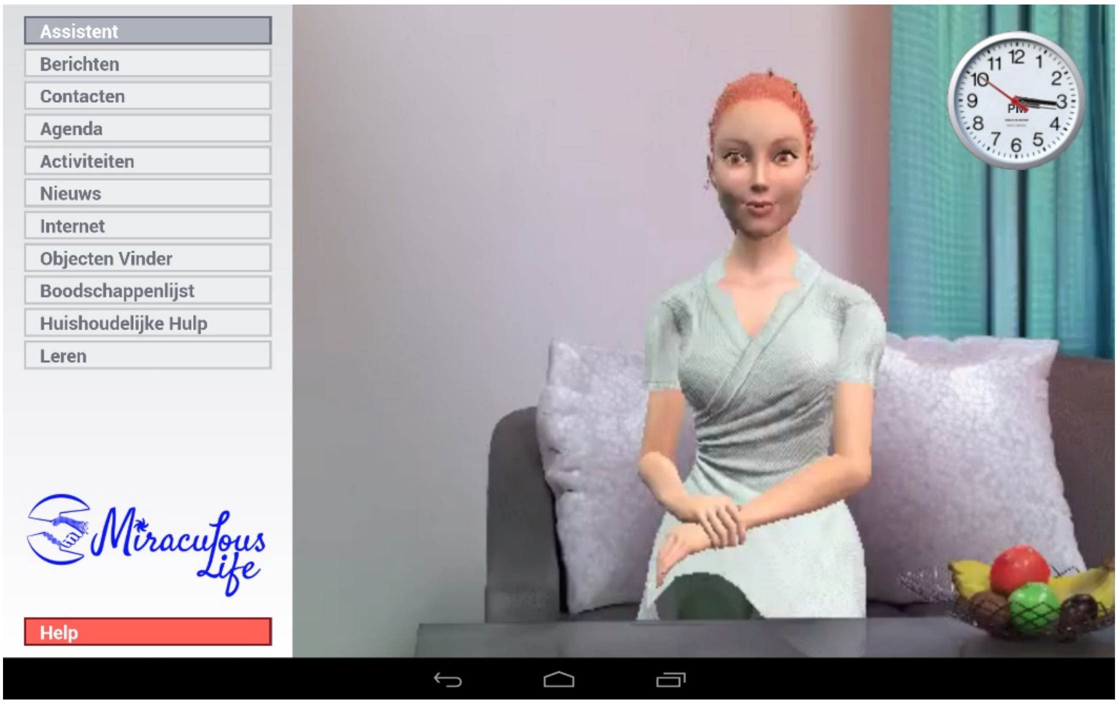


Figure 2.14: The end user frontend of the *Miraculous-Life* prototype illustrating the avatar named Mary on an Android tablet device [HSKSH16, p. 7].

The daily life support was also the objective of the project *Miraculous-Life* [8] [SBS+15, HSSH+15, HSKSH16, CKC+15]. However, instead of physical robot, the project utilized a virtual avatar as the embodied conversational agent. Figure 2.14 illustrates the end user frontend of the *Miraculous-Life* prototype rendered on an Android tabled device. The

[8] My contributions within the project: service integration, frontend co-development, reporting

avatar was able to interact with the user via speech recognition and also able to represent emotions via mouth movements, eye movements, head movements, hand gestures, facial expressions, and body posture.

Similar approach was used in the project *DALIA* [Kol17, Afaw18b]. The aim was also to build a solution which can assistant older adults in their daily life activities at home. It was designed to run on Android based consumer devices (TV, phone, tablet). The end user frontend was realized utilizing a virtual avatar, able to interact with the user via speech recognition. These projects illustrate very well that Companion-IxDO can be realized in various ways. While the first two projects (*CompanionAble* and *SocialRobot*) utilize physical robots as user's companion, the projects *DALIA* and the *Miraculous-Life* back on virtual avatars or Embodied Conversational Agents (ECAs) as user's companion. The *DALIA* project was a part of this work [TQBM^{+}16] that provides a comprehensive overview and a comparison between five projects utilizing ECAs for older adults.

So far, I have been involved in seven national and European funded research projects utilizing avatars as embodied conversational agents [HTSC15, Con18b, Afaw18e, Afaw18d, Afaw18a]. One of the main outputs of these projects was that naturalness of the avatar is one of the key factors for users regarding the acceptance of a virtual companion. As highlighted in my Work "Avatars 4 All – An Avatar Generation Toolchain" [SBMM16] our perception about what is natural, life-like, and anthropomorphic is influenced by various aspects, e.g., the natural body movement, the natural rhythm, and tone of voice or even the natural sensing and reproduction of moods, emotions, and personality. We have been implemented several fragments of these aspects to satisfy users' requirements towards a more affective interaction. Figure 2.15 and Figure 2.16 illustrate these first steps towards a more natural appearing avatar in Companion-IxDO, but it needs to be mentioned that future research and work in this field still need to be done.

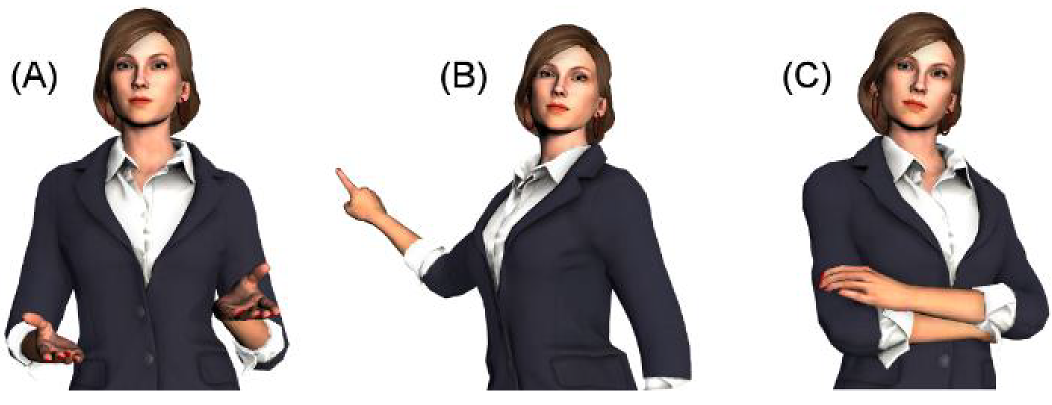


Figure 2.15: Illustration of three different poses (asking (A), pointing (B) and the idle position (C)) used in the Avatar Generation Tool-chain (AGT), developed by the AIT [SBMM16, p. 260].

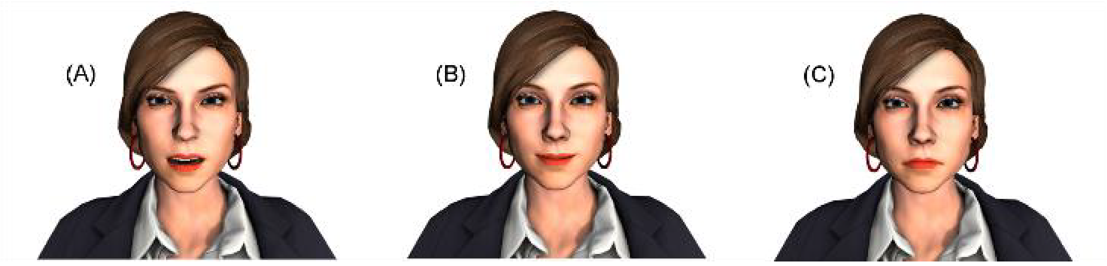


Figure 2.16: Illustration of three different moods (angry (A), happy (B) and sad (C)) used in the Avatar Generation Tool-chain (AGT), developed by the AIT [SBMM16, p. 260].

2.2.8 Tangible Interaction Design Opportunity (Tangible-IxDO)

Tangible-IxDO focuses on designing interactions that use physical and graspable components as the main interaction medium. As noted in [IU97, Ish08] tangible user interfaces provide physical form to digital information and computation, facilitating the direct manipulation of bits. Since Tangible-IxDO aims to connect digital data with the physical world, designers are requested to consider following three areas: (a) the existing UX regarding the non-digital physical object, (b) the intended UX regarding the new, digital-connected physical object, and finally (c) the technological possibilities and limitations regarding the connection process of the physical object with the digital data.

The existing UX regarding the non-digital physical object is the first crucial step since users need a basic meaning about the function or the intention about the non-digital physical object. The second step, the intended UX of the new, digital-connected physical object, targets the transformation of the existing UX into a new jet non-existing UX. The overall goal of the new digital-connected physical object is to provide a meaningful interaction pattern for the user utilizing his or her existing UX. The third step, the consideration of technological possibilities and limitations is an engineering oriented task. Designers are requested to form a vision about the hardware- and software-based inclusion of the new digital-connected, physical artifact into the interaction routines.

In our AAL field of practice, Tangible-IxDO is utilized in the ongoing project *KithNKin* [KDSH17, Afaw18c, Con18a]. The project tackles the problem of the progressive social isolation of older adults living alone and in far distance from their family members. It aims to foster the communication and interaction with family members and friends utilizing well-known communication and interaction patterns. *KithNKin* utilizes tangible objects which extend interaction capabilities of a standard tablet device. Figure 2.17 illustrates the concept and the first prototype of the project *KithNKin*. The system offers communication, picture sharing, and gaming services using tangible objects.

Tangible objects have also been used in an internal project which was development by the AIT. The project named *Fotokiste* [9] offered a photo sharing service on a multi-touch

[9] My contributions within the project: backend co-development, frontend testing, reporting

Figure 2.17: *KithNKin* prototype illustrating a standard tablet and a hardware platform for the tangible interaction [Con18a].

table using tangible objects. The prototype was installed and tested for a period of four months in the care center Gutenstein located in lower Austria [uL18]. The aim was to increase the social inclusion of care center residentials and their relatives and friends via the picture sharing service. Relatives or friends could use the system to upload their social media pictures and care center residents could use their private tangible object (shaped as a personal punch) to retrieve, view, and react on the shared pictures. Figure 2.18 illustrates the setting with the tangible object (red punch) that triggers the visualization of personally shared pictures. The tangible object was used as a private user key so that all pictures of a corresponding user disappeared once the punch was removed from the table. Evaluation results of the prototype have been published as a master thesis with the title "Evaluierung der Verwendung des Multitouch-Tisches nach einer 4-monatigen Anwendung im NÖ LPH Gutenstein beim Projekt FotoKiste des AIT Austrian Institute of Technology" written by Sandra Fischer and Petra Muck in the year 2014.

Figure 2.18: The "Fotokiste" prototype illustrating a tangible object shaped as a red punch that triggers the visualization of privately shared pictures.

2.3 User Experience in Product Design

As already pointed out in Section 2.1.8, UX plays an essential role in the IxD process. Moreover, UX and especially UxD encase IxD. This becomes very clear by viewing the disciplines of UxD as depicted in Figure 2.19 which was published by the Envis Precisely GmbH i.L. [i.L18]. In this figure one can see that UxD encase the IxD and that the UxD conducts variety of disciplines.

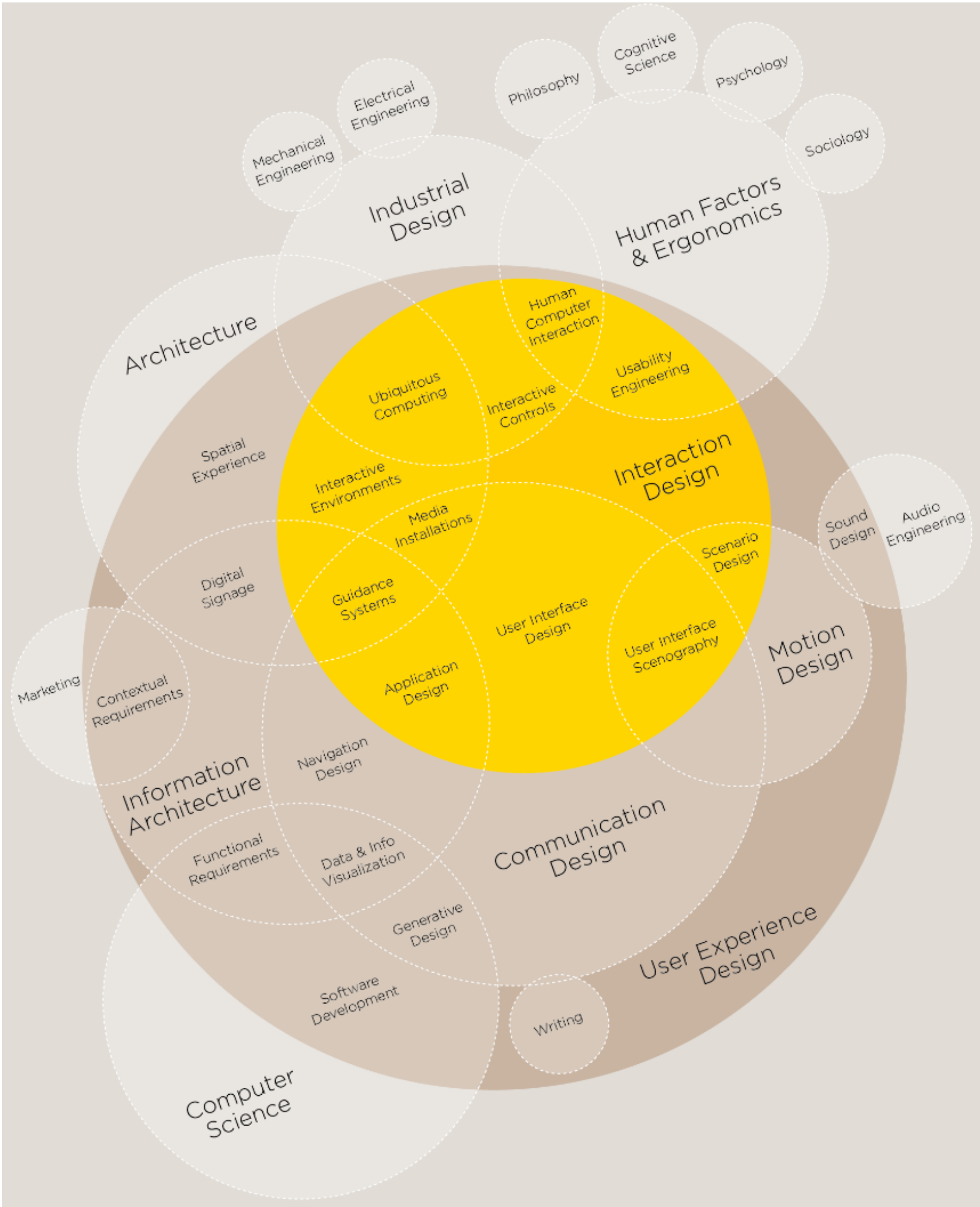


Figure 2.19: The disciplines of UxD [i.L18, p. 1].

However, since this work follows the concept that UX is seen as something desirable as mentioned in Section 2.1.8, the literature review does not focus on various disciplines and does not aim the identification of UX aspects within these disciplines but rather on aspects able to describe the term "desirable" in a more general manner and thus making it more graspable for the IxD.

2.3.1 Quality of Experience

An argumentative and integrative literature review in regarding desirable UX aspects leads to the work of Lauralee Alben with the title "Defining the criteria for effective interaction design" [Alb96]. As already mentioned in the introduction section, the work lists eight criteria that influence the quality of user experience. Here again, the term "quality" is not used as a measurement instrument but rather as an epitome for successful and satisfying experience. Figure 2.20 illustrates the eight criteria. The following section highlights key aspects of these criteria.

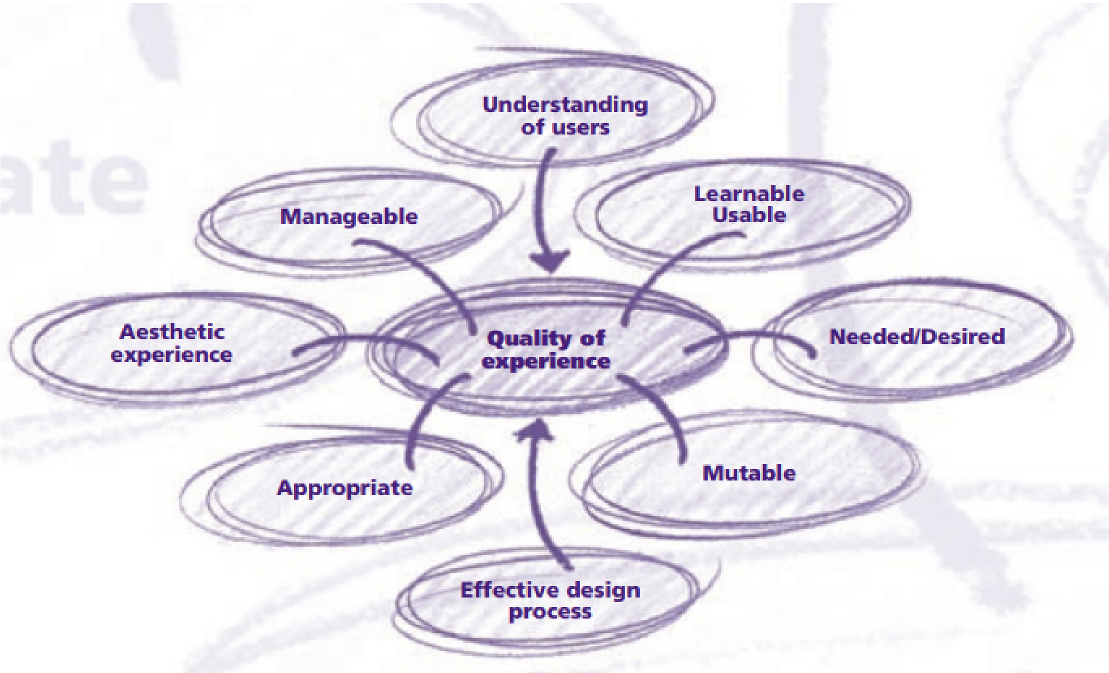


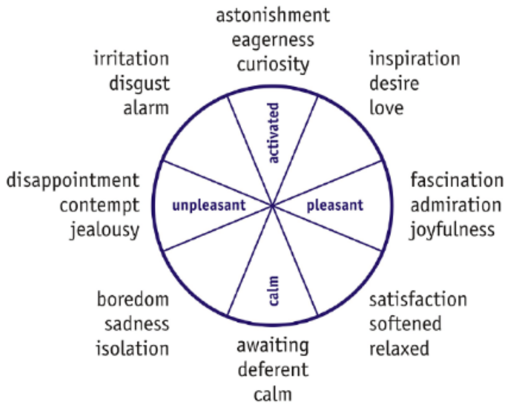
Figure 2.20: Eight criteria that influence the quality of experience [Alb96, p. 12].

- Understanding of users: This criterion focuses on the understanding of user needs, tasks and environments of users for whom the product will be designed.
- Learnable & Usable: This criterion addresses usability attributes, but it also focuses on the question if the product communicates a sense of its purpose. The goal is to provide self-evident and self-revealing products that support different ways people will approach and use it.

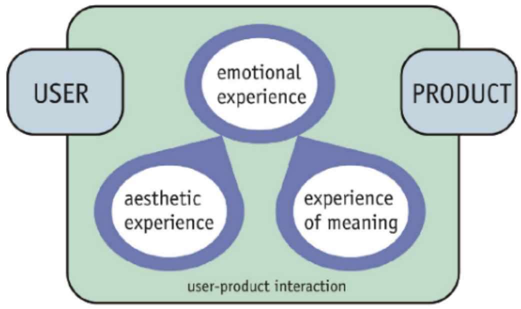
- Need & Desired: This criterion targets the identification of user needs and user desires. On a broader level, this criterion also questions the valuable contribution of the product for the user in respect to social, economic, and environmental inclusion.
- Mutable: This criterion focuses on particular needs and preferences of individuals and groups. Moreover, the criterion addresses also the ability of the product to change and to evolve on changing conditions.
- Effective design process: This criterion focuses on the design process, applied methodology, and the user involvement into the design process.
- Appropriate: This criterion questions if product can solve the right problem on the right level. Additionally, the criterion addresses efficiency aspects and the practically of the product.
- Aesthetic experience: This criterion focuses on pleasing aspects such as aesthetic-pleasure and sensual satisfaction. This includes also the consistency of spirit and style.
- Manageable: The last criterion addresses the entire context of use and questions if the product can support the user in tasks such as installation, training, maintenance, cost, and supplies. These questions need to be addressed on the individual as well as on the organizational level.

2.3.2 Framework of Product Experience

The previously presented quality of experience focused on aspects of effective interaction design. However, the presented work addresses UX on a meta level. In order to make UX more graspable, it is also necessary focus on the key message of UxD, namely on the desirable aspect. Here again, an argumentative and integrative literature review on desirable aspects in product design (since software and interaction with software is considered as a product, as it was pointed out in Section 2.1.8) leads to the work of Pieter Desmet and Paul Hekkert with the title "Framework of Product Experience" [DH07]. In this work the authors introduce a general framework for product experience that applies to all affective responses that can be experienced in human-product interaction. One of the remarkable parts of the work is the presented concept of "core affect" which is the combination of affect dimension with physiological arousal into a circular two-dimensional model. Figure 2.21a illustrates the circumplex model of core affect with product relevant emotions. This model summarizes very well all desirable aspects in the top, right and left quadrant. Moreover, the model includes also unpleasant core affects in the left quadrant. One could argue that the design of desired products targets the exclusion of these unpleasant affects, but this is not always the designers intention. One can think, for instance, of a task where the designers are asked to design an application that aims the evocation of irritation, e.g., for a horror movie game. The desirable affective responses, for this purpose, would be in this unpleasant quadrant.



(a) Circumplex model of core affects [DH07, p. 58].



(b) The framework of product experience [DH07, p. 60].

Figure 2.21: Circumplex model of core affects and the framework of product experience [DH07].

However, the circumplex model summarizes desirable affective responses, but it does not describe how these affects could be intentionally evoked. Later on in their work, Desmet and Hekkert present the framework of product experience which is conducted of three distinguish components, namely (a) aesthetic pleasure, (b) attribution of meaning, and (c) emotional response as depicted in Figure 2.21b. The authors describe that on the aesthetic level we consider a product's capacity to delight one or more of sensory modalities. At the level of meaning, cognition comes into play and lead to cognitive processes, like interpretation, memory retrieval, and associations. Through this process we are able to assess the personal or symbolic significance of products. The emotional level, we refer to those affective like love and disgust, fear and desire, pride and despair. Figure 2.21b also illustrates the relationships between these three components. According to this, an aesthetic experience and/or an experience of meaning have the ability to evoke an emotion experience to the user.

This framework targets more the goal of finding general applicable desirable aspects as the previously presented circumplex model. The aesthetic experience and the experience of meaning cause an emotional experience. This emotional experience is no longer bounded to positively associated (desirable) affects but can also cause an intended negatively associated (desirable) affect like in the previously mentioned example of an application design for a horror movie game.

However, even if the framework seems to be very useful for physical products, it has also some limitations when applying on software artifacts in a general manner. For instance, the social context plays a minor role in the presented framework. This aspect, on other hand, is especially for communication-related software artifacts a subject of matter, although the authors emphasize the importance of the social context as follows:

"... In addition, the experience is always influenced by the context (e.g., physical, social, economic) in which the interaction takes place" [DH07, p. 58], Nevertheless, the framework and especially the aesthetic experience and the experience of meaning will contribute to the design of the Model for Identification of Balanced HCI (MIB-HCI) in Section 5.

2.3.3 The Psychology of Decision Making in UX

An interesting approach in the field of UX was presented by Joe Leech in his talk "The psychology of decision making in UX" [Lee15]. In his talk, Joe was referring to two ways of thinking, namely "thinking fast" and "thinking slow" and how to design for those two sets of systems. The concept of two ways of thinking comes from the field of psychology and was introduced by Daniel Kahneman in his work "Thinking, Fast and Slow" [KE11]. Daniel argues that we have two systems in our brain; one that allows us to make decisions quickly, based on emotions and one systems that allows us to make decisions slowly, based on previous experience that allows us to predict what is going to happen. Joe takes up this concept and summarizes the design aspects as the following three-step rule set:

- Design for the slow: Match the mental model
- Design for the fast: Evoke the emotion
- Do first and second

The rule set highlights that our decision-making process is influenced by our mental model, our emotions, and by the designer which is in need to address both aspects in the same manner in order to provide a positive UX. The matching of the mental model is a multi-level process. On the one hand, it is related to aspects such as usability and accessibility including at least four of five usability attributes (learnability, efficiency, memorability, and error tolerance). On the other hand, it is related to the application fields, the workflows, and the interaction styles that are suited for the targeting user. However, the presented three-step rule set underlines that, next to pragmatic attributes, the emotional experience plays a major role for the acceptability of products. This goes along with the previously presented framework of product experience as depicted in Figure 2.21b.

2.3.4 The Kano Model and Approaches for Delightful UX

A second, inspiring presentation on this field was given by Jared Spool in his talk "Building a Winning UX Strategy Using the Kano model" [Spo15]. Jared utilizes the Kano model, as presented in this work [MH98], to highlight some useful design aspects but also to highlight some design failures. According to the Kano model, there are three types of product requirements, namely basic needs, performance needs, and delighters that influence customer satisfaction as depicted in Figure 2.22.

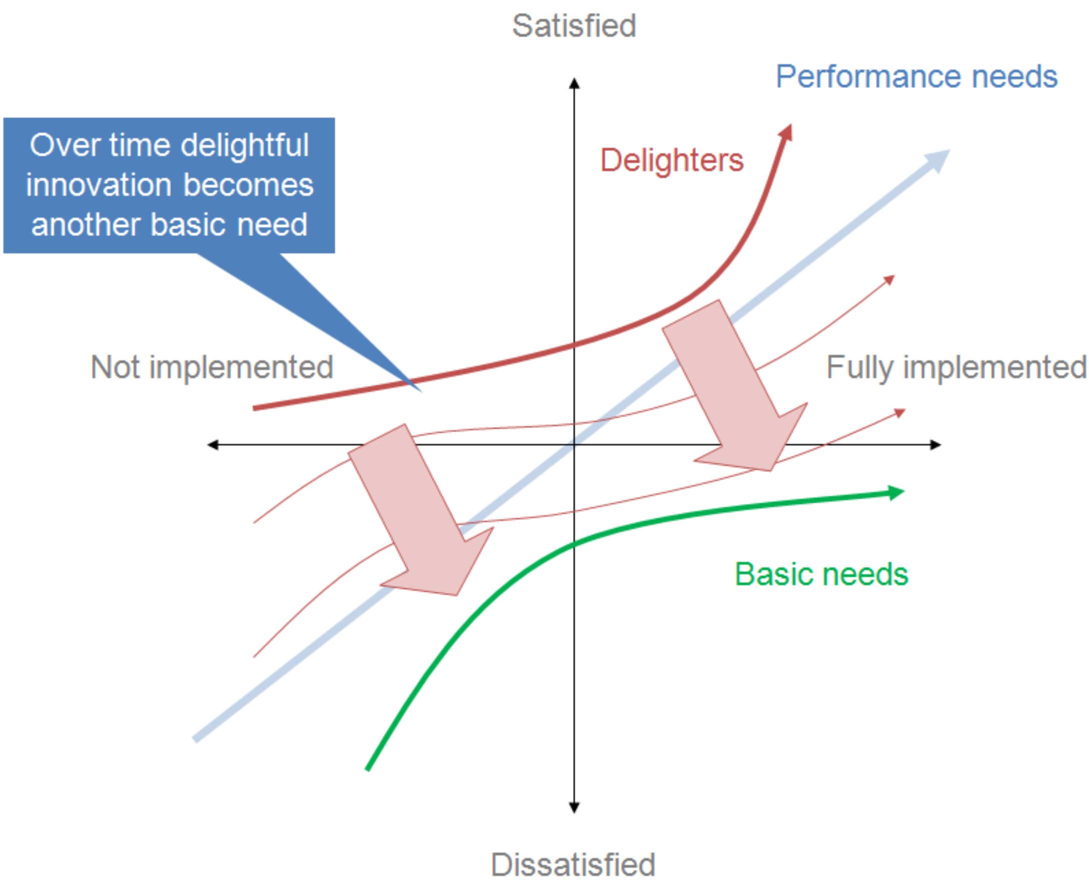


Figure 2.22: Description of how attributes' values change over time in the Kano model [Cra18, p. 1].

James Moultrie summarizes the three types of product requirements of the Kano model as follows [Mou16]:

- Basic needs: "attributes which must be present in order for the product to be successful".
- Performance needs: "... are directly correlated to customer satisfaction. Increased functionality or quality of execution will result in increased customer satisfaction".
- Delighters: "Customers get great satisfaction from a feature - and are willing to pay a price premium. ... these features are often unexpected by customers and they can be difficult to establish as needs up front. ... But, it should be remembered that customer expectations change over time, and a cup holder in a car may be today's delighter, but tomorrow it will be expected" [Mou16, p. 1].

Here again, regarding this work, the interesting product requirements are the delighters. Jared Spool, argues further and based on Dana's Chisnell framework [Chi10] that there are three different approaches for making experience delightful, namely: pleasure (in Dana's model referred as mindfulness), flow, and meaning. Dana describes these approaches as follows:

- "Mindfulness in design is about a pleasing awareness. In relationships, it can mean infatuation. It's knowing that this is good, that this makes me happy. It's satisfying... As the designer, you demonstrate that you have the user in mind and you understand her goals".
- "Flow describes the state that people enter when they are fully focused ... in a task or activity. As the designer, you incorporate psychological cues, language, social cues, and reinforcement to subtly motivate users to keep working or playing longer than they might without those design cues".
- "Meaning comes from a feeling of fellowship, contributing, and making the world a better place. ... As a designer, help users know where they fit in and what their effect is by thinking through exactly what you want the emotional and behavioral effects to be of using your design. You demonstrate intention (in the yogic sense) through clarity, simplicity, funneling, modeling outcomes" [Chi10, p. 1].

If we compare these three aspects with the presented framework of product experience, we can see some parallels. The mindfulness addresses pleasure aspects as the aesthetic experience targets the same goal. The meaning targets in both models the cognitive well-being. And the flow approach in Dana's framework describes in a global manner the positive emotional experience so that users keep using the system for a longer period of time.

2.3.5 The Pragmatic / Hedonic Model

So far, we have seen that the UxD and especially the design of desirable products is driven by two main characteristics, namely (a) the product needs to fulfill user's practicable needs, e.g., match the mental model, provide usability, satisfy basic needs, and (b) the product needs also to fulfill user's impracticable wishes, e.g., to evoke emotional experiences, to delight the user, and to embrace joy. Marc Hassenzahl addresses this two-folded goal in his work "The hedonic/pragmatic model of user experience" [Has07]. Marc argues that the model assumes that people perceive interactive products along two different dimensions, namely (a) the pragmatic dimension that refers to the product's perceived ability to support the achievement of "do-goals", and (b) the hedonic dimension that refers to the product's perceived ability to support the achievement of "be-goals". This correlates with the previously mentioned observation of driving forces in UxD and the design of desirable products. The fulfillment of users' practicable needs represents the pragmatic dimension, the "do-goal" for the product, and the consideration of users' impracticable wishes represent the hedonic dimension, the "be-goals" for the product.

Marc argues further that the model distinguishes three different facets of the hedonic dimension, namely stimulation, identification, and evocation where as the only one facet of the pragmatic dimension remains the manipulations [Has18]. These facets will also be used later and contribute to the design of MIB-HCI in Section 5. However, the remarkable point in Marc's model is that product characters emerge from the specific combination of pragmatic and hedonic attributes. Figure 2.23 illustrates Marc's view of product character.

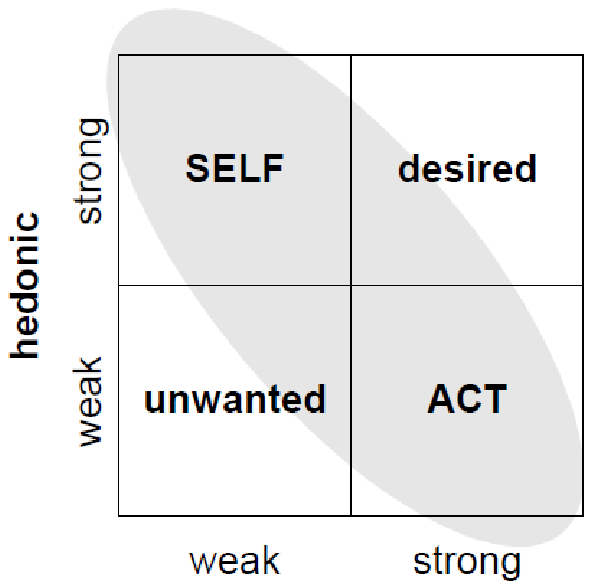


Figure 2.23: Product characters emerging from specific combinations of pragmatic and hedonic attributes [Has18, p. 307].

In his opinion, pragmatic and hedonic attributes are independent of each other and people's perception of pragmatic and hedonic attributes can be either weak or strong. Thus, in Figure 2.23 the hedonic attribute is arranged along the y-axis and the pragmatic attribute is arranged along the x-axis. As argues earlier, both attributes can be perceived as weak or as strong. Marc calls a product with strong pragmatic and weak hedonic attributes as an ACT product. As opposite, a product with strong hedonic and weak pragmatic attributes is named as a SELF product. The ACT product is inextricably linked to its users' behavior goal whereas the SELF product is inextricably linked to users' self, e.g., their ideas, memories, and relationships. Furthermore, he calls a product with weak hedonic and weak pragmatic attributes simply as unwanted and **a product with strong hedonic and strong pragmatic attributes as a product that is**

perceived as desirable by the user.

This is remarkable since this work investigates pleasure-oriented aspects with the aim to establish a long-standing engagement of the user with the offered interactive system. Products that are perceived as desirable contribute definitively to this goal. In summary, the UX literature research identified an additional dimension towards successful products. The well-known and mandatory dimensions **functionality** and **usability** need to be enriched by the dimension **desirability** in order to provide successful products and thus also successful software artifacts. At this point it needs to be mentioned that usability, considering all five usability aspects, already conducts the "engaging" aspect. However, in this work, usability is considered as a basic user need, but the perception of desirability goes a step beyond the satisfaction of basic needs. It delights users, it evokes users' emotional experience, and it embraces joy. This is the targeting goal of this dissertation thesis and this needs to be in a more direct manner.

2.3.6 The Four Types of Pleasure

So far, we have identified several pleasure-oriented aspects (desire, joy, to delight someone, etc.). As mentioned before, the aim of this work is to utilize these pleasure-oriented aspects and to address these aspects in the IxD in a more direct manner. In order to reach this goal, it is necessary to characterize pleasure in an abstract but structural way. There is the need to shift the focus from pleasure manifestations (see core affects in Section 2.3.2) towards a more general approach that characterizes the term "pleasure" base on our intrinsic perception of it.

Patric Jordan provides such an intrinsic perception-based definition of pleasure in his work "Designing Pleasurable Products" [Jor00]. Jordan starts with the definition of the Oxford English Dictionary which follows: "the condition of consciousness or sensation induced by the enjoyment or anticipation of what is felt or viewed as good or desirable" [Jor00, p. 12]. Here again, the phrase "... felt or viewed as good or desirable" [Jor00, p. 12] highlights that the previously mentioned aspects can be classified as pleasurable. However, Jordan argues based on Lionel Tiger's work "The Pursuit of Pleasure" [Tig17] that we experience four conceptually distinct types of pleasure, namely physical, social, psychological, and ideological pleasures.

- Physio-pleasure, related to the body and to pleasures derived from sensory organs. Examples are touch, taste, smell.
- Socio-pleasure, related to the enjoyment derived from the relationships with others. Issues such as status and image may play a role here. Examples are belonging to a social group, jewelery may attract comment,...
- Psycho-pleasure, pertains to people's cognitive and emotional reactions such as cognitive demands of using the product and emotional reactions engaged through experiencing the product.

- Ideo-pleasure, pertains to people's values and pleasures derived from 'theoretical' entities such as books, music and art.

Along other mentioned models, concepts and frameworks, the definition of four pleasure types will also play a role in the design MIB-HCI in Section 5.

CHAPTER 3

Interaction Design Framework

The aim of this work is to provide a conceptual Interaction Design Framework (IxD-FW) that supports UI designers and interaction designers in designing and developing new interactive systems. The focus is not on different application fields but rather on the right selection of the interaction design styles that potentially can establish a long-standing user engagement with offered interactive system. Thus, this work addresses two research areas, namely (a) the user-related research utilizing UX design, interaction design, and product design models, methods, and concepts, and (b) the practice-oriented research building the IxDO-RG that identifies different interaction design styles and Interaction Design Opportunities (IxDOs), respectively.

Figure 3.1 illustrates these two research areas, the user-related research area on the left side and the IxDO-RG, on the right side. Both research areas have an evolutionary character since they have been elaborated by using, combining, modifying, and retesting different concepts, approaches, and models. The user-related research area utilizes literature and theoretical principles originated from the UX, UX design, interaction design, and product design. This research activity targets the design of a dynamic user model that indicates the most beneficial IxDO for the targeting user and the context of use of the intended, to-be-designed interactive system. The IxDO-RG utilizes real design cases from the AAL field of practice. It provides a set of required and optional design aspects that designers may consider during the design process of new systems. The combination of these two research areas builds the final IxD-FW, illustrated as the enclosing blue box in Figure 3.1 that represents the result of this dissertation thesis.

Next to the two research areas, Figure 3.1 illustrates additionally different user roles, namely the targeting user on the left side and the end users on the right side. The targeting user represents the user for whom the interactive system will be designed for. Simplified, this is the user supposed to use the interactive system. End users, on contrary, are UI designers and interaction designers who are supposed to use the IxD-FW in order to design the intended systems for the targeting user.

Since the framework aims to find an optimal solution for the targeting user (located on the left side), this user represents the root of information flow within the IxD-FW as depicted by the horizontal arrows in the Figure 3.1. Starting from the targeting user, a dynamic user model, the Model for Identification of Balanced HCI (MIB-HCI) is generated. This dynamic user model indicates the beneficial and individual IxDO for the targeting user and the aiming interactive system. The identified beneficial IxDO is characterized in detail by the IxDO-RG, depicted on the right side of the figure. These IxDO characteristics can be used by UI designers and interaction designers to design an interactive system that targets (next to the primary purpose of the system) also the long-standing engagement of the user with the offered interactive system.

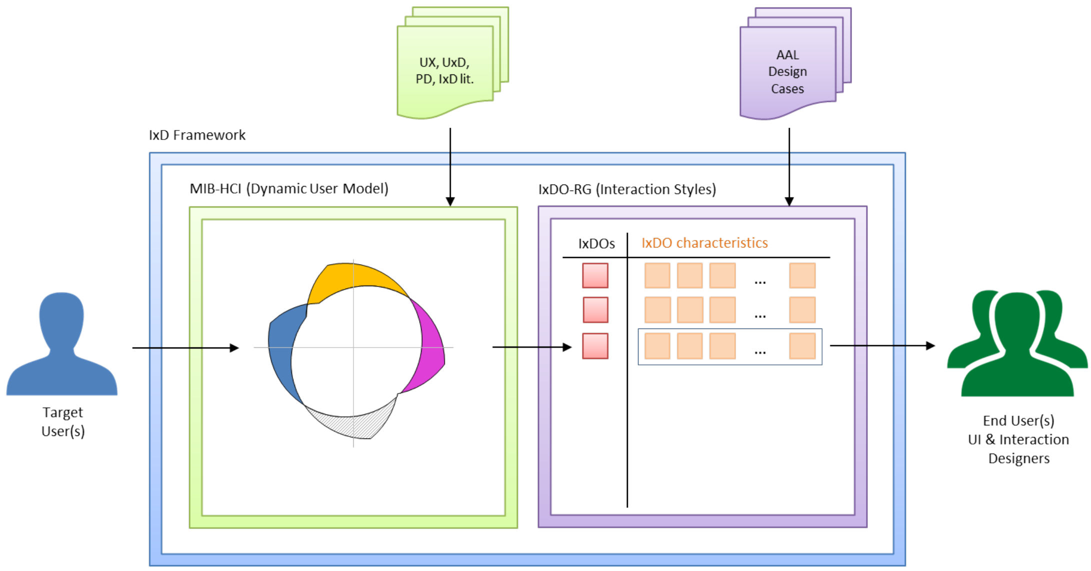


Figure 3.1: Two research areas of the IxD-FW conducted of the user-related research area building the MIB-HCI on the left side, outlined in green and the IxDO-RG on the right side, outlined in purple.

The presented IxD-FW utilizes a pleasure-oriented approach. The focus is on the identification of individual and inner values, wishes, and needs in beforehand, before the design of the interactive system. In contrary, displeasure-oriented approach focuses on the identification of problematic aspects in afterwards, after the interactive system was designed and tested by the user. However, both approaches target the same goal, namely the increase of users' satisfaction. Moreover, the UCD process relies on the interplay of both approaches. Thus, both approaches are valid, well in harmony, and mandatory for a good designed interactive system. Nevertheless, at this stage, namely at the beginning of the design process, designers do not have empirical data to apply the displeasure-oriented approach. Thus, the pleasure-oriented approach represents a valid starting point for the user involvement in the design process and this dissertation thesis targets exactly this goal.

The following sections discuss the evolutionary design and the characteristics of the two depicted research areas in more details. The starting point represents the IxDO-RG since this research area served as as basis for the development of the second research area, namely the MIB-HCI structure.

CHAPTER 4

Interaction Design Opportunity Research Grid

The Interaction Design Opportunity Research Grid (IxDO-RG) evolved from the awareness that different projects lead into the development of different Interaction Design Opportunities (IxDOs). This section describes the evolutionary design of the IxDO-RG starting from the grid structure, the design method, over the arrangement and relationships between different IxDOs towards the cross-cutting perspectives that finally lead to the development of the Model for Identification of Balanced HCI (MIB-HCI) model, as explained in Section 5.

4.1 IxDO-RG Structure

Figure 4.1 illustrates the structure of the IxDO-RG. The first column summarizes the involved projects followed by the corresponding IxDOs. The remaining columns represent co called cross-cutting issues of different IxDOs. These cross-cutting issues highlight IxDO attributes that are clustered by thematic affiliations such as the technological perspective, the design perspective, or the pleasure-oriented perspective.

These attributes are not meant to be holistic nor universal applicable. In the state-of-the art Section2.2, we have seen (based on the *ibi* project) that the presented technological concepts are not exclusively reserved for one particular IxDO, but rather they can be used in several IxDOs. Thus, the presented cross-cutting issues and their attributes are rather seen as orientation and support for the designer with the aim to provide a broader picture of considerable design aspects during the design process. However, apart from the non-exclusivity, these cross-cutting issues and their attributes were distinguishable enough and meaningful enough to serve as the basis for the development of the MIB-HCI. This was primary achievable by the involvement of the UX perspective and the reflection of UX characteristics and IxDO characteristics.

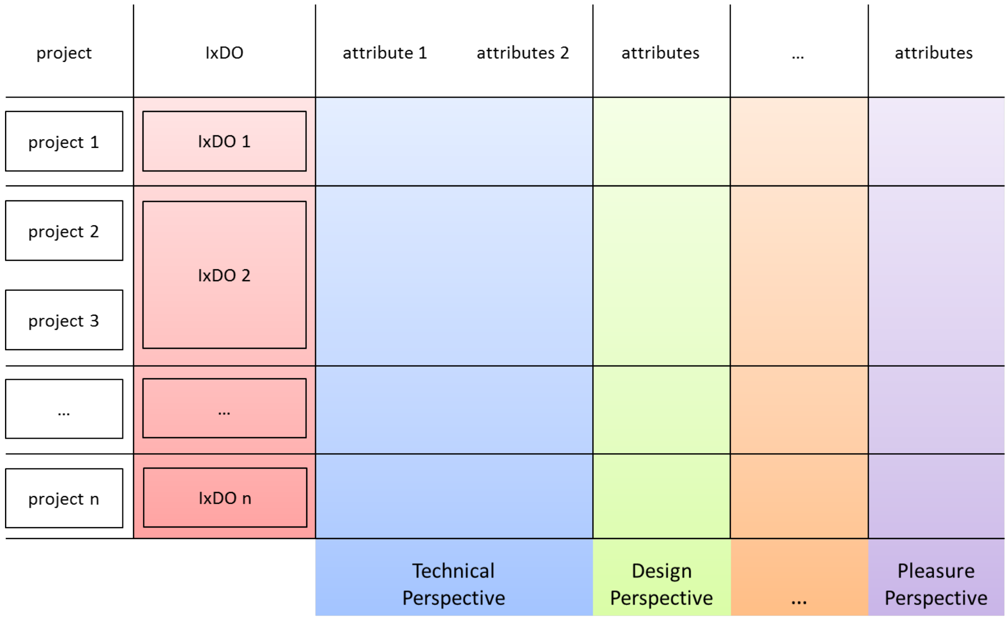


Figure 4.1: IxDO-RG structure depicting the involved projects and the corresponding IxDOs on the left side and the cross cutting issues in terms of clustered attributes on the right side.

4.2 IxDO-RG Design Process

The IxDO-RG was developed by the design thinking method that utilizes dynamic, haptic, and visual aspects. Sticky notes (Post-its) were used as working items which have been arranged and repeatedly rearranged on the given design space (flip chart paper sheet).

Figure 4.2 illustrates the design process of placing Post-its on the flip chart paper. The process was framed/guided by the mentioned IxDO-RG structure as described in Section 4.1. Color coding was used to reflect thematic affiliations like the projects section, the IxDOs, the technological attributes, or the design attributes. The limited writing space on Post-its helps to name the working items uniquely and to specify their key characteristics compactly. This compact information representation helped to convey initial ideas and to reflect on it with colleagues. The agile process of arrangement and re-arrangement of Post-its helped to reconsider the position and thus the cluster affiliation of each working item. This task took several iterations until the final state was reached.

4.3 Objectives of IxDOs

The state-of-the art Section 2.2 presented eight distinguishable IxDOs which were identified based on various design case studies in the AAL field of practice. Various project aspects influenced the decision about the to-be-applied IxDO in every single project.

Figure 4.2: The Design thinking method utilizing Post-its during the development phase of the IxDO-RG.

However, even if each design case study had its own characteristics, it is noticeable that IxDOs have a common set of criteria, which when group together, lead to one primary objective of the corresponding IxDO. The following section lists these IxDO objectives and serves as the basis for the upcoming arrangement and their dependency ranking within the IxDO-RG.

4.3.1 App Interaction Design Opportunity (App-IxDO), the classical setting

The App-IxDO represents the classical as well as the minimal setting in the development of interactive systems. It is understood that App-IxDO addresses basic needs regarding functionality and usability, but they are also able to provide pleasure and to provoke emotions. One can think, for instance, of a simple photo application. Even if the interaction design style is kept deliberately simple, for the user that took the pictures and that views the pictures afterwards this interaction process is able to provide joy, e.g., in terms of pleasurable memories.

4.3.2 Multi App Interaction Design Opportunity (MApp-IxDO), the comfort setting

The MApp-IxDO targets the comfort setting inclusively the increase of usability aspects like the accessibility and error tolerance. This becomes possible by the utilization of complement modalities on multiple devices. The independence regarding the input device is able to increases the comfort because the user-system interaction can be started, interrupted, and continued at any available device. Similarly, complement modalities targets the increase of accessibility as well as the increase of error tolerance because users can change the interaction modality if the chosen one is inaccurate or does not fit their requirements.

4.3.3 User Group Tailored Interaction Design Opportunity (UGT-IxDO), the supporting setting

The UGT-IxDO focuses on the enhancement of accessibility and usability especially for the target group that very often suffers from digital exclusion as presented in these works [Wat11, PH06, EH11]. Thus, UGT-IxDO addresses values that support the independent use of interactive systems for individuals with physical or sensory impairment. Moreover, UGT-IxDO also targets the enforcement of aspects responsible for users' security, social inclusion, and self-respect.

4.3.4 Adaptive Interaction Design Opportunity (Adaptive-IxDO), dynamical supportive setting

The Adaptive-IxDO targets the user specific and dynamic adjustment of the interactive system utilizing the 5E-usability attributes as presented in Section 2.1.6. These are effectivity, efficiency, error tolerance, easy to learn and engaging. Thus, Adaptive-IxDOs address changing conditions such as the change of user's physical or mental state during the aging process. Like the UGT-IxDO, the Adaptive-IxDO supports the preservation of self-respect via the user-specific adjustment of the interactive system and helps users to independently fulfill their tasks and to increase their self-esteem and consequently to gain esteem from others.

4.3.5 Ambient Intelligence Interaction Design Opportunity (AmI-IxDO), the environmental setting

The AmI-IxDO targets the support of users in managing their daily life routines and it utilizes users' physical environment. AmI-IxDO focuses on spatio-temporal aspects to provide support actions with a pinpointed and "on demand" characteristic (e.g., the pinpointed delivery of a reminder messages on the near-by device if the user is currently idle and not occupied with another activity). Next to the cognitive support, AmI-IxDO addresses the inclusion of techniques that aim the support of physical activities.

4.3.6 Personal Assisted Interaction Design Opportunity (PA-IxDO), the assistive setting

The PA-IxDO targets the personal and cognitive support of daily life activities. Analogous to the Adaptive-IxDO and the AmI-IxDO the focus is on the personal user needs, delivered via the own, intimately, assistive interactive system.

4.3.7 Companion Interaction Design Opportunity (Companion-IxDO), the friendship setting

The Companion-IxDO represents the evolvement of the PA-IxDO toward an individual entity with a friend-like characteristic. The focus is not limited to the cognitive and/or physical assistance, but the Companion-IxDO targets also the sense of belonging and the recognition and reflection of emotional states.

4.3.8 Tangible Interaction Design Opportunity (Tangible-IxDO), the graspable setting

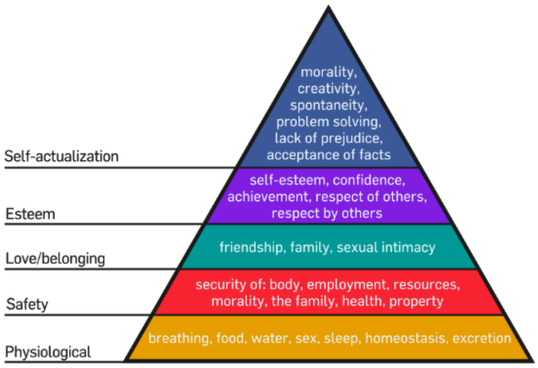
The Tangible-IxDO targets the inclusion and the emphasis of the graspable artifacts in the user-system interaction. The application field ranges from utilitarian, operative, and pragmatic level to the non-utilitarian, non-physical, and hedonic level. The former utilizes tangible objects for direct related purposes (e.g., physical manipulation of the tangible object correlates to the manipulation of the digital object) and the latter utilizes tangible object for indirect related purposes (e.g., the aesthetic appearance or the familiar shape of the object provides a positive cognitive memory or the confidence to the user using the object).

4.4 The Hierarchical Arrangement of IxDOs

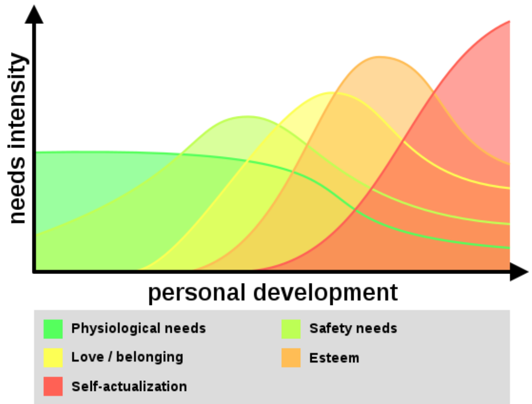
So far, basic ideas and main purposes regarding different IxDOs have been explained. As mentioned before, these main purposes serve as basis for the arrangement within the IxDO-RG. The right position is a major step towards the final goal, namely the recommendation of a concrete IxDO (inclusively the listing of its main constituent parts) for a specific user and the intended, to-be-designed interactive system. The following sections discuss this major steps using the main purposes of the IxDOs as the starting point for the arrangement decision. Later, in the Section 4.5, this arrangement will be refined based on the IxDO dependency structure and the inheritance of IxDOs on their conceptual level.

The presented purposes of IxDOs identified that the App-IxDO represents the classical and minimal setting for the design of an interactive systems. Thus, the App-IxDO represents an initial candidate for the entry point in the IxDO-RG. This causes the question how to arrange the remaining seven IxDOs and how the listing of their purposes can contribute towards the identification of their position within the IxDO-RG? A further analysis of these main purposes clarifies that each IxDO purpose aims to address certain user needs. Thus, one could cluster these needs and arrange them according concepts and models found in the literature. An argumentative literature review on this topic highlights Maslow's pyramid of needs, as a possible tool for that task [McL07].

Maslow's pyramid of needs was introduced 1943 and is based on the believe that people are motivated to achieve certain needs. Maslow distinguish between five different classes of needs, namely physiological need, safety need, social need, esteem need, and self-actualization need. These needs are arranged in a hierarchical order starting from the physiological need towards the self-actualization need. Maslow believed that a person needs to fulfill the lower ranked need before she or he can seek for the higher ranked need. Figure 4.3a illustrates the classical illustration of Maslow's pyramided of needs utilizing sharp borders between different classes of needs. These sharp borders are often used as an aspect against the theory since it is understood (as it is in this work) that a product or a service can satisfy several needs at once. Figure 4.3b, on the contrary, depicts an alternative version that utilizes dynamic borders. These dynamic borders form overlapping need areas and illustrate that the personal development is a continuous process and that users seek to fulfill more than one need at a certain point of time.



(a) Maslow's pyramid of needs highlighting distinguishable levels of user needs with sharp borders between the levels [Fac18, p. 1].



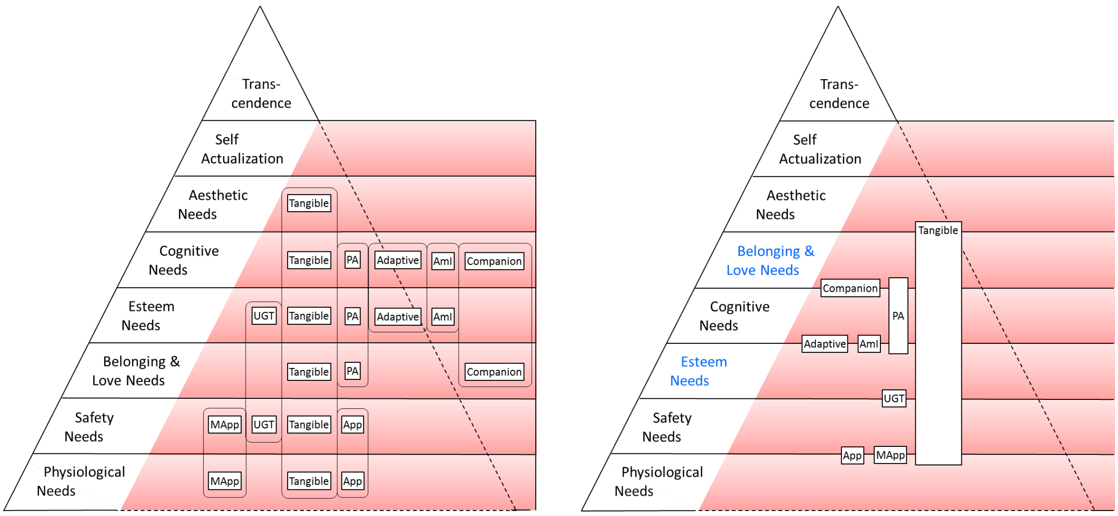
(b) Maslow's pyramid of needs highlighting dynamic levels of user needs with overlapping ares [Gut18, p. 1].

Figure 4.3: The design space of the MIB-HCI.

Maslow's pyramid of needs was, next to the mentioned sharp border problem, discussed controversially. Abulof Uiel presents in his work "Introduction: Why We Need Maslow in the Twenty-First Century" [Abu17] an excerpt of the controversial debate. He encourages the model with the argument: "The continued resonance of Maslow's theory in popular imagination, however unscientific it may seem, is possibly the single most telling evidence of its significance: it explains human nature as something that most humans immediately recognize in themselves and others" [Abu17, p. 508]. On the other side, he also highlights that the model cannot be tested empirically along other opinions such as:

- The thesis does not capture universal human needs since the lower needs are animalistic and the higher needs reflect only the nature of modern democratic societies.
- The emphasis on self-actualization comes increasingly at the expense of basic needs [Abu17, p. 508].

Regardless the controversial discussion about the accuracy and the validity of Maslow's pyramid of needs, the basic concept of different needs, arranged in a certain order, goes very well with the previously identified listing of main IxDO purposes and their addressed users' needs. However, at this point it needs to be mentioned that the work utilizes different classes of needs, as defined by Maslow, but it does not rank them according a priority level. From the end user perspective, interactive systems have to address user's current appearing problem and her or his current need. Thus, from this perspective, the priority level as shown on Maslow's pyramid of needs is regardless as long it is addressed correctly and timely. Similarly, from the Interaction Design (IxD) perspective an IxDO aims to address certain needs. For the IxDO itself the priority level, as defined by Maslow's pyramid of needs, is regardless. Thus, in this work the ranking of IxDOs is not meant to be used for priorization purposes but rather for the demonstration of relationships and dependencies between different IxDOs. The following section elaborates the position of each IxDO based on the underlying needs which were gained from the listing of main purposes and Maslow's pyramid of needs-structure.



(a) First arrangement of IxDOs within Maslow's pyramid of needs.

(b) Simplified arrangement of IxDOs within an modified version of Maslow's pyramid of needs.

Figure 4.4: The arrangement of IxDOs within the pyramid of needs.

Figure 4.4a illustrates the initial arrangement of IxDOs within the pyramid of needs. It is noticeable that one single IxDO can be assigned to several levels of need. App-IxDO, for instance, can be assigned to the physiological need class as well as to the safety need class. Similar applies for other IxDOs. Using this arrangement as the basis, we can rearrange the initial setting to reduce the complexity of the illustration. Following two actions provide a simplified version: (a) IxDOs can be placed between need classes. This is valid since needs do not have a sharp border as depicted in the Figure 4.3 but rather fuzzy borders as depicted in Figure 4.3b, and (b) need classes within the pyramid can be rearranged. This is also valid since, as mentioned previously, the hierarchical structure of need levels is not relevant form the IxD nor from the targeting user perspective.

Figure 4.4b illustrates the simplified arrangement within the modified pyramid of needs that covers both modifications. As one can see, two need classes ("esteem needs" and "belonging & love needs") swapped their places. Moreover, it is noticeable that the PA-IxDO and Tangible-IxDO over span multiple need classes. This highlights that these IxDOs target the satisfaction of multiple needs. Conclusively, the initial arrangement within the pyramid of needs provides the following structural ranking: App-IxDO, MApp-IxDO, UGT-IxDO, Adaptive-IxDO, AmI-IxDO, PA-IxDO, Companion-IxDO, and in parallel to this listing the Tangible-IxDO that over spans all other IxDOs. The presented structural ranking is also influenced by the dependency structure of IxDOs as described in the following section.

4.5 IxDOs and their Dependency Structure

Despite the hierarchical arrangement delivered from Maslow's pyramid of needs, one main output of the IxDO-RG design process is the awareness that the eight identified IxDOs build dependencies upon each other. They build dependencies on the technological complexity level, but they also inherit from each other on the conceptual level. Dependencies on the technological complexity level derive from the fact that more complex IxDOs utilize and extend technological concepts and methods that are used in less complex IxDOs.

Inheritance on the conceptual level results from the continuous reuse of IxDO concepts. This is comparable to generalization and specialization of classes in the Object Oriented Paradigm (OOP) paradigm [Weg90]. Using this analogy leads to following argumentation; More complex IxDOs represent subclasses of less complex IxDOs. Thus, more complex IxDOs are based on their predecessor IxDOs. Of course, this analogy is only used for descriptive purposes. A more detailed description of the inheritance on the conceptual level can be found in the following Section 4.6.

Figure 4.5 illustrates the final dependency structure of the eight identified IxDOs. The illustration highlights the structural ranking based on Maslow's classes of needs and the rising technological complexity level. The inheritance of concepts is represented by the arrows between the blocks and the IxDOs, respectively. It is noticeable that three IxDOs over span multiple technology complexity levels, namely the UGT-IxDO, the PA-IxDO, and the Tangible-IxDO. This is in line with the previously elaborated structural ranking and it is fine-tuned using the mentioned dependency factor. Following

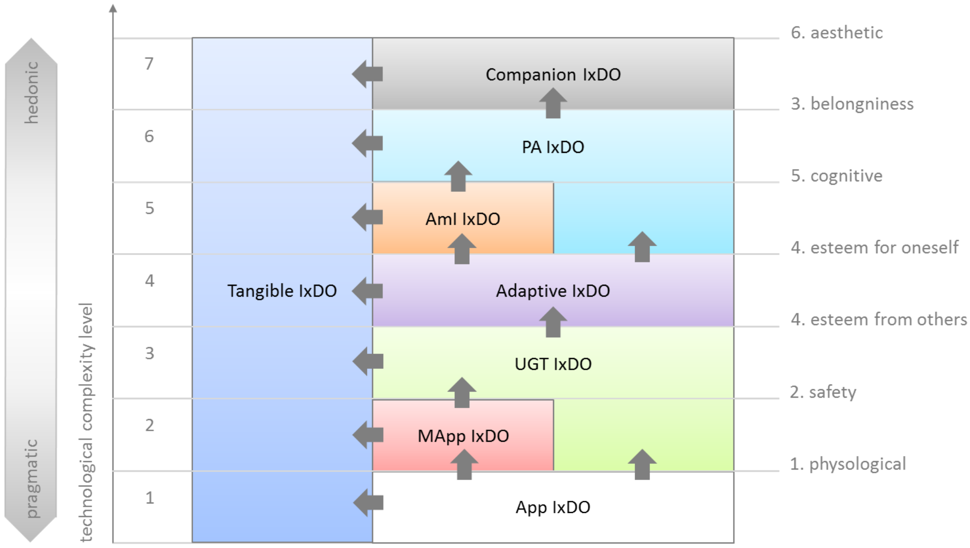


Figure 4.5: Dependency structure of the eight identified IxDOs

example illustrates the background of this process. The UGT-IxDO, e.g., can be evolved either from the App-IxDO (located on the technological complexity level 1), or from the MApp-IxDO (located on the technological complexity level 2). Using the former, results in an UGT-IxDO that is located on the technological complexity level 2, and using the later, results in an UGT-IxDO that is located on the technological complexity level 3.

4.6 Inheritance of IxDO concepts

As mentioned before, IxDOs inherit their concepts towards higher ranked IxDOs. Using the OOP paradigm for descriptive purpose would provide the interpretation that higher ranked IxDOs specialize lower ranked IxDOs.

Table 4.1 summarizes this concept applied on all eight IxDOs including their specialization and their inheritance. The table is meant to be interpreted as follows: **App-IxDO** represents the lowest complex IxDO that does not specialize any other IxDOs. **MApp-IxDO** represents a collective App-IxDOs. In other words, MApp-IxDO inherits all concepts from the App-IxDO and specializes the new concept using the "collective" attribute. Thus, if a designer aims to design an interactive system using the MApp-IxDO, she or he is asked to fulfill all App-IxDO concepts and to enhance the intended system towards a multiple App-IxDO within each App-IxDO contributes to the work of the whole interactive system. On the technological perspective this means the provision of an interactive system that orchestrates the interaction between multiple interaction points (devices) using different modalities. **UGT-IxDO** represents a tailored App-IxDO or a tailored MApp-IxDO. **Adaptive-IxDO** represents an automatically and continuously adjustable UGT-IxDO. **AmI-IxDO** represents an Adaptive-IxDO on demand. In this

IxDO	specialization	inheritance from...
App-IxDO	-	-
MApp-IxDO	collective	App-IxDO
UGT-IxDO	tailored	App-IxDO or MApp-IxDO
Adaptive-IxDO	re-adjustable	UGT-IxDO
AmI-IxDO	on demand	Adaptive-IxDO
PA-IxDO	supportive	AmI-IxDO or Adaptive-IxDO
Companion-IxDO	personality enriched	PA-IxDO
Tangible-IxDO	physical	App-IxDO, MApp-IxDO, UGT-IxDO, Adaptive-IxDO, AmI-IxDO, PA-IxDO, or Companion-IxDO

Table 4.1: Specialization of IxDOs on the conceptual level highlighting the specialization attributes and the lower ranked IxDOs that serve as the source for the inheritance.

setting the users' environmental surrounding can be used to trigger the interaction more precisely and on demand. **PA-IxDO** represents either a supportive AmI-IxDO or a supportive Adaptive-IxDO. **Companion-IxDO** represents a PA-IxDO which is enriched by the personality factor. **Tangible-IxDO** represents the physical manifestation of any other IxDOs starting from the lowest complex IxDO, the App-IxDO, towards the most complex IxDO, the Companion-IxDO.

The IxDO-RG in Section 4.1 highlighted the three cross-cutting issues, namely the technological perspective, the design perspective, and the pleasure-oriented perspective. These perspectives have been developed in a successive process, started from the technological perspective in the AAL field of practice, over the design perspective to the pleasure oriented perspective. Design results from the technological perspective (in form of dedicated arrangement of involved technological aspects) have been used for the development of the design perspective. Results from the design perspective (again in form of dedicated arrangement of interaction design purposes), have been used for the development of pleasure-oriented perspective. The pleasure-oriented perspective was the basis for the development of the MIB-HCI structure which refers back to IxDOs, their main purposes, and the benefits for the targeting user of the interactive system. The following section describes the three cross-cutting issues and their attributes. The goal is to provides a comparative list of considerable aspects in the design process on the technological level and to highlight aspects that led to the development of the MIB-HCI which will be described in detail in the Section 5.

4.6.1 Technological Cross-Cutting Issue

The technological cross-cutting issue targets the identification of considerable aspects based on three chronological arranged design pillars, namely on modeling, architecting, and implementing pillar. Figure 4.6 illustrates the chronological order of design pillars and their main purposes.

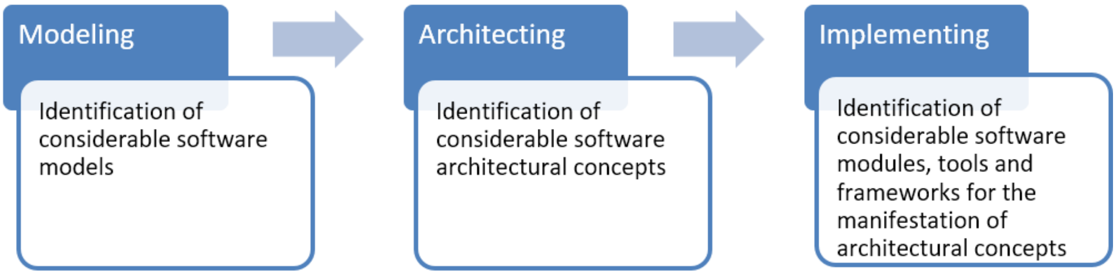


Figure 4.6: Three chronological arranged design pillars highlighting the clustering of considerable aspects within the technological cross-cutting issue.

The following section elaborates the three design pillars in more details. Some of the presented aspects are strongly related to a dedicated IxDO and influence its main characteristic and some are not clearly assignable to a specific IxDO but can rather be used for multiple IxDOs. Moreover, it is understood that the provided listing of cross-cutting attributes is domain specific, meant to be minimalistic, and to some extent also exemplary. Designers can use these attributes as a starting point for the design process and extend them in respect of raising needs, expectations, and the changing settings such as the application field or the context of use.

At this point it is also worth to reconsider the action radius of the technological cross-cutting issue in respect to the IxD. A good overview about the architecture compliance is given by the "CAST Architecture Checker" [.In18] as illustrated in Figure 4.7. The two bottom most layers are responsible for data storage and data access. The depicted framework layer structures the data and manages the handling. The business logic layer provides the workspace for the implementation and the runtime interpretation of the concrete application. And finally, the two most top layers represent the interface towards the user via HCI artifacts rendered on concrete physical devices.

Next to the presented layers, Figure 4.7 also depicts three different detail levels, the system level, the technology level and the program unit level. The technological cross-cutting issue, as presented in this work, acts on the technology level of the cast architecture checker. The focus is not on data types, their structure, or the used framework for data management nor on the programming language, the generated UI, the used device, or the separate interaction modality. The focus is rather on intra-technology architecture, intra-module communication and architectural design on the application level. It is understood that designers and engineers are capable to assemble the needed and, from their point of view, preferred components on the remaining layers in order to develop a whole solution on the system level.

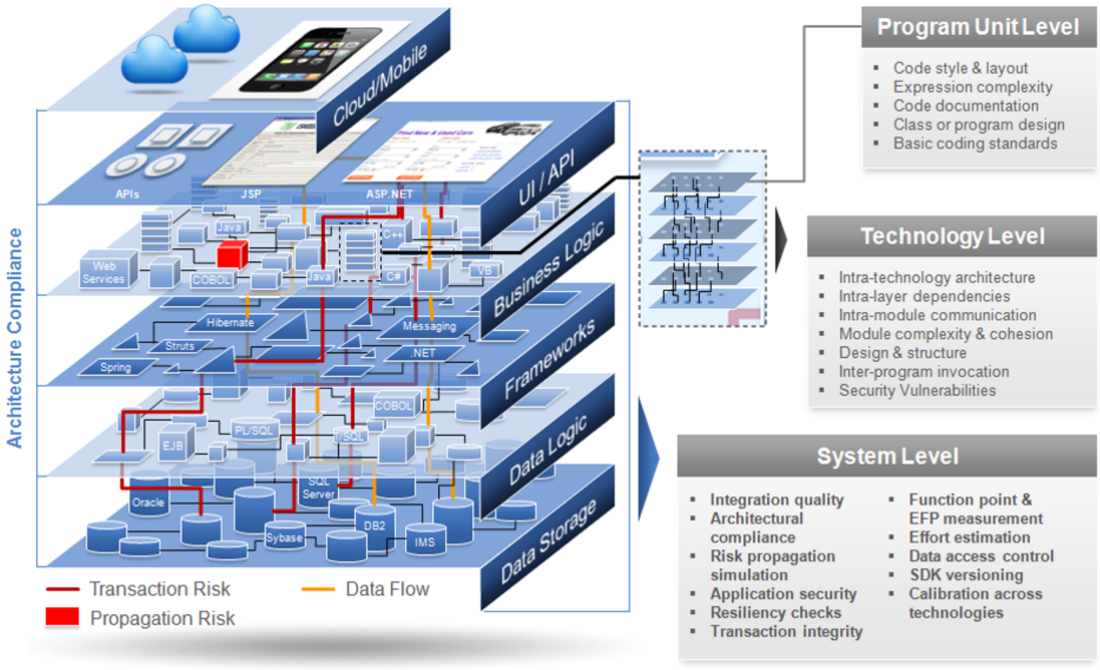


Figure 4.7: Cast Architecture Checker highlighting different architectural layers [.In18, p. 1].

4.6.2 The Modeling Pillar

Software models represent one remarkable thematic aspect of the technological cross-cutting issue. As we know, all models simplify reality in order to improve understanding of it [KHK+96]. Unfortunately, the simplification process decreases the validity of reflected reality to some extent. On the other side, it also allows the definition of a finite set of considerable variables within the system. Thus, models are essential in software design and thus also a key element in the technological cross-cutting issue.

If we focus on the eight identified IxDOs and the AAL field of practice, then we can identify the following minimal set of software models, namely the task model, the interaction model, the user model, the environmental model, the social model, the AI model, and finally the UX model. The following listing summarizes their main purposes.

- Task models define what needs to be done.
- Interaction models define how these tasks (defined by the task model) needs to be performed.
- User models define for whom these interactions (defined by the interaction model) are designed for.
- Environmental models define where and when these interactions take effects.

- Social models define to whom to involve into these user-system interactions.
- Dialog models define the conversation (a sequence of user interactions) between the system and the user. They are closely related to task models since each dialog consists of at least one task [LCCV03, Ber15].
- UX Model reflect users' capabilities and expectations at the current level but also capabilities and expectations at the intended level during and after the experience of the HCI artifact.

It needs to be mentioned that the listing targets primary the user-human interaction perspective related to the eight identified IxDOs. In another context, targeting another purpose, the listing would not be conclusive enough. For instance, in a greenhouse setting, the environmental model would probably be used for the control of the greenhouse with the aim to minimize human interventions. The environmental model, in such a setting, would probably not be used for the improvement of the human-computer interaction, although it is not explicitly excluded.

Another relevant point regarding models is that models can be expressed implicitly, explicitly, or as a combination of both. Implicit expressed models are not directly visible and very often interwoven into the system, the logic, and/or interaction styles. One can, for instance, think of an ordinary desktop application with a classical GUI-based design that utilizes the Model-Viewer-Controller design pattern [KP+88]. Logically, the definition of tasks belongs to the controller part. At the same time, the controller has the duty to coordinate and handle change events (e.g., user events and data change events). Thus, the definition of the tasks is implicit and interwoven with the event handling. A second example for implicit modeling can be constructed by the utilization of the user model. If one thinks of a simple application that does not require the modeling of the targeting user (e.g., a use independent current-local-time-viewer application), then the user model is defined implicitly by the designer during the design process. The designer has a concept about the targeting user of the system and their capabilities regarding the understanding and manipulation (interaction) of the presented information.

Explicit models, on the other hand, are focused, self-contained and require an interpreter to take effect. One can think, e.g., of a user model defined by a set of key/value preference pairs. To be able to use this information in an interactive system there is the need for an interpreter that utilizes the user model and the underlying data in order to provide concrete system actions, e.g., to change the application font size according user's preference set.

Regardless the expression type of a model, the focus in the IxDO-RG design process is on the identification of necessary software models and on the identification of their mandatory level. Figure 4.8 illustrates the identified software models along the eight identified IxDOs. The mandatory level is indicated by the color gradient. As one can see, the UX model (usually implicit expressed) and the task model are mandatory for all IxDOs. The user model starts to become mandatory at the UGT-IxDO and above. The same applies for the interaction model above the Adaptive IxDO, the environmental model above the AmI-IxDO and the social model as well as the dialog model above the PA-IxDO.

Figure 4.8 reflects also the technological complexity level since the higher an IxDO is ranked, the more models are involved.

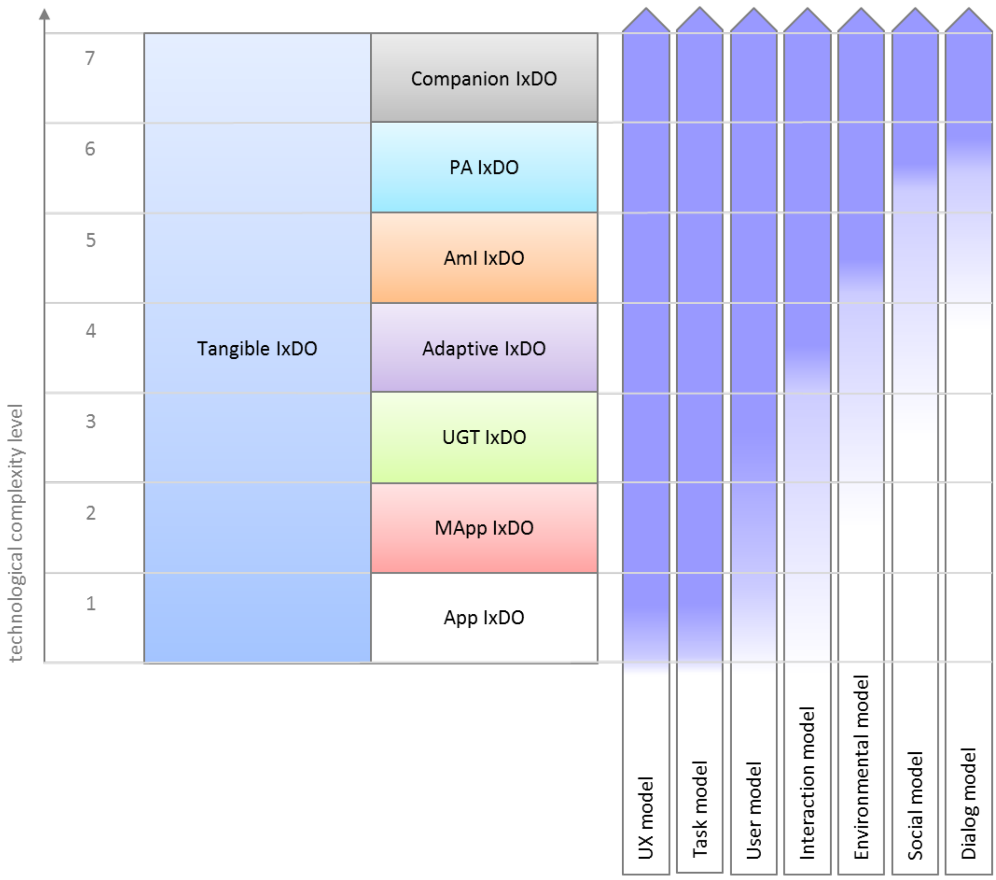


Figure 4.8: Software models in respect to their contributory value for the eight identified IxDOs and their mandatory level based their utilization within AAL research projects with AIT involvement.

4.6.3 The Architecting Pillar

The second pillar focuses on the identification of considerable software architectural concepts useful for the design of the eight identified IxDOs. Within our AAL projects we have been utilizing following architectural concepts:

- Intra-technology communication: This architectural concept focuses on technologies that support the information exchange between different systems.

- Intra-module communication: This architectural concept focuses on techniques that support the development of a modular system and on techniques that allow the information exchange between these modules within the same system.

- Modality handling: This architectural concept focuses on techniques for modality selection, modality fission and fusion as well on techniques for an automatic modality conversion.

- Data mining: This architectural concept focuses on techniques for data aggregation and on techniques for data interpretation. Data mining is defined as the process of discovering patterns in data [WFHP16].

- Machine learning: This architectural concept focuses on technologies that support the automatic identification of patterns [Rob14]. According this definition, machine learning can also be used for data mining.

- Dialog systems: This architectural concept focuses on techniques for dialog modeling as well as on techniques that support the execution of user-system interaction sequences (conversation).

- AI reasoning: This architectural concept targets the reflection of human intelligent behavior. Negnevitsky highlights this in his work "Artificial intelligence: a guide to intelligent systems" with the following statement: "Artificial intelligence is a science that has defined its goal as making machines do things that would require intelligence if done by human" [Neg05, p. 18]. However, it is understood that AI reasoning represents the "holy grail" of reasoning methods. Classical reasoning methods, e.g., the rule based reasoning are already required at the lowest ranked IxDO, namely the App-IxDO. Thus, classical reasoning are self-evident and are not explicitly highlighted in this listing.

Figure 4.9 illustrates the identified architectural concepts along the eight identified IxDOs. The mandatory level of the software model is indicated by the color gradient. Here again, one can see that higher ranked IxDOs involve more architectural concepts and this in turn increases the technological complexity level. In contrary to the software models, it is noticeable that the modality handling mandatory decreases towards higher ranked IxDOs. This is because the Companion-IxDO represent an individual entity with friend-like characteristics, embodied as a human-like character, as a comic character, or as an abstract AI character. This embodiment is perceived as a unique entity and represents a single point of interaction. Thus, as the user expects a single point of interaction, it is not necessary to provide a broad band of interaction modalities but rather to utilize only few interaction modalities like the speech interaction and the visual representation.

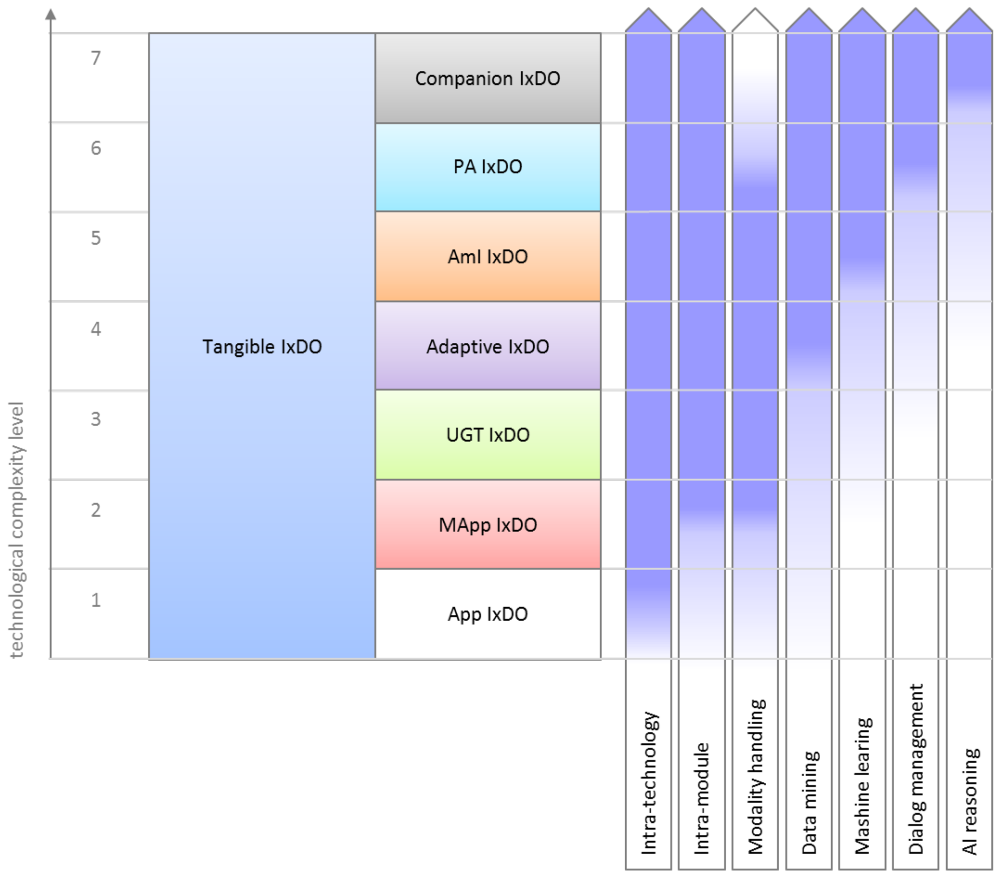


Figure 4.9: Architectural concepts in respect to their contributory value for the eight identified IxDOs and their mandatory level based on their utilization within AAL research projects with AIT involvement.

4.6.4 The Implementing Pillar

The third pillar focuses on the identification of considerable software concepts, modules, tools and frameworks for the manifestation of the previously presented architectural concepts. Table 4.2 summarizes utilized architectural concepts within our project in the AAL domain. Details regarding the used methodology and technological factors such as standards, algorithms, 3rd party solutions can be found in the Appendix Section 8.4.

Purpose	*HOMER*	*moduLAAr*	*iWalkActive*	*RelaxedCare*	*Fotokiste*	*Miraculous-Life*	*KithNKin*	*TrainAndWin*	*Memento*	*CogniWin*	*ibi*	*ION4II*	*YouDo*	*SUCCESS*	*AALuis*
Intra-technology communication															
Multi device comm. (IP)	x	x		x					x		x				x
Cloud communication	x	x	x	x	x	x	x	x	x		x	x	x	x	x
Object identif. (NFC)	x	x													
Bluetooth communication	x	x							x	x		x			
Object identif. (2Dvis.)					x	x	x		x						
Motion sensing (3Dvis.)						x		x		x					
Device control (HDMI)											x		x		
Device comm. (SMS)	x	x													
Device control (IR)	x	x									x		x		
Position local. (GPS)	x	x	x						x			x			
Position local. (WLAN)			x			x		x				x			
Smart Home interaction	x	x		x							x				
Activity Recognition	x	x						x							
Intra-module communication															
SW release automation	x	x		x		x	x		x	x		x		x	x
Flexibility in software design	x	x													x
Flexibility in software design			x	x	x	x	x	x	x	x	x	x	x	x	
Modality handling															
Modality selection	x	x		x		x		x			x			x	x
Modality selection															
Modality provision					x	x				x	x		x	x	x
Modality fusion	x	x		x	x	x	x		x	x	x				x
Modality fusion												x			
Modality fission	x	x		x		x			x		x				x
Modality conversion				x		x			x		x		x	x	x
Data mining															
Activity & Presence detection	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Behavior pattern recognition	x	x		x		x		x	x	x			x	x	
Motion recognition						x		x							
Gesture recognition						x		x		x					
Position localization	x	x	x	x		x		x				x			
POI analysis										x					

Machine learning															
Purpose	*HOMER*	*moduLAAr*	*iWalkActive*	*RelaxedCare*	*Fotokiste*	*Miraculous-Life*	*KithNKin*	*TrainAndWin*	*Memento*	*CogniWin*	*ibi*	*ION4II*	*YouDo*	*SUCCESS*	*AALuis*
Behavior pattern rec.	x	x		x		x		x	x	x			x	x	
User identification	x														
Facial emotion rec.															
Speech emotion rec.				x		x					x			x	
Reasoning															
Rule-based reasoning	x	x	x		x		x				x	x			x
Case-based reasoning				x		x		x	x				x	x	
Fuzzy-based reas.	x	x													
AI reasoning						x				x					
Reasoning															
Workflow definition				x		x				x	x			x	x
Speech recognition						x					x				
Speech synthesis	x					x		x			x	x	x	x	x
Natural language															

Table 4.2: Matrix of architectural concepts and their utilization in research projects with the involvement of the AIT.

4.6.5 The Design Cross-Cutting Issue

The technological perspective focuses on the identification of considerable software concepts, modules, tools, and frameworks. The design perspective focuses on the identification of interaction purposes and utilizes concepts which were presented in the state-of-the-art Section 2.3 under the consideration of the eight identified IxDOs. The fundamental idea behind the arrangement of interaction purposes within the IxDO-RG is the stronger consideration of targeting user needs, to be more precisely, targeting basic user needs in respect to the offered interaction style. This cross-cutting issue is mainly influenced by following works [DH07, Has07, Jor02, Lee17, Spo15].

Figure 4.10 illustrates the initial arrangement of interaction design purposes along the eight identified IxDOs. The arrangement is based on the initial assumption that low ranked IxDOs aim primary the satisfaction of functional values, middle ranked IxDOs aim the satisfaction of usability values and high ranked IxDOs aim the satisfaction of pleasure values. It needs to be mentioned that this initial design was lately reconsidered during the depth elaboration and analysis of the MIB-HCI. Nevertheless, the initial arrangement still includes general aspects, e.g., the pragmatic/hedonic juxtaposition which remain till the final MIB-HCI structure as presented in the Section 5.

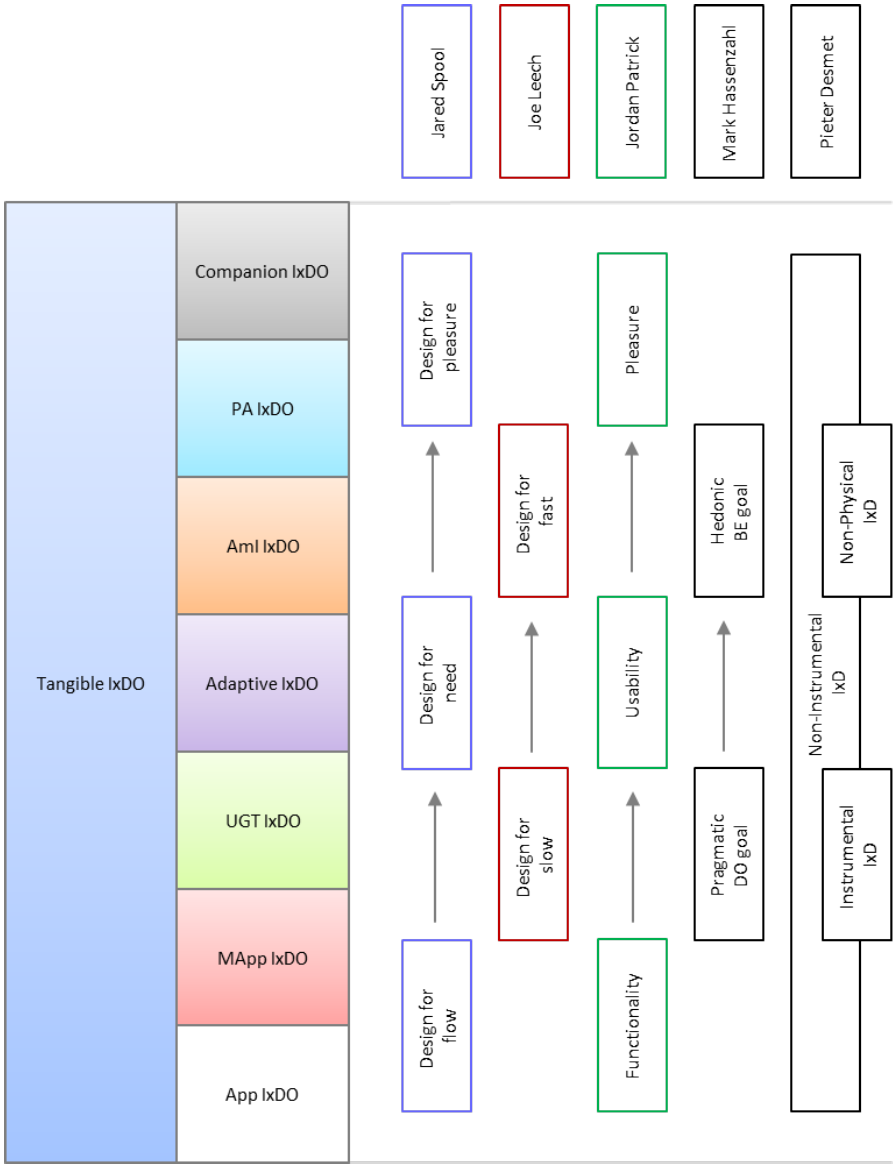


Figure 4.10: Initial arrangement of interaction design purposes along the eight identified IxDOs.

At this stage it needs to be emphasized that the arrangement of different interaction purposes along the IxDO-RG it is not meant to be holistic, accurate, consistent, nor completely valid. It highlights rather the roots of the development of the MIB-HCI structure and the development pathway from the technical perspective, over the interaction design style perspective towards to the UX and pleasure-oriented perspective.

4.6.6 The Pleasure-oriented Cross-Cutting Issue

The design perspective focused on the identification of interaction purposes. Admittedly, interaction purposes are closely related to the UX and if we consider UX as something "desirable" (see Section 2.1.8) UX is also related to the pleasure-oriented perspective. Nevertheless, the design perspective targets the manifestation of supportive aspects whereas the pleasure-oriented perspective addresses the problem on a higher level, namely on the identification of supportive aspects utilizing pleasure as the key tool set. The fundamental idea behind the arrangement of pleasure aspects along the IxDO-RG is the stronger consideration of the targeting user and their **inner** needs in respect to the offered interactive system. This cross-cutting issue is mainly influenced by following works [DH07, Jor00, Jor98]. Here again, at this stage the arrangement it is not meant to be holistic, accurate, consistent, nor completely valid, but it highlights that the MIB-HCI utilizes primary pleasure oriented aspects in order to identify users' inner wishes and needs.

Figure 4.11 illustrates the initial arrangement of pleasure-oriented aspects along the eight identified IxDOs. Moreover, the figure highlights the clusters of displeasurable feelings without a dedicated arrangement along different IxDOs. The listing of these displeasurable feelings is only mentioned for completeness. As pointed out earlier in the Section 3, the Interaction Design Framework (IxD-FW) utilizes the pleasure-oriented approach. Thus, these displeasurable feelings are out of the scope of this dissertation thesis. However, some of these initial pleasure-oriented aspects have been evaluated in more depth in the following MIB-HCI structure (e.g., Jordan's four types of pleasure), and others, (e.g., the concrete manifestation of pleasurable feelings) have been used just for inspiration purposes. The main reason for giving less attention to these aspects is primary justified by the target goal of this work. This work relies on the designers input regarding the concrete application field of the intended, to-be-designed interactive system. Without this fundamental information, it is impossible to provide a recommendation that targets the manifestation of one or more pleasurable feelings, such as freedom, security or pride. Thus, the work utilizes more generalizable pleasure aspects, such as the four types of pleasure.

Despite the problematic arrangement of pleasure type manifestations (pleasurable feelings), Figure 4.11 highlights also that the underlaying research grid is also only conditionally suitable for the arrangement of generalizable pleasure types. This leak of unique assignability is visualized by arrows in Figure 4.11. While the arrangement of the psycho-pleasure and the arrangement of the physio-pleasure seem to be halfway logical, the current arrangement of the ideo-pleasure and the socio-pleasure are not clearly reasonable. Nevertheless, as mentioned before, at the current stage these pleasure-oriented aspects have been used just for inspiration purposes and their further elaboration is described in more details in Section 5.

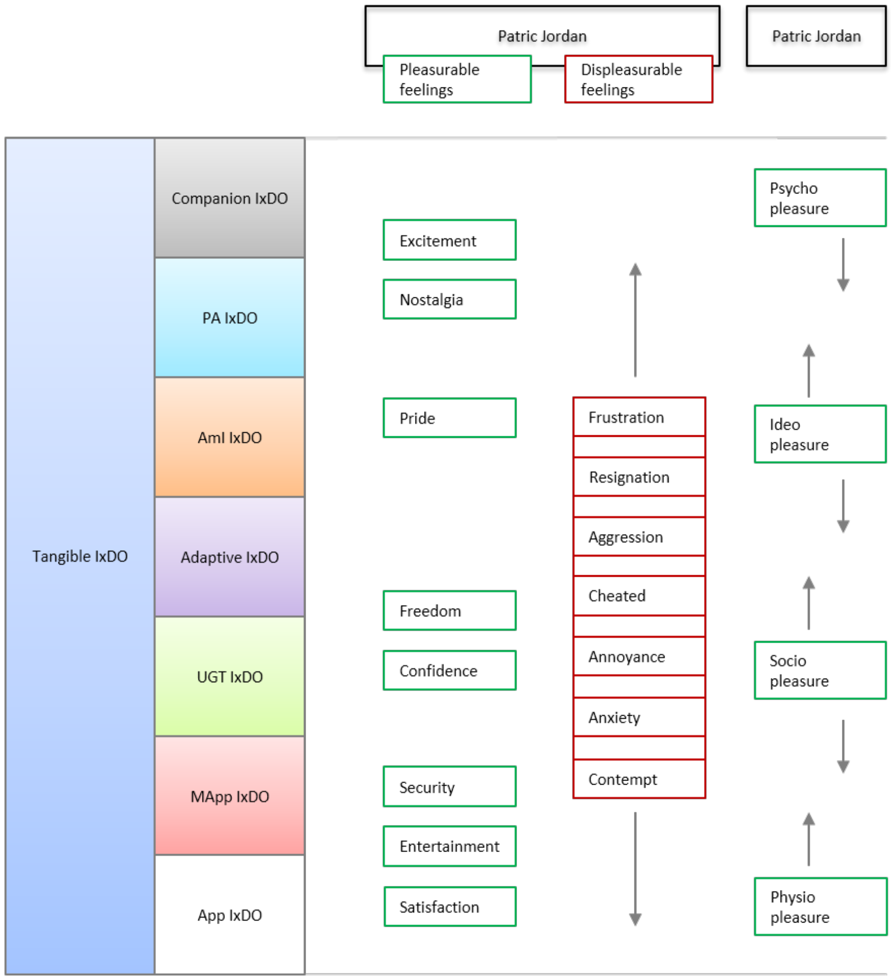


Figure 4.11: Initial arrangement of pleasure-oriented aspects along the eight identified IxDOs.

4.6.7 Transition to the MIB-HCI

By using the IxDO-RG we have been elaborated different IxDOs, their arrangement, and their relation to each other. Additionally, we have been elaborated their technological perspective in more depth. In contrary, the interaction design perspective and pleasure-oriented perspective have been elaborated only superficial within the IxDO-RG. As mentioned before, the cross-cutting issues have been developed in a successive process, started from the technological perspective in the AAL field of practice, over the design perspective to the pleasure oriented perspective. The underlaying research grid was very useful for the technological perspective since the arrangement of technological aspects correlated with the identified IxDOs and their arrangement within the research grid. The elaboration of the design perspective and especially the elaboration of the pleasure-oriented perspective highlighted that the underlaying research grid is only conditionally suitable for this task. These two perspectives require a more user-centered approach that places the targeting user into the center of the investigation. The following section targets this approach and elaborates the design perspective and pleasure-oriented perspective under the consideration of the targeting user in a more centered and structured manner.

CHAPTER 5

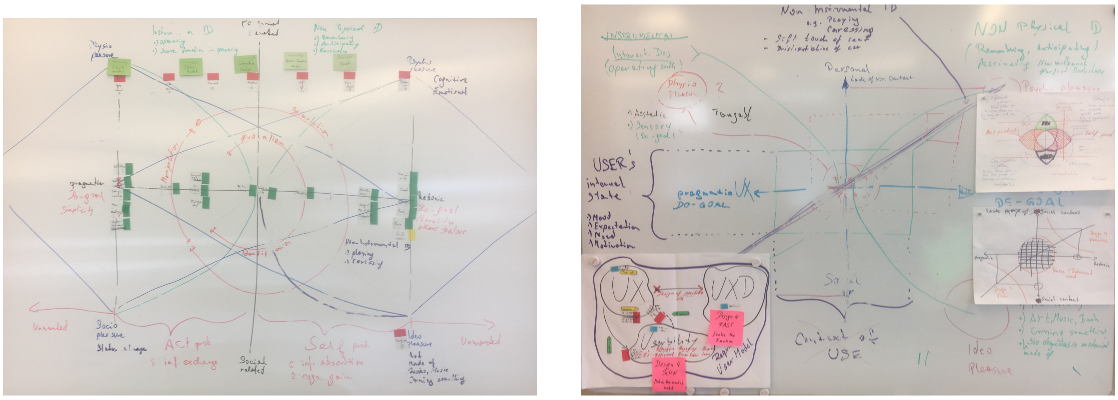
Model for the Identification of Balanced HCI

The overall goal of this dissertation thesis is to provide a structured and shorthanded method for the identification of individual inner values, wishes, and needs that are able to increase user's satisfaction and that in turn contribute towards the long-standing engagement of the user with the offered product. Thus, it is obvious that at some point of the development process the involvement of the targeting user is needed. The Model for Identification of Balanced HCI (MIB-HCI) addresses this need and provides a dynamic user model that reflects user's current pleasure preference set and that highlights less pronounced areas from whom, when addressed, the user potentially could benefit from.

The following Section 5.1 describes the evolutionary design of the MIB-HCI structure utilizing various concepts, methods, and models from the UX, UX design, interaction design, and product design research field. Section 5.2 investigates the evolved MIB-HCI from a holistic point of view and evaluates its operational coherence. Section 5.3 highlights possibilities to address UX characteristics which are essential for the targeting user and the intended, to-be-designed interactive system. The Section 5.4 utilizes the evolved MIB-HCI structure in order to reflect user's current set of pleasure preference set and Section 5.5 presents the concept that uses the gained pleasure preference set to identify so-called promotion-worthy areas and to guide the model towards its application field, namely the identification of most beneficial Interaction Design Opportunities (IxDOs) for the targeting user and the intended, to-be-designed interactive system. The process of the identification of the most beneficial IxDOs is described in the final Section 5.6.

5.1 Evolutionary Design of the MIB-HCI

The MIB-HCI was developed in a utilitarian as well in an evolutionary manner. It utilizes and combines models from the field of sociology, UX, User Experience Design (UxD), Interaction Design (IxD), and Product Design (PD). Like the Interaction Design Opportunity Research Grid (IxDO-RG), the design process was guided by the design thinking method and the utilization of dynamic, haptic and visual aspects. Figure 5.1 illustrates the two working sets for the development of the MIB-HCI.



(a) The design space of the MIB-HCI utilizing sticky notes.

(b) The design space of the MIB-HCI utilizing white board.

Figure 5.1: The design space of the MIB-HCI.

In total, the model experienced seven iteration steps towards its final state. Every one of these steps was characterized and influenced by concepts, models and frameworks that have been presented in the state-of-the-art Chapter 2.3. Figure 5.2 illustrates the iteration steps depicted on a single flip chart paper.

5.1.1 Personal vs. Social Context

The first iteration step is influenced by the own observation regarding project developments in the AAL field of practice. An holistic view about multitude project developments in this field highlight that interactive systems that target primary the personal context require more descriptive attributes as interactive systems that target primary the social context. For instance, during the user requirements engineering process users expressed their need for a daily life support services that targets the communication in a simpler, accessible, and straightforward way with their relatives and friends (*moduLAAr*,*ibi*,*RelaxedCare*,*KithNKin*). Others, for instance, highlighted their need for services that target the personal context such as mobility support, cognitive support, or physical state improvement in a more "guided" and dialog-forming way(*AALuis*,*ION4II*,*CogniWin*,*Miraculous-Life*,*CompanionAble*,*TrainAndWin*).

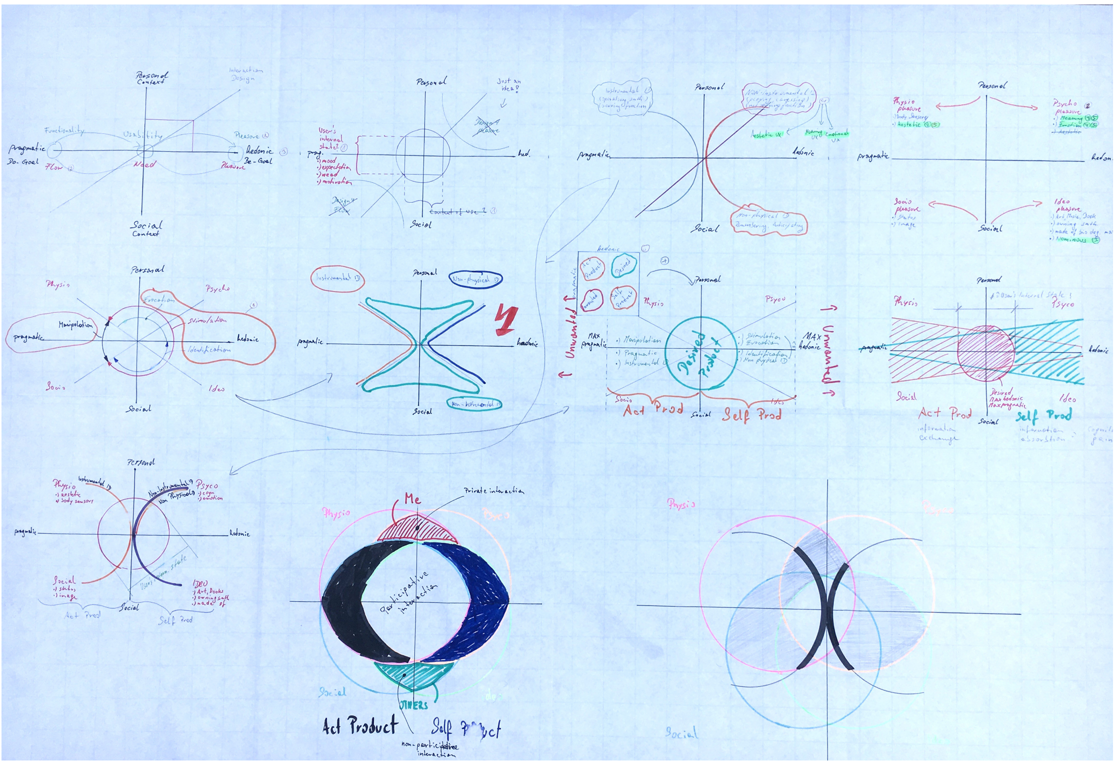


Figure 5.2: The evolutionary design of the MIB-HCI illustrating the main iterative steps towards the final MIB-HCI structure.

Admittedly, this diversity of service types is probably driven by different project goals and their focus on concrete sub aspects of users' daily life support. Nevertheless, the key manifestation characteristics are observable across different projects. On the one hand, users are seeking for simpler, more accessible, and more directed solutions for social-related issues. On the other hand, they are seeking for more "guided" and more dialog-forming solutions for personal-related issues.

This observation, when taken out of the AAL context, could possibly explain the popularity of messaging systems. The primary goal of messaging systems is not the interaction with the system itself but rather the communication and exchange with friends and relatives. It is noticeable that the functionality set in popular messaging systems (e.g., whatsApp, Snapchat, Telegram) is limited. These interactive system focus more on the social connection establishment and on the content delivery and less on interaction style with the device. The offered UIs in these systems are rather classical and straightforward.

Thus, the first iterative design step was driven by the practice-oriented observation that interactive systems designed for the private purpose require more descriptive IxD styles and that interactive systems designed for social purpose require more goal-oriented IxD styles. This distinction between two different IxD styles correlates with the pragmatic/hedonic

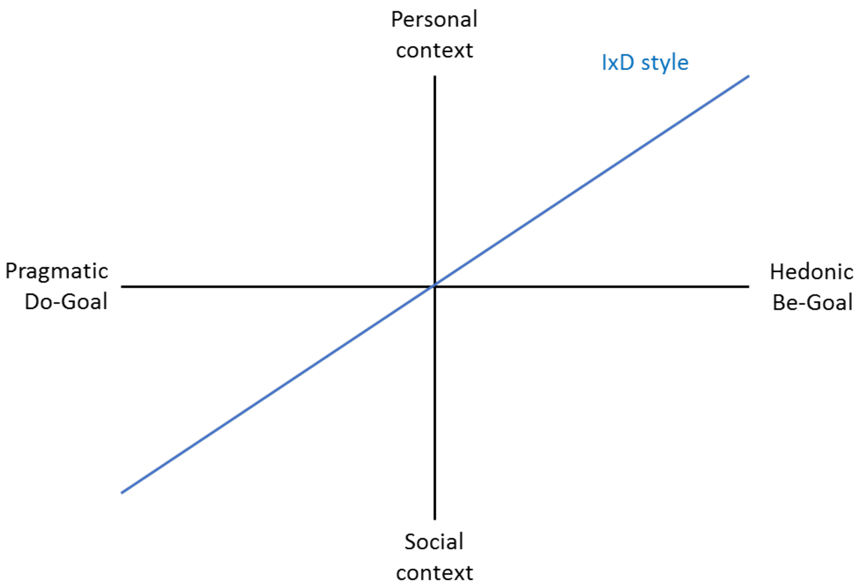


Figure 5.3: The two dimensions representing the basic structure of the MIB-HCI structure. The personal vs. social context along the y-axis and the simple and quick vs. guided and dialog-forming aspects along the x-axis.

model which was presented in the state-of-the-art Section 2.3.5. Goal-oriented IxD styles can be summarized as the pragmatic dimension that refers to the product's perceived ability to support the achievement of "do-goals", and descriptive IxD styles can be summarized as the hedonic dimension that refers to the product's perceived ability to support the achievement of "be-goals". From hereinafter we will use the pragmatic/hedonic dimensions as synonyms for goal-oriented IxD styles and descriptive IxD styles, respectively.

Figure 5.3 illustrates this first design step that focuses on these aspects and their implication on the IxD style. It is noticeable that the x-axis reflects the pragmatic/hedonic dimension and that the y-axis reflects user's social/personal context. These two dimensions represents the basic MIB-HCI structure which will be enhanced and validated using other concepts, methods and models from the UX, UxD, IxD, and PD research field. Next to these two dimensions, Figure 5.3 utilizes a linear function to define the mentioned key manifestation characteristics for the IxD style in respect to the social context and private context along the y-axis.

5.1.2 Ranking of Consumer Needs

The second iteration step elaborates the pragmatic/hedonic dimensions in more details utilizing two IxD concepts which were represented in the state-of-the-art Section 2.3.4. Firstly, Jordan's hierarchy of consumer needs [MCS15, Jor02] which are: functionality, usability, and pleasure and secondly, Dana's framework for making experience delightful

[Chi10] which is conducted of: flow, meaning, and pleasure.

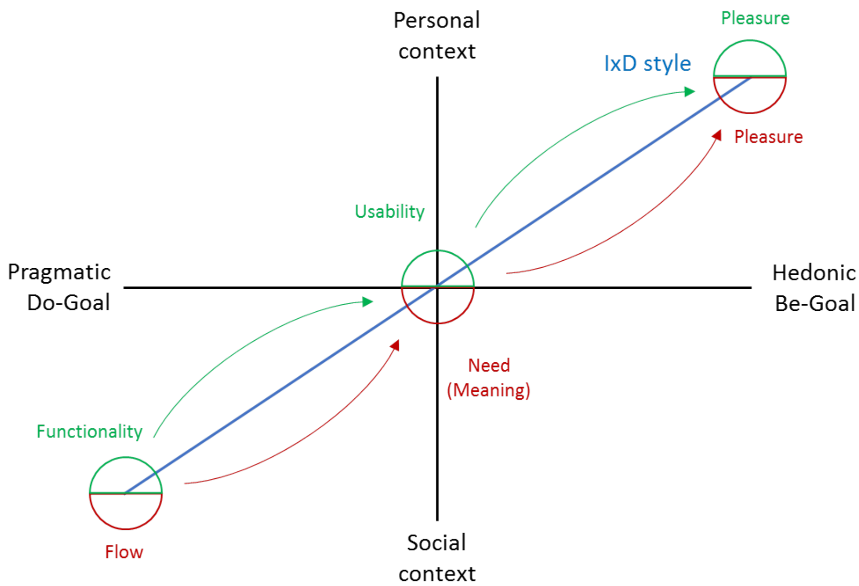


Figure 5.4: The arrangement of Jordan's hierarchy of consumer needs and Dana's framework for making experience delightful along the IxD style function reflecting the goal-oriented vs. descriptive aspects along the x-axis.

Figure 5.4 illustrates the arrangement of these concepts along the initial MIB-HCI structure. These concepts relate primary to the pragmatic/hedonic dimension which is arranged along the x-axis, but since the IxD style is defined by the linear function these concepts have been translated to the straight 45°IxD style line. Starting with Jordan's consumer needs [MCS15, p. 300] the fundamental ideas behind this inclusion can be summarized as follows:

- Functionality
  Interactive systems, primary designed for the use in the social context such as the human-human communication and social inclusion, need to focus on the exchange with the the remote user and the remote target group, respectively. It is important to shift the focus from the individual interaction with the system towards the content generation (e.g., messages, audio/video streams, emotion representations, shared pictures) and the content delivery. An overhead on system features that does not serve the primary human-human communication over-complicates the system and can potentially reduce its functionality. The "group effect" is a factor that should not be underestimated in such applications. Following aspects highlight this "group effect" factor:

  – Users can help each other to overcome comprehensive and thus usability issues. Moreover, users are able to inspire remote users to explore the functionality set of the system via the delivered content. This is, for instance, the case if users retrieve unusual or outstanding media elements during an usual and from their point of view familiar conversation style. An audio snippet embedded in an conventional text-based whatsApp message exchange represents such an unusual and outstanding media element for those who explore this element for the first time.

– The "common sense" about users' expectations regarding functionality and usability. This aspect highlights that users can resign themselves to the common situation (e.g., in terms of a common interaction technique) if the focus is not on the personal level but rather on the social level. Arguments like "it's ok, everyone is doing this it in that way" emphasizes user's perception as a member of a specific group and its belonging to this group that shares the same situation. This in turn can alleviate the immediate requirement for an improvement of the offered interaction technique or the change of the offered interactive system.

- Pleasure
  The previous section highlighted that users can resign themselves to the common situation in the social context. This is not self-evident in the private context. If key factors such as the belonging to a specific group or the expected help from other users are missing, then the driving force for the continuous usage of the offered system is shifted to the system itself. Thus, users' pleasure and the designers consideration of these pleasures plays a key role in interactive systems which are primary designed for the private context. The overall goal is to provide the right functionality, but also to incorporate individual aspects such as the individual interaction style within the system to emphasize user's pleasure perception during the accomplishment of individual tasks.

- Usability
  In a mixed context, which is partly situated in the private context and partly situated in the social context, there is the demand to balance the two previously mentioned factors. On the one hand, interactive systems need to focus on the right set of functionality. On the other hand, they also need to address user's individuality and need to focus on pleasurable aspects. In such a setting, the usability factor plays an essential role. Usability improvements can help to alleviate negative impacts on the user, regarding system designs that act in a reduced social context (reduced help from other users and the reduced belonging perception to a specific group) and in a reduced private context (reduced focus on user's individuality and its pleasures).

Similar applies for Dana's framework for making experience delightful [Chi10, p. 1]. Since the key aspects remain the same as in Jordan's consumer needs [MCS15, p. 300], the following listing describes the fundamental ideas behind the inclusion of these aspects in more compact manner:

- Flow is essential for interactive systems in social context. The user needs to focus rather on the to-be-accomplished task and less on the system interaction itself.
- Pleasure is essential for interactive systems in personal context. The system reflects user's uniqueness by an individual user-system interaction style.
- In a mixed context (partly in social context and partly in private context) the meaning is essential since the system needs to overcome the reduced social context and the leak of acknowledgment by providing the feeling that the user contributes to something valuable.

5.1.3 UX as the Consequence of Three Aspects

The third iteration step reconsiders the initial idea regarding the IxD style function within the basic MIB-HCI structure as depicted in Figure 5.3. The reconsideration focuses on the linearity of the IxD style function and questions its validity in terms of generalization among different users. Users' are individuals and their perception of the private context and the social context also needs to be treated in a individual manner. Thus, the same linear function cannot be representative for every user in every situation.

This iteration step points out that the current MIB-HCI structure requires more flexibility regarding the reflection of individual user aspects. Marc's work "User experience – a research agenda" [HT06] contributes towards this goal. Marc describes UX as follows: "UX is a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within the interaction occurs (e.g. organizational/social setting, meaningfulness of the activity, voluntariness of use, etc.). Obviously, this creates innumerable design and experience opportunities" [HT06, p. 95].

Figure 5.5 illustrates the inclusion of Marc's UX consequences. The y-axis reflects the context of use, and the x-axis reflects user's internal state. The center of these two dimensions represent the characteristics of the system. Based on these thee aspects, the individual IxD style for a corresponding user can be located within the boundaries of the structure that these three aspects span. In the Figure 5.5 this is represented by the arcs "IxD style user 1" and "IxD style user 2". It is obvious that the new structure provides more flexibility regarding the individuality of the user (internal state) and the intended, to-be-designed interactive system. Admittedly, the structure lefts open how to define and how to map user's internal state and the characteristics of the system on the x-axis and the y-axis. Nevertheless, at this point this question will be let open and readdressed in a later iteration step.

5.1.4 Three types of Human-Product Interactions

The fourth iteration step incorporates Desmet's definition of three types of human-product Interaction purposes [DH07]. Desmet defines in his work the following interaction

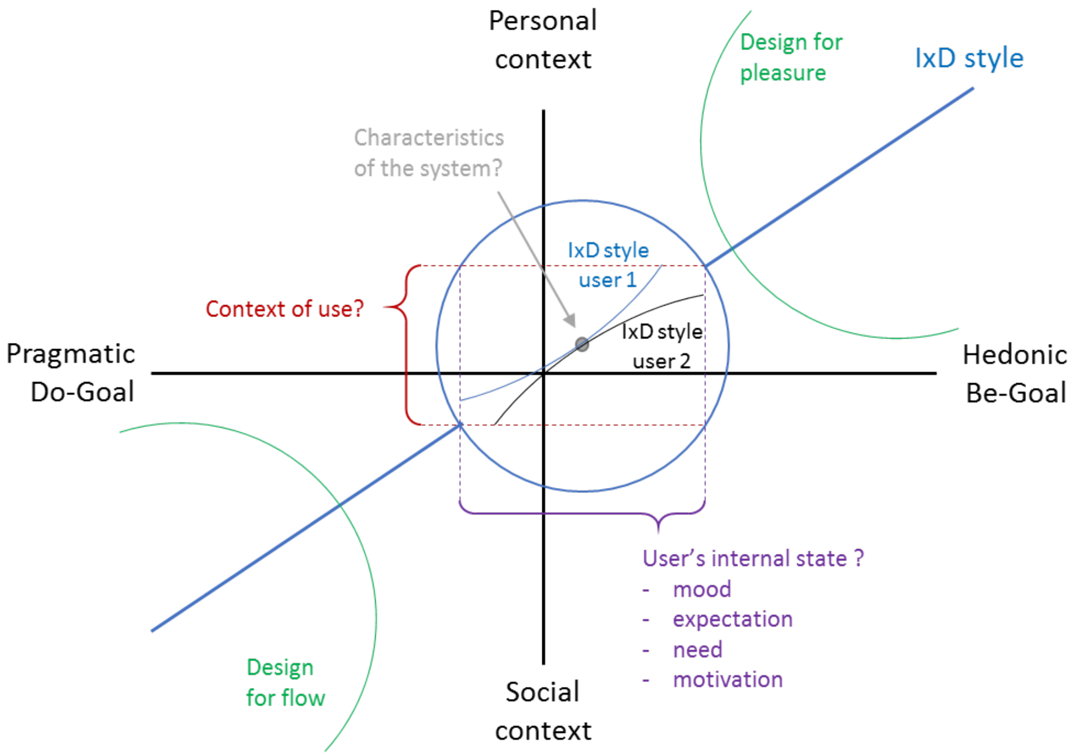


Figure 5.5: Incorporation of user's internal state, the context of use and the characteristics of the system into the MIB-HCI structure.

purposes: (a) instrumental interaction, (b) the non-instrumental interaction, and (c) the non-physical interaction. Instrumental interactions is used to operate and manage products. He quotes following example for the instrumental interaction: "One can, for example, experience irritation when the TV does not respond to the remote control or pleasure when a well-designed online booking system proves to be easy to operate" [DH07, p. 58]. Non-instrumental interactions, on the contrary, are described as: "Non-instrumental interactions do not directly serve a function in operating a product, such as playing with or caressing the product. Someone can be delighted by the soft touch of a seat or inspired by the brilliant shine of a car" [DH07, p. 58]. And finally, he defines non-physical interactions as experiences that refers to fantasizing about, remembering, or anticipating usage. He illustrates non-physical interactions with: "One can anticipate interaction (I expect this handle to break when I push it too hard) or fascinate about interaction (My computer thinks it knows what I want, but it does not have a clue)" [DH07, p. 58].

Figure 5.6 illustrates the inclusion of Desmet's three types of human-product interaction purposes [DH07, p. 58] within the MIB-HCI structure. Since the pragmatic dimension, the do-goals, are located on the left side of the model, the instrumental interaction suits

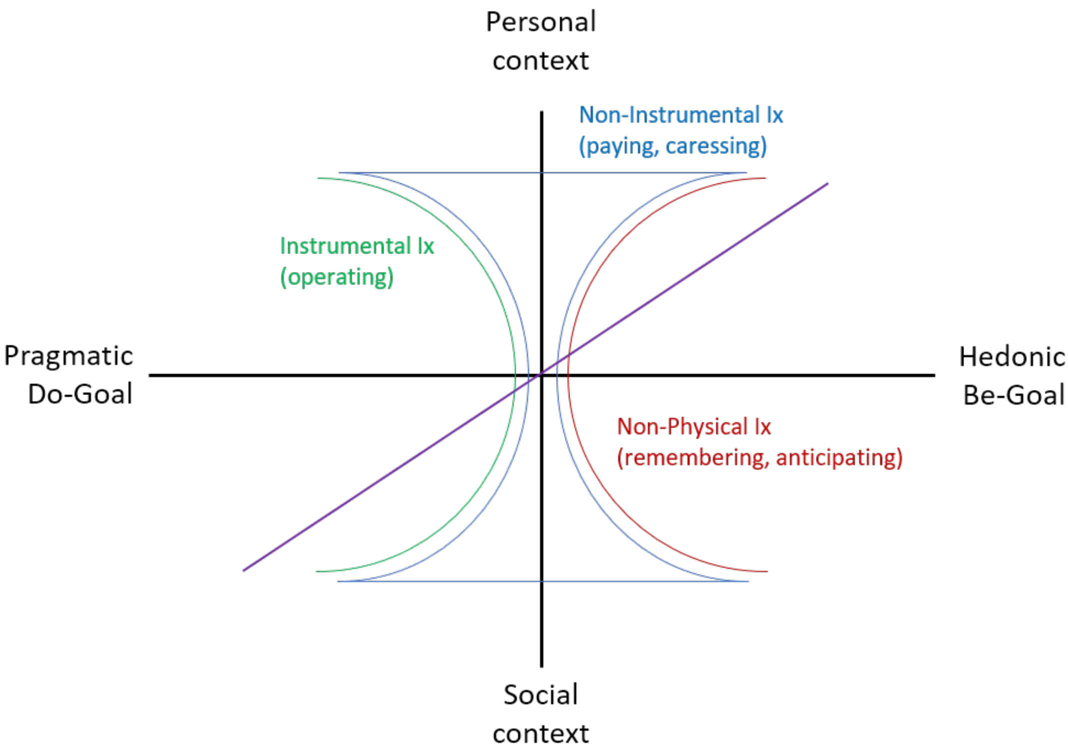


Figure 5.6: Incorporation of Desmet's three types of human-product interactions purposes [DH07, p. 58] into the MIB-HCI structure.

the best on this side of the model. On the opposite, the right side of the model depicts the hedonic dimension, the be-goals. Thus, the non-physical interaction suits the best on this side. The inclusion of the non-instrumental interaction is not so clear and the arrangement is debatable. On the one hand, it is logical to arrange the non-instrumental interaction opposite to the instrumental interaction, namely on the right side of the MIB-HCI structure. On the other hand, Desmet defines non-instrumental interaction using attributes such as playing, caressing, or delighting. These attributes go along with attributes assignable to aesthetic. Later in this section we will see that aesthetic aspects are arranged along the pragmatic dimension. Thus, non-instrumental interaction is also, to some extent, assignable to this pragmatic dimension on the left side of the MIB-HCI structure.

In conclusion, non-instrumental interaction ranges from the left side, the pragmatic dimension towards the right side, the hedonic dimension. Figure 5.6 illustrates the arrangement of all three interaction styles.

Admittedly, the depicted hard and very strict borders are chosen just for the illustration purposes. They highlight the arrangement primary along the pragmatic/hedonic x-axis based on the prior argumentation. However, it can be assumed that the interaction types, when arranged within the structure of the MIB-HCI, have a fluid overlapping since they are also defined in a non-unambiguous manner using key fragments in Desmet's work such as "... do not directly serve a function" or "... refer to" [DH07, p. 58].

We can also utilize Desmet's attributes in another manner to emphasize the broad range of the non-instrumental interaction. If we explore the playing aspect in more detail, for instance, then it becomes obvious that the playing activity influences both, the pragmatic dimension as well as the hedonic dimension. In interactive systems designed primary for the game genre users are confronted with pragmatic interaction elements to play the game, but at the same time the game setting and the game design addresses hedonic characteristic in order to evoke activating and peasant core affects such as curiosity, eagerness, fascination, and joyfulness. These core affects have been presented in the state-of-the-art Section 2.3.2.

5.1.5 The Four Types of Pleasure

The fifth iteration step incorporates Jordan's four types of pleasure (physio-pleasure, psycho-pleasure, ideo-pleasure and socio-pleasure) as presented in [Jor00, p. 13] and in Section 2.3.6. These pleasure types are, along with the used pragmatic/hedonic model and the personal/social context, the most dominant concepts within the MIB-HCI structure. As already mentioned before, this work investigates pleasure-oriented aspects which target the long-standing engagement of the user with the offered interactive system. Thus, it is consequential to elaborate the arrangement of the four pleasure types within the MIB-HCI structure.

Figure 5.7 illustrates the result of the arrangement of Jordan's four types of pleasure [Jor00, p. 13] within the MIB-HCI structure. The arrangement is based on following arguments: The physio-pleasure and the psycho pleasure are self-oriented pleasures. The experience of these pleasure types results from the own body arousal or from the own cognitive and emotional reactions to a sensual affect. Thus, it seems reasonable to place these two types of pleasures in the upper part of the MIB-HCI structure that refers to the personal context. In contrary, the socio-pleasure and the ideo-pleasure are pleasure types that can be experienced in coexistence with other human beings. The arrangement of socio-pleasure is self-descriptive. The arrangement of the ideo-pleasure can be explained by the definition of the term ideology, e.g., using the Cambridge Dictionary: "ideology, noun, a set of beliefs or principles, especially one on which a political system, party, or organization is based" [20118, p. 1]. The definition highlights that the term ideology involves multiple persons and their body of thought. Moreover, examples of ideological pleasure as depicted in Figure 5.7 also highlight the multi-personal character. Art, music, and books are the results of social development and they are also gaining on importance and on variety in combination with the society. Thus, it seems reasonable to place these two types of pleasure in the lower part of the MIB-HCI structure that refers to the social context.

On the horizontal level, one must decide which two pleasures are more related to pragmatic

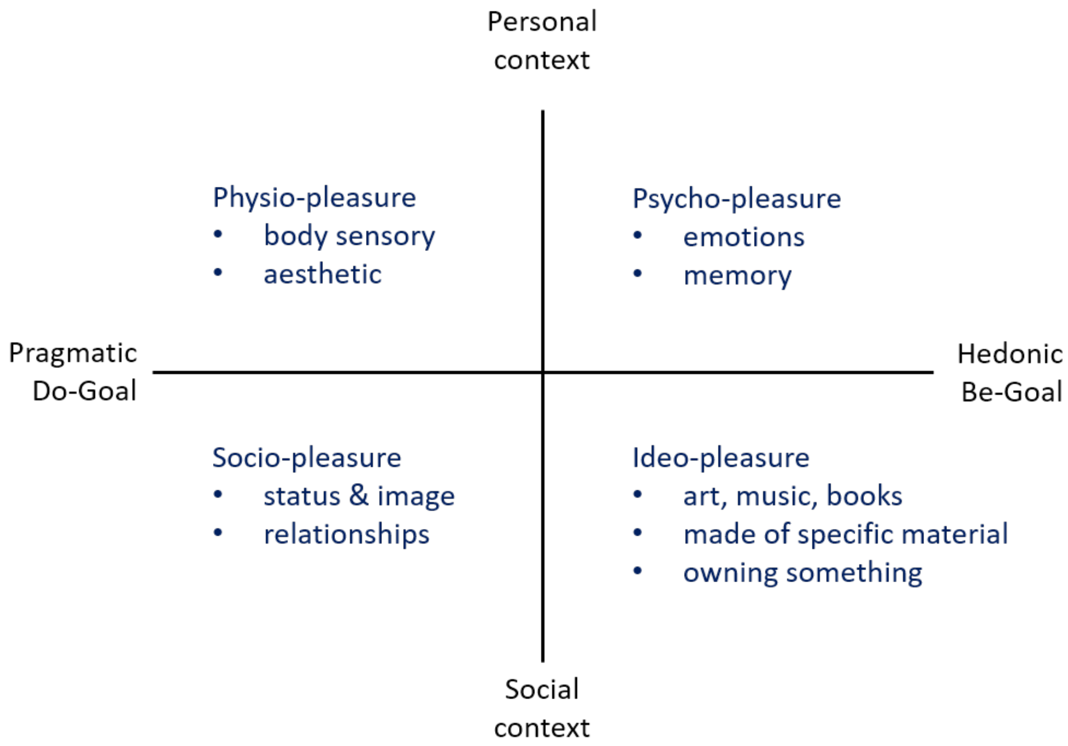


Figure 5.7: Incorporation of Jordan's four types of pleasure [Jor00, p. 13] into the MIB-HCI structure.

dimension and which are more related to hedonic dimension. According to the first iteration step and the basic thought (interactive systems designed primary for the private purpose require a higher hedonic IxD style and interactive systems designed primary for the social purpose require a higher pragmatic IxD style), the social context is likely more to be arranged on the left, the pragmatic side. This implies that the ideo-pleasure is arranged on the right, the hedonic side. Similar arguments follow for the arrangements of the physio-pleasure and psycho-pleasures. Using aspects of the fourth iteration step, namely the location of the non-physical IxD within the MIB-HCI structure (see Section 5.1.4), leads to the arrangement of the psycho-pleasure on the hedonic side and this in turn implies the arrangement of the physio-pleasure on the pragmatic side.

The transition from physio-pleasure (body sensory or sensual affect) towards psycho-pleasure (emotional affect and meaning) is also illustrated by Anastasia's work "User Experience with Physical and Digital Objects" [VW16]. According to Anastasia, aesthetic is one attribute of the sensual affect (curiosity/novelty is the second mentioned one). Thus, aesthetic belongs to the physio-pleasure because it is something that can be sensed by our body. This is also confirmed by Desment's work with the phrase "When the user is pleased by the sensuous shape of a vase, the silent but harmonic sound of a cellular phone, or the soft and fluffy texture of a seat, these experiences refer to aesthetic experiences" [DH07, p. 61]. However, Anastasia argues further that the one attribute of the emotional affect, namely the interpretative thinking, is a by-product of user's connection with the object through its aesthetic or novel qualities. Thus, psycho-pleasure in terms of emotions, meaning, memory, thinking etc., is a consequence of sensual affects that are located on the physio-pleasure side.

5.1.6 Pragmatic and Hedonic Attributes

The sixth iteration step incorporates further aspects of pragmatic and hedonic attributes. In his work "The Think and I: Understanding the Relationship Between User and Product" [Has18], Marc takes a closer look at two universal groups of attributes that define the product character and the underlaying human needs that they aim to address. According to this work, the pragmatic attributes of software products are "clear", "supporting", "useful" and "controllable" [Has18, p. 4]. The main aim of a pragmatic product is the manipulation of the environment. Hedonic characteristic, on the opposite, are defined by attributes like "outstanding", "impressive", "exciting" and "interesting" [Has18, p. 5]. The main aims of hedonic product are: (a) stimulation, (b) identification, and (c) evocation.

Marc summarizes these two concepts as follows: "Whereas pragmatic attributes emphasize the fulfilment of individuals' behavioural goals, hedonic attributes emphasize individuals' psychological well-being" [Has18, p. 4]. This aspect also indicates the right arrangement of the four pleasure types within the structure of the MIB-HCI as presented in the previous Section 5.1.5. However, the incorporation of these aims is depicted in Figure 5.8. The arrangement of manipulative aim (including its attribute "clear", "supporting", "useful" and "controllable") emphasizes that pragmatic products are not just function-able, but that they also have the duty to fulfill individuals' behavioral goals. Thus, usability aspects (including all five usability attributes as presented in Section 2.1.6) are required and a central element in all IxD styles.

This argumentation and arrangement seems to be a contradiction to the second iteration step which used Jordan's consumer needs [MCS15, p. 300] and Dana's framework for making experience delightful [Chi10, p. 1] as presented in Section 5.1.2. This second step started from the assumption that there is only one pleasure type and that pleasure can be realized only on the hedonic dimension. However, since then the model evaluated further and the current MIB-HCI structure assumes that pleasure can be achieved on several levels. Furthermore, considering the Kano model [Spo15] and the fact that basic needs must be present to make a product successfully, the current model assumes that functionality and usability are indispensable conditions and that pleasure can be only achieved if these two conditions are satisfied.

Nevertheless, referring to the arrangement of the pragmatic and hedonic product aims, Marc argues that hedonic products can be subdivided into providing stimulation, communicating identity, and provoking valued memories [Has18, p. 5]. Since products can provoke memories, the evocation aspect is arranged between physio-pleasure and

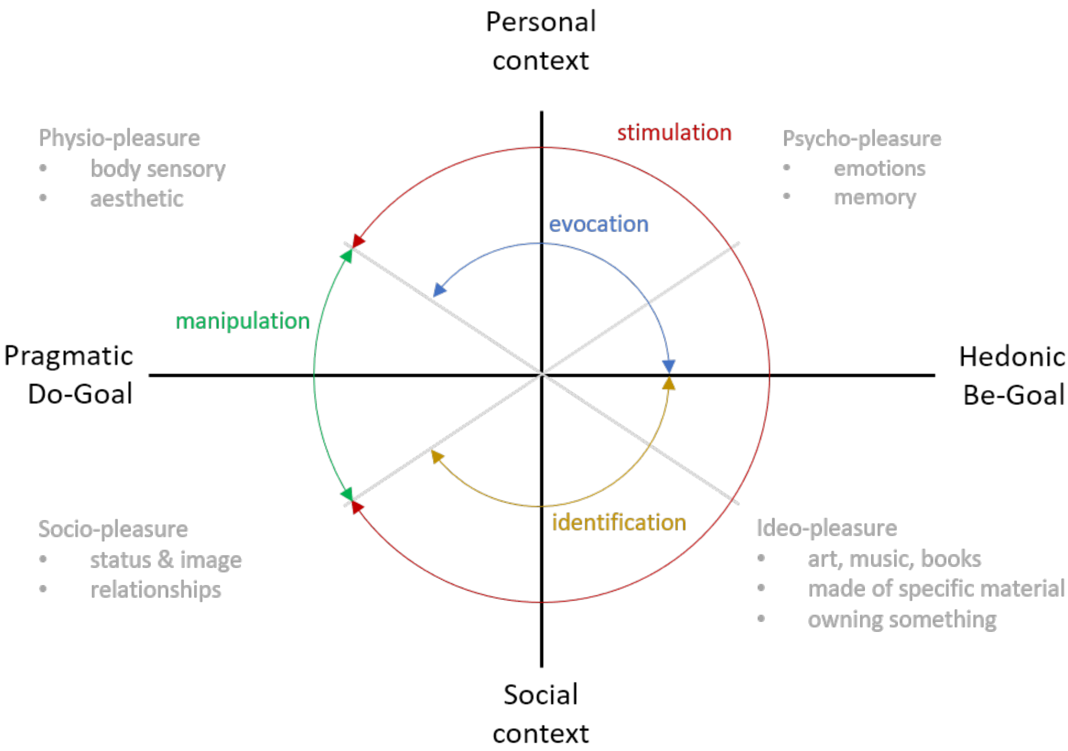


Figure 5.8: Incorporation of pragmatic product aims (manipulation) and hedonic product aims (stimulation, evocation and identification) into the MIB-HCI structure.

psycho-pleasure. This underlines also arguments presented in Section 5.1.4, namely that physio-pleasure (body sensory or sensual affect) cause psycho-pleasure (emotional affect and meaning). The arrangement of the identification is argued by following two statements: "Individuals express their self through physical objects – their possessions. . . . Individuals want to be seen in specific ways by relevant others" [Has18, p. 5]. Thus, it is consequent to arrange the identification aim between the socio-pleasure and ideo-pleasure. And finally, the last hedonic aim, the stimulation is an aspect that over spans all four pleasure quadrants since every pleasure and every mix of pleasures may cause a stimulus for the personal development. Here again, the depicted hard and very strict borders are chosen only for illustration purposes. It is assumed that the product aims (analogous to the previously presented incorporation of Desmet's three types of Human-Product interactions) have a fluid overlapping arrangement.

5.1.7 The Act, Self and Desired Product

The seventh iteration step incorporates once more Marc's work "The Think and I: Understanding the Relationship Between User and Product" [Has18]. This time, the focus is on the combination of pragmatic and hedonic attributes. The concept was presented in state-of-the-art Section 2.3.5 utilizing the Figure 2.23. Marc calls product with strong pragmatic and weak hedonic attributes as **Act** products. On the opposite, product with strong hedonic and weak pragmatic attributes are named as **Self** products. Furthermore, he calls a product with weak hedonic and weak pragmatic attributes as **Unwanted** and a product with strong hedonic and strong pragmatic attributes as **Desired** products. If we assume that the pragmatic the hedonic characteristics range from strong to weak (following Marc's arguments), then this leads to an overlapping of these characteristics within the MIB-HCI structure and this leads to the manifestation of **Desired** and **Unwanted** areas.

Figure 5.9 illustrates Marc's concept of **Desired** products applied on the MIB-HCI structure. The intersection circle in the center colored green indicates the area with maximum pragmatic attributes under the consideration of coincident maximum hedonic attributes. This is the preliminary target of the MIB-HCI structure, namely the identification of user-specific setting within this green highlighted area that represents a balanced interaction set. The following sections utilizes this final version of the MIB-HCI structure.

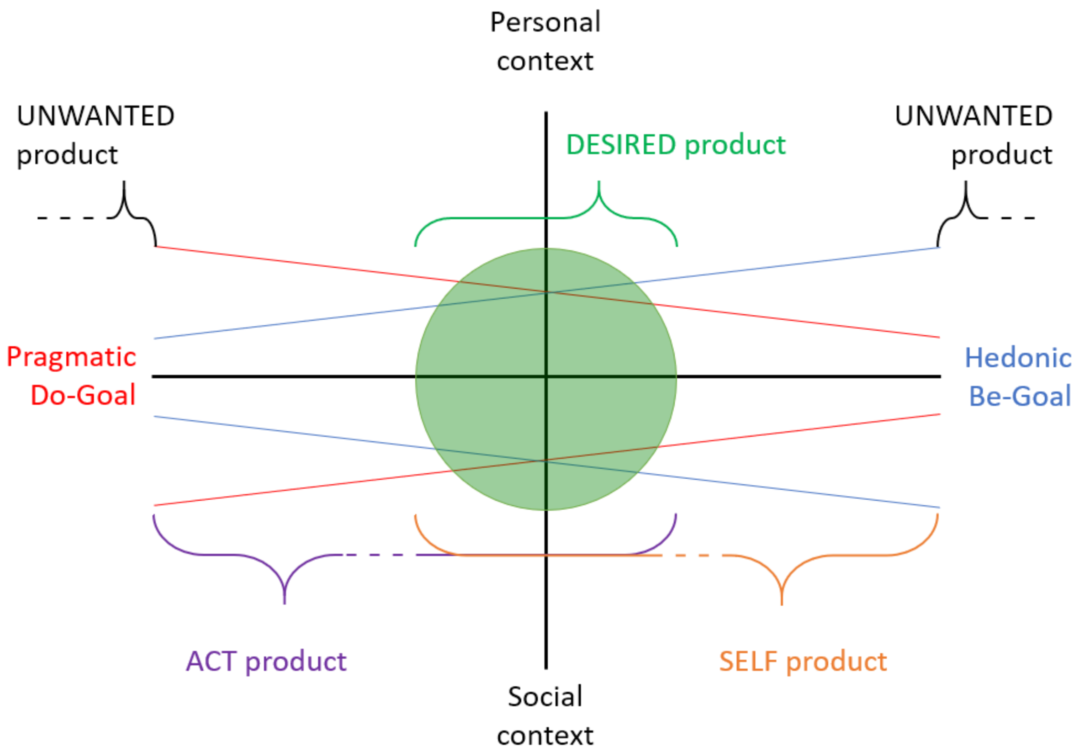


Figure 5.9: Incorporation of the combination of pragmatic and hedonic values building the **Desired** and the **Unwanted** product into the MIB-HCI structure.

5.2 The Coherence of the MIB-HCI

So far, seven iterative steps have been shown. At this point, it is time to step back and to observe the MIB-HCI structure from a holistic view.

The evolved model incorporates following aspect:

- The juxtaposition of hedonic and pragmatic attributes.
- The juxtaposition of personal and social context.
- The three types of human-product interactions.
- The four types of pleasure.
- The proposition that a balanced mix of hedonic/pragmatic attributes cause a desirable product.

Considering these aspects, we can postulate the hypothesis - if the combination of maximum pragmatic and maximum hedonic attributes lead to a desirable product, then potentially the right mix of pragmatic associated pleasure types and hedonic associated pleasure types could also be beneficial for the user and provide "more" pleasure. The following aspects support the postulated hypothesis.

The MIB-HCI model presumes that users feel the urge to experience pleasure. Moreover, the model presumes that users experiences different levels of pleasure types such that the statements "I'm pleasant", 'I'm more pleasant" and "I'm very pleasant" does not need to be existential proven. Thus, by deductive reasoning it is consequential that the motto, "the more pleasure the better" holds. At the same time, the model does not consider all four types of pleasure as equal important for every user. This fact is also highlighted by Jordan's works and the argument: "Whilst it may be useful to consider all four types of pleasure when approaching the issue of how a product can please those for whom it is designed, there is no suggestion that all product should provide all four types of pleasure" [Jor00, p. 15]. However, as it has been previously highlighted in Sections 2.3, 5.1.5, and 5.1.6, the four pleasure types influence each other.

Following examples underline this aspect:

- Aesthetical experience (physio-pleasure) causes emotional experience (psycho-pleasure).
- The belonging to a social group (socio-pleasure) may cause the rethinking of own ideological values (ideo-pleasure).
- Own emotions and feelings (psycho-pleasure) may cause a change the relationship to friends, partners and/or relatives (socio-pleasure).

As we can see from these inductive reasoning examples, even if a user weights its importance level for one or a few types of pleasure as low, it is also important to address these low ranked pleasure types in order to evoke user's higher ranked pleasure types. Thus, it is reasonable that the balanced mix of pleasure types provides beneficial values for the user. The broader addressing supports, on the one hand, the motto "the more pleasure the better". On the other hand, this approach also promotes already high ranked pleasure types. Thus, it can be assumed that the hypothesis holds.

If we agree on the validity of the first hypothesis, then this consequentially raises the question if pragmatic and hedonic attributes can be mapped to pragmatic associated and hedonic associated pleasure types? Or the same question put into another perspective – is the arrangement of the four pleasure types along the pragmatic and hedonic axis valid?

The reasoning for the assumption of the right arrangement of the four types of pleasure has been presented in Sections 2.3, 5.1.5, and 5.1.6. Moreover, the assumption seems to hold since pragmatic and hedonic attributes utilize different pleasure types (or at least effects of pleasure types) to describe and to define themselves. Admittedly, some pleasure types have a stronger relationship with the underlined pragmatic/hedonic model (e.g., the psych-pleasure with hedonic attributes as defined in Section 5.1.6), and some derive their relationship only by an implication (e.g., the arrangement of the physio-pleasure on the pragmatic side because, as defined, hedonic attributes emphasize psychological well-being and both can be assigned to the private context). Nevertheless, at this point it is understood that pleasure types, as arranged in the MIB-HCI structure, reflect primary pragmatic attributes on the left side and primary hedonic attributes on the right side of the x-axis.

The next step in the coherence check, if we agree on the validity of previous steps, is to question the relation between pleasure types and interaction styles. The goal of this task is to support the following hypothesis by inductive reasoning - if the balance of pleasure types is beneficial for the user, then the balance of interaction styles can also be beneficial for the user.

The three types of human-product interactions and the reasoning for their arrangement within the MIB-HCI has been presented in Section 5.1.4. If we further consider that interactive systems are products, as highlighted in Section 2.1.6 and 2.1.8, then we can see that products are inherently connected to its interaction. Since we experience products only through its interaction, it is evident that desired products (defined by balanced mix of pragmatic and hedonic values) imply that its interaction also needs to address these attributes. One can think of an intended, to-be-designed product which targets mainly hedonic attributes (e.g., evocation or stimulation). Without pragmatic attributes (e.g., the ability to sense or to manipulate the product) we would not be able to address evocation, stimulation, or identification which in turn provides psychological well-being (see Section 5.1.6). Thus, interaction with the product requires also, to some extent, in a balanced state.

We can also guide this argument to a broader basis via the transfer of characteristics of a single product to a set of products that users operates (use) in their daily life. Here again, some products target primary pragmatic values and some products target primary hedonic values. Under this consideration and from a broader point of view, users require a balanced set of products and consequently a balanced set of interaction styles. However, the presented argument does not suggest that every single user-product interaction is in need to provide equal values on the pragmatic and hedonic values. The argument rather suggests that users are in need for a balanced set of user-product interactions involving several products in their daily life.

5.3 Addressing UX Values

The previous section focused on the development of the MIB-HCI and the evidence that desired products imply a balanced mix of pleasure types. In this section the focus is on the involvement of the targeting user and the intended, to-be-designed interactive system. This is necessary since the perception of pleasure is something that occurs on the personal level. The fundamental basis for the targeting user involvement are UX factors and the outlined characteristics that UX is seen as something desirable (see Section 2.1.8).

Thus, the addressing of UX aspects within the MIB-HCI structure, which in turn will addresses desirable values, will close the loop towards a balanced set of pleasure types and consequently to balanced set of interaction styles. According to the Section 5.1.3 UX is a consequence of: (a) user's internal state, (b) context of use, and (c) characteristics of the designed system. Thus, the MIB-HCI structure is in need to reflect these three aspects. This is accomplished in the following manner: User's internal state can, to some extent, be reflected by the user specific weighting of the four types of pleasure. Similar applies for the context of use and the characteristics of the system. The context of use can be reflected by the personal/social context of the MIB-HCI structure and the characteristics of the designed system can be reflected by the junction of these two factors. The following listing elaborates the reflection of these aspects in more details.

5.3.1 User's Internal State

User's internal state is characterized by attributes such as predispositions, expectations, needs, motivation, mood, etc. These attributes can, to some extent, be reflected by the four types of pleasure and the individual weighting of each pleasure type. Some users might rank their socio-pleasure higher as their physio-pleasure. Others might rank their psycho-pleasure higher and some might not emphasize any type of pleasure. Relating to user's internal state attributes (need, mood, expectation, etc.) could be represented as follows:

- Need, for instance, could be represented by the urge to increase the pleasure on one or more levels.

- Mood, for instance, could be represented by the current importance rating of the psycho-pleasure.
- Expectation, for instance, could be represented by the entirely set of individual weights. This is because users rate their personal pleasure importance set based on their expectation towards the system which they keep in mind.

However, this approach is not meant to be holistic or 100% accurate. It can rather be used as an indicator for a personal attitude based on the user's assessment.

5.3.2 Context of Use

Context of use is characterized by attributes such as organizational/social setting, meaningfulness of the activity, voluntariness of use. The MIB-HCI distinguishes not that many facets of context. Indeed, it considers only the private and the social context. It is highly possible that the private/social context in the working setting differs from the private/social context in the leisure setting. Furthermore, MIB-HCI does not take the voluntariness of use into the consideration. It assumes that voluntariness of use is present since it targets the gain of four types of pleasure. Thus, the MIB-HCI structure might not be directly transferable from one setting into another setting. Nevertheless, since the model is bases on pleasure-oriented aspects it relies on users' assessment and individual consideration of the current setting in order to address users' needs and wishes regarding each type of pleasure. Consequently, it might be necessary to survey a user multiple times in respect of the intended, to-be-designed interactive system and the specific context of use. It is likely possible that the user assessment targeting the design of an application for the working environment differs from the user assessment targeting the design of an application in leisure environment.

5.3.3 Characteristics of the Designed System

Characteristics of the designed system include aspects such as complexity, purpose, usability, functionality. As already argued before in Section 5.1.6, the model assumes that pleasure can only be established if the functionality aspect and the usability aspects are satisfied. Thus, functionality and usability are implicit addressed within the MIB-HCI structure. The remaining aspects are complexity and purpose of the interactive system.

Admittedly, the MIB-HCI does not reflection the system complexity at this stage. The utilization of the MIB-HCI within the Interaction Design Framework (IxD-FW) incorporates the complexity factor but without a direct user involvement at this stage. At this point, one can also raise the question if and how complexity could possibly influence user's perception of pleasure. If one thinks in terms of process complexity (workflow, interaction techniques & modalities, data representation) then this could be a relevant issue. If one thinks in terms of technological complexity (architecture, network, protocol, data structure and data processing, hardware communication), then this could be less relevant for the targeting user, especially from the interaction point of view. However, since the MIB-HCI does not provide user involvement on the system complexity level, this aspect needs to be forwarded towards the designer and her or his estimation about the intended, to-be-designed interactive system and the resulting users' experience.

The last aspect, the purpose of the system can be reflected, to some extent, by the MIB-HCI. Firstly, by the four pleasure types (physio-pleasure, psycho-pleasure, socio-pleasure, and ideo-pleasure) and secondly, by the juxtaposition of the personal and social context. It is undoubtedly that different applications address pleasure types differently. For instance, an application designed for medical purpose would address the physio-pleasure and/or psycho-pleasure more intensively as the socio-pleasure or the ideo-pleasure. Moreover, an application for medical purpose is also rather related to the private-context and targets only in exceptional cases the social-context. Thus, the purpose of the intended, to-be-designed interactive system can, to some extent, be reflected by the MIB-HCI structure and users might give more precisely answers about their pleasure-preference if they know the purpose of the intended, to-be-designed interactive system.

Genre	Physio	Psycho	Ideo	Socio	Private Context	Social Context
Utilities	x			x	x	x
Weather	x	x			x	
Finance		x			x	
Productivity	x	x		x	x	x
Reference		x	x		x	
Navigation		x	x		x	
e-commerce		x	x	x	x	
News		x	x	x	x	
Medical	x	x			x	
Health-care	x	x	x		x	
Communication		x		x		x
Lifestyle	x	x	x	x	x	x
Travel		x	x	x	x	x
Sport		x	x	x	x	x
Social net		x	x	x		x
Games		x		x	x	x
Books		x	x		x	
Photography		x	x	x	x	x
Entertaiment		x			x	

Table 5.1: Possible assignment of application genres and their targeting pleasure types including the private/social context.

Table 5.1 provides an overview about one possible assignment setting of application purposes (genres) and the pleasure types that they might primary target. The presented genres are based on Xu Qiang's work "Identifying diverse usage behaviors of smartphone apps" [XEG+11]. The table is not meant to be holistic nor universal applicable. One can always argue that an application classified to a specific genre targets other pleasure types as presented in Table 5.1. For instance, a designer might aim to design an application for book lovers to share their experience across other users and to provide recommendation about books worth reading. This application might be classified as the "book" genre but the focus would be, next to the psycho-pleasure, on the socio pleasure. On contrary, one can also argue that this intended, to-be-designed application belongs to the "socio-net" genre. This example illustrates that the genre classification and the purpose of the application have various facets and that the clear communication to the user about the intended, to-be-designed application is from uttermost importance.

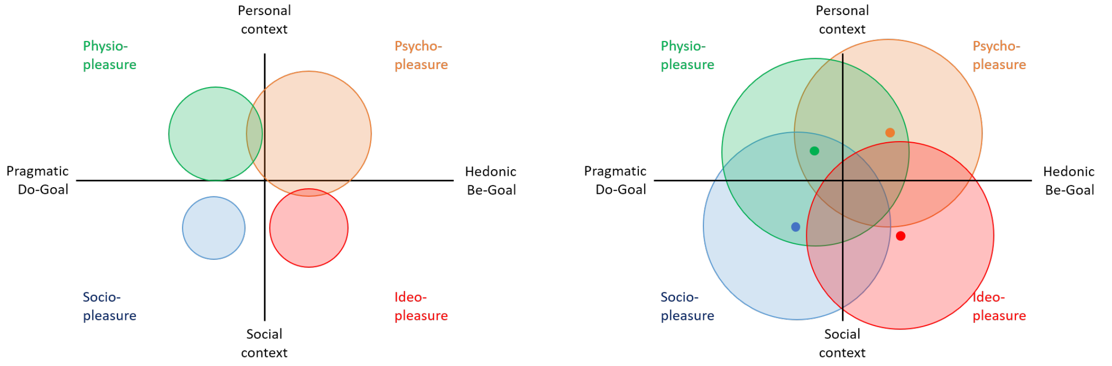
5.4 Reflection of User's Set of Pleasure Preferences

In the previous section, we have seen that user's internal state can be represented, to some extent, by the four pleasure types and their individual ranking of each of these pleasure types. Moreover, since we have also seen that the four types of pleasure influence each other the next step would be to find an adequate metric to reflect these two aspects jointly. From the targeting user's perspective we are seeking for a one-dimensional metric that describes user's individual ranking for a specific pleasure type. On the other side we are seeking for a possibility to join this metric with a second dimension in order to reflect the relationship between other pleasure types.

The simplest solution to addresses both aspects is to define the pleasure not as a single value but as a two-dimensional shape, e.g., by a circle. If we place a circle for each pleasure type within the MIB-HCI structure then we will gain so called "pleasure ranges" for each pleasure type. The user's individual ranking for the specific pleasure can be reflected either by the diameter of the circle, by the center of the circle, or by a combination of both attributes. For simplicity reasons I will exclude the last opportunity, namely the combination of the diameter and the circle center. The other two opportunities are exemplary depicted in Figure 5.10.

The diameter approach is depicted in Figure 5.10a and the center approach is depicted in Figure 5.10b. The illustration highlights yet another problem regarding the circle diameter approach. The approach does not seem to be the right tool since it alleviates the relationship between different pleasure types. One can see in Figure 5.10a that, e.g., the depicted socio pleasure is isolated in its own quadrant and does not influence, as expected and argued in Sections 2.3, 5.1.5, and 5.1.6, any of the other pleasure types. The circle center approach, on the contrary, involves for each type of pleasure also all remaining types of pleasure. Admittedly, this feature is provoked by the structural design (by the limitation of the center distance from the coordinate origin), but this is concurrently intended to satisfy that dependency relations between pleasure types as previously argued.

Thus, the MIB-HCI will utilize the circle center approach to reflect user's current set of pleasure interests. In order to gain overlapping areas between pleasure types we will limits the pleasure circle center to a maximum distance from the coordinate. If we assume



(a) Example of user's importance estimation for each of the four pleasure types based on the diameter parameter.

(b) Example of user's importance estimation for each of the four pleasure types based on the circle center parameter.

Figure 5.10: Two approaches to reflect user's individual ranking for a each of the four pleasure type within the MIB-HCI structure.

that the center of the circle can only move along a straight 45°line, which is additionally limited to a maximal length in each quadrant, then we would be able to satisfy also the end user's perspective, namely a simple and one-dimensional metric that depicts user's individual ranking for a specific pleasure type. I will name this straight 45°line as "pleasure action line". Figure 5.11 illustrates this concept.

A zero value represents a low subjective importance for the specific pleasure type, whereas the one value represents a high subjective importance for the specific pleasure type. At this point it is not unambiguously defined how to map user's importance estimation for a pleasure type into the scale ranging from zero to one. This aspect will be discussed in more details in the critical reflection Section 7.2.8. Nevertheless, one common approach targeting this goal is the direct ratings of importance-method [JBA86]. This approach utilizes either a numeric interval scale ranging from 0-5 (in some cases from 1-5) or terms ranging from "Not at all important", "Slightly Important", "Important", "Fairly Important" to "Very Important" SusanEDeFranzo2011, rogers2002importance, schrepp2017design. Using this background information, the simplest solution for the mapping would be to survey the user in a direct rating manner utilizing terms since they appear to be more intuitively. Simultaneously, it is advisable to eliminate the first importance term, the "Not at all important", since the model presumes that users feel the urge to experience pleasure which would be a contradiction to the first term. The linear mapping of four remaining terms to a scale ranging from 0 to 1 is a straight forward process.

Figure 5.12 illustrates an example of two pleasure circles with different circle centers for the psycho-pleasure in Figure 5.12a and the socio-pleasure in Figure 5.12b. This approach, when applied on all four pleasure types results into an area-based representation of user's current set of pleasure interests as depicted in Figure 5.13. The structure has two main advantages, namely a) it prevents the omission of pleasure types and b) it provides more

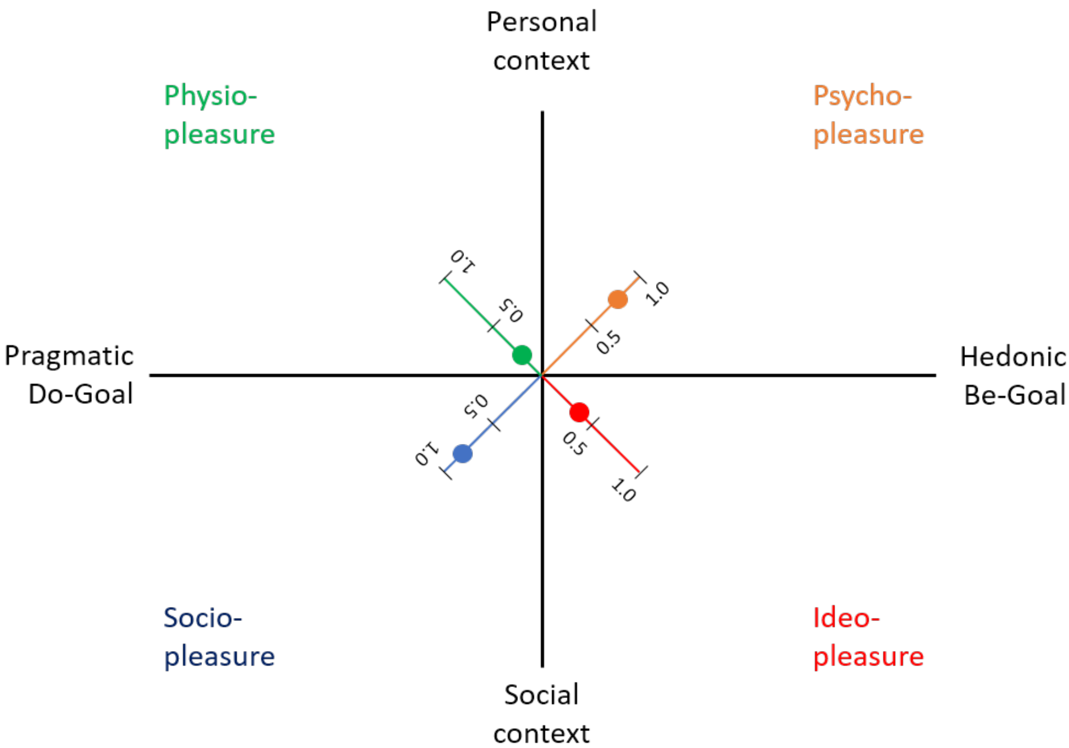
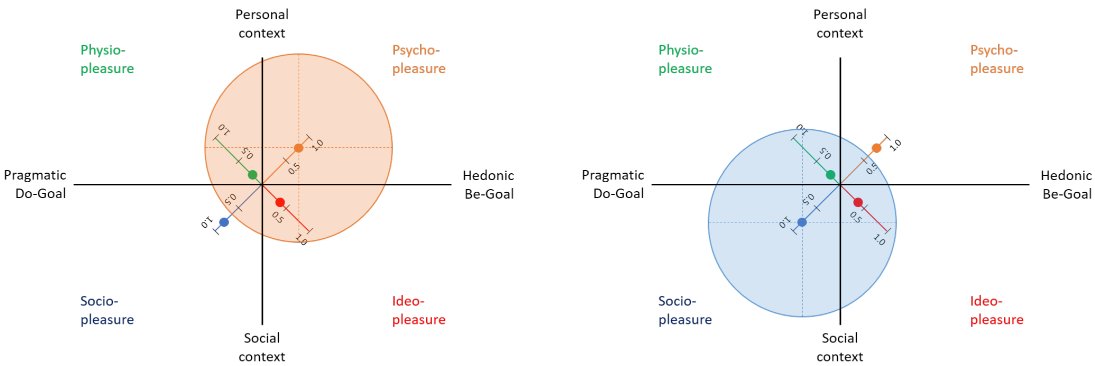


Figure 5.11: Example of importance estimation for each pleasure type represented by a dot on the scale between 0 and 1 in each quadrant.

and less overlapping areas which can be used as an indicator for the identification of strong and weak pronounced pleasure types.



(a) Example of psycho pleasure estimation. (b) Example of socio pleasure estimation.

Figure 5.12: Two examples of pleasure importance estimations.

The prevention of omission of pleasure types is a necessary criterion for the model since, as argued before, pleasure types influence each other. For instance, the missing, of the physio-pleasure would consequently result in loss of the ability to experience psycho pleasure. The structure prevents this state using the 45°pleasure action line. Even if the user rates her or his pleasure importance for a specific pleasure as "Slightly Important" this will result into a pleasure circle center which is located in the coordinate origin of the MIB-HCI structure. Thus, also a low ranked pleasure type has still the ability to influence other pleasure types since it radiates into other quadrants. Additionally, if the user does not emphasize any pleasure type, all pleasure circles will equally overlap in the center of the MIB-HCI structure and still traverse all four pleasure types satisfying the model assumption that users feel the urge to experience pleasure.

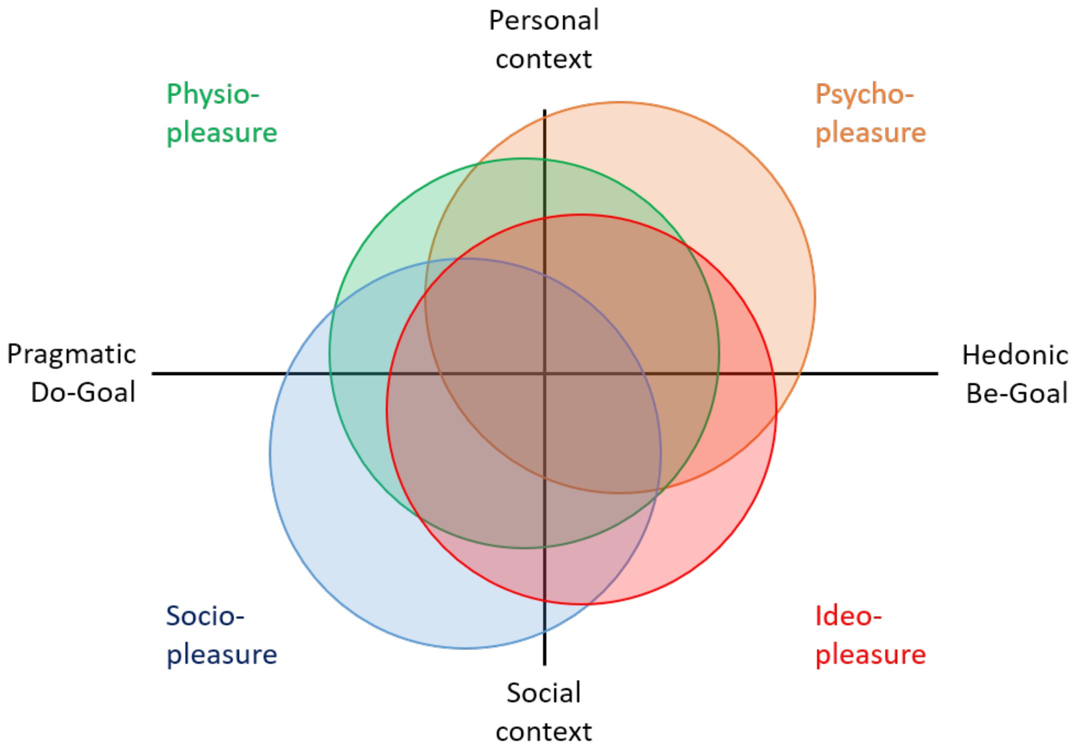


Figure 5.13: Area-based representation of user's current set of pleasure interests.

The second aspect, the provision of more and less overlapping areas is the provisional target of the MIB-HCI. Previously we have observed that if the user does not emphasize any pleasure type, then this will result in a unique overlapping circle, located in the center of the MIB-HCI structure. If the user ranks a pleasure type higher, this will push the pleasure circle center along the pleasure action line towards the center of the corresponding quadrant. Consequently, this produces more and less overlapping areas. The model distinguishes four types of overlapping areas. An area build of four overlapping areas is named as "knowing area", an area build of three overlapping areas is named as "pronounced area", an area build of two overlapping areas is named as "promotion-worthy area" and finally the "blind area" located at the bottom of the y axis and built by the union of the socio-pleasure and the ideo-pleasure that constitutes an exceptional case which will be elaborated shortly.

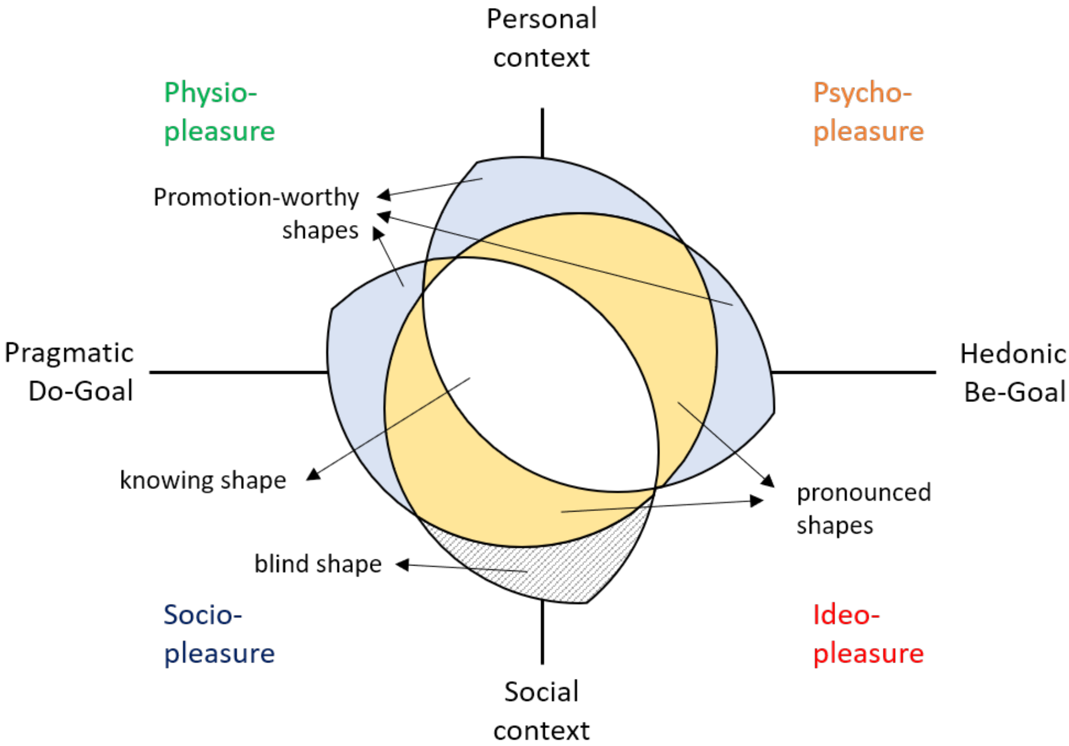


Figure 5.14: Four distinguishable shapes (knowing-shape, pronounced shape, promotion-worthy shape and blind shape) of the MIB-HCI representing user's strong and weak pronounced areas.

Figure 5.14 illustrates the four distinguishable areas of the MIB-HCI. The following section describes the key characteristics and the interpreted meaningfulness of the four overlapping areas in more details.

- The knowing area: This area overlaps all pleasure types and represents user's well-known and self-defined desired and confident area. This defines the minimum pleasure setting that a user strives for.

- The pronounced area: This area overlaps only three of four pleasure types. Users are satisfied within this area for a certain period of time, but from a long-term perspective they probably strive to incorporate the remaining pleasure type.

- The promotion-worthy area: This area overlaps two out of four pleasure types. This as the name already suggests, is the area which should be addressed in order to provide a balanced set of interaction styles.

- The blind area: This area located at the bottom of the y axis and built by the union of the socio-pleasure and the ideo-pleasure constitutes an exceptional case. If we consider the private/social context axis and assume that the private context does not range all the way down till the maximum of the social context, then we would have the similar setting of an blind spot as defined in the Johari window that aims to illustrate relationships in term of awareness [LI61]. In this model the blind spot is defined as an area by "what is unknown by the person about him / herself but which others know" [LI61, p. 1]. Similar applies to the blind area in the MIB-HCI. In this area, neither the physio-pleasure nor the psycho-pleasure are involved. Thus, it is assumed that the user is not aware of this area since her or his perception is not included. Even if this argument might be too far-fetched, there is another aspect which underlines the exceptional case of the blind area. If we consider the purpose of the MIB-HCI, namely the identification of a balanced set of interaction styles in order to design a new interactive system, aka product, then we are automatically addressing also the private context since the product is meant to be used and experienced by the user. The blind area without the presence of a product would mean that the user is simply experiencing the company of other users without technical support. In this case, the looking for a technical-driven support would be obsolete.

Admittedly, the listing reflects the personal and subjective interpretation of the overlapping areas based on own experiences of daily life. It is debatable if this view can be universalized for all users. This will also be discussed in the critical reflection in Section 7. Nevertheless, the aim of this dissertation thesis is to provide a conceptual IxD-FW that supports UI designers and IxD in designing new interactive systems and it is understood that a further research on this field needs to be done.

5.5 From Promotion-Worthy Areas to Balanced Interaction Setting

For simplicity reasons, the next step combines the knowing area with the pronounced area to build a union named "action area". The idea behind this union is that knowing and pronounced areas do not need to be pronounced additionally. The focus is more on the remaining and surrounding promotion-worthy areas as illustrated in Figure 5.15.

So far, we have been able to identify promotion-worthy areas for a specific user. The arising question is how to interpret these areas and which implications do these areas have. The answers to these questions are elaborated in the following section. To clarify the meaning of each single promotion-worthy area it is necessary to step back and to

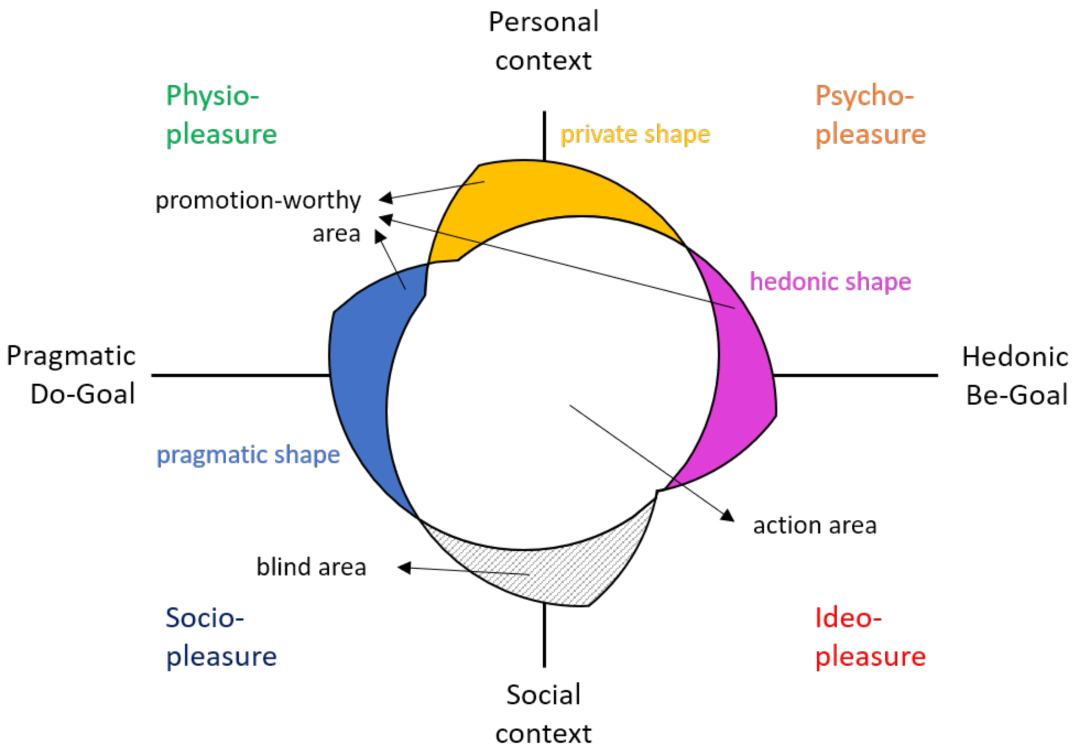


Figure 5.15: The union of the knowing area and the promoted areas into the union named as action area.

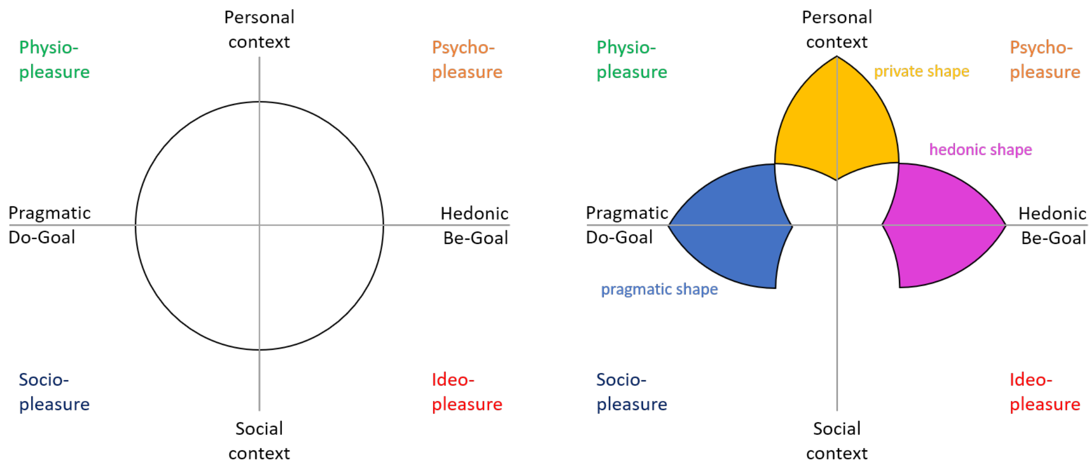
explore the areas from a new perspective that takes all three MIB-HCI components into account. The private and social associated pleasure types are arranged along the y-axis. Private associated pleasure types (physio-pleasure and psycho-pleasure) on the on the positive y-axis, and social associated pleasure types (socio-pleasure and ideo-pleasure) on the negative y-axis. Similar applies for x-axis. Pragmatic associated pleasure types (physio-pleasure and socio-pleasure) on the negative x-axis and hedonic associated pleasure types (psycho-pleasure and ideo-pleasure) on the positive x-axis. Considering this setting following meanings can be allocated:

- The pragmatic promotion-worthy shape: The pragmatic promotion-worthy shape, outlined as the blue colored area on the left of the Figure 5.15 is built by the union of the physio-pleasure and the socio-pleasure. Since both belong to the pragmatic associated pleasure types, the resulting union is supposed to support the user in pragmatic oriented goals.
- The hedonic promotion-worthy shape: The hedonic promotion-worthy shape, outlined as the purple colored area on the right of the Figure 5.15 is built by the union of the psycho-pleasure and the ideo-pleasure. Since both belong to the hedonic

associated pleasure types the resulting union is supposed to support the user on hedonic oriented goals.

- The private promotion-worthy shape: The private promotion-worthy shape, outlined as the yellow colored area on the top of the Figure 5.15 is built by the union of the physio-pleasure and the psycho-pleasure. Since both belong to the private associated pleasure types the resulting union is supposed to support the user in private related goals.

Now, as the promotion-worthy shapes have been identified it is time to elaborate the two extreme cases, namely the zero raking of each pleasure types and the maximum rating of each four pleasure types. Figure 5.16 illustrates the two extreme cases, zero ranking for each pleasure type in Figure 5.16a and maximum ranking for each pleasure types in Figure 5.16b.



(a) Zero ranking of each pleasure type. (b) Maximum ranking of each pleasure type.

Figure 5.16: Two extreme cases of pleasure types ranking.

As expected, if the user does not emphasize any type of pleasure, then all pleasure circles will equally overlap in the center of the MIB-HCI structure, building the action area and no promotion-worthy shapes. If the user ranks all four types of pleasure as maximum, then this will produce three promotion-worthy areas under the exclusion of the blind area in the bottom of the MIB-HCI structure. The resulting implications are:

- No pleasure preference implies that no statements about a promotion-worthy area can be made.
- Maximum pleasure preferences imply that all three promotion-worthy areas need to be supported in an equal manner.

So far, we have been using shapes and visual representation in order to identify and depict promotion-worthy areas. Thus, we have been provided a tool for designers to estimate promotion-worthy areas simply by an estimation of the surface of the resulting shape. In order to provide comparable numerical values instead of estimable surface shapes it would be necessary to measure the surface of each promotion-worthy shape. This task can be realized, for instance, by the Monte Carlo Estimation or by the Quadtree Approximation as suggested in this work [Fre13]. However, this is a mathematical problem and out of scope of this dissertation thesis. Moreover, it is assumed that an exact determination of numeracy values does not provide benefits for the designer because of following two aspects:

- We are utilizing subjective and fuzzy values for the estimation of personal pleasure preferences. The exact numerical determination of the resulting surfaces would be based on these data and the resulting conclusion would not be more accurate as the underlying data.
- Even if we would provide an exact numerical value for each promotion-worthy shape, then this would raise the question how to handle equal (or almost equal) surfaces? One would need to define a routine or a threshold value which selects only one of the two equal shapes. This would incorporate another fuzzy and subjective value into the ecosystem.

Thus, at the current stage of the concept it is not necessary to focus on an exact numerical evaluation of shape surfaces and the assessment of the correct and for the user beneficial interpretation is handed to the designer that is situated into the setting and that has the ability to consider the targeting user and the intended, to-be-designed interactive system in details.

5.6 From Balanced Interaction Setting toward Beneficial IxDOs

The goal of this dissertation thesis is to provide an indication about interaction design styles which could be beneficial for the targeting user and the intended, to-be-designed interactive system. This requires the mapping of the four types of pleasure and IxDOs that support the corresponding type of pleasure. The basis for the mapping are, on the one hand, the hierarchical arrangement of IxDOs within the pyramid of needs and their dependency structure as presented in Sections 4.4 and 4.5 and, on the other hand, the presented human-product interaction types which were introduced in Section 5.1.4.

Since we have three types of human-product interaction types and three types of promotion-worthy areas which are circularly arranged within the MIB-HCI structure, it is logical to group the eight identified IxDOs into three clusters and to arrange these clusters also in a circular manner within the MIB-HCI structure. Once again, we can utilize

Dana's framework for making experience delightful [Chi10] as presented in section 2.3.4 for the clustering process. Dana's approaches for making experience delightful supports the reflection of the three human-product interaction styles as well as the reflection of promotion-worthy areas and their corresponding types of pleasure. Consequently, this results in following three interaction design clusters:

- The flow cluster: The flow cluster is located on the left, the pragmatic side of MIB-HCI structure. It supports mainly the instrumental interaction and addresses the socio-pleasure and the physio-pleasure. In terms of Dana's framework for making experience delightful, designers are in need to incorporate and reinforce psychological clues, language, social cues to subtly motivate users to keep working or playing longer then they might without those design cues
- The meaning cluster: The meaning cluster is located on the top of the MIB-HCI structure and related to the private context with equal amount of pragmatic and hedonic values. It supports mainly the non-instrumental interaction and addresses the physio-pleasure as well as the psycho-pleasure. In terms of Dana's framework for making experience delightful, designers help users to know to identify where they fit in and what emotional and behavioral effects they can achieve by using the new design.
- The mindfulness cluster: The mindfulness cluster located on the right, the hedonic side of MIB-HCI structure. It supports mainly the non-physical interaction and addresses the psycho-pleasure and the ideo-pleasure. In terms of Dana's framework for making experience delightful, designers are in need to address aspects making the user happy and satisfied. They demonstrate that they have the user in mind and understand their goals.

Now as the three clusters are identified, it is time to incorporate the eight identified IxDOs. As mentioned before, this is based on the arrangement of IxDOs within the pyramid of needs, their dependency structure and their main objectives as presented in Sections 4.5, and 4.3. Figure 5.17 illustrates the final interpretation mask which depicts the three elaborated interaction style clusters and the corresponding IxDOs.

The App Interaction Design Opportunity (App-IxDO) (the classical setting) and the Multi App Interaction Design Opportunity (MApp-IxDO) (the comfort setting) are arranged within the flow cluster since they address mainly pragmatic attributes and instrumental interaction style. In the pyramid of needs they are related to the physiological and safety needs. The User Group Tailored Interaction Design Opportunity (UGT-IxDO) (the supportive setting), the Adaptive Interaction Design Opportunity (Adaptive-IxDO) (dynamical supportive setting) and the Ambient Intelligence Interaction Design Opportunity (AmI-IxDO) (the environmental setting) are arranged within the meaning cluster since they address both, pragmatic as well as hedonic values and non-instrumental interaction style. In the pyramid of needs they are related to esteem needs (from others and

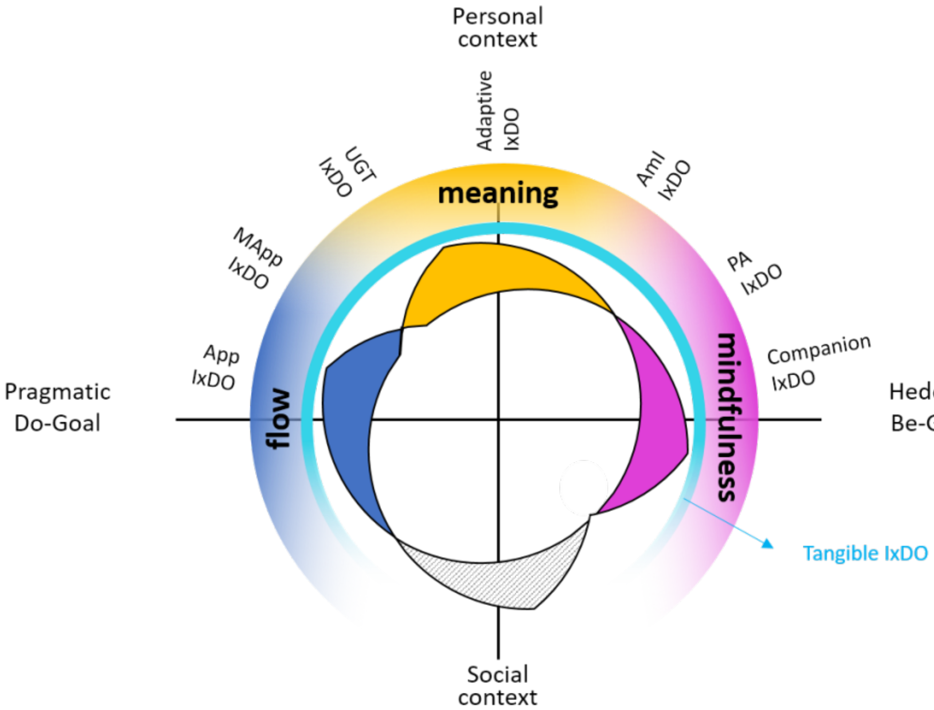


Figure 5.17: The interpretation mask conducted of three interaction style clusters and their corresponding IxDOs.

from oneself) and cognitive needs. The Personal Assisted Interaction Design Opportunity (PA-IxDO) (the assistive setting) and the Companion Interaction Design Opportunity (Companion-IxDO) (the friendship setting) are arranged within the mindfulness cluster since they address mainly hedonic attributes and non-physical interaction styles. They are related to cognitive needs and to belongings in the pyramid of needs. As already expected, the Tangible Interaction Design Opportunity (Tangible-IxDO) cannot be assigned only to one cluster since it represents the graspable manifestation of any other IxDO. This is also highlighted by the 5.17 that illustrates the dependency structure of the eight identified IxDOs ranging from the utilitarian, operative and pragmatic level to the non-utilitarian, non-physical and hedonic level.

At this point and once again, it needs to be mentioned that the provided interpretation mask serves as a guideline for the designers and is not meant to be universally applicable in every setting and for every purpose. So far, we have seen that users' importance estimation for the four pleasure types represents a fuzzy process involving several aspects. Moreover, we have also seen that pleasure types influence each other and that product attributes and their interaction styles are not exclusively reserved for one specific purpose. This implies that the allocation of IxDOs to different interaction style clusters is also meant to be, to some extent, fuzzy. This is also highlighted by the color progression of the interaction design clusters and the approximated position of corresponding IxDOs in Figure 5.17. Thus, once the promotion-worthy shapes have been identified it is the responsibility of the designer to choose the best suited IxDO in order to meet user's needs and expectations under the consideration of the given the setting, context of use, and the main purpose of the intended interactive system.

CHAPTER 6

The Interaction Design Loop and the User Centered Design Incorporation

So far, we have been elaborated different interaction styles based on projects and prototypes developed in AAL field of practice. These interaction styles have been used as a starting point for the development of the Interaction Design Opportunity Research Grid (IxDO-RG) that is conducted of the Interaction Design Opportunities (IxDOs) and the three cross-cutting issues, namely the technological perspective, the design perspective, and the pleasure-oriented perspective. The design perspective and the pleasure-oriented perspective have been used as the starting point of the development of the Model for Identification of Balanced HCI (MIB-HCI) structure. The final MIB-HCI was enriched by the interpretation mask that assigns each of the identified IxDOs to a certain region of the MIB-HCI structure. This closes the interaction design loop and building the Interaction Design Framework (IxD-FW) that provides a clear workflow for the designer as depicted in Figure 6.1. Designers can use the MIB-HCI structure to reflect the targeting user's internal state. This, of course, needs to be done in respect to the intended, to-be-designed interactive system and the purpose of the system. The MIB-HCI structure uses the interpretation mask to refer back to one concrete IxDO, or to a small set of IxDOs, that is/are considered as supportive for the targeting user and the intended, to-be-designed system. The IxDO characteristics, mainly from the technical perspective, can be used by designers to form the cluster of considerable aspects in their designs process in order to manifest the concrete IxDO of the interactive system.

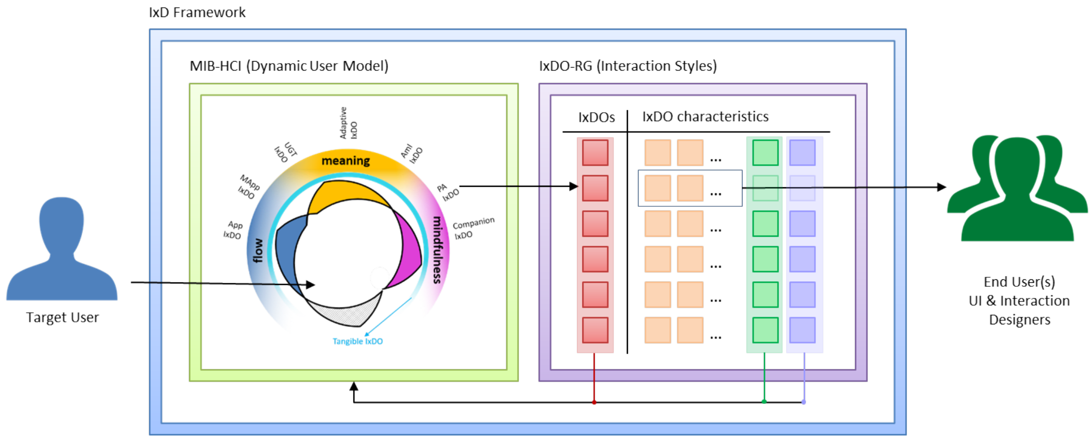


Figure 6.1: The IxD-FW depicting the interaction design loop between the IxDO-RG and the MIB-HCI structure, highlighting the workflow starting from the reflection of the targeting user, over the MIB-HCI utilization, over to IxDO selection till the listing of considerable design aspects in order to manifest the corresponding IxDO.

6.1 Interaction Framework within the User Centered Design process

The previous chapter presented the final IxD-FW and the workflow within the framework. The arising question is how to incorporate the IxD-FW into the UCD process. This targets the research question of this dissertation thesis, namely: **How can the UCD process be enriched in order to provide a stronger user involvement on an individual level, considering their inner values, wishes, and needs?**

Figure 6.2 highlights the incorporation of the presented IxD-FW workflow within the UCD process.

As one can see, the IxD-FW represents an extensional module in the UCD process. It takes effect in the specification of the user and the organizational requirements. At this stage designers can utilize the MIB-HCI to reflect about user's inner desires but also to reflect about the context of use and the characteristics of the intended, to-be-designed interactive system, as pointed out in Section 5.3. Based on these inputs, the model builds promoted and promotion-worthy areas. These results support the designers in a two-folded manner:

- MIB-HCI results can be used to optimize the intended interactive system on the non-functional level.
- MIB-HCI results can be used to reconsider the application field on the functional level.

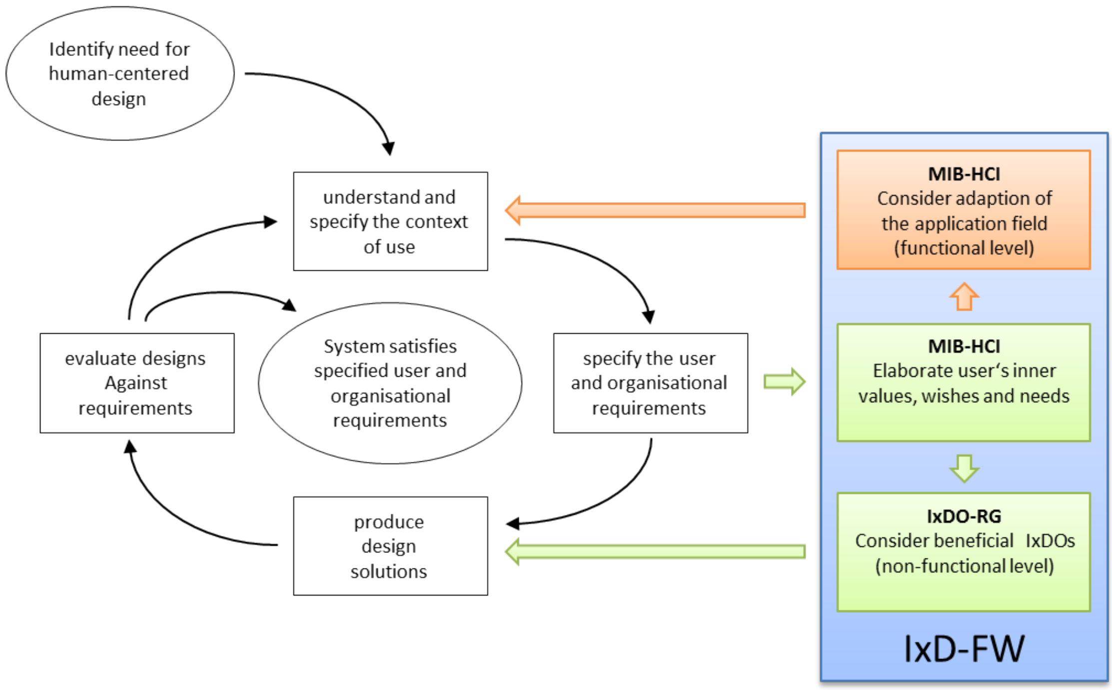


Figure 6.2: The interplay between the UCD process and the IxD-FW highlighting that the MIB-HCI can be used in combination with the IxDO-RG or on the singular basis. Adapted from [JIMK03, p. 55].

The first option is depicted in the right bottom corner of the Figure 6.2. It utilizes the presented interpretation mask (see Section 5.6) to identify beneficial IxDOs for the targeting user, the context of use, and the intended, to-be-designed interactive system. Moreover, using the technological cross-cutting issue of the IxDO-RG, designers can gain an overview about considerable aspects in all three technological pillars, starting from the modeling task, over the architecting task, towards the implementing task (see Section 4.6.1). However, this approach does not change the functionality or the purpose of the intended system since it modifies eventually and only the interaction style.

The second option allows designers to reconsider and to modify the intended application field. This is very useful if the intended, to-be-designed interactive system pursues a higher aim. Gamification, for instance, is a stereotypical example where the offered system pursues an higher aim.

The following simplified scenario from the the AAL domain illustrates an use case that is guided by the classical UCD process, where a consideration of the application field could be beneficial for the targeting user. The first part highlights the classical UCD approach and the second part highlights potential problems of the classical UCD approach and emphasizes the added values of the IxD-FW.

- Step 0 of the UCD process: The Identification of needs for the human-center design. It is well known that physical activities can increase the overall well-being state of older adults. The head of a care and residential facility that offers physical trainings for their residents on a regular basis is unsatisfied about the current situation that only few users attend the trainings. Any attempt to reconfigure the physical trainings (e.g., in form of training diversity, time re-scheduling, or the change of the involved supervisor) did not succeed so far. First interviews with targeting users highlighted that the "right timing"-factor could be one of the possible reasons which might explain the low number of attendees. She is curios whether technology could support the concrete problem identification and if technology could help to solve the problem in this context.

- Step 1 of the UCD process: The understanding and the specification of the context of use. Given the current setting, ICT specialist started to investigate the current situation and to specify the context of use. Given the "right timing"-factor designers started to sketch how technology could overcome this obstacle and came up with the "virtual trainer" solution that can be used time independently on a regular basis.

- Step 2 of the UCD process: The specification of the user and the organizational requirements. The first user involvements during the requirements analysis phase supported the initial concept since users confirmed the "right timing"-factor problematic and that an time independent version would probably increase their attendance. Moreover, the user highlighted their need for personal fulfillment and development, and they expressed their wish regarding the functionality of the "virtual coach". The wishes can be summarized as follows: (a) the solution shall support personal progress tracking and its visualization, and (b) the "virtual coach" shall be configurable in terms of appearance and environmental settings (e.g., the coach presents the exercise steps in a spring landscape).

- Step 3 of the UCD process: The production of design solutions. Inspired by the first user involvement, ICT experts started the development of the "virtual coach" prototype. This task involved specialist of other domains such as psychotherapist and care facility staff members. The solution includes the modeling of the physical activities using motion-capturing devices, the rendering of these activities via a 3D avatar, and the 3D sensing of users' physical movements in order to provide a decision about their accuracy and in order to track the personal progression. The development of the prototype was a complex process that requires a high amount of efforts. Nevertheless, since the approach utilizes the UCD approach it was foreseen to repeat the UCD Steps 1-4 several times in order to enhance the system and to increase users' satisfaction.

- Step 4 of the UCD process: The evaluation of the design again the requirements. The evaluation process highlighted several issues regarding usability and accessibility of the system. For instance, the testing of the first prototype highlighted that users in this age are not always all able to raise their hands so high to reach the system control section and the navigation, respectively. This was solved in the second prototype by placing the navigation bar on the bottom of the presentation screen. All these enhancements contributed toward the coverage of basic user needs in terms of functionality, usability, and accessibly. However, the unsupervised long-term evaluation highlighted that a significant number of users reduced the usage time of the system and that various users stopped the usage of the provided system during the long-term evaluation.

The presented scenario is only partially fictive. It incorporates aspects and personal experiences from previous and ongoing projects in the AAL field.

However, the scenario highlights that user's basic needs have been addressed in an appropriate manner, but also that the approach potentially failed in addressing user inner desires. The consultation of the MIB-HCI in the first iteration Step 2 could potentially highlight that a significant number of user, for instance, have a high expression on the ideological pleasure. This pleasure type includes aspects such as art, music, and books. It is not unreasonable to reconsider the application field for this target group and to address these inner needs in combination with the overall goal, namely to increase the physical activity. One can think, e.g., of organized excursions to various museums. A second example could be the ICT-based organization of physical meetings of book-discussion groups out of the regular action radius of the care and residential facility. All these activities would target the increase of users' physical activities but on a individual level that is driven by users' inner and very often uncontentious needs.

Admittedly, these scenarios and examples are sometimes out of the scope from the Interaction Design (IxD) perspective and ICT experts expect often clear formulated user needs in order to start the design and the development of the intended solution. Nevertheless, these examples highlights that even ICT designers are allowed to question the main purpose of the intended, to-be-designed interactive system. This is very often more contributive for the targeting user as the design of a complex system that focuses on the problem-solving exclusively from the technological perspective.

CHAPTER 7

Critical Reflection

This section provides a critical reflection of the work. It is subdivided in two thematic areas. Firstly, the comparison of the output of this work with related works, and secondly, the discussion of open issues and how these issues can be addressed in future work.

7.1 Related Works

In respect to the related work it is challenging to find existing works, concepts, methods, and developments that aim the same goal as this dissertation thesis, namely the fusion of two research areas in order to provide a self-contained framework with supportive characteristics for the end user and the designer, respectively. This plan becomes even more demanding, if we take the practice-oriented approach of the second research area into account. Thus, so far, the literature research regarding relevant work did not highlight any comparable works that describe a similar approach on this level of granularity.

Nevertheless, even if it is uncertain whether the research community has already tackled the problem statement as a self-contained framework, it is doubtless that the scientific field has already addressed each of the research areas separately. Thus, the following section will primary focus on the same approach and compare the outcomes of this dissertation thesis with related works on to each research area separately.

7.1.1 Framework for Improving User Experience in Ambient Assisted Living

One related work that underlines the challenging character of the related work study is the presentation of the EASY LINE+ project [RPG08]. The work is situated in the AAL domain and it presents a framework for the improvement of UX within this field. In this work UX is defined as users' perception of the system in respect to four factors, namely usability, functionality, content, and branding. Although these factors are in line with the ISO 9241-210 [fS18b] definition of UX, the work focuses more on the general UCD process as on concrete UX aspects. The work limits the broad and astonishing vision of UX to address only accessibility and usability problems. On the contrary, in this work UX is understood as something that is able to shift the focus to user affect, sensation, and the meaning as well as value of such interactions in everyday life (see also in Section 2.1.8). UX is seen as something desirable. Thus, UX and the user are the central components and the driving force in this work. Despite the doubtful instrumentalization of the UX term, the work also fails in addressing the AAL field. It is clear that the presented work was performed in the AAL domain, but the work does not highlight any developments or achievements that relate to the AAL fields.

This work highlights the challenging character of the related work study. It is only one striking example for related works that target the enhancement of developments within AAL domain by utilizing UX and User Experience Design (UxD) aspects. Indeed, this is a good progress since it highlights the awareness of the added values of the UX field in the AAL domain. However, a detailed listing of works with a similar character would shift the core statement of this chapter into a wrong direction. It would highlight the evidence of the performed research, but it would not provide a comparison to related works. Thus, the following sections will focus more on the core statement, namely on works that provide a holistic perspective in each research field.

7.1.2 Engaging with Practices

One related work addressing the practice-oriented research area was presented by the University of Siegen and the work named "Engaging with Practices: Design Case Studies as a Research Framework in Computer Supported Cooperative Work (CSCW)" [WRPS11]. The work presents a framework which is based on a collection of design case studies in the CSCW fields of practice. Moreover, the work utilizes the "cross-cutting issue" approach to compare and aggregate insights between design case studies. Figure 7.1 illustrates this research program for practice-based computing. This framework shows certain similarities to the Interaction Design Opportunity Research Grid (IxDO-RG) as presented in this work and indeed, the framework was the driving force for the structuring of the own research field that resulted in the design of the IxDO-RG.

The depicted application domains in the Figure 7.1 are comparable to the Interaction Design Opportunities (IxDOs) of the IxDO-RG. The cross-cutting issues (appropriation infrastructure, end user development, and embedded design) are comparable to the cross-cutting issues in the IxDO-RG, namely the technical perspective, the design perspective, and the pleasure-oriented perspective. Although the technical perspective within the IxDO-RG is subdivided in three pillars (modeling, architecting, and implementing), all three pillars belong to the same cross-cutting issue.

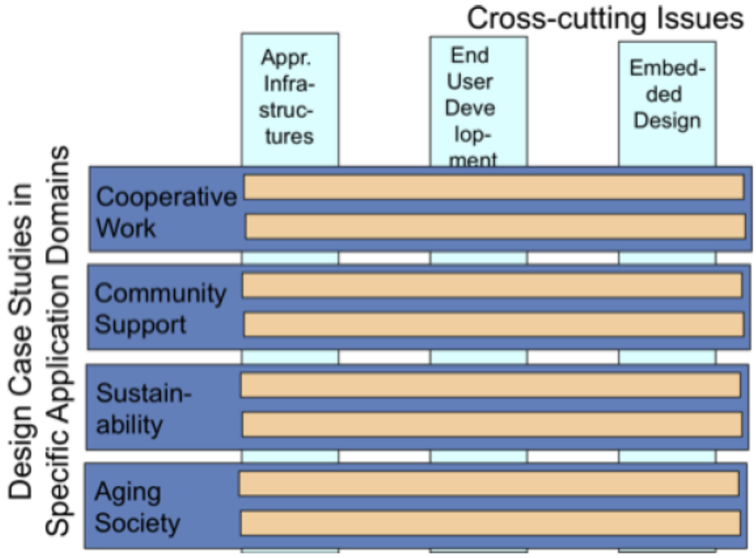


Figure 7.1: The research program for practice-based computing highlighting different design case studies and the cross-cutting issues [WRPS11, p. 507].

The design case study research framework emphasizes following aspects:

- The framework is useful to structure different research activities and thus for the provision of the holistic view of the research field.
- It can be used to highlight relations between research activities (via cross-cutting issues).
- It can be used to highlight the applied science, even if it might not be very significant on an atomic level it has still a value for the research filed.

7.1.3 The CUBI User Experience Model

One related work that addresses the user-related research is the Content User Business and Interaction model (CUBI) User Experience model [Ste16]. The model was designed by Corey Stern with the aim to simplify, modernize, and organize existing user experience models, frameworks, and representations in terms of UX diagrams. The CUBI UX model is a framework that supports the understanding of key components of user experience. It can also be used to improve client communication and to identify gaps during the generation process of effective experiences. The framework focuses on four thematic areas, namely on Content, User Goals, Business Goals, and Interaction. The initial capital letters of these thematic areas were used for the naming of the model. Figure 7.2 illustrates the CUBI UX model with the four thematic areas in the center of the model. These thematic areas are surrounded by several layers that represent considerable aspects during the design process.

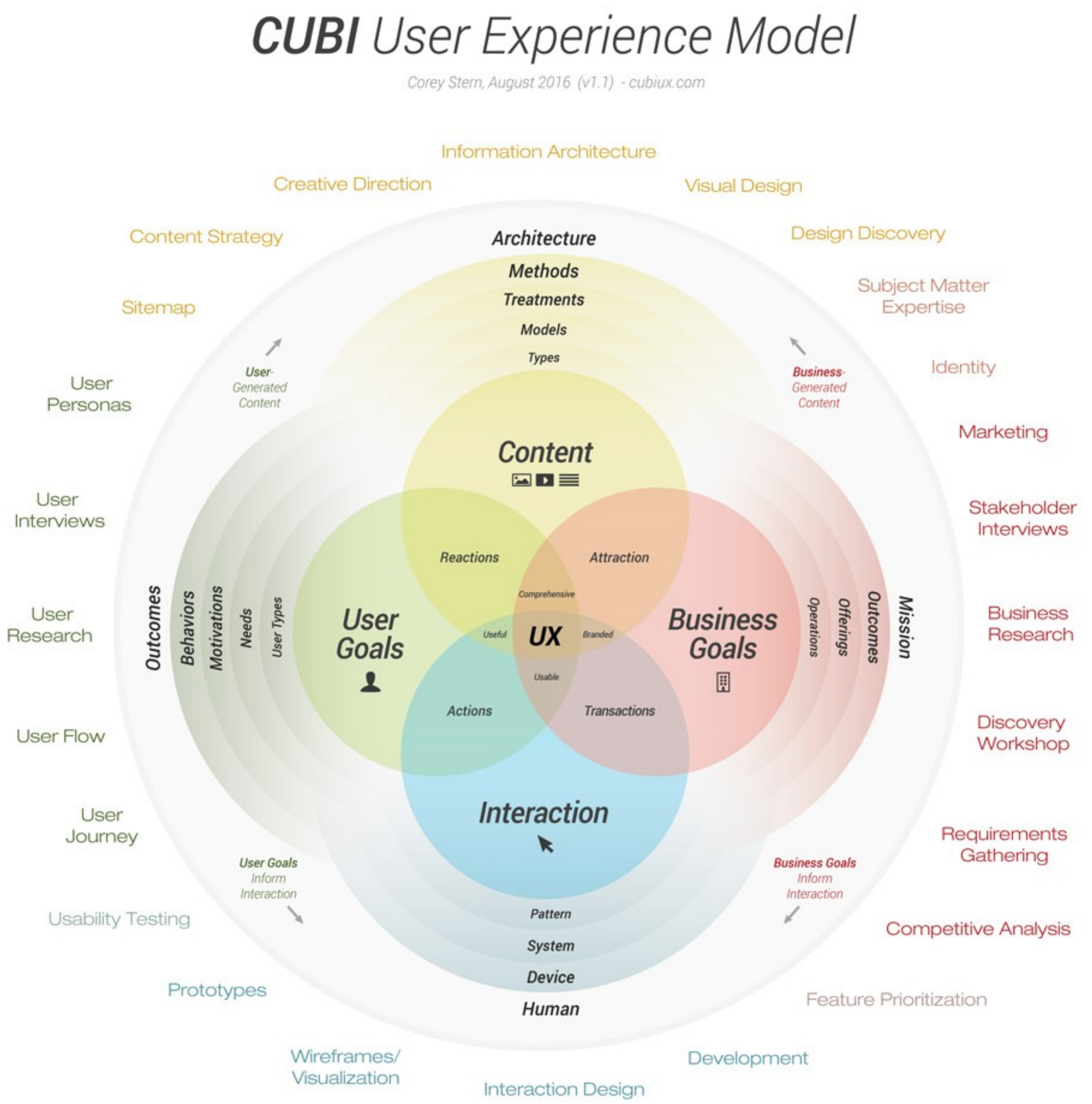


Figure 7.2: The CUBI UX model highlighting the four thematic areas in the center of the model, surrounded by layers representing considerable aspects during the design process [Ste16, p. 1].

The UX factor is represented by the overlapping areas in the center of the model that form an overlapping of three thematic areas. Corey defines following UX classes: brand experience, the comprehensive experience, the useful experience, and finally the usable experience. The brand experience provides next to the visual brand identity also tonality and totality of the entire brand experience for a customer at any touch point. The comprehensive experience is, on the one hand, in terms of understandable, clear, organized, properly labeled and, on the other hand, extensive providing the sense of completeness. The useful experience satisfies user needs and makes them feel empowered or productive. Moreover, it helps user to achieve their end goals efficiently. The usable experience considers aspects like easy to use, intuitive, findable, learnable, and legible. This experience provides prompts and feedback to communicate their progress in a system or process.

The model defines next to these experiences also four action cycles, namely the attraction, the reaction, the action, and the transaction. These are formed by the overlapping of two thematic areas. These action cycles form a loop starting from the attraction (how to attract the user), following by user's reaction (user's decision if the product is valuable), over to action (user's action if the product was classified as valuable for the user), to the transaction (the transaction to the business goal, e.g., in terms of purchasing the product).

And finally, the very outer ring depicts UX disciplines, task, and methods that support the identification of potential tasks and efforts needed for the execution of the product strategy.

The model highlights several similarities to the presented Interaction Design Framework (IxD-FW). It utilizes user goals, interaction, and the consideration of the content. In IxD-FW user goals and the UX factor are integral parts of the Model for Identification of Balanced HCI (MIB-HCI). The content processing is an integral part of the IxDO-RG. The interaction part is an integral part of both, the MIB-HCI and the IxDO-RG. The representation of UX, formed by overlapping areas, has strong similarities with the representation of pleasures and promotion-worthy areas in the MIB-HCI. It reflects that UX and UxD is a multidisciplinary field that involves several aspects simultaneously. Additionally, to these similarities, the CUBI model incorporates also business aspects which makes the model, from the company's perspective, very valuable. The outer ring highlights considerable tasks in the product design, development, and distribution chain. Thus, the model is very multifaceted and provides useful and considerable aspects in product design.

However, there are also several differences between IxD-FW and the CUBI model. The first noticeable distinction is the different focus. Where the CUBI model focuses more on the companies' perspective, the IxD-FW focuses more on the user and her/his individual perspective. The IxD-FW does not incorporate aspects such as, marketing, stakeholder interviews, or competitive analysis. It puts the user straight into the center of the design process and it requests the designer to additionally address, if needed, the business goals. The second distinction is that the IxD-FW builds a closer bound between the interaction, and consequently also to the content, and the user. This highlights again, the stronger focus on individualities and it highlights possibilities to provide more fine-tuned UX added values for the single user.

7.1.4 A Simplified Model of User Experience for Practical Application

One closely related work to the presented CUBI UX model is the Simplified Model of User Experience for Practical Application [JG07]. This model utilizes, like the CUBI model, organizational values such as marketing, branding, and business communication. Figure 7.3 illustrates the concept of the simplified model for UX highlighting the relationship between user values, the product, and the organizational values. In this work the authors argue that these organization values are deeply interwoven in the perceived UX and thus also a central component of the UxD process. This is highlighted by the following paragraph "Today many manufacturers consider their products as interfaces between them and their customers, which mediate much more than just a feeling of satisfaction after successful task completion or dissatisfaction after tasks remained unsolvable" [JG07, p. 106]. From a broader perspective, I fully agree with this argument. At the same time, I am also convinced that organizational values primary aim the shaping of users' expectations and that they can only be reused if once these expectations have been positively satisfied. Admittedly, user expectations are something that is multifaceted. They can range from "owning something because others do so" up to "experiencing something useful because it provides the right balance between functionality and usability".

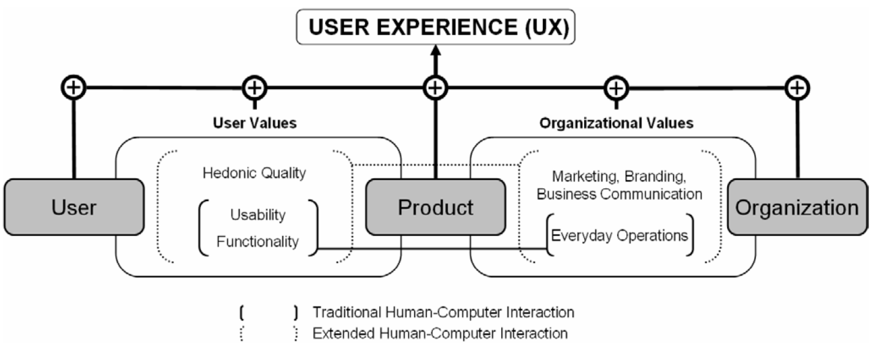


Figure 7.3: The simplified model of UX highlighting the relationship between user values, the product, and organizational values [JG07, p. 107].

However, as mentioned before the IxD-FW does not utilize these business oriented aspects directly. Nevertheless, the model highlights several shared aspects with the IxD-FW. The first noticeable aspect is the presence of the hedonic and pragmatic qualities. This is also a key element of the IxD-FW. A second aspect is provided by the flexibility of the IxD-FW. The IxD-FW does not support the reflection of business aspects directly, but its flexibility provides the possibility to reflect these aspects indirectly. If user's expectation regarding a product relies in, for instance, "owning something because other do so" then this expectation can be reflected by the ideo-pleasure of the MIB-HCI. If user's expectation regarding the product is about the "experiencing something useful because it provides the right balance between functionality and usability", then this can be reflected by the pragmatic side of the MIB-HCI. Thus, the indirect reflection of organization values can, to some extent, also be reflected by the IxD-FW.

7.1.5 Summary of Related Work

The comparison with existing works, concepts, methods, and developments was a challenging process. All elaborated related works focused only on partial aspects of this dissertation thesis and not on the provision of a self-contained framework that fusions the holistic view of practical outcomes from the AAL field with the UxD field.

A retro perspective view about the related work highlights that the presented related work act mainly on the model and meta level. They provide considerable aspects and approaches, but they fail in addressing practical deployable recommendations or guidelines. Nevertheless, the presented approaches highlight also some similarities which support the argumentations and the procedures applied in this work.

7.2 Discussion of Open Issues

The following section discusses identified open issues of the work and potential approaches to address these issues. This section reflects the gap between the current status of the work and the future work.

7.2.1 Domain Transfer

The work addresses two research areas. Firstly, the user-related research area building the MIB-HCI, and secondly, the practice-oriented research area targeting the identification of IxDOs and its characteristics form the AAL field of practice. These two research areas build together the IxD-FW that represents the result of this dissertation thesis. These two research areas are meant to be used as composition. However, since the practice-oriented research area was designed within the AAL context, it is likely possible that the composition, as it is presented in this work, is not transferable to another domain. For instance, in the educational domain with primary young children, the composition would possibly provide wrong recommendation and the basic concept of the framework could fail. Nevertheless, since the work addresses two research areas that have been elaborated separately in more depth, it is also possible to apply each of these concepts in a separate manner. The MIB-HCI model can, for instance, be used as a stand-alone-tool to reflect the internal state of the targeting user in respect of the intended, to-be-designed interactive system. The IxDO-RG, for instance, can also be used independently to identify considerable aspects in the design process of AAL technologies. Thus, the framework at this stage and as a whole might not be directly transferable to other domains, but at least its two components might provide added values for the design process of new interactive systems.

7.2.2 User Involvement and the Evaluation of the IxD-FW

One noticeable aspect of this work is that it seems in leak of targeting user and end user (interaction designers) involvement during the development phase of this dissertation thesis. This view is only partially valid since this work is based on concrete design case studies in the AAL field of practice. Thus, the work incorporates the collective knowledge dozens of interaction designers including my own contribution and evaluation results of hundreds of target users. This was also highlighted by the foreground aspect in the introduction Section 1.4. The second noticeable aspect is that it leaks in terms of the testing of the final IxDO-RG. This, on the contrary, is a valid observation that requires further explanations. Following arguments highlight why the evaluation of the IxD-FW was considered as out of the scope of this dissertation thesis.

The work utilizes pleasure-oriented aspects in interaction design. As mentioned before, pleasure can only be addressed if users' basic needs are satisfied. An intentionally and artificially manufactured elaboration of this pleasure-oriented enhancements of interactive systems without a detail identification of concrete basic needs would automatically doom this framework to failure. It requires real targeting users, situated in their daily living environment, to elaborate their basic needs and to address their basic needs in terms of technological developments (design and development of the interactive system) and in terms of non-technological configurations such as the incorporation of their habitat. Only if these preconditions are met, then the IxD-FW would be able to unfold its usefulness and functionally.

The establishment of this precondition, on the other side, is a tedious process. In the AAL context, for instance, it would be necessary to incorporate private and/or organizational routines and activities of daily life in order to identify and address users' basic and inner needs. Moreover, in this context it would also be necessary to incorporate external factors such as social and cultural participation. As one can see, the evocation of pleasure can be a complex process that needs to be addressed in a broader and more structured way.

At the same time and as highlighted in Section 6.1 the IxD-FW can be used in a two-folded manner. Designers can use the outputs of the MIB-HCI in order to reconsider the application field to pursue an higher aim of the intended, to-be-designed interactive system. This approach could help to focus on the single user and to target its inner values, wishes, and needs directly. Nevertheless, as also pointed out in Section 6.1, the IxD-FW is an extension of the UCD process. Even then, if this shortened approach would be chosen in order to test the usefulness of the framework, this would still require the full execution of all UCD activities. Moreover, it would require the execution of these activities in several iterations in order to satisfy user's basic needs (e.g., functionality, usability, and accessibility). This is considered as out of the scope of this work since this dissertation thesis targets the development of an conceptual framework. Nevertheless, this will be addressed in future work.

As highlighted in the methodology Section 1.4, the future work of this dissertation thesis aims the deployment of the framework in the AAL domain. This is mainly due to the fact that the findings which lead to the development of the framework originated in the AAL domain. Thus, it is consequently logical to elaborate this framework in the own domain before it can be transferred to other domains. This in turn will involve targeting users (older adults and their ecosystem) and end users (interaction designers) of the IxD-FW. More details about the future work that targets this goal can be found in the Section 8.

7.2.3 Consideration of Target Groups

The current MIB-HCI focuses on the reflection of individual pleasure types. This raises the question if this model can only be applied on individual basis or if it is possible to utilize the model on behalf of a set of users? The answer to this question is only partially satisfiable. If a set of users arrange their individual preference set in a similar manner, then it can be assumed that the MIB-HCI can be used for the whole set of users. Admittedly, this is only a partially satisfied result since the MIB-HCI needs to be applied on each individual in order to identify the set of similar preferences. Here again, this example highlights the weakness of the MIB-HCI because to avoid an involvement on the individual basis, it is up to the interaction designer to predefine the target group that, in an ideal case, will generate a similar preference set. This once more opens the space for self-interpretation and works again the intention of this work, namely to provide a recommendation of a concrete IxDO.

However, this argument highlights that the model can also be used in another manner. It can be used to identify similar users that share the same set of preferences. From this perspective, the model could contribute, e.g., in the identification of focus groups that support the specification, sometimes the development, and also the evaluation of the intended, to be-designed interactive system. This is, of course, at this stage only an assumption which needs to be addressed in detail in further research.

7.2.4 Measurement of Satisfaction and Long-Standing Engagement

This work argues that user's satisfaction is a key indicator for a long-standing engagement. Although this seems to be a reasonable approach, the work does not directly address this topic. This assumption is based on the literature study and the recommendations regarding desirable product design. Thus, the work at this stage is in leak to provide the right metrics to measure the impact on itself. However, this does not imply that the topic was not considered in this dissertation thesis. On the contrary, following works have been reviewed which address the measurement of user experience [LH07, LVHB07, SSI+16, SHT17]. Nevertheless, the provision of concrete measurement metrics was considered as out of the scope of this work due to following factors:

- The conceptual purpose of this work: As highlighted by methodology Section 1.4, the framework as it is at this stage has reached its final purpose, namely to form a concept for satisfaction reflection of the targeting user via the consideration of her or his individual aspects during the interaction design process. It is up to its deployment in the domain, which will be addressed in future work, to define the metrics for users' satisfaction and to define what is considered as a long-standing engagement.

- Reference values: In order to measure the efficiency of an entity, it is necessary to provide reference values of another entity. This is closely related to the previously mentioned aspect that the framework needs to be deployed in the domain, utilizing the same setting as a conventional approach that does not consider pleasure-oriented aspects on this level as the IxD-FW does. Here again, the measurement criterions for satisfaction and long-standing engagement need to be predefined in beforehand for both approaches in order to gain values and reference values that can draw a conclusion about the efficiency of the pleasure-oriented aspect of the framework.

- The optimization factor: As highlighted by this section and as highlighted by the methodology Section 1.4, the framework at this stage is located close to the preparation phase for its deployment in the domain. This preparation phase can be named as optimization phase. In this phase it is from utter most importance to address all open issues and to form the area of use. This aspect will be described in more detail in the future work Section 8.

7.2.5 The Relevance of a Broad Variety of Interaction Design Styles

This topic is closely related to the domain transfer topic. The synthesis of different interaction design styles emerged out of the AAL context and various design case studies performed in various AAL research projects. It is debatable whether other contexts require also this variety of interaction design styles. Moreover, it is also debatable if the AAL context requires the broad variety of interaction design styles. Would it be not enough to cluster the App Interaction Design Opportunity (App-IxDO), the Multi App Interaction Design Opportunity (MApp-IxDO), and the User Group Tailored Interaction Design Opportunity (UGT-IxDO) to one single cluster named "Flow IxDO", the Adaptive Interaction Design Opportunity (Adaptive-IxDO) and the Ambient Intelligence Interaction Design Opportunity (AmI-IxDO) to one single cluster "Supportive IxDO" and the Personal Assisted Interaction Design Opportunity (PA-IxDO) and the Companion Interaction Design Opportunity (Companion-IxDO) to one single cluster named "Mindfulness IxDO"? Would that not be enough? Indeed, this is a valid question and since different IxDOs build relationships upon each as we have seen in Sections 4.4 and 4.5, this could easily be realized by the elimination of lower ranked IxDOs. On the other side, as we have seen Section 4.6.1, the higher an IxDO is ranked, the higher its complexity becomes. To avoid unnecessary complexity, this work elaborates rather a broad variety of interaction design styles and it is up to the final interaction designer to decide which interaction design style is appropriate for the current user, the current setting, and the current purpose of the intended, to-be-designed interactive system.

7.2.6 Interaction Style vs. the Purpose of the Interactive System

The work focuses on different interaction styles. Section 5.3 highlighted that the MIB-HCI model also addresses, to some extent, the context of use and the characteristics of the designed system such as the complexity, the purpose, or the functionality. From this perspective, it is not unreasonable to utilize the MIB-HCI not for the identification of supportive interaction style/styles but for the identification of supportive application genres that contribute towards a higher ranked goal. Following fictional example illustrates such a setting started from an identified higher ranked goal, e.g., to encourage the user to increase her or his physical activity, the MIB-HCI could be used in following manner:

If the MIB-HCI identifies user's priority for a certain type of pleasure particularly high, e.g., ideological pleasure is significantly higher, then the model could recommend the design of an interactive system that is related to the "Books" or "Photography" application genre. Creating photos in the nature or the participation in book discussion group might contribute towards the higher ranked goal of increasing user's physical activity. This aspect was also discussed in details in Section 6.

This constructive example highlights the benefit of the MIB-HCI, but at the same time it also highlights that the MIB-HCI on its own might not be strong enough to reach the main goal, namely to provide a long-standing engagement of the user with the offered interactive system. It is debatable if and how far the interaction style on its own can change user's internal state (mood, expectations, need, and motivation) if the purpose of the interactive system is predefined. However, as argued before, this work targets the user involvement on an individual level, considering her or his inner values, wishes, and needs. It is understood that users' basic needs (in terms of problem identification and problem-solving utilizing functionality and usability) are align with the purpose of the intended, to-be-designed interactive system. If otherwise, it can be assumed that the fine-tuning of the offered interaction style won't take any effects on the particular user.

Nevertheless, despite the ability of the model to change users' internal state, the potential power of the model towards identification of supportive application genres (as presented in the previous example), also needs to be elaborated and evaluated in more details. This represents one possible improvement step in further research.

7.2.7 Estimation of Pleasure Type Importance

One open issue on the contextual level is the estimation of pleasure types importance. The estimation of importance levels was addressed in Section 5.4 via the utilization of common, literatur-based approaches (direct rating and term rating). These common approaches leak of control questions and thus, the gained results might be biased. One optimization aspect could be to transfer these direct rating questions into a survey that evaluates users' pleasure types importance indirectly by a set of context-sensitive questions regarding each of the four pleasure types. This in turn is a multidisciplinary approach that requires the involvement of various experts such as experts from the sociology, physiology, and computer science field. Nevertheless, this is also considered as future work and will be addressed in the optimization phase of the framework.

7.2.8 Numerical Values for Promotion Worthy Areas

This topic was already stressed in the Section 5.5. Moreover, the section provided suggestions about concrete approaches that target this problem and that can provide concrete numerical values for overlapping areas. As mentioned before, this is considered as a mathematical problem and it is assumed that concrete numerical values that are based on a fuzzy datasets do not provide additional information content. The additional information can be found in the ordinary noticeable ratio unbalance between concrete promotion-worthy areas. Thus, at this stage of the work it is assumed that the visual representation is sufficient for the utilization of the framework.

However, if we assume an automatic process that utilized the previously mentioned assessment for pleasure type estimations, then this topic would gain on importance. This represents a concrete task for future work. At the same time, the development of an automation process is only relevant if the added value of the process is identified. Thus, this task can only be tackled after the survey was elaborated and after the framework was tested in the field.

CHAPTER 8

Summary and Future Work

This chapter summarizes the outcomes of this dissertation thesis and proposes possible future work.

8.1 The Overall Outcome of This Work

The work discusses the research question how the UCD process can be enhanced towards a stronger user involvement on an individual level, considering her or his inner values, wishes, and needs. It provides a structured and shorthanded method for the identification of these inner desires and an approach that addresses these desires on a non-functional level, in terms of concrete recommendation of interaction design styles that could be beneficial for the targeted user, the targeted context of use, and the intended, to-be-designed interactive system. Moreover, the work highlights that the concept can also be used for the identification of functional needs in a early stage of the design process.

The concrete output of this work is a conceptual Interaction Design Framework (IxD-FW) that supports user interface designers and interaction designers in addressing these inner desires already on the conceptual level of the design process in order to provide a better understanding of users' expectations and to alleviate additional efforts during the design process. The framework is meant to be used as an additional (but optional) approach within the UCD process in order to foster users' satisfaction for the intended, to-be-designed interactive system.

8.2 Research Objectives in Detail

Chapter 1 highlights that the user involvement during the design process of interactive systems is from utter most importance and that individual user characteristics are very often considered only on superficial level which leads to dissatisfaction and frustration in latterly use of the systems.

The chapter sketches the statement of motivation for this work to investigate elaborated interaction design achievements in the AAL field of practice from the holistic perspective with the aim to identify patterns and their characteristics that could be supportive for future design and development.

The problem statement points out that the UCD approach is the right tool for the user involvement in the design process, but the statement also highlights that the approach can be extended in order to draw a higher attention on users' individual and inner values, wishes, and needs.

Chapter 2 highlights the diversity of Interaction Design (IxD) styles from the general HCI perspective and from the domain specific AAL perspective.

The chapter points out that in order to design desirable products designers are requested to address not only pragmatic values such as functionality, usability, and accessibility but also hedonic values such as novelty and curiosity.

Additionally, the chapter highlights that in order to evoke users' emotions designers need to address various experiences such as aesthetic experience, meaning experience, and mindful experience.

Chapter 3 sketches the overall outcome of this work. It highlights the interplay between two research areas, namely the user-related research area that lead to the development of the Model for Identification of Balanced HCI (MIB-HCI) and the practice-oriented research area that lead to the development of the Interaction Design Opportunity Research Grid (IxDO-RG). Both developments are bound to one practicable unit, namely the developed IxD-FW that represents the main output of this work.

Chapter 4 provides a commutative perspective of different Interaction Design Opportunities (IxDOs) utilizing the IxDO-RG. This commutative view summarizes the eight identified IxDOs, and thus it addresses the first objective of this dissertation thesis.

Further, the chapter presents the main purposes of the identified IxDOs as well as their hierarchical arrangement and their dependency structure. This addresses the second objective of this dissertation thesis, namely the identification of relationships between IxD patterns.

The chapter also presents three cross-cutting issues, the technological cross-cutting issue, the IxD cross-cutting issue, and the pleasure-oriented cross-cutting issue. These cross-cutting issues addresses the third objective of this dissertation thesis, namely the elaboration of characteristics of IxD patterns. The technological perspective provides useful information for designers on three different levels. The modeling level, the architecting level, and the implementation level. All levels highlight considerable aspect in the design process in respect to the identified IxD and their structural dependencies and relations.

Chapter 5 presents the evolutionary design of the MIB-HCI that address the fourth, fifth, and the sixth objective of this dissertation thesis, namely the identification aspects that make products delightful for the user, the identification of aspects that are able to reflect the user on a individual level, and the fusion of these aspects.

Further, the chapter highlights that the model is capable to address all three UX aspects, namely user's internal state, the context of use, and the characteristics of the designed system. Additionally, the chapter presents an approach for the direct reflection of these UX aspects and their implications in respect of the design of desirable products and IxD styles.

Finally, the chapter provides the interpretation masks that maps results gained from the utilization of the MIB-HCI into recommendations of concrete IxDOs. This addresses the seventh objective of this dissertation thesis, namely the incorporation of IxDs patterns and their characteristics.

Chapter 6 presents the final outcome of this dissertation thesis, namely the final IxD-FW that bounds the two research areas (user-related research and practice-oriented research area) and their outcomes into one practicable unit. The provides the workflow from the targeting user involvement, over to the MIB-HCI utilization, over the IxDO-RG consultation, towards the listing of considerable design aspects in order to manifest the corresponding IxDO.

Chapter 7 provides a critical reflection about the work. It lists similarities and distinction to related works, approaches, and methods form each of the two research fields. It highlights that the fusion character of the work that additionally includes a practice-oriented approach, makes a direct comparison difficult.

Further, the chapter lists open issues and provides concepts how to address these open issues in future work.

And finally, this Chapter 8 summarizes the outcomes of this dissertation thesis and proposes a global plan how this work might be contributively used in future work.

8.3 Contributions

The list publications with my personal contributions regarding the relevant topics for this work can be enumerated as follows:

1. Miroslav Sili, Matthias Gira, Christopher Mayer, Martin Morandell, and Martin Petzhold. A framework for the automatic adaptation of user interfaces. *Assistive Technology: From Research to Practice: AAATE*, 2013:1298–1304, 2013.

2. Miroslav Sili, Martin Morandell, Barbara Prazak-Aram, Christopher Mayer, Sasha Fagel, and Tamara, Palkovic. ibi - A lightweight information and communication system for older adults, their relatives and formal caregivers. *Poster presentation AAL Forum 2013 – Impacting Individuals, Society and Economic Growth Conference*, 2013.

3. Christopher Mayer, Martin Morandell, Matthias Gira, Miroslav Sili, Martin Petzold, Sascha Fagel, Christian Schüler, Jan Bobeth, and Susanne Schmehl. User interfaces for older adults. *International Conference on Universal Access in Human-Computer Interaction*, pages 142–150. Springer, 2013.

4. Miroslav Sili, Christopher Mayer, Martin Morandell, Matthias Gira, and Martin Petzold. A Practical Solution for the Automatic Generation of User Interfaces - What Are the Benefits of a Practical Solution for the Automatic Generation of User Interfaces? *International Conference on Human-Computer Interaction*, pages 445–456. Springer, 2014.

5. Miroslav Sili, Matthias Gira, Markus Müllner-Rieder, and Christopher Mayer. Interaction Model-Based User Interfaces: Two Approaches, One Goal-Comparison of Two User Interface Generation Approaches Applying Interaction Models. *International Conference on Information and Communication Technologies for Ageing Well and e-Health*, pages 185–197. Springer, 2015.

6. Miroslav Sili, Daniel Bolliger, Jürgen Morak, Matthias Gira, Kerstin Wessig, Dominik Brunmeir, Johannes Kropf, and Hilda Tellioğlu. YouDo-we help!-An Open Information and Training Platform for Informal Caregivers. *Studies in health technology and informatics*, 217:873-877, 2015

7. Sten Hanke, Hugo Meinedo, David Portugal, Marios Belk, João Quintas, Eleni Christodoulou, Miroslav Sili, Miguel Sales Dias, and George Samaras. CogniWin - A virtual assistance system for older adults at work. *International Conference on Human Aspects of IT for the Aged Population*, pages 257–268. Springer, 2015.

8. Miroslav Sili, Jan Bobeth, Emanuel Sandner, Sten Hanke, Stephanie Schwarz, and Christopher Mayer. Talking faces in lab and field trials. *International Conference on Human Aspects of IT for the Aged Population*, pages 134–144. Springer, 2015.

9. Miroslav Sili, Matthias Gira, Markus Müllner-Rieder, Christopher C. Mayer. Interaction Modeling in PRACTICE - CTT vs. SCXML - A Comparison of Two Practical Solutions Applying Interaction Modeling Techniques for Multimodal User-System Interaction. *ICT4AgeingWell 2015 - 1st International Conference on Information and Communication Technologies for Ageing Well and e-Health*, pages 243-250, 2015

10. Sten Hanke, Christiana Tsiourti, Miroslav Sili, and Eleni Christodoulou. Embodied Ambient Intelligent Systems. *Recent Advances in Ambient Assisted Living – Bridging Assistive Technologies, e-Health and Personalized Health Care*, 20:65-85, 2015.

11. Miroslav Sili, Markus Garschall, Martin Morandell, Sten Hanke, and Christopher Mayer. Personalization in the User Interaction Design. *International Conference on Human-Computer Interaction*, pages 198–207. Springer, 2016.

12. Martin Morandell, Sandra Dittenberger, Andrea Koscher, Emanuel Sandner, and Mirsolav Sili. The simpler the better: How the user-inspired innovation process (UIIP) improved the development of RelaxedCare - The entirely new way of communicating and caring. *International Conference of Design, User Experience, and Usability*, pages 382–391. Springer, 2016.

13. Christopher Mayer, Gottfried Zimmermann, Andrej Grguric, Jan Alexandersson, Miroslav Sili, and Christophe Strobbe. A comparative study of systems for the design of flexible user interfaces. *Journal of Ambient Intelligence and Smart Environments*, 8(2):125–148, 2016.

14. Miroslav Sili, Elisabeth Broneder, Martin Morandell, and Christopher Mayer. Avatars 4 all: An avatar generation toolchain. *10th EAI International Conference on Pervasive Computing Technologies for Healthcare*, pages 257–261. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 2016.

15. Miroslav Sili, Christopher Clemens Mayer, and Daniel Pahr. Wireframe Mockups to ConcurTaskTrees. *The Tenth International Conference on Mobile Ubiquitous Computing, Systems, Services and Technologies*, pages 120-126. International Academy, Research, and Industry Association (IARIA), 2016.

16. Miroslav Sili, Matthias Gira, and Christopher Mayer. Usability Matters. *International Conference on Human-Computer Interaction*, pages 384–394. Springer, 2017.

17. Miroslav Sili, Emanuel Sandner, and Lukas Roedl. Explicit and Implicit Human Computer Interactions in Ambient Intelligence Environments. *The Eighth International Conference on Ambient Computing, Applications, Services and Technologies*, in press.

8.4 Future Work

As pointed out before, open issues and concepts to address these open issues have been presented in Chapter 7. This section focuses not on these enhancement details but on the global view how to anchor the outcomes of this work in future work.

The basic ideas regarding this anchorage have been presented in the methodology Section 1.4 of the introduction Chapter 1. The steps can be summarized as follows:

- Optimazation of the IxD-FW unit and/or of their parts MIB-HCI and IxDO-RG.
- Deployment in the AAL domain.
- Transfer to other domain(s).

The optimization process requires a deeper investigation of the identified open issues and a further elaboration of those. Moreover, this process requires the involvement of experts from other HCI domains such as experts in sociology and psychology.

The deployment process in the AAL domain requires the embeddedness of the IxD-FW unit and/or of their parts MIB-HCI and IxDO-RG within new AAL projects that utilize the UCD approach. This process is not mandatory decoupled from the optimization process. On the contrary, the optimization and the embedding of the current outcomes can be very well combined within a large research project that initially involves experts from complement domains.

From the current perspective and by my affiliation with the AIT there are plans to incorporate outcomes of this dissertation thesis in following projects:

- **vCare** [vPC18].
- **TACTILE**. AAL-JP [ASS18a] call 2018 project idea, currently in the clarification and negotiation phase.
- **AgeWell**. AAL-JP [ASS18a] call 2018 project idea, currently in the clarification and negotiation phase.

The domain transfer process is scheduled behind the optimization process and the deployment and the evaluation in the AAL domain. However, preliminary approximations took already place by the consideration of added values of the development MIB-HCI in the cardiovascular field. This domain transfer activities can be addressed, e.g., in a near future proposal for the NineSights proposal request: "Technologies linking Cardiovascular Risks and Type II Diabetes within the Patient Community" [NH18].

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Appendix

Details regarding the used methodology and technological factors in the implementing pillar of the technological cross-cutting issue.

Purpose	Method	Technology, Standards, Algorithms & Used Methods	3rd Party Tools and Solutions
Intra-technology Communication			
Multi Device Communication	IP-based Data Exchange	HTTP, UPnP, REST, SOAP	Smartphones, Tablet Devices, Set-Top-Boxes, SmartTVs
Cloud Communication	IP-based Data Exchange	HTTP	OwnCloud Google Services, Skype,WebRTC
Object Identification	NFC-based Data Acquisition	NFC	ACR122U USB NFC Reader
Multi Device Communication	Bluetooth-based Data Exchange	BlueTooth, BLE	Smartphones, Tablet Devices, Wearables Bluetooth Devices
Object Identification	Visual Sensing	QR Reader, Visual Object Recognition	Samsung SUR 40, Tobii

Purpose	Method	Technology, Standards, Algorithms & Used Methods	3rd Party Tools and Solutions
Intra-technology communication			
Motion Sensing	Visual Sensing	3D Sensing	Leap motion, Kinect
Device Control	HDMI-based Data Exchange	USB-HDMI-CEC adapter	PULSEEIGHT USB-CEC Adapter
Device Communication	SMS-based Data Exchange	SMS Gateway	Handywelt.at
Device Control	IR Signal Broadcasting	USB-IR Adapter	ACTiSYS FIR-USB Adapter
Position Localization	Outdoor Positioning	GPS Tracking	Smartphones Tablet Devices
Position Localization	Indoor Positioning	BLE, WLAN, 3D sensing	iBeacon, WLAN, Leap motion, Kinect
Smart Home Interaction	AmI-based Data Exchange	Smart Home devices	KNX, enOcean, xComfort
Activity Recognition	Step Counter		SmartLab walk B
Intra-module Communication			
Flexibility in SW Design	Frameworks for Modular SW Design	OSGi	Apache Karaf
Flexibility in SW Design	Programming Language Interfaces		
SW Release Automation	Build Management Frameworks		Gradle, Maven, MSBuild

Purpose	Method	Technology, Standards, Algorithms & Used Methods	3rd Party Tools and Solutions
Modality handling			
Modality Selection	Rule-based	Decision Trees	
Modality Selection	Case-based	Statistical Analysis, Interpolation	
Modality Provision	Plug-able Digital Media	File System, DB, Cloud Services	OwnCloud
Modality Fusion	Rule-based		
Modality Fusion	Confidence-level-based	MMI	
Modality Fission	Rule-based	Decision Trees, UPnP	
Modality Conversion	Rule-based	TTS,ASR, Image Generation Image Processing, Handwriting Recognition	Loquendo, Google Assistant, Cortana,Siri, Alexa
Data Mining			
Activity& Presence Detection	Event Tracking	Device Interaction Smart Home Interaction	
Behavior Pattern Recognition	Statistical Analysis		
Motion Recognition	Event Tracking	3D Sensing, Gyroscope, Accelerometer, Magnetomer	Kinect, Perception Neuron
Gesture Recognition	Motion Tracking	Visual & 3D Sensing	Kinect, Tobii

Purpose	Method	Technology, Standards, Algorithms & Used Methods	3rd Party Tools and Solutions
Data Mining			
Position Localization	Outdoor & Indoor Position Localization	Smart Home Devices, RSSI, Geo-fencing	iBeacons, WLAN, GPS
POI Analysis	Visual Sensing	Eye Tracking, Head Tracking	Tobii
Machine Learning			
Behavior Pattern Recognition	Probabilistic Modeling	Basian Networks, Deep Learning, HMM	
User Identification	Face Recognition	Visual Analysis Tool	Tobii
Emotion Recognition	Facial Expression Analysis	Visual Analysis Module	openFace
Emotion Recognition	Speech Analysis	Speech Analysis Module	openEar
Reasoning			
Decision Making	Rule-based Reasoning	Finite state machines	
Decision Making	Case-based Reasoning	Nearest Neighbor Search, Interpolation	
Decision Making	Fuzzy decision systems	Fuzzy Logic	
Decision Making	AI Reasoning	Cognitive& Knowledge Modeling, Contextual Sensing, Neuronal Networks	

Purpose	Method	Technology, Standards, Algorithms & Used Methods	3rd Party Tools and Solutions
Dialog Management			
Workflow Definition	Dialog Modeling	CTT, State Charts, Finite State Machine	DialogFlow, XAML, Alexa Skill Kit
Voice Interaction	ASR	ASR modules	Google Assistant, Cortana,Siri, Alexa
Voice Interaction	Speech Synthesis	Speech Synthesis Modules	Loquendo, Google Assistant, Cortana,Siri, Alexa
Voice Interaction	Natural Language Processing	not used jet	

Glossary

AALuis Research Project targeting the development a middleware user interface generation layer that can automatically adapt the user interface according users' wishes and needs. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL-2010-3-070). 21, 22, 65, 66, 72, 127

`http://www.aaluis.eu`

ACR122U NFC Contactless Payments - ACR122U USB NFC Reader ACS. 133

ACTiSYS USB to RAW SIR Serial adapter. 134

`http://www.actisys.com`

AgeWell Project idea targeting the development of a virtual coaching system to support a healthy and meaningful life of older adults and employees in their retirement process. AAL-JP [ASS18a] call 2018 project idea, currently in the clarification and negotiation phase. 126

AIT Austrian Institute of Technology GmbH. 30, 31, 62, 64, 66, 126, 128, 131, 140

`https://www.ait.ac.at`

Alexa A virtual assistant developed by Amazon. 26, 135, 137

`https://developer.amazon.com/alexa`

Android Mobile operating system developed by Google. 15, 18, 29, 30, 127, 128

`https://www.android.com`

CogniWin Research Project targeting the development of an integrated framework which provides personalized support to overcome eventual age-related memory degradation and gradual decrease of other cognitive capabilities. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL-2013-6-114). 26, 27, 65, 66, 72, 127

`http://www.cogniwin.eu`

CompanionAble Research Project targeting the development of an Integrated Cognitive Assistive & Domotic Companion Robotic Systems for Ability & Security. Funded by the European Union (FP7/2007-2013). 28–30, 72, 127

Cortana A virtual assistant created by Microsoft for Windows 10. 135, 137

`http://microsoft.com/en-us/windows/cortana`

DialogFlow Google's development framework for human–computer interaction technologies based on natural language conversations. 137

`https://dialogflow.com`

DOREMI Research Project targeting the Decrease of cOgnitive decline, malnutRition and sedEntariness by elderly empowerment in lifestyle Management and social Inclusion. Funded by the European Union, Grant agreement no: 611650. 16, 127

`http://www.doremi-fp7.eu`

enOcean An energy harvesting wireless technology used primarily in building automation systems. 134

`https://www.enocean-alliance.org/portfolio/encelium`

Fotokiste Internal project focusing on tangible interaction, development by the AIT. 31, 65, 66

Gamification The process of adding games or game-like elements to something (such as a task) so as to encourage participation. 16, 105

Google Assistant Google Assistant is a virtual assistant powered by artificial intelligence and developed by Google. 26, 135, 137

`https://assistant.google.com`

Gradle Open-source build automation system. 134

`https://gradle.org`

HOMER Internal Research Project targeting the development of an middleware platform for AmI environments, developed by the AIT. 23, 24, 65, 66

`http://homer.aaloa.org`

iBeacon Protocol developed by Apple for nearby portable device localization. 134

ibi Research Project targeting the development of a communication system that connects older adults in need of care, their relatives and the formal caregivers. Co-funded Funded by the benefit programme of the Federal Ministry for Transport, Innovation and Technology (BMVIT) of Austria. 16, 22, 26–28, 49, 65, 66, 72, 127

ION4II Research Project targeting the development of an assistive system for visually impaired or blind older adults living in a care and residential facility. Co-funded by the benefit programme of the Federal Ministry for Transport, Innovation and Technology (BMVIT) of Austria. 18–20, 65, 66, 72, 127

http://www.ion4ii.at

iWalkActive Research Project targeting the development of a highly innovative, attractive, open walker platform that greatly improves the user's mobility in an enjoyable and motivating way. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL-2011-4-112). 65, 66

http://www.iwalkactive.eu

Karaf A modular open source OSGi runtime environment. 134

https://karaf.apache.org

Kinect Discontinued motion sensing input devices that was produced by Microsoft. 134, 135

https://developer.microsoft.com/en-us/windows/kinect

KithNKin Research Project targeting the increase of communication and interaction between older adults and their family members and friends utilizing well-known communication and interaction patterns. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL-2015-2-091). 31, 32, 65, 66, 72, 128

http://www.kithnkin.eu

KNX An open standard for commercial and domestic building automation. 134

https://www.knx.org/knx-en/for-professionals/index.php

Leap motion Company that manufactures and markets a computer hardware sensor device that supports hand and finger motions as input, analogous to a mouse. 134

https://www.leapmotion.com

Loquendo Speech enabled self-service solutions for small businesses includes powerful Automatic Speech Recognition (ASR) and Text-to-Speech (TTS) technologies. 135, 137

https://www.nuance.com

Maven Apache Maven is a build automation tool used primarily for Java projects. 134

https://maven.apache.org

Memento Research Project targeting the development of a solution for helping people with dementia to life with a decline of memory. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL-2016-069). 65, 66

http://www.memento-project.eu

Miraculous-Life Research Project targeting the development and the evaluation of an innovative user-centric technological solution, the Virtual Support Partner (VSP), attending to the elder (65+) daily activity and safety needs, while the elder goes about his normal daily life. Funded by the European Union. Grant agreement no: 611421. 29, 30, 65, 66, 72, 128

http://www.miraculous-life.eu

moduLAAr Research Project targeting the development of a scalable system for silverager located in assisted living homes. Co-funded by the benefit programme of the Federal Ministry for Transport, Innovation and Technology (BMVIT) of Austria. 15, 65, 66, 72, 127

http://modulaar.at

MSBuild Free and open-source build tool set for managed code as well as native C++ code. 134

https://docs.microsoft.com/en-us/visualstudio/msbuild

openEar Munich Open-Source Emotion and Affect Recognition Toolkit developed at the Technische Universität München (TUM). 136

https://sourceforge.net/projects/openart

openFace Free and open source face recognition with deep neural networks. 136

https://cmusatyalab.github.io/openface

OwnCloud OpenSource Cloud Collaboration Platform. 133, 135

https://owncloud.org

Post-it Small notepad with an adhesive strip on the back of each sheet that allows it to stick to smooth surfaces and be repositioned. 50, 51, 128

https://www.post-it.com/3M/en_US/post-it

RelaxedCare Research Project targeting the development a solution for informal caregiver which can reduce the necessity of regularly checking the status of a bellowed person, in need of care, living at home. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL-010000-2012-1). 25, 65, 66, 72, 127

http://www.relaxedcare.eu

Samsung SUR 40 Interactive Display SUR 40. 133

`https://www.samsung.com`

Siri A virtual assistant created by Apple. 26, 135, 137

`https://www.apple.com/ios/siri`

Skype Communication tool for free calls and chat. 133

`https://www.skype.com/en`

SmartLab walk B Step Counter with Bluetooth API. 134

`https://hmm.info/de/products/`

Snapchat Snapchat instant messenger. 73

`https://www.snapchat.com`

SUCCESS Research Project targeting the development of an innovative mobile training application to support formal and informal caregivers to appropriately interact with people with dementia. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL-2016-089). 65, 66

`http://www.success-aal.eu`

TACTILE Project idea targeting the alleviation of dementia effects and the prevention of social exclusion with mixed reality technology. AAL-JP [ASS18a] call 2018 project idea, currently in the clarification and negotiation phase. 126

Telegram Snapchat instant messenger. 73

`https://telegram.org`

Tobii A product for eye control and eye tracking. 133, 135, 136

`http://www.tobii.com`

TrainAndWin Research Project targeting the development of a gamified training solution for the improvement of quality of life utilizing an avatar based feedback oriented mobilization program. Co-funded by the benefit programme of the Federal Ministry for Transport, Innovation and Technology (BMVIT) of Austria. 65, 66, 72

`http://fitdaheim.com`

vCare Research Project targeting the development of a smart coaching solution grounded on personalized care pathways. Grant agreement no: 769807. 126

`https://vcare-project.eu`

Wearables Small computing devices (nowadays usually electronic) that are worn under, with, or on top of clothing. 133

WebRTC Web Real-Time Communication. Open-source project that provides web browsers and mobile applications with real-time communication. 133

`https://webrtc.org`

whatsApp WhatsApp instant messenger. 73, 76

`https://www.whatsapp.com`

xComfort Building automation system developed by the company Eaton. 134

`http://www.xcomfort.at`

YouDo Research Project targeting the provision of special training programs for informal caregivers in order to help them to improve the quality of their nursing. Co-funded Funded by the EU Active and Assisted Living Joint Program (AAL 2012-5-155). 17, 65, 66, 127

Acronyms

AAL Active and Assisted Living. 2–5, 7, 14, 15, 18, 21, 23, 25, 26, 28, 31, 45, 50, 58, 60, 62, 64, 69, 72, 73, 103, 105, 107, 109, 110, 115–118, 122, 126, 128

Adaptive-IxDO Adaptive Interaction Design Opportunity. 19–23, 52, 53, 56–58, 99, 118

AI Artificial Intelligence. 24, 27, 60, 63, 136

AmI Ambient Intelligence. 15, 22–25, 127, 140

AmI-IxDO Ambient Intelligence Interaction Design Opportunity. 22–25, 52, 53, 56–58, 62, 99, 118

App-IxDO App Interaction Design Opportunity. 14–16, 18, 19, 51, 53, 55–58, 63, 99, 118

ASR Automatic Speech Recognition. 135, 137

BLE Bluetooth Low Energy. 133, 134

CAS Context-Aware System. 15, 16, 21

Companion-IxDO Companion Interaction Design Opportunity. 27, 28, 30, 53, 56, 58, 63, 100, 118

CSCW Computer Supported Cooperative Work. 110

CTT Concur Task Trees. 22, 137

CUBI Content User Business and Interaction model. 111, 113, 114

ECA Embodied Conversational Agent. 30

eHCI Explicit Human Computer Interaction. 10, 11, 17, 20

GPII Global Public Inclusive Infrastructure. 19

GUI Graphical User Interface. 2, 10, 15, 16, 18–20, 61, 127

HCI Human Computer Interaction. 1, 2, 5, 9–13, 59, 61, 122, 126

HMM Hidden Markov Model. 136

HTTP Hypertext Transfer Protocol. 133

ICT Information and Communication Technology. 2, 16, 106, 107

iHCI Implicit Human Computer Interaction. 10, 11

IO Input/Output. 22

ISO International Organization for Standardization. 13, 14

IxD Interaction Design. 4, 5, 7, 9, 10, 12, 14, 16, 19, 34, 35, 42, 55, 56, 59, 72–75, 77, 81, 82, 95, 107, 122, 123, 129

IxD-FW Interaction Design Framework. 4, 7, 9, 45, 46, 68, 88, 95, 103–105, 113–118, 121–123, 126, 128–130

IxDO Interaction Design Opportunity. 15, 22, 26, 45, 46, 49–51, 53–59, 62, 63, 100, 101, 103, 104, 117, 118, 123, 129

IxDO-RG Interaction Design Opportunity Research Grid. 7, 14, 45–47, 49–51, 53, 56, 58, 61, 66–69, 72, 103–105, 110, 113, 115, 116, 122, 123, 126, 128–130

IxDOs Interaction Design Opportunities. 14, 15, 45, 49–51, 53, 55–64, 66–69, 71, 98–101, 103, 105, 110, 115, 118, 122, 123, 128, 129, 131

MApp-IxDO Multi App Interaction Design Opportunity. 16–18, 22, 52, 56–58, 99, 118

MIB-HCI Model for Identification of Balanced HCI. 7, 38, 41, 43, 46, 47, 49, 58, 67–69, 71–75, 77–91, 93–99, 103–105, 107, 113–117, 119, 122, 123, 126, 128–130

MMHCI Multimodal Human-Computer Interaction. 11

MMI Multimodal Architecture and Interfaces. 135

NFC Near Field Communication. 133

OOP Object Oriented Paradigm. 56, 57

OSGi Open Services Gateway initiative. 134

PA-IxDO Personal Assisted Interaction Design Opportunity. 26, 27, 53, 56, 58, 62, 100, 118, 127

PD Product Design. 5, 9, 72, 74

REST Representational State Transfer. 133

RSSI Received Signal Strength Indication. 136

SOAP Simple Object Access Protocol. 133

Tangible-IxDO Tangible Interaction Design Opportunity. 31, 53, 56, 58, 100

TTS Text To Speech. 135

UCD User Centered Design. 2–4, 12, 13, 46, 104–106, 110, 116, 121, 122, 126, 127, 130

UGT-IxDO User Group Tailored Interaction Design Opportunity. 17–20, 52, 56–58, 62, 99, 118

UI User Interface. 10, 12, 14, 19, 21, 22, 26, 45, 46, 59, 73, 95, 127

UPnP Universal Plug and Play. 133, 135

URC Universal Remote Console. 19

UX User Experience. 9, 14, 31, 34–36, 38, 42, 49, 60, 61, 68, 71, 72, 74, 77, 87, 109–114, 123

UxD User Experience Design. 5, 9, 34, 36, 40, 72, 74, 110, 113–115, 128

XAML Extensible Application Markup Language. 137

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