A Model for Making User Interaction Design Decisions in AmI Environments

Pascal Hamisu, Felix Kamieth
Fraunhofer Institute for Computer Graphics Research IGD
Fraunhofer Str. 5
64283 Darmstadt
{pascal.hamisu, felix.kamieth}@igd.fraunhofer.de

Abstract*— This paper focuses on User Interaction (UI) in an Ambient Intelligence (AmI) environment. The number and diversity of advanced electronic (multimedia) devices used in our homes or neighboring (neighborhood, office, and city) spaces today is growing exponentially, thus leading to an increase in the complexity of interaction with these devices. In the near future, it will be almost impossible to maintain an overall picture of all the functionality and services accessible through these devices. We have identified this problem and suggest here a novel approach on how to work around this in future. In this paper we identify different types of interaction techniques and I/O devices, their data types/formats, a mapping to multimodal appliances/actuators and a task by data type classification of interaction techniques since the interaction affordance could be suggestive to appropriate modality fusion or fission. We also exploit useful information from existing research work on user and world models to incorporate into our analyses. Finally, we summarize our results in form of a table to equip UI design engineers with a toolset that will enable an easy selection and/or adaptation of new interaction techniques that can provide the end user with a more natural and intuitive multimodal interactive experience with his/her device ensemble.

***Index Terms*—design methodology, home communication systems, multimedia systems, user interaction**

I. Introduction

CURRENT market trends [1] portray an ever increasing development of new product lines for consumer electronics which are also becoming more and more powerful with sophisticated digital or analogue interfaces. These electronic devices span a broad spectrum of consumer needs ranging from multi-media and infotainment services to health and fitness gadgets as well as sanitary and cooking assistants.

HMI (Human Machine Interaction) design engineers are faced with the challenge of integrating the huge functionality offered by individual components in a device ensemble to form an easy, coherent and more natural interface for the end user. This requires methods and tools that combine the full potential of using our natural senses complemented with agent interaction techniques to realize a specific end user goal at any given time.

For example if you are sitting in front of a computer screen with a mouse, it will certainly be much easier to *point* to something on screen and employ a more natural communication ability of the user like merely saying *"Tuesday" or "enlarge"* than to first select the object on one screen area then move the mouse to a different screen area to pull down a menu or drag a UI element to invoke the same action. We believe that with a better understanding of common tasks (use cases) performed at home coupled with an analysis of available interaction techniques and I/O devices, their data formats, their limitations and where they can be employed in the most appropriate way, it can help us generate a toolset that would facilitate the selection interaction techniques, which when combined with the more natural communication abilities of the user would enable a better realization of a specific end-user goal.

Another important aspect is the categorization of the end-users; as two groups of end-users may prefer different interaction modalities to achieve the same goal. In some cases it is not even a matter of preference but that of limited abilities (e.g. by the elderly or the disabled). UI design engineers have to be able to identify both interaction affordance and interaction ability in any given situation.

Another reason for a model of design decisions is the fact that, the process of designing an intuitive interface for an AmI environment requires a high level abstraction of the problem, where some sets of decisions have to be made depending on the engineer's ability to break down end-users into categories and their goals into subtasks or use cases identified in common scenarios defined in [1] and [3].

In our approach we describe in detail these sets of decisions which are relevant in a UI design process and how these key decisions when combined with our toolset can serve as a guide in rapidly prototyping intuitive UIs that abstract interaction in an AmI environment.

The rest of this paper is organized as follows: in the next section we relate our work to the state of the art. Thereafter we describe the concept employed in deriving our toolset and the results achieved using our concept. In section four we demonstrate how such a toolset can be employed in a simple prototype application to interact with home multimedia appliances such as a TV set. The paper concludes with an outlook into future work

II. Related Work

At present there is a lot of ongoing research effort (in academia and EU-Projects) in deriving guidelines and toolkits that will facilitate the development of innovative UI solutions aimed at making HMI in general easier and user interaction in AmI environments more intuitive. Gellersen in [4] proposes a toolkit for modality abstraction whereby the UI design is based on two sets of high level decisions: one for capturing logical interaction in a device ensemble (thus dependent on the type of information exchanged between human and machine) and the other designing the appearance of the UI. This approach offers a first step in introducing informational and operational abstraction in the UI design process. A UI design engineer should consider and distinguish the logical interactions from the physical interactions in a device ensemble. This ensures a goal-oriented design approach tailored towards *what* the end-user wants to do before addressing the *how*. However the methodology employed in capturing the modality abstraction is too technology driven as it uses I/O devices as sources for extracting information rather considering common scenarios and use cases from an end-user point of view. Coutaz et al [4] identify a set of properties characterizing interaction techniques and their temporal relationships in a multimodal interaction system. An abstraction of the identified set of properties (*based on the notions of state, goal, modality and temporal relationships*) could provide valuable information for a UI design process in AmI environments. But this approach does not fully address how the user perceives a goal, how the goal can be sub tasked to enable an easy selection of interaction techniques and how the user's world model and context can affect her interaction affordance. Coen et al in [6] and [7] describe some design principles for a distributed software agent system (developed in MIT's Intelligent Room project) which models complex behavior in an AmI environment using relatively simple interacting agents that link various components of a room (such as tracking cameras and speech recognition systems). Bobick et al in [8] propose some design decisions for building perceptual-based interactive and immersive spaces. However the scope is narrowed to using computer vision for implicit interaction. Brumitt et al in [9] (EasyLiving Project at Microsoft Research) propose a system for HMI in AmI environments which allows dynamic integration of diverse I/O devices into a single coherent user experience. But the system is focused on implicit interaction, leaving little control for the user. Bourguet in [10] suggest a toolkit for creating a testing multimodal Interface design using recognition based interaction technologies such as speech and gesture inputs. Franklin et al in [11] provide a plan-based approach for modeling user tasks in terms of their logical sequences. However the work is narrow in scope to incorporate other relevant aspects in a complete UI interaction cycle. In [12], Saponas et al explore new interaction techniques that directly sense and decode human muscular activity. This is a step towards more natural intuitive interactions.

III. Design Decisions and Concepts

For an AmI environment, the UI design engineer is faced with a set of key decisions to make and a consideration of different parameters in generating an interface for the end-user to interact intuitively with his device ensemble. A set of decisions have been proposed in other research works but they are either too general to specifically address the complexity of interaction in an AmI environment or they are too narrow in scope to tune different parameters that an end-user is faced with in an AmI environment. Our research on the analysis of use cases in common scenarios and the categorization of end-users as well as a survey on existing interaction techniques and advanced I/O devices have led us to identify the following sets of key decisions and parameters for interaction in an AmI environment:

- *Who is the user (end-user categorization) and what are his/her interaction affordances?*

A profiling of the end-user and her abilities should be considered in interaction cycle. This means the preferences of a user in the generation 65+ or a user with some kind of physical or mental impairment play a significant role in the selection of the interaction techniques and the chosen natural communication abilities employed in accomplishing a goal.

- *What does the user want to accomplish?*

This is a key user-centric design decision that has also been identified in several related research works going back as far as to Donald Norman's Action-model (7 stages of action) in a user interaction Cycle [13]. A user interaction requires a cognitive modeling of the interaction intent (goal formation) or a planning phase. Nielsen lists a number of steps in [14] that can be considered in the planning phase of an interaction cycle:

  - Identifying the subtasks that constitute the goal
  - Structuring the subtasks in the form of a dialog with necessary feedback loops
  - Determining the commands and features in the device ensemble that realize the subtasks

- *How does the user accomplish the goal and with which modalities (interaction techniques)?*

To accomplish a goal is to perform an action in an interaction cycle that takes a set of parameters from the previous two points. In other words an action predicate in the interaction cycle could be expressed mathematically as function with the following parameters:

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ACTION (subtasks, scheduling algorithm,
and interaction techniques)
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The scheduling algorithm employed should govern the selection, combination (modality fusion/fission) and synchronization of interaction techniques based on subtasks constituting a user goal and the data types supported by chosen interaction techniques during an action. This is described in detail in related papers [14],

[16] and [17]

- *When and how does the system provide feedback to an action in an interaction cycle?*

  The type of feedback depends on the interaction affordances of the user, available interaction techniques and the structure of the scheduling algorithm employed in an action (previous point).

Based on these corner decisions we model a UI interaction cycle identifying the main stages and corresponding components' integration sequences. A User Interaction Cycle could be viewed as a chain of activities involved in realizing an entire user scenario. A scenario is further broken down into use cases (subtasks). Each use-case is accomplished using one or more interaction techniques. Each interaction device supports a given data format which is suggestive of what use-cases it can realize. Following this logical sequence, we have identified within our model for a UI interaction cycle, an average of 4 states. In the first state we collect information regarding the interaction affordances of the user based on his world model. This is followed by the goal formation. The goal formation state identifies which use-cases support reaching the goal and which interaction techniques could be employed in realizing the corresponding use-cases. A third state has an action predicate which is triggered to realize the use-cases based on a scheduling algorithm and selected interaction techniques This concept is depicted in figure 1 below.

IV. Device Descriptions

To implement an interaction concept, a description of available interaction devices with regards to the data they provide and a description of available output devices with regards to the data they require and display are needed. This way, one can choose the devices needed to realize an interaction function based on the devices' respective properties. We present two lists of devices which provide such descriptions. Table I and II display an exemplary excerpt from the respective lists.

Table I contains descriptions of several input devices and details the data formats supported by these devices. A main distinction here is made between continuous, discrete and binary interaction data. This allows for an easy choice of devices based on the type of modalities the user needs to perform the necessary interaction. To set a specific value along a spectrum, for example, a continuous mode of interaction is required whereas for a choice between several alternatives a discrete mode is more fitting. The input devices are described along with the data formats that they support. There are several groups of devices described in the list. Table II contains descriptions of output devices and details the output modality (auditory, visual, haptic) as well as the available interfaces to the device. This lets the designer choose the device best suited for the feedback he wants to give the user, be it visual or auditory or even haptic feedback.

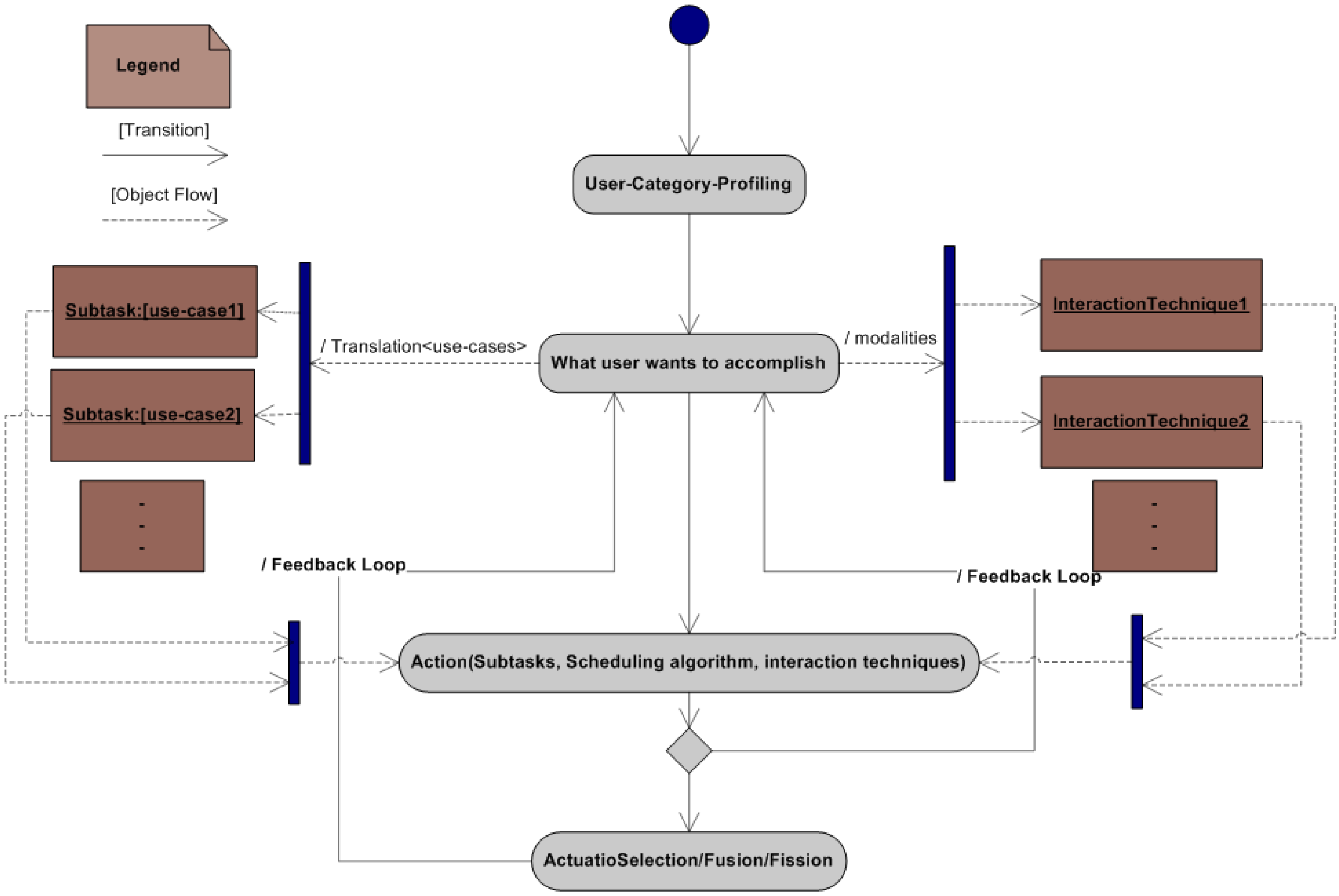

Fig. 1. User Interaction Cycle stages and Components Integration

TABLE I
INTERACTION DEVICES

Interaction Devices	Interaction table	…
Description	Tangible objects on table, measures position of devices on table	…
Data Format	x/y position of devices on table (continuous)	…
Application Areas	Architecture, meeting rooms	…
Suggested Output Devices	TV Set, Plasma Display, Light Bulbs, Stereo Set, Media Center, Media Player, Wireless Music Station, Smart Board, LCD Display, Surround Sound System	…

Excerpt from the list describing a variety of interaction devices. Here an interaction table is described. One can see the description of the device, the available data format in abbreviated form, application areas and suggested output devices.

Both lists include recommendations from the other list, interaction device recommendations for a certain output device and output device recommendations for a certain input device. These provide –at a fast glance- commonly used and easily employable devices from the other list to combine with the respective device, making the choice of additional devices easier once the decision has been made to use one device already.

V. Sample Scenario Realization based on Model

To demonstrate our concept we consider a simple scenario in a home environment from which the following relevant data have been extracted:
User category: an elderly of the generation 65+
Her Interaction affordances: speech, tangible interaction, gestures
Her goal: To interact with a TV set in the living room preferably using her more natural communication abilities
Available interaction devices: Tangible table, a microphone and headset
Multimedia appliances: A setup box, a TV set and HiFi set.

Using this data as input into the model described above, a UI design engineer has the simplified task of only identifying the subtasks constituting the goal and mapping these to a knowledgebase of common use cases and recommended interaction techniques appropriate for a specific category of users. The mapped use-cases and recommended interaction techniques are then channelled to the next state which is the action state for physical interaction with the environment. For this simple scenario we implemented a prototype that enables the user to use simple tangible artefacts on a table combined with speech input to interact with his TV set via a setup-box. By moving tangible artefacts on the table based on predefined movement patterns triggers specific signal that are combine with voice input to realize the identified use-cases constituting the goal. Figure 2 illustrates the interaction concept.

TABLE II
OUTPUT DEVICES

Output Devices	**TV Set**	…
Description	A Telecommunication system with a tuner for receiving different broadcast or video formats including motion pictures and sound Two kinds: Analogue and Digital TV	…
Output format	<Composite video> with three source signals called Y, U and V with sync pulses and in the following standard formats: NTSC (USA), PAL (UK) or SECAM (FRA) [Analogue TV] MP2 audio streams within MPEG-2 progema streams [Digital TV]	…
Suggested Interaction Devices	remote control mouse microphone keyboard buttons sliders, EFS wii remote, table with tangibles	…

Excerpt from the list describing a variety of output devices. Here a TV set is described. One can see the description of the device, the available output formats and the suggested interaction devices.

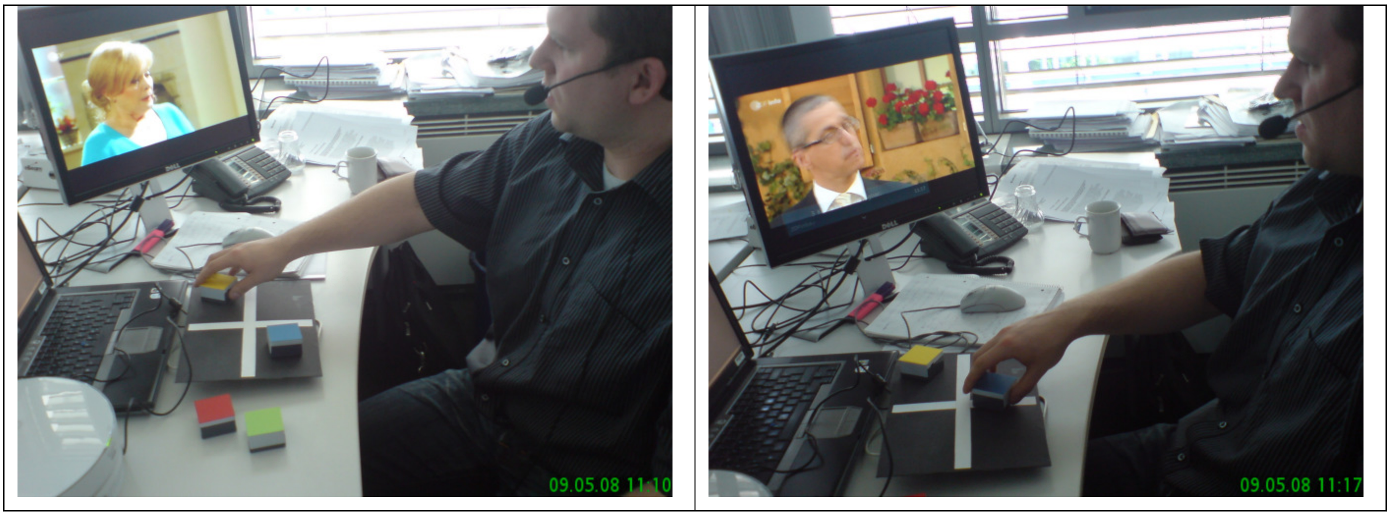

Fig. 2. Interacting with TV using interaction table with tangible artefacts and voice

VI. Summary And Outlook

In this paper we described a model which makes user interaction design decisions easier. Current market trends show an increase in the range and complexity of electronic devices. Interacting with this multitude of technology is a rising challenge. A look at related work suggested the need for a system to make user interaction design simpler for the AmI developer. We devised a concept which described the fundamental decisions needed during development of an AmI interaction system regarding the user's interaction affordances and goals, the modalities of the interaction and the way feedback is given to the user. Based on this we developed reference tables for both interaction and output devices, which described the devices' fundamental characteristics regarding user interaction design decision making. The combination of these allows for an easier and faster development of AmI interaction systems.

We then give an example of such a development supported by our model, which resulted in a system working with a combination of a tangible interface and speech recognition.

Improvements in our model will be made first by increasing the already existing knowledge base for interaction devices. This adds more variety and choice to the development process and allows the designer to fit his system better to the goals and needs of the respective user. The next step is the development of a knowledge base containing already solved use-cases and the interaction devices used therein. This will support rapid prototyping by providing the designer with a library of already solved problems from which he can easily draw when creating a new design. Such a database also provides the designer with a detailed look at the varied usages of different interaction techniques and their combinations.

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