Information Sky: Exploring the Visualization of Information on Architectural Ceilings

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Abstract

In this paper we suggest the ceiling as a new physical surface for information visualization. To provide a design framework for application designers, we present the notion of 'information sky'. This concept is based on (1) the metaphor of the natural sky, (2) historical examples of ceiling art and (3) recent computing paradigms, including mediatecture, ubiquitous computing and ambient display. We further introduce three distinct categories that denote potential application domains for ceiling-based data visualizations. Finally, we present four different application scenarios we have developed using prototyping and user-centered design techniques, and discuss how they relate to the categories.

Keywords--- **Ambient display, ceiling display, physical visualization, responsive environments, interactive architecture, mediatecture**.

1. Introduction

In the information society of today, we are surrounded by 360 degrees of visual "noise". Information exists all around us, embodied as traditional (e.g. billboards) or digital (e.g. screens) media. The only surface that seems to remain free, open, and available is the architectural ceiling. The conceptual counterpart of the ceiling in a natural environment is the sky, since both are visually accessible by looking up. In history the architectural ceiling has often been associated with the natural sky and has become decorated with elements resembling the natural sky, including stars, clouds or birds. As an example, consider ancient ceiling art found inside of Egyptian tombs (see Figure 1, right).

In terms of representing information, the sky is richer than a typical indoor ceiling: it provides us with several clues about time, location and environmental conditions. In the natural world, when people needed to know *what*, *when* and *where*, they usually began by looking up. Based on the observation that humans learned to look up to increase knowledge about their situational awareness, we argue that the ceiling represents a natural opportunity to provide *contextual information* and *guidance* in indoor environments based on the metaphor of the sky.

In Native American storytelling, stars often constructed the stage for ancient tales about gods. The concept of using the space "up" for *narrative representations* is further supported by historic European ceiling art. For example, ceiling frescoes from the Renaissance period typically feature stories with historical or biblical origins.

Based on these observations, we introduce the concept of *information sky*, which consists of the augmentation of the ceiling with information that supports people who pass through that space, in and during their daily activities. We suggest that the ceiling as an information space has the potential to reduce the visual noise in the everyday environment by moving particular bits of information onto the ceiling and into the periphery of our perception. On the other hand, it can also serve as a default space for monitoring critical information, since a ceiling is a large-scale prominent surface that is visible from various viewing angles within the space it covers.

In this paper, we define three categories for information sky, *contextual information*, *navigation and guidance*, and *storytelling*, and investigate their applicability for visualizing information. We further describe four application scenarios based on the notion of information sky and relate them to the presented categories.

2. Foundational paradigms

This chapter elaborates on the contributing paradigms that set the stage for the notion of information sky. They provide an inspirational, conceptual and technological design framework for applications in that realm. We briefly explain each paradigm and discuss its contribution to the framework.

Figure 1. Examples of ceiling arts: cave paintings at the Altamira cave in Spain (left) and an ancient Egyptian ceiling inside the tomb of Sethi I (right)

Figure 2. LED display ceiling covering a new shopping mall in Beijing (left) and multimedia sky above the winter garden of the Bertelsmann residence in Berlin (right)

2.1. Ceiling art

We ground the design framework partly on the specific subdomain of *ceiling art*. The architectural ceiling has been used as a platform for visualizing information throughout many centuries. Based on this observation we argue for the rediscovery of the ceiling for visualizing digital data.

Ceiling art can be traced back to the first days of human evolution. Cave art represented an intellectual instrument, which encouraged discussion and storytelling [1]. In that respect the ceiling at that time was not treated different to other surfaces, such as walls (Figure 1, left[1]). In contrast, ceilings from ancient Egyptian temples featured elements that are associated with the sky, such as stars and flying birds representing different protective deities (Figure 1, right[2]). This was due to the fact that every Egyptian temple was built like a microcosm and the ceiling in the halls consequently visualized the sky of this temple microcosm.

Some of the most impressive examples for ceiling art can be found during the Medieval and Renaissance periods. The purpose of ceiling frescoes was storytelling and reflecting major beliefs of that period. From a social perspective the intention of ceiling frescoes was to communicate the power and wealth of the proprietors to the people visiting the architectural space.

Historical examples of ceiling art often encode small bits of information using a rich set of visual expressions. For example, the richly decorated wooden ceilings at the Alhambra in Granada, Spain, reflect the emperor, who was in power at the time the ceiling was created. There are several rooms next to each other, featuring different decorations, such as emblems and other symbols, representing different emperors.

2.2. Mediatecture

We used *mediatecture* as one of the foundations for information sky, arguing that projects from this field are based on the same motivation, which is the integration of digital media and architecture. Particularly, it reflects the state-of-the-art in display technology, pointing out emerging trends in this area.

Mediatecture applications typically exploit large-screen displays situated in public or semi-public environments for display of simple arbitrary patterns or visualizations of data. The data, such as weather data or stock data, may be represented figuratively (e.g. temperature value) or abstract (e.g. light patterns). Most contemporary ceiling display applications belong to the category of mediatecture. A few of the most impressive and well-known interactive ceilings are the Fremont Street Experience in Las Vegas, or the LED display of 250 meters length installed in the ceiling of a shopping mall in Beijing, showing a fake fish tank and other animations (Figure 2, left[3]). Both ceiling displays aim to add to the experience of the architectural environment, but do not aim to represent nor communicate environmental relevant data. The multimedia sky above the winter garden of the Bertelsmann residence in Berlin (Figure 2, right[4]) is an example for a large-scale media ceiling display that represents dynamic information, such as real-time weather data retrieved from a nearby weather station.

2.3. Ubiquitous Computing

As another foundation of information sky, we draw on recent advancements in *ubiquitous computing* technology and user-driven application development. Of particular interest in this respect are techniques that allow interaction over a distance (e.g. pointing) and the scientific exploration of large-scale display technologies. However, the ceiling is a very distinctive area, compared to others that have already been explored more thoroughly in the context of ubiquitous computing concepts, such as the wall [2] or the floor [3]. It is therefore important to particularly design and evaluate interaction concepts for ceiling-based scenarios, when borrowing them from related ubiquitous computing research. In previous work we investigated laser pointing and free hand pointing for ceiling interaction and derived initial design implications from our results [4].

[1] retrieved from http://museodealtamira.mcu.es
[2] retrieved from http://www.osirisnet.net
[3] photo by AP / Andy Wong
[4] retrieved from http://www.bertlesmann.com

The field of ubiquitous computing envisions an environment, where computing technology dissolves into the background of everyday environments. Applications from that realm are generally characterized by being non-obtrusive and do not require full attention of the user. The research field has seen a promising development in recent years, especially due to significant advances in both information and communication technologies. Ceiling applications specifically rely on the progress of display technologies towards a future ideal of interactive wallpapers: affordable displays that can be easily distributed in our environment and used for large-scale visualizations.

2.4. Ambient information visualization

Ambient information visualization or *ambient display* refers to the visualization of information at the periphery of human attention [5]. An ambient display provides specific bits of information without requiring full attention of the user. Only if an event occurs that needs immediate response, the user is alerted to focus on the ambient display. Matthews et al. identified several levels of notification: ignore, change blind, make aware, interrupt and demand action [6].

The architectural ceiling literally sits at the periphery of human perception and therefore represents a natural opportunity for ambient display of information. The theory of ambient display consequently represents an important foundation for information sky.

The field of *information visualization* aims to provide users with tools that achieve a better insight into complex data structures and new interaction paradigms that enable effective navigation within the resulting representations [7]. Techniques used for visualizing data provide a potential toolset for designing the visual concept of information sky applications.

2.5. Responsive environments

As another foundation, we base information sky on the recent field of *responsive environments*. Projects from this field follow the same motivation as information sky, which is the enrichment of architectural spaces with information relevant to the inhabitants.

A responsive environment is a space that interacts with the people who use it or passers-by [8]. Applications from that realm are therefore different to mediatecture applications since they explicitly enable interaction. They use sensor technologies, such as motion tracking or face detection for detecting the presence and activities of people. Applications from this paradigm exploit and enhance available architectural structures or spaces. In this respect, it is different to the paradigm of ubiquitous computing, which includes the augmentation of physical objects.

The field of responsive environments is distinctive since it spans new media art installations. In recent years, many new media artists have been exploring the application of new information and communication technologies in the context of art projects (see [8] for examples). Concepts that emerged from this work, such as social architecture [9], represent an important foundation for information sky applications.

3. Information sky categories

The design framework for information sky applications is grounded on the natural metaphor of the sky and the paradigms described above. The categories of the framework, which we already introduced in the introductory section of the paper, are *contextual information*, *navigation and guidance* and *storytelling*. In this chapter we define these categories and describe how they relate to each other.

3.1. Contextual information

This category is mainly based on the concept of ambient display. We suggest augmenting the ceiling with contextual information that users need to be aware of while focusing on other tasks. The fact that the ceiling is located at the periphery of human perception allows users to maintain a continuous awareness of the information displayed. Similar to ambient display, applications from this category should alert users, exploiting the aforementioned notification levels.

Foundation. The underlying principle for this category is the behavior of looking up for receiving further information in the natural world. The sky constantly provides us with additional contextual and peripheral information, such as the current time and upcoming weather conditions through light conditions, clouds and the relative position of the sun.

Example. An illustrative example for this category is a research project by Meagher et al. [10] that investigates the integration of sensors into the ceiling for measuring environmental conditions, such as humidity or temperature. The goal of this project is to allow space occupants to select their work location based on a ceiling-based representation of environmental conditions.

Data. Any data can be represented that features characteristics defined by the concept of ambient display, such as non-vital, dynamic, context-related, etc. Particularly, the visualization of spatial data denotes a promising application area for ceiling-based representations, since it allows a direct mapping of the physical location onto the ceiling. Examples of spatial data are environmental conditions (see above), sound level and network coverage (e.g. Wi-Fi reception) within a closed space.

3.2. Navigation and guidance

For the second category we suggest the application of the ceiling for navigation and guidance within architectural environments. The advantage of the ceiling as a platform for navigational cues is that it is not already occupied by other kinds of information displays. This also suggests the application of the ceiling for displaying

information in emergency cases, such as indicating dangerous areas and directions towards the closest exit.

Applications within this category provide relevant information about directions or places. They either show general information that changes depending on parameters like the time of the day or user-specific information. The latter presumes that the environment is aware about both the presence and the intentions (i.e. where the person wants to go to) of people passing through that space. There is a broad body of research in context recognition available that addresses these issues.

Foundation. This category exploits the natural behavior of looking up for receiving a sense of orientation. In case the immediate environment is lacking specific clues, people are still able to derive knowledge about directions and their location from looking at the sky, based on the position of the sun or the stars.

Example. A notable example for guidance within a building is OMA's design concept for the Seattle library. Their original concept featured real-time navigational cues on the floor, exploiting the spatial nature of a library to support visitors in their orientation [11].

Data. Any data that helps people orient themselves within an architectural space falls into this category. This can be either a visualization that points the user towards a certain direction (e.g. a sign) or a representation that maps spatial information (e.g. the location of a specific spot within a large room) onto the ceiling.

3.3. Storytelling

Storytelling makes an important part in the life of humans. While the importance of physical objects for storytelling has been acknowledged [12], there is also scientific evidence that digital artifacts possess similar potential [13]. Based on this research, we suggest exploiting the architectural ceiling as a platform for displaying digital information that evokes storytelling. The narrative aspect can further arise from the information itself, informing people about historical events or conversations that happened in that space. Due to the spatial location of the ceiling, applications from this category should not aim at involving users in long interactions that require constant awareness. In an initial study we found that interacting with a ceiling-based representation over a long period tends to be tedious and should be limited to five tasks in a row [4]. Applications should therefore take advantage of the peripheral character of the ceiling and engage users in short dialogues.

Foundation. We base the category of storytelling on the observation that throughout human history people used the space above them (both the sky and the ceiling) as a framework for storytelling, e.g.: Native American tales were often based on the stars. Ceiling paintings typically featured a story, but also inspired people to tell stories to each other about historical events and personal experiences.

Example. Similar to ceiling frescoes from the Renaissance time, the ceiling could be exploited for visualizing the arrival and history of e-mails and e-mail conversations, based on the metaphor of storytelling (compare [13]).

Data. Most time-varying data can be used for creating stories. Examples are ambient data (e.g. noise level or amount of movement), remote data (e.g. presence patterns of distant people) and digital/virtual data (e.g. e-mail conversations).

3.4. Discussion

The categories presented above suggest a classification scheme for information sky, but at the same time also serve as potential application areas. The first two categories, *contextual information* and *navigation and guidance*, describe application scenarios of very practical nature: they add to the quality of the architectural space by augmenting it with context- or user-related digital information and can potentially improve the problem of visual "noise" overload by porting information into the periphery of human perception. The most promising category is *contextual information*, which suggests that most applications will fall into this category. Applications within the third category, *storytelling*, primarily aim at creating an ambience, similar to Renaissance ceiling frescoes, but based on dynamic visualizations and enhancing social interactions between passers-by.

In the following chapter we discuss four application scenarios that we developed based on the notion of information sky to gain further insights into the categories and their value for application designers. We briefly describe the prototypes and discuss how they relate to the proposed design framework.

4. Applications

4.1. The weather ceiling display

The weather ceiling display [4] conveys information about the short-term weather forecast as an ambient display projected onto the ceiling. The concept is based on the behavior of looking up in the natural world for receiving information about the upcoming weather. The weather data is visualized in an abstract and iconic way. Temperature is represented as color and weather conditions are embodied as symbols. A blue ceiling anticipates a cold day, while a yellowish color promises a warm day. Animated water ripples or snowflakes floating over the ceiling inform the user about rain or snowfall respectively.

The application was prototyped using a projector pointed towards the ceiling in one of the offices at our research group (Figure 3, left). The metaphor of the sky applied to an indoor ceiling for visualizing weather data was well understood by people passing by. However, the animated symbols turned out to be too distracting for people working in the office room. Further evaluation is required to determine the application's usefulness and impact in its foreseen context, which would be a hallway.

Figure 3. The peripheral weather application showing cold temperature and rainfall (left) and the sound-responsive ceiling display visually reflecting the sound level inside a space (right)

The weather ceiling display represents an example for the category of *contextual information*. It augments the context of a hallway or any other space where people pass through before leaving a building with information about the short-term weather forecast at the current location. The information is displayed at the periphery of human perception and does not require any user interaction.

4.2. Sound-responsive ceiling

The sound-responsive ceiling display consists of an array of 12 micro-units that cover the ceiling of a room. The system visualizes the current distribution of the room's sound level in real-time through the changing of ambient light patterns (Figure 3, right). Each unit is equipped with a microphone that features a directional characteristic (i.e. it reacts more sensitive to sounds received directly beneath the microphone) and an LED. The units are networked to each other, and each unit puts the measured value representing the sound level on the network, which allows adapting the light intensity of each LED to the overall sound inside the room.

The application is still work in progress and we are currently developing a second revised generation of micro-units. As an application scenario we foresee the installation of the ceiling display in a café or bar. This would allow visitors to choose their table based on the current distribution of the sound level within the space by simply glancing at the ceiling.

The sound-responsive ceiling provides additional information within a space in terms of representing the spatial mapping of acoustic data onto the ceiling. It therefore represents an example for the category of *contextual information*.

4.3. A sound-aware ceiling display for the deaf

This prototype addresses the issue that deaf people have difficulty in keeping track of ambient sounds [14]. Examples for ambient sounds are children playing in the next room, a fire alarm, or the knocking on a door. These sounds constantly provide us with important clues about our immediate environment – information that is often lost for deaf people.

To explore the ceiling for representing spatial ambient sound information, we followed a user-centered design process, involving expert interviews, questionnaires and a design workshop with 10 deaf and hearing-impaired participants [15]. This work led to a design prototype, consisting of two separate systems. One of the systems represents a ceiling display that shows the spatial location of ambient sounds by projecting ripples onto the ceiling. The color of the ripples is mapped to the pitch and the number of ripples is based on the volume. In the design workshop the deaf and hearing-impaired participants from our study appreciated and understood well the idea of locating sounds inside a room through the visual representation on the ceiling. They also suggested the application of this system in public environments, like shopping malls, hospitals and subway stations. However, they preferred having a traditional screen for receiving further information about sounds (e.g. identification) inside their flat.

Depending on the actual scenario, mapping acoustic data onto the ceiling provides either *contextual information* (e.g. the sound of a household device in operation) or *navigation and guidance* (e.g. the knocking on a door).

4.4. Ceiling-based long-distance communication

In this project we investigated the application of the ceiling as an ambient display to provide remote awareness about distant loved-ones, through various means, such as motion, noise level, etc. The project was inspired by recent research that investigated the potential of ubiquitous computing technologies to improve intimate long-distance communication [16]. The goal was to create an environment that enhances traditional explicit communication (such as a phone call) with implicit means of communication. While explicit communication requires people to have a reason for contacting someone [16], concepts based on implicit communication aim at providing a continuous awareness about the partner's (remote) presence and/or his/her emotional state.

We conducted qualitative interviews with six participants that lived in a long-distance relationship at the time the interviews were completed. Findings from the interviews were reported in [17].

One of the application scenarios that received a high rating from the qualitative interviews allowed users to create patterns on the ceiling (Figure 4). Throwing a ball at a pixel changes its color, thus enabling entertaining interaction over a distance. This particular application engages distant people in an abstract communication, allowing them to express their (emotional) state. Created patterns would fade out over time, providing a trace of past events and "conversations". Thus, this application corresponds to the category of *storytelling*.

The application was implemented as a wizard of oz prototype [4] and we are currently working on an

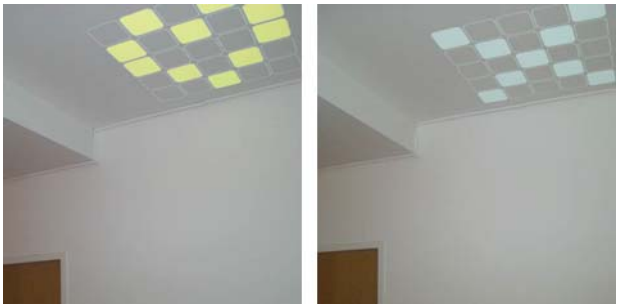

Figure 4. Design prototype for an application that enables users to interact over a distance, painting patterns that eventually create stories over time and usage

interactive version that would allow a longitudinal evaluation of the concept.

5. Conclusions

We introduced the concept of information sky as a design framework for ceiling-based information visualization. The framework is grounded on historical examples of ceiling art as well as recent computing paradigms. Historical examples span different epochs of human history from cave art to the Renaissance period. Based on the discussion of historical and contemporary influences, we identified three categories for information sky: *contextual information*, *navigation and guidance*, and *storytelling*. We also described examples for each category and identified lists of data that can be represented on the digital sky. In the remainder of the paper we presented four application scenarios based on the notion of the digital sky that we developed at our group and discussed how they relate to the presented categories.

The purpose of the framework described in this paper is to point out potential application areas for projects that exploit the ceiling for the visualization of information. It supported us in our research in terms of selecting application scenarios for information sky. It has further proven to be a valuable design tool for reflecting on the data that we wanted to convey in our applications. The definition of information sky as a surface for visualizing information constrains the means of data that can be represented, thus also defining the design space for information sky applications. The framework should therefore help application designers to decide whether the ceiling represents an appropriate surface for the data they want to visualize. We also highlighted specific design considerations in this paper, which we plan to incorporate into a set of design implications in our future work.

References

[1] P. Johnson. *Art: A New History*. Harper Collins, 2003.

[2] N. Streitz, T. Prante, C. Röcker, D. Van Alphen, C. Magerkurth, R. Stenzel, D. and Plewe. Ambient Displays and Mobile Devices For the Creation of Social Architectural Spaces. *Public and Situated Displays*, O'Hara, K. et al. (eds.), Kluwer Academic Pub., 2003.

[3] M. Graves-Petersen, P. Gall Krogh, M. Ludvigsen and A. Lykke-Olesen. Floor interaction HCI reaching new ground. *Extended Abstract on Human factors in computing systems (CHI'05)*, ACM Press, Portland, Oregon, 1717-1720, 2005.

[4] M. Tomitsch and T. Grechenig. Reaching for the Ceiling: Exploring Modes of Interaction. In *Adjunct Proceedings of the International Conference on Ubiquitous Computing (Ubicomp'07)*, 2007.

[5] J. Mankoff, A. Dey, G. Heish, J. Kientz, S. Lederer and M. Ames. Heuristic evaluation of ambient displays. In *Proceedings of the International Conference on Human Factors in Computing Systems (CHI'03)*. ACM Press, 169-176, 2003.

[6] T. Matthews, A. Dey, J. Mankoff, S. Carter and T. Rattenbury. A toolkit for managing user attention in peripheral displays. In *Proceedings of the ACM symposium on User interface software and technology* (UIST'04), ACM Press, 247-256, 2004.

[7] A. Vande Moere. Form follows Data: the Symbiosis between Design and Information Visualization. In *Proceedings of International Conference on Computer-Aided Architectural Design (CAADfutures'05)*. OKK Verlag, Vienna, Austria, 31-40, 2005.

[8] L. Bullivant. Responsive Environments: Architecture, Art and Design, V&A Publications, London, UK, 2006.

[9] L. Bullivant. 4dsocial: Interactive Design Environments. *Architectural Design*, vol 77 (9), Wiley-Academy, London, UK, 2007.

[10] M. Meagher, J. Huang and D. Gerber. Revisiting the Open Plan: Ceilings and Furniture as Display Surfaces for Building Information. In *Proceedings of International Conference Information Visualization (IV'07)*. IEEE, 601-606, 2007.

[11] OMA/LMN. *Seattle Public Library*. Actar, 2005.

[12] S. Whittaker. Things to talk about when talking about things. *Human-Comp. Interact.*, 18 (1-2), 149-170, 2003.

[13] F.B. Viegas, D. Boyd, D.H. Nguyen, J. Potter, J. Donath. Digital artifacts for remembering and storytelling: posthistory and social network fragments. *Proceedings of the Annual Hawaii International Conference on System Sciences*, IEEE, 1-10, 2004.

[14] T. Matthews, J. Fong and J. Mankoff. Visualizing non-speech sounds for the deaf. In *Proceedings of the International ACM SIGACCESS Conference on Computers and Accessibility (ASSETS'05)*, ACM Press, 52-59, 2005.

[15] M. Tomitsch and T. Grechenig. Design Implications for a Ubiquitous Ambient Sound Display for the Deaf. In *Proceedings of the Conference & Workshop on Assistive Technologies for People with Vision & Hearing Impairments* (CVHI'07), 2007.

[16] R. Etter, C. Röcker and D. Gilgen. Supporting emotional communication between multiple users in intelligent home environments. In *Proceedings of the International Conference on Interactive Environments (IE'06)*. IET, 41–50, 2006.

[17] M. Tomitsch, T. Grechenig and S. Mayrhofer. Mobility and Emotional Distance: Exploring the Ceiling as an Ambient Display to Provide Remote Awareness. In *Proceedings of the International Conference on Interactive Environments (IE'07)*. IET, 164-167, 2007.