Methods for Designing Tangible UI: A First Comparative Case Study

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Abstract
In this work-in-progress, we present early comparative experiences with methods for designing tangible user interfaces (TUIs). Groups of designers used different approaches for design in the context of a concrete case study: a TUI for controlling LED lighting within hotel rooms. From the results of the groups and methods, we wish to discuss the first comparison between different approaches. Eventually, our aim is to provide a consensual comparison of benefits and drawbacks of each approach, as such a consensual result could be highly beneficial to designers.

Author Keywords
Tangible User Interfaces; Design Methods; Case Study

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

General Terms
Design, Experimentation.

Introduction
The design of mixed reality interfaces and TUIs can be driven by different approaches: e.g., by interaction paradigms, interaction models, creativity methods, or special concern for respecting ergonomics and human

factors. Alternately, design can be engaged ad-hoc, without a specific formal approach; or by ensembles of multiple approaches. Here, we begin to consider the comparison of such approaches. It is not an easy task for designers to find the appropriate approach for a given design problem. Providing them with a consensual comparison of benefits and drawbacks of each approach can be of important benefit.

However, the comparison is a difficult problem as design methods can be compared from many different points of view. Examples include quality of results, ease of understanding by designers, number of alternatives designed, or rapidity of use, to name a few. In this paper we report on experiences from a workshop conducted to compare the results and processes of different design approaches applied on the same topic: creative approach, paradigm-driven approach, interaction model approach, ergonomic approach and free approach. Our aim is to find what differences can appear with different approaches and to see if complementarities can be observed.

Related Works

Experimental comparisons between design approaches are infrequently described in the academic literature. Most related work, like in [6], compare propositions in a theoretical way with related work.

Another previous work proposed three dimensions from interaction models: descriptive, comparative, and generative power [1]. Generative power is the ability of the model to help design new ideas. These criteria could be used for an experimental evaluation of design approaches, whether model-based or not. For instance, the number or novelty of solutions generated by the approaches could be assessed.

Other works like [8] can inspire additional criteria for the experimental comparison of approaches. For instance, thresholds and ceilings, or the path of least resistance can be assessed, by evaluating the time needed to generate a solution and the limitations of, or the similarities between designed solutions.

However, such conceptual criteria have yet to be experimentally applied to methods for designing TUIs. In this paper, we propose a first step for an experimental comparison between different approaches for designing TUIs.

Case Study: Designing for LED lighting

In contrast with traditional lighting technologies, LEDs are smaller and digitally controlled with greater flexibility. Where past lighting systems might contain one or a few light bulbs, future systems may contain many hundreds of LED light sources embedded in the environment. Far beyond simple on/off control, we will be able to control lighting intensity, heat, color, etc. As a consequence, replacing the traditional light switch, the user interface(s) for future LED lighting likely remain(s) to be invented.

As a concrete scenario, we provided participants in a design charrette with a scenario concerning clients for a hotel where rooms are equipped with LED lighting. **Figure 1** illustrates a possible setting of the lights of such a room.

We proposed the following tasks for the participants of our workshop to design a TUI for this scenario:

- Turn all lights on/off, e.g. when leaving the room
- Choose among predefined scenarios, e.g., arriving, night reading, relaxing, sleeping, etc.
- Choose a particular LED module to vary its heat/color or its intensity. E.g., customize the intensity of a bedside lamp in order to read textual materials; or change the colors of LED modules in the room to customize the ambiance.
- Choose a particular area of the room to be illuminated, e.g., desk, cabinet, etc.

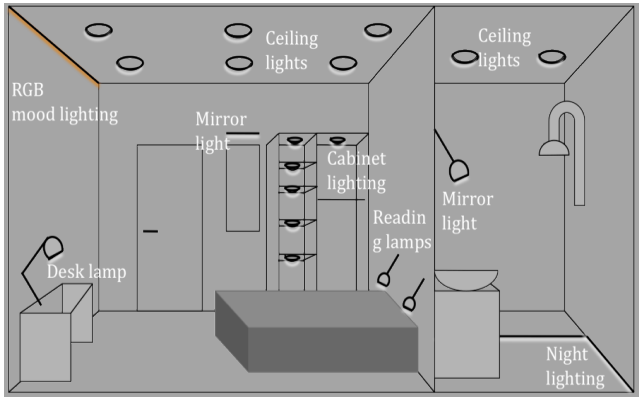

Figure 1. Hotel room equipped with simple LED lighting.

The participants were senior researchers, PhD students and post-doctoral researchers, with experience in TUI design or with a long term awareness of TUIs. They came from the HCI field, computer graphics or industrial design.

Prior to designing a TUI by groups, our participants brainstormed in order to agree on criteria for the evaluation of the TUIs for this specific context of the hotel room lighting. During this half hour discussion, we agreed that the interfaces should:

- Take into account the number of people/users
- Be easy to use
- Adapt to the user's profile
- Offer good affordances
- Be able to transition between contexts
- Provide flexibility
- Be secure for the user/the hotel
- Take cost into account
- Support tasks presented
- Provide control for hotel staff
- Support emotional feeling, e.g. change in valence and arousal dimension of emotion [5].

Outcomes of the Workshop by Approaches

Participants were given one hour to sketch a TUI while respecting the scenario's constraints and methodology.

Creative approach

The guideline for this three-person group was to use a creativity method. The team proposed a minimally-intrusive solution using hotel keycard(s) or smartphone(s) and a graphical multi-touch interface integrated in the desk to control the lighting of the room. When the user enters the room, s/he can place the card in an array of slots. Each slot stands for a scenario, e.g., a welcome state, TV watching, sleeping, taking a bath, etc. Each scenario could be customized prior to or during the stay through a web interface, or at check-in. For the better control of the user, common devices, e.g., switches, overrule scenario settings.

Paradigm-driven approach
The constraint of this three-person group was to design a tabletop-based TUI. They proposed a set of tangible tokens representing meaningful groups of lights, e.g., cooking area, living room or child's bed. These tokens could be placed on the surface displaying the controls, e.g., the color space, in order to modify the lighting in the corresponding area. To provide extended control and creativity (in the context of an envisioned trio of child occupants, with their parents residing in a separate room), this approach allowed them to keep control of private areas by hiding tokens, e.g., under a pillow or in a pocket.

Interaction Model approach
This two-person group was requested to use two systematic approaches for exploring the design space: the 7-questions framework described in [4] and the Mixed Interaction Model (MIM) [3]. Numerous solutions were designed with these frameworks, e.g. using a miniature room for pointing at lights and areas, using the keycard of the hotel or using a painting where a color or an ambiance can be selected. By using MIM, they proposed a spherical object with a laser pointer that users can orient and scale up/down in order to point at a target and modify the light intensity of it.

Ergonomic Approach
The main objective of this three-person group was to take into account the user experience of interaction with the future TUI. During the brainstorming they referred to the user experience research framework proposed by Mahlke [7]. Thus the final solution had not to be only useful and usable, but also aesthetic, symbolic and motivating for its user.

This proposal tries to remain close to traditional uses associated to a hotel room assuming that it is generally difficult to change habits. It is therefore not a question of removing switches, for example, but an aesthetic question, focused on relaxation. For this purpose, this is the only group having modified the initial hardware setup. It proposed a ceiling covered with LEDs instead of scattered lighting spots, in order to have a very flexible way to adapt to users. Firstly, about displacements in the room, the user can draw lines on a tablet computer, associated to various times of the day, that are reproduced on the ceiling by the LEDs. Secondly, in the bathroom, they imagined a metaphor with bath salts that control the color of light. Small plates with colored bath salts are provided around the bath, the user pours salts in the bath or in a cup, and in function of the lack of salts in each small plate the light is adapted in the bathroom. Then, they are complying with the use of salt in a bathroom; the bath salts retain their first function but the proposal enhances its main objective: the relaxation.

Free approach
As a baseline, we had a four-person group working with no constraints or guidelines, except the tangible criteria. In fact, the group first generated ideas individually. Then they confronted their ideas to converge to a final design.

They proposed a personal object called *Magic Light*, given by the hotel to the customer. This object could be the keycard or a dedicated magic wand. First, the user points towards its target. Then s/he gestures from there, in opposite directions to turn on/off the light. S/he can gesture perpendicularly to change the color of the light. In addition, s/he can use a magic gesture,

e.g., bump the wand, in order to retrieve its personal favorite light settings. A skin conductivity sensor is used on the wand to set the light according to the affective state of the user.

Discussion

This very first experience of comparison of methods for designing TUIs leads us to notice interesting facts. Note that our work is in its first steps and we do not wish to present them as final results, but would rather like to discuss them, and our experience, with the TEI conference attendees. The final aim is to reach a consensual comparison of benefits and drawbacks of each approach, as such a consensual result could highly benefit to designers.

First, we had two kinds of approaches: instrumented with a framework, e.g. the ones from [4], [3] or [7], and the approaches that were not instrumented, like the free or paradigm-driven approaches. We noticed that the participants applying a framework had to learn the framework beforehand if they were not already expert of it, in addition to relying on the designers' experience of TUIs like the free or paradigm-driven approaches. The high threshold [8] of the frameworks is a drawback, but we envisioned that, as a consequence, the results of the design were less dependent on the participants' individual skills and could be more easily repeated.

Second, the participants using interaction models were the only ones providing with several alternatives. Providing with as many alternatives as possible was not an instruction, but it is the aim of these methods to explore the design space in a systematic way, making it easier to design different solutions. We noticed as well that this approach leads to solutions that remind some elements from other approaches, like the picture or the keycard, even though the design was not as detailed because of the limited time. As a consequence, these approaches can be good candidates for generation phases [1].

Third, the solution from the paradigm-driven approach was the only one to provide support for multiple users and to deal with possible conflicts between them. We explain this feature by the fact that the paradigm constraint, i.e. the tabletop, is an opportune one for multiple users to interact. The other approaches more naturally lead to a tangible object targeting a single user.

Fourth, two of the approaches allowed using current switches for turning on and off the lights, in addition to new interactions: the ergonomic approach and the creative approaches. Indeed, the study of existing solutions is part of these two approaches, on the contrary to other approaches where this is left to the designers' initiative. As a consequence, these approaches can be good candidates for designing a TUI where a lot of related interfaces already exist.

Finally, our aim was to take a first step towards the evaluation of the approaches' ability to lead to good solutions. For this, following the design session, the participants proposed a common, rough evaluation of the interfaces produced. This very early result will have to be repeated across several design sessions in order to be confirmed.

	Creative approach	**Paradigm-driven approach**	**Interaction model approach**	**Ergonomic approach**	**Free approach**
Provide emotional feeling				Yes	Yes
Take into account the number of people		Yes			
Be easy to use	Yes			Yes	
Adapt to the user's profile	Yes	Yes		Yes	Yes
Offer good affordances	Yes		Yes	Yes	Yes
Be able to transition between context			Yes		Yes
Provide flexibility			Yes		
Be secure for the user/the hotel	Yes				
Take cost into account	Yes		Yes		Yes
Cover tasks presented	Partially	Partially	Partially	Partially	Partially
Provide control for the staff		Yes			

Table 1: Assessing evaluation criteria to the solutions produced.

As one can notice in **Table 1**, none of the approaches were able to comply all the criteria in such a short time (one hour). It would be interesting to provide a longer time for the participants so that they are able to exploit the full potential of their method.

Future Work

This work is a first step towards an experimental comparison of methods for designing TUIs. In this first experience, the results cannot be generalized yet due to the correlation to individual designers' skills. The next step of this work is to conduct more workshops of this kind in order to vary designers so that the

comparison can be generalized. For instance, a next step after more workshops could assess the path of least resistance of the approaches, independently of the designers' individual specificities.

We also noted that the creative approach was only partially followed. However, this could happen to any approach. A way to improve this limitation could be to have an external group leader or a physical support guiding the process, ensuring that the group follows the assigned approach.

Moreover, an ongoing work is to integrate the use of more frameworks for designing TUIs, like RBI [6] or TAC [9].

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