ABSTRACT

With the recent emergence of a wide range of information displays that reach beyond the traditional graphics-based computer screen, it seems that the original definition of ambient display, and its focus on user attention and aesthetics, has become diluted. Instead, we propose a taxonomy alternative information displays that is based on context, in terms of the data it represents and the environment it is located in. The resulting model described three different categories: visualization as Translation, visualization as augmentation and visualization as embodiment. This model aims support visualization designers and developers in considering the correct visualization as well as display medium. [Article copies are available for purchase from InfoSci-on-Demand.com]

Keywords: 7 or less.

INTRODUCTION

Since its conception about 15 years ago, most discussions in the field of information visualization have focused on the graphical representation of data on screen-based output media. The use of traditional screens (including light projections) for the purpose of presenting information graphically possesses several obvious qualities, including: 1) its dynamic frame-rate to update the displayed content quickly and frequently, 2) its huge, detailed display resolution to convey a large amount of visual objects simultaneously, and 3) its capability to “immerse” people within the presentation, in particular for applications that require user interaction. Due to evolving character of modern technology, the very nature of digital screens is in constant flux. A wide spectrum exists between the ultra-bright LED screens as large (and strangely proportional) as skyscrapers, and e-paper displays
as thin, light and flexible as real paper. For all the obvious qualities such displays enjoy, they still generally require dedicated flat surfaces, brightly illuminate their surrounding environments, are less perceivable in daylight, tend to obtrude everyday tasks by grabbing visual attention, and often remind users of advertising and work-related tools rather than an informational medium that encourages contemplation, analysis or reflection of the content being shown.

Therefore, the question can be asked whether displays, and in particular those displays located in public or environmental contexts, should mimic the inherent discrete nature of computing by utilizing pixel-based graphics. Instead, we propose that such displays should be inspired by how our everyday physical environment is able to communicate meaning and functionality by natural and easily understood affordances. By considering what exists “beyond the screen”, novel display techniques might emerge that are less disruptive, but more enjoyable, in conveying information in meaningful and effective ways. Naturally, an inherent trade-off exists between the communication bandwidth and the obscurity of the physical embodiment (in the sense of the giving a material shape) of information. However, we claim that what a non-graphic pixel-less display might lose in information resolution, it could make up in a richer, more intriguing and memorable experience that nonetheless is able to communicate insight and contemplation.

The concept of displaying information in alternative, non-screen based ways is not new. In particular, the field of ambient display (sometimes also labeled as peripheral display (Matthews, Dey, Mankoff, Carter, & Rattenbury, 2004), ambient visualization (Skog, Ljungblad, & Holmquist, 2003), informative art (Redström, Skog, & Hallnäs, 2000), (Skog et al., 2003), ambient awareness device (Brewer, Williams, & Dourish, 2005) or ambient information system (Pousman & Stasko, 2006)) has focused on representations that primarily target the periphery of human awareness. However, with the recent emergence of a wide spectrum of alternative information displays, as overwhelming as architectural facades (ChaosComputerClub, 2001), and as subtle as electronic jewelry (Fajardo & Vande Moere, 2008), it seems that the original definition of ambient display has become diluted, in spite of various existing models (Pousman & Stasko, 2006), (Tomitsch, Kappel, Lehner, & Grechenig, 2007) and heuristic evaluations (Mankoff et al., 2003). This article therefore reaches beyond the concept proposed by ambient display and its main focus on functionality, user attention and aesthetics, by presenting a concise taxonomy of alternative information displays that is instead based on context. It merges and builds upon previous models on Physical Data Visualization (Vande Moere, 2008) and the Invisible Display (Offenhuber, 2008), in capturing the essence that drives most, if not all, approaches towards conveying information beyond the traditional screen.

THE DEFINITION OF CONTEXT

In academic literature, the discussion of ambient displays is mainly limited to their intrinsic qualities. Displays are regarded as solitary objects - only the relationship between observer and display is taken into account. Yet, the relationship between a display and its context is equally important for the experience, especially when the display is seamlessly embedded into the public, architectural environment. In the
scope of this article, we approach the notion of context from a data oriented (i.e. internal context) and an environmentally oriented (i.e. external context) point of view.

The internal context emerges from the relationship between the data and its representation. This relationship involves 1) the denotations - the literal meaning of the data, its quantities and patterns; 2) connotations or suggestive meanings evoked by the design of the display, its aesthetic or persuasive qualities, and 3) interactions with external sources of information. For example, the interpretation of presented information might change, if other displays with conflicting messages are placed next to it.

In turn, the external context refers to the environmental setting of a display – its social, physical, and informational background. Existing cultural codes of representation, as well as the social inscriptions of a place, time or situation form the social context of the display. Environmental influences, such as light situation or ambient noise, as well as the display’s architectural setting and visibility are examples of the physical context. Information and messages presented in the display’s vicinity make up the informational context (i.e. whether a display is placed in the solitude of a country road or in a highly information-saturated environment).

Internal and external context form the background of our proposed taxonomy. We classify alternative visualization displays based on their relationship with the data they represent, as well as their apparent relationship to their environment. One should note, however, that the term “context”, remains undefined. While several aspects have been described above, its conclusive assessment is not possible a priori. Context is not to be understood as a stable representation of a setting, but rather, as Paul Dourish puts it, it is actively constructed as “an emergent feature of the interaction, determined in the moment and in the doing” (Dourish, 2004).

**ALTERNATIVE DISPLAY MODEL**

In this section, we present three different categories of alternative displays, based on the context of how the information is represented: through translation, augmentation or embodiment. These are not meant to be exclusive, and examples of overlapping exist.

**Visualization as Translation** – The display without context. Many information displays exist that have no contextual relationship with the data that is shown, and whether a display is placed in the solitude of a country road or in a highly information-saturated environment. Internal and external context form the background of our proposed taxonomy. We classify alternative visualization displays based on their relationship with the data they represent, as well as their apparent relationship to their environment. One should note, however, that the term “context”, remains undefined. While several aspects have been described above, its conclusive assessment is not possible a priori. Context is not to be understood as a stable representation of a setting, but rather, as Paul Dourish puts it, it is actively constructed as “an emergent feature of the interaction, determined in the moment and in the doing” (Dourish, 2004).

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**Figure 1. From left to right: Ambient Orb (Ambient Devices), Domestic Shoe Production 1960-1998 (J. Salavon), Heatsink (Arroyo et al.), Nuage Vert (HeHe), PingPongPixel (J. Breejen, M. Deenstra), Of all the people in all the world (Stan’s Cafe).**
where it is shown and whom it is shown to. Most traditional information visualization approaches, for instance, are inherently context-less, due to their drive towards evaluating and optimizing effectiveness and efficiency considerations. For such applications, data sets are treated objectively, neutral and emotionless. The focus is on how to best represent the patterns “within” the data, regardless of what the data stands for. Accordingly, an identical bar graph technique can be used for depicting food ingredients as well as to denote the catastrophic effects of climate change. Most traditional ambient displays also exist in this realm. While aesthetically fully adapted to dissolve within their physical environment, there is generally no relationship between the representation and the data, or its meaning. Accordingly, the Mondrian style used in the informative art project (Skog et al., 2003) has the ability to represent a bus time table, as well as the weather around the world. The colors of the Ambient Orb (Ambient Devices, 2002) might equally reflect the stock market, sailing conditions or football match scores. Here, context is purposively ignored to obscure the fact that the display is a visualization, what is visualizes or how it visualizes the data (Holmquist, 2004). Accordingly, information and display dissolve their relationship and thus exist independently, in that even without knowing that the display in fact is a visualization, users still enjoy its existence in different context, such as artistic or architectural.

The display becomes a direct translation of the data into an abstract language, which must be “learned”, often over a relatively long period of time, in order to be understood. The connection between the information (and its meaning), and its representation on the display is relatively arbitrary. However, translated techniques retain their intrinsic meaning, even without the displayed information: the Mondrian painting can be enjoyed as piece of computer art, while the ambient orb remains a calm, beautiful light object. However, the potential realm of what data can be translated into is infinite, as any known human stimulus can ultimately be driven by some sort of real-time or historical data source. Accordingly, some “data art” designers and artists have explored the boundaries of our visual sense (e.g. Jason Salavon’s “Shoes, Domestic Production 1960-1998 (Salavon, 2008)), as well as the possibilities of alternative sensorial modalities, such as sound, touch, smell, or taste, to represent information (Vande Moere, 2008). Due to the immense realm of opportunities, this field is still in an explorative state, even while there might exist the more functional goal to use alternatively sensorial channels to free and augment our visual sense for parallel activities.

Visualization as Augmentation – The display within context. Other forms of alternative information displays are specifically designed within the functionality of a specific physical context, making use of the physical affordances provided by the physical object they are directly embedded within. A tension exist between the object, which exists independently from the display, and its secondary use as a display: both object and display are perceived as one as the natural affordances provide sufficient cues to steer and focus the process of understanding the displayed content. However, the display requires both the existence and functionality of the object to exist; by separating display and object, the display looses its meaning. From color-coded water streams (Arroyo, Bonanni, & Selker, 2005) to data-driven illuminated clouds
(HeHe, 2008), such information augmented objects might have the particular quality to be more “ambient” and “peripheral” than many existing displays that claim to fall within the traditional definition of ambient visualization, due to the tight coupling between information and the environment, so that the display becomes less obtrusive and more intuitively understandable.

Another field in this category, so-called wearable visualizations, are based on representing information within the context of a person “wearing” the display. Wearable visualizations are thus “performed” by a wearer, and the fact that it is perceived as being worn provides the meaning to the display. Similar to the difference whether a slogan is printed in a book or on a T-shirt, wearable data-driven electronic fashion pieces receive meaning through the relationship to the person wearing it, as well as through the situation in which it is worn (Fajardo & Vande Moere, 2008).

Due to its unique characteristics, visualization augmentation has a huge potential to accomplish the vision of the ubiquitous computer (Weiser, 1991) as well as that of the original ambient display (Wisneski et al., 1998). However, its development is mainly hampered by the constraints to represent information within the physical affordances of everyday objects.

Visualization as Embodiment – The display is context. Some information displays fully determine the contextual systems by their own existence. For instance, pixel sculptures, physical installations that utilize matrices of small, repeated objects to simulate text and objects, draw their aesthetic effect from the complexity and sophistication involved in materializing, and dynamically transforming, physical pixels. Although all pixel sculptures communicate specific content, very few go beyond addressing the physical medium of the display itself: often, the display medium overwhelms the meaning of the content, and in fact, the message “is the medium”. The “pixel material”, ranging from ping-pong balls (Breejen & Deenstra, 2007) to well synchronized water drops (Rayner, 2007), is rarely chosen in accordance to a contextually relevant factor, and these sorts of displays are driven by factors of originality (to be the first in implementing a specific sort of display) or effects (overwhelming users with the technical or visual quality of the display). However, even with a disconnection between information and medium, it is unlike the translation category. The display cannot exist without the information: a pixel sculpture’s “raison d’être” is representing information, and without information, the pixel sculpture becomes a collection of dynamic items without unity or meaning. More outspokenly, the emerging field of data sculptures addresses the materialization of information into three-dimensional form. Such sculptures often play with the distance between sign (the information) and object (the materialization of the information) in that their metaphorical distance plays an important role in how the information is interpreted. The representation of people as grains of rice (Stan’s_Cafe, 2008) forms such as an example: the sheer magnitude of rice grains might well impress the audience, but only because the mountains of rice have a small, informational label to denote their meaning.

Overlapping categories. The boundaries between the categories of translation and embodiment are fluid. While in the first category the emphasis is set on the representational language, it is the materiality of the display’s components that make up the second category. However, some ex-
amples combine both aspects. For instance, a single Ambient Orb (Ambient_Devices, 2002) highlights the translation of data into color, while a matrix of nine Ambient Orbs driven by an appropriate data-set shifts the emphasis to its materiality as a pixel sculpture. Yet, even in this borderline case, the experience is determined by display’s relationship to its context. While one orb shows no such relationship, the spatial arrangement of many orbs establishes a network of relationships between its components, thus creates its own context. Table 1 further exemplifies the distinctions between the three categories. It differentiates between: 1) Shape, the correspondence between the physical manifestation of the display and the information it conveys (e.g. does the shape still make sense without the information represented?); 2) Functionality, the question whether the display fulfills other purposes (i.e. artistic or utilitarian) without its secondary function of conveying information; and 3) Environment, the connection between the display and its environment (e.g. does the display change its meaning significantly in a different physical environment?).

**CONCLUSION**

In the current age of rapid experimentation by artists, designers and developers, information visualization is increasingly moving towards becoming a medium in

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**Table 1. Alternative information display model**

<table>
<thead>
<tr>
<th>CATEGORY</th>
<th>Mapping</th>
<th>Augmentation</th>
<th>Embodiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design fields.</td>
<td>Ambient Display</td>
<td>Object Augmentation</td>
<td>Data Sculpture</td>
</tr>
<tr>
<td></td>
<td>Alternative Modality</td>
<td>Wearable Visualization</td>
<td>Pixel Sculpture</td>
</tr>
<tr>
<td>Shape. Display’s shape dependent from information?</td>
<td>No.</td>
<td>No.</td>
<td>Yes.</td>
</tr>
<tr>
<td>Functionality. Display functionality dependent from information?</td>
<td>Yes.</td>
<td>Yes.</td>
<td>No.</td>
</tr>
<tr>
<td>Negative Issues.</td>
<td>Learning information mapping rules required.</td>
<td>Limited possibilities of physical affordances.</td>
<td>Complexity of display. Medium is more important than message.</td>
</tr>
<tr>
<td>Potential Applications Focus.</td>
<td>Traditional information visualization. Focus on patterns within data.</td>
<td>Focus on functionality of information augmented object. Data must be conceptual connected to object.</td>
<td>Focus on communication medium. Reinterpretation of data.</td>
</tr>
</tbody>
</table>
its own right. Accordingly, the traditional definition of ambient display, with its main focus on cognitive issues like peripherality and aesthetic value, seems to have become insufficient to capture the current developments towards more explorative ways of representing information. By focusing on three different contextual approaches by which the information is represented, we present a concise model that aims to capture the main research directions, and to inform the design decisions of future display developers.

REFERENCES

Stan’s Cafe. (2008). Of all the people in all the world.


Andrew Vande Moere is a senior lecturer in design computing at the Design Lab of the Faculty of Architecture, Design and Planning of the University of Sydney. He studied architectural engineering at K.U.Leuven, Belgium, and received his PhD from ETH-Zurich, Switzerland. His research interests include data visualization and visual design, from traditional screen-based media to more explorative and innovative applications ranging from electronic fashion to media architecture. His teaching comprises interaction design, physical/wearable computing and 3D real-time multimedia. Andrew is also the sole author of a weblog called “information aesthetics,” a daily updated online repository collecting intriguing and creative forms of information representation.

Dietmar Offenhuber studied architecture at TU Vienna and Media Art and Sciences at the MIT Media Lab. From 1995-2004 Offenhuber worked at the Ars Electronica Futurelab as a designer, exhibition developer and curator, most recently as key researcher for interactive spaces. In 2004, Offenhuber was a Japan Foundation Fellow at the IAMAS institute in Gifu, Japan, followed by a professorship at the University of Applied Sciences in Hagenberg. From 2006 to 2008 he worked as research assistant at the MIT Media Lab. Since 2008 he is professor at the Art University Linz and key researcher for information visualization at the Ludwig Boltzmann Institute for Media Art Research.