

# A Matter of Taste

Alois Ferscha

Institut für Pervasive Computing  
Johannes Kepler Universität Linz  
Altenberger Strasse 69, 4040 Linz, Austria  
ferscha@soft.uni-linz.ac.at

**Abstract.** Ambient information systems, often referred to as ambient displays, peripheral displays or informative art systems (IAS), aim at providing users with information considered relevant at arbitrary points of work or living engagement, in easy and quickly to convey, aesthetic and artful style. Adhering principles of visual perception, visualization and design, information coming from various different (hardware and software) sensors is aggregated through abstraction and selective omission, and displayed at the periphery of a user's attention. A broad range of visual metaphors ranging from the fine arts, abstract art, naive art, comic drawings up to photographic images or technical drawings have been proposed, but all grounded on the “I-throw-it-out-there-and-watch” design paradigm<sup>1</sup>, totally excluding the user, his background knowledge and his aesthetic appreciation from the design process. This paper advocates for a user-oriented, participatory design process for IASs. Addressing canvas style IASs, i.e. displays that decorate apartments, offices, foyers and the like in the first (but not the only) place, in our approach the choice of the IAS canvas *theme* is left to the user. To steer the (design) process of identifying *symbols* within a chosen theme we have developed categories of metaphors like *color*, *space*, *shape*, *abstraction*, *scale* and *dimension*, and discuss their potential with respect to pre-attentive and interpretative cognition. From experiments with users we find, that the choice of themes and the identification of metaphoric symbols are considered as a means of personal emotional expression (or in other words, as “*a matter of taste*”). Aesthetic attractiveness turns out to be a dominant factor of IAS appreciation. A general purpose software framework for IASs is presented, implementing sensor data acquisition, context recognition, aggregation and filtering, as well as 2D/3D graphics engine, dynamically controlling the visual appearance of themes and symbols.

**Keywords:** pervasive computing, ambient information systems, peripheral displays, informative art, ambient intelligence, intelligent user interfaces.

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<sup>1</sup> The term was created and used by Gregory D. Abowd in his PERVASIVE 2007 Tutorial “Evaluation of Real Deployments in Ubicomp”, in J. Krumm, . Pfeifer (Eds.): Pervasive Computing Tutorials 2007, Fifth International Conference, Pervasive 2007, Toronto, Canada, multicon verlag 2007.

## 1 Informative Art

In an age in which computers are everywhere and nowhere, where tiny computing devices are continuing to pervade into everyday objects, users presumably do, and increasingly will not notice them anymore as separate entities. Appliances, tools, clothing, accessories, furniture, rooms, machinery, cars, buildings, roads, cities, even whole agricultural landscapes increasingly embody miniaturized and wireless, thus invisible information and communication systems. Information technology rich systems and spaces are being created, radically changing the style of how we perceive, create, think, interact, behave and socialize as human beings, but also how we learn, work, cultivate, live, cure, age as individuals or in societal settings. A major issue in such technology rich settings is how we perceive information, how we interact with digital media, how we manage to sustain attentive to information of interest, how we stay aware of the dynamics and changes of information, or how we manage perceptual complexity and information overload.

With all the technological options that fertilize and accelerate the pervasive and ubiquitous computing field of research, we are taught to maintain a certain skeptical view on things and scenarios that are “technologically possible” [30] (see also footnote 1) – and are challenged to remain grounded in the real world, encouraged to propose systems that augment the real world, that facilitate human interactions – that are “socially acceptable”. Designing and building pervasive computing systems and applications has become more an “artistic challenge”, rather than an “engineering task”, as addressed in [4], relating the aim of the “Gesamtkunstwerk” of the “Vienna Moderne” (1895-1930) (*The aim for the “Gesamtkunstwerk” (the “total artwork”) lead to the unification of art and the re-evaluation of the role of craftsman and designers. The understanding of an artist dedicated to the Gesamtkunstwerk was “to impress beauty upon every aspect of our lives, that the artist should no longer simply paint pictures, but rather create whole rooms, or even whole dwellings, with wallpapers and furniture as well as paintings”.*) to the aim of a hypothetical “Gesamtcomputer”, reinterpreting Weiser’s Vision as follows: *“The understanding of a computer scientist dedicated to the ”Gesamtcomputer” is to impress computing upon every aspect of our lives, that the computer scientist should no longer simply build personal computers, but rather create whole rooms, or even whole dwellings, with wallpapers and furniture as well as personal computers.”*

In an attempt of relating the understanding of science and the understanding of art, [31] postulates scientists to see only the “*observed in the material world*”, while the artist sees the “*spiritual*”: *“While the scientist describes and predicts, the artist distills and presents. Interpreting science [...] means balancing the desire of scientists to spew data with the artistic urge to create a transcendent experience.”* In quintessence, “Informative Art” is art with electronics, with content and presentation being primary, while technology, form and function is fused and secondary. Following Buckminster Fuller’s belief, that as technology advances, art begins to resemble science [30], this paper addresses the process of “creating an experience” from “data spews” by means of artful display installations, often referred to as informative art or ambient displays.

This work is organized as follows. We first (Section 2) identify the focus of this paper as being concerned with ambient information systems of visual type only (visual displays). We give an indication in which areas of application such systems have been developed so far, and discuss how this was done. We assess the design process for IAS system based on user studies (Section 3), and identify shortcomings and misconceptions. For systems dealing with visual art as information displays (informative art systems, IASs) we propose a user centered, participatory design process, in which the choice of the visual “theme” of an IAS is left to the user. To steer the (design) process of identifying symbols within a chosen theme we present categories of metaphors, and discuss their potential with respect to pre-attentive and interpretative cognition. We have developed a versatile IAS architecture and have implemented a corresponding software framework in order to display 2D/3D IAS theme dynamics in arbitrary canvas like settings. Finally, findings are discussed (Section 4).

## 2 Visual Informative Art

### 2.2 Ambient Displays: Creating Experience from Data

A variety of definitions for ambient information systems have been proposed in the literature, using slightly different characterizations [28]. Their common core is the aim to deliver information through visuals that are quickly and easily perceived while doing other tasks [19]. As an example, ambient displays are understood as “*aesthetically pleasing displays of information which sit on the periphery of a user’s attention. They generally support monitoring of non-critical information*” [16]. Ambient displays have been proposed to provide users with information considered relevant at arbitrary points of work or living engagement, originating from many different – mostly geographically dislocated– sources, and presented at the periphery of human (visual) perception [14]. Monitoring the display should cause minimal distraction from the user’s focus of attention [10] [15]. The display and its delivered experience move to the focus of attention only if desired or appropriate in a certain situation, hence justifying the synonym “peripheral display”. Everyday life examples of peripheral displays are thermometers and barometers in the kitchen window weather station, wall clocks, windsocks at bridges on the highway, etc. The purpose, type, physical appearance, modality of interaction and notification level of ambient information systems is manifold [29]. While physical, touchable, auditory and even olfactory display types have been proposed, justifying the more general term “ambient information systems” [29], we here restrict to displays of visual type and artistic nature.

As of today, we observe a whole landscape of colorful expressions of art connotating information, motivated with different aims, designed according to different principles and exhibiting a variety of different characteristics. Common to all of them is the fact that information dynamics are subtly encoded by modifying the shape, color and appearance details of some elements of the graphical or pictorial artwork, or of its

overall impression. The application domains are ample: ambient information systems have been designed to support for group awareness in work groups in virtual [6] [7] [9] or in physical [23] [26] [27] [28] space settings, for knowledge dissemination in enterprises [19], for users of instant messaging systems [2][3], for deaf users [11], to keep in touch with family members [22], or to display a cities health information in public places [1] – to name a few. Metaphorically, abstract art has been proposed to serve as the visualization paradigm for contextual information [24], design principles and guidelines have been developed [13] [16], upon which software frameworks and development toolkits [17] [18] have been built. Evaluation guidelines have been developed [13][16], and assessment studies have been conducted, e.g. relating comprehension of peripheral displays (i.e. how well a user understands and uses such artifacts) to the time span of their use [12].

For a technical discussion of IASs consider the two expressions of physical and visual ambient displays in Fig. 1. While an USB-memory stick growing and shrinking according to the degree of “loadedness” is designed as an information displaying physical artifact (Fig. 1, *left*), the figural informative art installation (Fig. 1, *right*) is designed to rely on a (computer) screen for output. While the former is a design that augments a real world physical object, the latter one abstracts from a physical representation and assumes a 2D graphical representation.



**Fig. 1.** A physical object (memory stick) designed for the purpose of being an ambient display – it intuitively displays the amount of used storage by the shrinking and growing size of the object (Flashbag: <http://www.plusminus.ru/flashbag.html>, left). The People Garden [33] figural Informative Art design shows user activities in terms of message densities from posting onto a message board (*right*).

*Representation*, i.e. the distinction of having a physical (or tangible) object or a 2D visualization is just one design dimension, among the many discussed in the literature [15] [29]. Further design dimensions are the number of *information sources*, *level of abstraction*, *transition*, *notification level*, *intrusiveness*, *modality* of use, degree of *interactivity*, *location*, and *aesthetics* – which we briefly discuss along the People-Garden IAS: PeopleGarden proposes a flower and garden metaphor to visualize participation of members of a web community on a message board [33] (*information source*). Community members posting to the message board are abstracted as flowers,

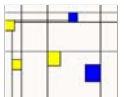
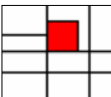
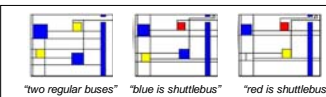


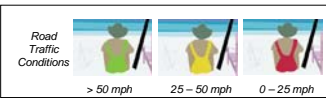
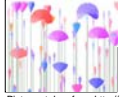




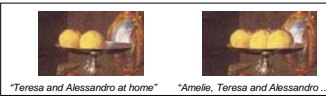


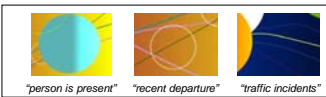





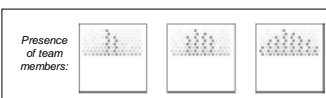

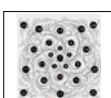

with the height of the stem indicating the time span of their contribution history. Petals abstract the number of posts, with blue petals indicating posts, and red petals indicating replies (*low level of abstraction*, i.e. the source data is displayed with little modification). A single message board is abstracted by a whole garden of flowers, with an inherent legibility of the meadow metaphor delivering an “at-a-glance” impression of the board activity: active boards appear as a flower rich, luscious bloom flower garden, while a fading group with just a few participants occasionally checking the board appears “as a neglected garden, with a scattering of tall, scraggly plants that are mostly stem and little flower” [15] (*high level of abstraction*, i.e. the source data is displayed in a collective aggregate of the individual participant activities). On both levels of abstraction (contributor and board), the “at-a-glance” impression delivers an intuitive understanding of the underlying situation, resembling the evocative character of the flower metaphors. The visual encoding of posting patterns to flower growth and shape is based on a direct mapping of the data as it evolves, thus conveying a *slow transition* in the visual appearance within the display. Fast *transition* as a design option would allow to express fast switches in the level of attentiveness of the user. The *notification level* of an IAS is the indication of the degree at which a system alerts the user, and maybe enforces actions to be taken in the indicated situation. *Notification level* metrics like *ignore*, *change blind*, *make aware*, *interrupt* and *demand attention* have been proposed in the literature [16] [17] [18]. The *modality* of PeopleGarden is one of pure visual perception. IASs however are not limited to visual designs, but could as well involve *auditory*, *tactile*, *olfactory* or *degustation* elements. The degree of *interactivity* is reduced to a one way communication in PeopleGarden, and the *location* where one would typically deploy and operate a display like this is the *private* desktop. IASs have been designed for *public* installations as well.

## 2.2 Design Dimension Aesthetics

The design dimension of *aesthetics* is one that is claimed important by almost all contributions to informative art designs [29], but is presumably the least understood [6] [8]. Again, to explain it with an example, the aesthetics of PeopleGarden are borrowed from naïve art (*primitivism*), which is a style characterized by simplicity and the lack of formal qualities of painting (like unrefined color, perspective, etc.), resulting in charmingly awkward artwork. The design finds the good balance between simplicity of the visual elements and their descriptive power (stem and bloom of flowers), and copes well with the problem of semantic overloading of the symbolic representation (it uses just one visualization concept and thus avoids ambiguities in interpretation : “*If a visualization evokes meaning beyond the direct mapping of the data, there needs to be information in that data that guides the choice and shape of the visualization. If there is no such guiding information, then the evocative quality of the visualization is likely to be misleading and inappropriate*“ [15]). Beyond some appropriateness of the visualization concepts, the design dimension of aesthetics is not addressed.

In almost all the systems proposed in the literature (see Fig. 2) we find that aesthetics follow the “I-throw-it-out-there-and-watch” design paradigm, totally excluding the

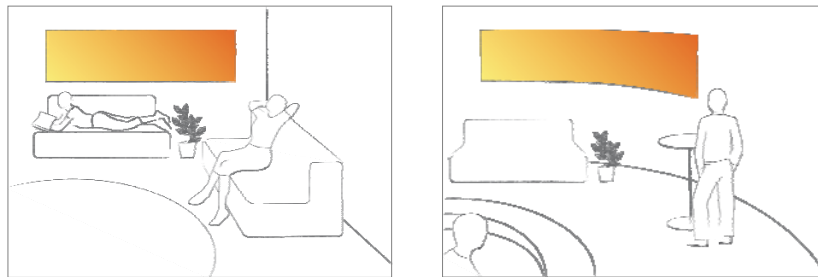
user and his personal appreciation of beauty from the design process. This is even true for the Kandinsky systems [8], the first contribution postulating that an ambient display has to be aesthetically interesting in the first place, and convey information in the second place (here an artist specifies the aesthetic template of a collage, which then is used to present photographic images). So far, we have to conclude, are there no general rules steering the process of finding themes and display elements for IASs, and hypothesize, that they are highly dependent to the individual aesthetical appreciation of a user. Observing that the theme of wallpaper, a poster or a painting decorating the living environment of a person is an expression of personal taste, we advocate for a user-oriented, participatory design process, and propose to leave the choice of visual metaphors and the overall visual appearance of the display with the user.

	Theme	Symbol	Connotation
Mondrian Informative Art [23]			 <p>"two regular buses" "blue is shuttlebus" "red is shuttlebus"</p>
Info Canvas [27]			 <p>Road Traffic Conditions            &gt; 50 mph 25 – 50 mph 0 – 25 mph</p>
People Garden [32]			 <p>"group with a dominating voice" "democratic group"</p>
Aesthetic Awareness Display [6]			 <p>"Teresa and Alessandro at home" "Amelio, Teresa and Alessandro .."</p>
AuraOrb [24]			 <p>"person is present" "recent departure" "traffic incidents"</p>
Coursework Indicator			 <p>"semester has started" "semester has finished"</p>
Hello.Wall [27]			 <p>Presence of team members:</p>
Weather Patterns			 <p>Growth patterns based on the golden ratio: Atmospheric Conditions</p>

**Fig. 2.** Aesthetics in previous work structured according to *Themes, Symbols and Connotations*.

### 2.3 Appreciation of Informative Art Aesthetics

To investigate whether and to which extent IAS themes underly an individual appreciation of visual design we conducted an empirical study aiming at the isolation of personal preferences with respect to (i) *visual appearance*, (like e.g. color, form, shape, etc.), (ii) *concreteness* and (iii) *harmonic embedding* into everyday environments (see Fig. 3). Taking the goal of designing a canvas like IAS for a home (Fig. 3, *left*) or office (Fig. 3, *right*) setting, it is important to not only investigate on the aesthetics of what the display shows (visual appearance, indicated by the orange canvas in Fig. 3), but also its physical shape (frame like, rectangular, oval, sculpture like; concreteness), and how it fits into aesthetics of other artifacts in such environments.



**Fig. 3.** Questioning on the desired visual appearance, concreteness and harmonic embedding of IAS into everyday environments. Living room setting (left). Office setting (right).

A set of artifacts typically available in home or office scenarios were selected, representing computing technology (Phone/PDA, Monitor, Printer), media technology (Bigscreen, Touchpad), gadgets (Lightcolumn, ColorBricks, FlowerLamp, Laserpod), appliances (Humidifier, Scent), decorations (Painting, Photos, Poster, Pinboard), “natural” things (Fruits, Plants, Aquarium) and dishware (TeaPot). The choice of artifacts aimed at identifying personal preferences according the three criteria in Fig 3.



**Fig. 4.** Questioning on the desired visual appearance, concreteness and harmonic embedding of IAS into everyday environments. Living room setting (left). Office setting (right).

To this end, a group of  $n=20$ , all students of art, design, computer science and mechanics at an age from 21 to 29, was asked to respond on the aesthetic appreciation of decorative artifacts at the levels (1) “I would never want to have such a thing in my

environment”, (2) “I don’t like it, but I could try to live with”, (3) “I would appreciate to have such thing” and (4) “Wow, this thing is fascinating!”. The group was informed on the principle purpose of the poll, namely to develop a metric for the aesthetic appreciation of IASs – physical or visual – but was not concerned with any particular purpose or connotation of an artifact at display.

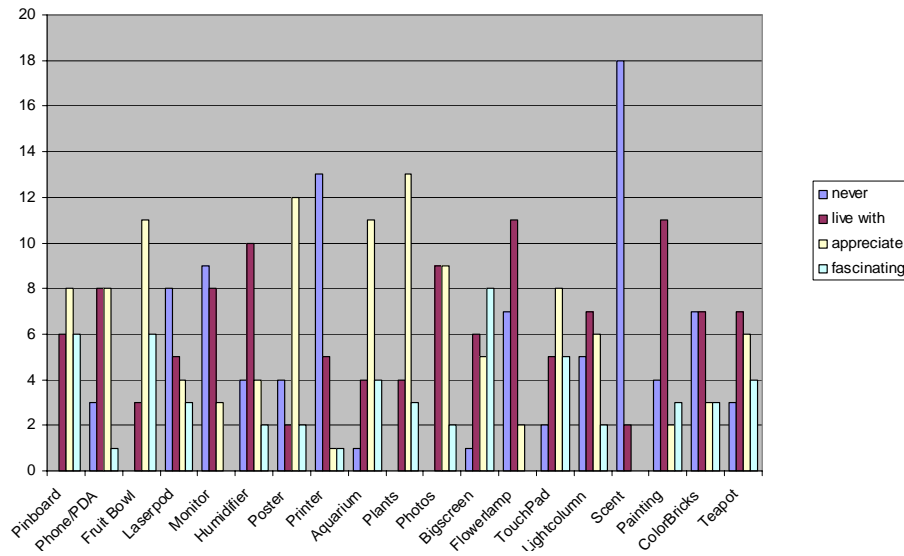


Fig. 5. Samples and Scores of Aesthetic Appreciation of Everyday Artefacts.

The survey (scores in Fig. 5) indicates evidence for the appreciation of artifacts that are not related to (media or computer) technology, like computers, printers or monitors. On the other hand, everyday items exhibiting a certain decorative character like pin boards, fruit bowls, the aquarium or the tea pot found fascination. The variation in the sample was smallest with “living” artifacts like fruits, plants and animals (fish), indicating that people strictly prefer “natural” settings over “technical” ones. In that preference, they cannot even be “fooled” by a “techno-natural” artifact like the FlowerLamp, which is consistently declined. The Bigscreen artifact which seems to contradict the central message from the survey was appreciated for what it displays (a natural landscape expressing the beauty of nature in the mountains), rather than what it is (a media technology artifact).

The findings of this survey lets us hypothesize, that users, based on their cultural background, cognitive skills, situative environment, contextual settings, but most of all their aesthetic appreciation, have dedicated, individual and personal attitudes towards the preferred overall appearance of an IAS. Empirical evidence explicates critical importance to the design dimension of aesthetics, and suggests to respect the individual aesthetic sense of users at highest priority throughout the whole IAS development process – in particular at the very beginning, since eminently already the choice of an IAS theme is a (very personal) “*matter of taste*”.

### 3 Informative Art to Your Taste

We have attempted the design dimension of aesthetics already with previous work [6], relating the choice of the visual elements of an ambient display to factors that seem to be highly impacting aesthetic appreciation: the *cultural context* (geolocation, cultural background of society, etc.) within which information is being displayed, the *application context* (e.g. team awareness, event notification, time series monitoring, etc.) within which the IAS is used, the *environmental setting* (like home, transport, office, public places) where the IAS is installed, the extent to which individuals have the freedom of choice for a personal emotional expression (*personal aesthetic appeal*), and the *disruption free transition* in the visual appearance of color, light, smoothness, shininess, brightness, etc. The way how a certain IAS theme is chosen follows a user-centered design approach: While the theme is allowed to be chosen by the user, the symbols are derived as the result of a metaphor driven structured design process.

#### 3.1 Categories of Metaphor

The main IAS design concern is the choice of a *theme* which (i) meets the aesthetic appreciation of the user, and (ii) at the same time provides sufficient degree of metaphorical freedom within the contained *symbols*, to be able to encode the information to be delivered with the display. Previous work [24][27][32] has followed a creative artistic approach to design *themes* and *symbols*, and present the result “as is” to the user (see Table 1).

In an approach based on information visualization principles, an analysis of (i) which information is to be displayed, (ii) how it is displayed, depicted and conveyed, and (iii) how *external representations* (information conveyed using an artifact of some kind) are related to *internal representations* (information maintained in the human mind) precedes the design activities. From theories of visual perception it is well known, that the process of perceiving information visually performs in two phases:

- (i) in the first phase, the *preattentive phase*, low level features are extracted from the raw images projected to the retina in highly parallel, neural processing schemes. This phase detects features like size, shape, orientation, proximity, curvature, color, shading or texture very fast, way before we are attentive to them or aware of them. These basic features can carry meaning, and are then called *sensory symbols*. A box embracing a set of dots, or a line connecting two areas to indicate connectivity would be simple examples. Sensory symbols, require no learning, are stable across cultures, time and individuals.
- (ii) in the second phase, the *interpretative phase*, objects and relations are identified and related to previously stored information in working memory, one by one. This comparatively slow second phase is goal-driven, i.e. we attend to the information that is most relevant for our goals. This phase detects features of arbitrary kind, so called *arbitrary symbols*. They only carry meaning by convention, they must be learned, are easy to forget, are embedded in culture and

applications, and can evolve (e.g. “emoticons” within email cultures). Arbitrary symbols can be overlearned, even to the extent that they seem like sensory symbols (e.g. the number digits 0 – 9 to everybody has been learned so well, that they are perceived just like sensory symbols. For most of us it would be impossible to relearn their meaning).

Most visualizations, or visual impressions fall along the continuum between sensory and arbitrary symbols, and (visual) metaphors build on the preattentive and interpretative recognition of symbols. Metaphors used in human computer interfaces for example, like “folders” or “trash” for document management, ground on arbitrary symbols that have been learned in the office domain, and are exploited in the computer domain. Generally, (interface) metaphors combine visuals, actions and procedures in order to exploit specific knowledge that users already have of other domains. In some sense the “borrow” ideas from the familiar in order to understand the unfamiliar. Consequently, the perception of a metaphor is closely coupled to an individual’s knowledge and experience. Metaphors are specific to the individual.

This is one more reason to involve the user of an IAS already at the time of *theme* choice. Selecting a theme according to the users appreciation, not influenced or affected by any constraints rooted in design, implementation or technology, preserves the chance of a systematic exploitation of knowledge the user already has wrt. the visual context of the theme. Sometimes it is even necessary to change or reconfigure the theme at runtime, due to e.g. learning based changes, cultural changes, or even changes in the target audience.

The second step is then to identify *symbols* contained in that chosen theme, so as to be able to exploit the mechanism of preattentive and interpretative recognition. Having the user participate in the symbol identification process helps to reflect his knowledge, and thus his perceptual aptitude for metaphors (We are guided by the assumption that symbols favored by the user will implicitly reflect a better metaphoric perception of the connotated information, but do not have empirical evidence for this yet.). Symbol identification hence is a process at the confluence of respecting user preference and adhering to visualization principles. In order to steer this process, we have developed guidelines for identifying concepts in themes and symbols along (i) *color*, (ii) *space*, (iii) *shape*, (iv) *abstraction*, (v) *dimension* and (vi) *orientation*. We discuss them based on artwork which might be considered to serve as themes (see Fig. 6 – 10).

**Color.** An intuitive category of metaphor is *color*. Mapping data values to color attributes (*color coding*) is a well understood from scientific visualization. For IADs, the metaphoric expressiveness of color is of interest. As for example wrt. *sense*, blue is perceived as hard, red as rough, yellow as soft and pink as very soft; wrt. *temperature*, blue is perceived as neutral, red as spicy or crisp, green as bitter, yellow as sweet, pink as sweetish; wrt. *taste* blue is perceived as hard, red as rough, yellow as soft and pink as very soft; and wrt. *hazard* green is perceived as safe, blue as uncritical, yellow as slightly critical, pink as critical, red as dangerous.



**Fig. 6.** Wassily Kandinsky (1886-1944), Squares with Concentric Circle, 26.3x29.3 in, [http://www. www.artexpression.com](http://www.artexpression.com) (left), and a set of symbol variations (right).

An example of a *theme* illustrating in an impressive way combinations of ranges of color is given in Fig. 6. The theme could serve as an awareness display for a work-team (one square per team member). Variations of the color appearance of one team member (Fig. 6, right top) could encode “mood” (neutral, happy, bitter), or the agenda of a work day (Fig.6, right bottom) (research=red, teaching=green, administration=blue). Color is an effective, yet problematic category of metaphor. It can be perceived very differently in different situations by different people. It is less feasible for representing quantitative data, but more for categorization or the expression of emotions.

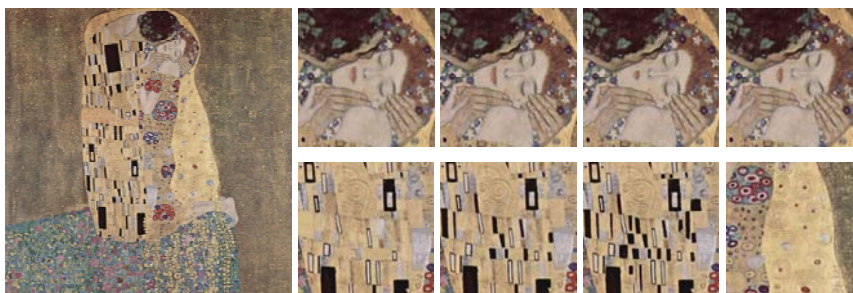
**Space.** When forming images, our mind separates *figure* and *background*. Figure is often described as the “*useful field of view*” (UFOV), i.e. the area from which useful visual information can be extracted in a single glance. It is roughly oval shaped, and varies in size depending on information density and cognitive load. It is the part of an image which we attend to, while background gives context. The more variation the background has, the more difficult it is to perceive and interpret figure (visual clutter).



**Fig. 7.** Caspar David Friedrich (1774-1840), Das Eismeer (The Arctic Sea) – “Die gescheiterte Hoffnung”, (1823/24), oil on canvas, 96,7x126,9 cm, Hamburger Kunsthalle, <http://www.hamburger-kunsthalle.de> (left), and figure / background variation (right).

An example of a theme encouraging to alter the perception of *space* by varying the amount of detail in the figure (*right top*), or in the background (*right bottom*) is given in Fig.7. Aside figure/background variation, the scene in the painting encourages to alter the perception of *space* by subtle modifications of depth cues like shading, lighting and shadowing, occlusion, attenuation, changes in perspective of parts of the scene, stereopsis, accommodation and texturing. Candidates for IAD symbols are the floe peak for expressing e.g. dynamic information (at the viewers focus) by varying the shading and lighting, the distant peak for less prominent information items by varying e.g. the attenuation from visible to totally invisible, the chunks of ice to express information by modifying their texture and relative position, and maybe the nuggets to indicate discrete value information by e.g. adding and removing individual nuggets of different size, shape and color to the scene.

**Shape and Abstraction.** Promising strategies driving the selection of IAD *symbols* are identification of *shapes* and form in a theme that offer certain degrees of freedom for harmonious variation, and the identification of abstract or figural elements that can support variations of the degree of *abstraction* used for information visualisation. A well interpreted piece of artwork expressing these categories of metaphor is given in Fig. 8. While the female character in the painting is coated in a texture with strictly curly, circle like and roundly ornament *shapes*, the male character is coated in a strictly rectangular, geometric and squarish ornament shaped texture. Both abstract ornament (color, size, proximity, inclusion, alignment, direction, horizontal, vertical, inside, outside, cyclic, spin, connection, hole, crack, fissure, boundary, presence, absence, count), as well as figural metaphors can be attempted based on this theme. As for the abstract concepts, spatial areas of the two coats in the theme allow to express the amount (number of rectangles (Fig.8, *right bottom*, *left to right*: ranging from “few”, to “some”, to “many”), number of curls) or the proportion of information entities.



**Fig. 8.** Gustav Klimt (1862-1918), Der Kuß, (1907/08), oil on canvas, 180x180cm, Österreichische Galerie, Wien, <http://www.belvedere.at> (*left*), and IAD symbol variations (*right*).

Important entities can stand out by further size and color coding, selective omission can simplify visualisations, and spatial arrangement of ornaments can help to better organize information. As for the more figural concepts, connotating information into the facial expression of characters appears as a very rich, yet intuitively perceivable

symbolic instrument. Much like *Chernoff Faces*, which are motivated to visualize multivariate data in the shape of a human face (eyes, eyebrows, nose, mouth etc. represent values of variables by their shape, size, placement and orientation), the figural face in the theme could encode multivariate information entities. With the realism of this painting, the idea behind using faces for data visualisation because humans can easily recognize faces and notice small changes therein without difficulty, is even enforced (Fig.8, *right top, left to right* shows indicative lip and eyebrow variation).

**Scale and Dimension.** The metaphor categories identified so far are less suitable for the encoding of information entities that represent quantitative data, given e.g. in scalar, vector or tensor format. For visualisations that need to reflect information on a metric scales (discrete or continuous), the relative “distance” of information entities (translation, rotation, scaling), their relative importance as perceived facts, or the size of the information domain as such, the identification of symbols supporting the metaphor categories of *scale* and *dimension* are important. By *metaphor of scale* we refer to learned symbols on standards of measurement or estimation (like a ruler), or an entity of reference by which to gauge or rate. A *metaphor of dimension* is based upon properties of space, or an extension in a given direction. A *theme*, which due to its strictly geometric composition (straight lines, segments, string cords, rulers, tickers) bears a rich variety of IAD symbol candidates is given in Fig. 9. The variation of the number, spatial position (in the front, in the back) and relative height of the pillar meters in Fig. 9 (*right*) intuitively encode quantitative data like economy indexes or stock analysts ratios.



**Fig. 9.** Rudolf Hausner (1914-1995), *Adam maßstäblich*, (1972), 54,0x55,5cm, signed, <http://www.artnet.com> (*left*), and symbol variations (*right*).

**Activity.** IADs used for the purpose of delivering awareness in families, work teams, interest groups or discussion forums demand for “at-a-glance” perceivable symbols of the activities of individuals. Fig. 10 identifies symbol candidates from an activity awareness IAD. The level of attentiveness to a shared electronic document is encoded in the raising and lowering of the head (Fig. 10, *right upper*), the availability for interaction is encoded into body postures (think, turned away, ready for discussion) (Fig. 10, *right lower*). As a drawing study with detailed figure only for some parts of

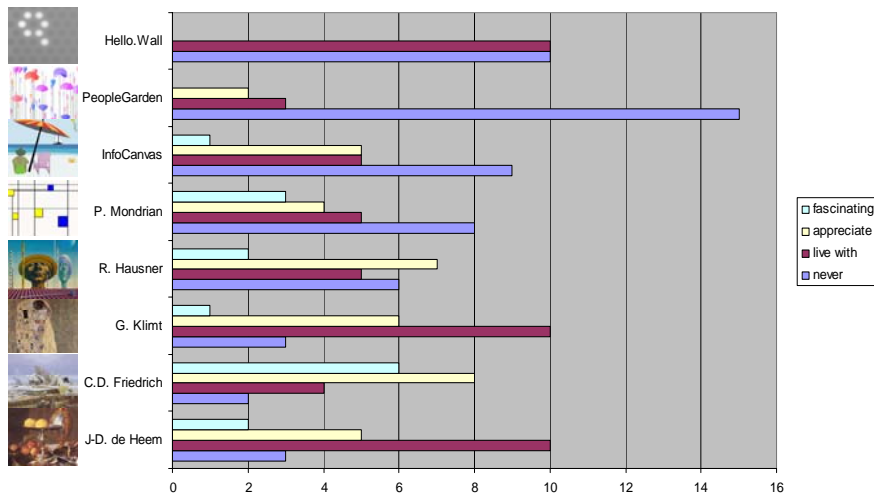
the human body, the theme in an outstanding way supports UFOV, highlighting indicative body postures as attentional spotlights.



**Fig. 10.** Leonardo da Vinci (1452-1519), Study of nude men, pen and ink on paper, <http://www.kunstkopie.de> (left), and a set of symbol candidates (right, (a), (b), (c), (d)).

### 3.2 Aesthetic Appreciation

Having proposed a participatory design process, and having developed a series of design metaphors, all implemented in our *IAS software framework*, we have again tested the aesthetic appreciation of our metaphors against the ones proposed and used in previous work.



**Fig. 11.** Aesthetic appreciation of Informative Art themes: then and now.

Involving the same group as with the survey in 2.3, we now asked to respond on the metaphors and overall appreciation of ambient displays levels (1) “I would never want to have such a display”, (2) “I don’t like it, but I could try to live with”, (3) “I

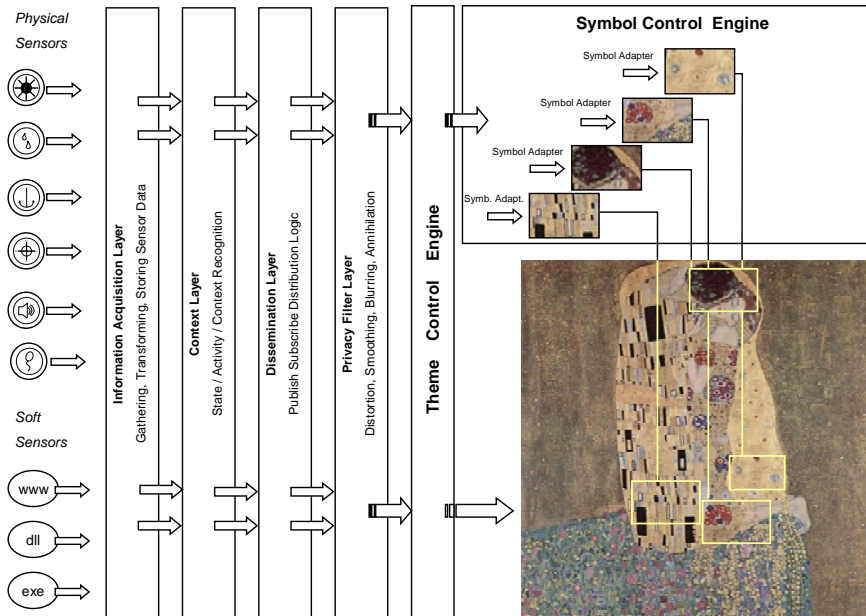
would appreciate to have such display” and (4) “Wow, this is fascinating!”. The results of the survey are summarized in Fig. 11. Surprisingly enough, the traditional styles of ambient displays like the Hello.Wall, PeopleGarden and InfoCanvas do not find much of aesthetic appreciation, PeopleGarden not at all. Well known artwork, like G. Klimt, The Kiss, is considered mouldy due to its worldwide popularity, but people would accommodate to it, given it is installed. To some extent the same is true for de Heem’s Stilleven, and Redström’s Mondrian metaphor. The most fascinating impressions are delivered by monumental artwork that does not have broad popularity, and somehow reflects a very personal expression of taste (C.D. Friedrich’s Arctic Sea). The style of “Phantastic Realism” (“Wiener Schule des Phantastischen Realismus”) by R. Hausner – which was intentionally chosen as a compromise combining stylistic elements from fine arts and photo realism with pictorial elements from engineering (meters, scales, strings, etc.) – turned out to polarize appreciation: about the same amount of respondents strictly declined and appreciated the artwork as an ambient display – a minority was fascinated.

### 3.3 IAS Software Framework

We have developed a versatile IAS software framework, which implements sensor data acquisition, context recognition, data aggregation and dissemination, privacy preserving data filtering, as well as a 2D/3D graphics engine to dynamically control the visual appearance the IAS display (Fig. 12).

The *Theme Control Engine* as container dynamically manages the life cycle of a symbols, which are implemented as individual software components (*Symbol Control Engines, SCEs*), packaged in OSGi bundles. An SCE is responsible to visualize an information entity associated with a spatial (2D or 3D) subregion of the whole theme, by transforming changes in the data in real time into visual effects concerning this subregion.

The framework is implemented on top of an OSGi runtime environment (OSCAR), involves physical sensors like noise, temperature, light and humidity sensors, accelerometers and gyroscopes, WLAN and GPS positioning systems, RFID based identification sensors, card readers, HR frequency and even ECG sensors. Soft sensors are processes collecting data from the Internet via http, from computational processes (exe, dll) or from special purpose monitoring systems. A complex context analysis subsystem handles multi sensor data fusion, context extraction and context prediction. High end graphics components (OGRE 3D, Flash) implement the dynamics of themes and symbols. An XML based configuration management tool allows to “hot-plug” sensors, or to “hot-swap” themes and symbols at runtime. The IAS software framework is fully functional and has been used in an activity awareness application “connecting” dislocated workteams from four different continents



**Fig. 12.** The IAS SF collects information of interest via hardware or software sensors (Acquisition Layer), identifies the context (Context Layer), distributes context information according to a publish subscribe principle (Dissemination Layer), and restrains it with respect to privacy policies (Privacy Filtering Layer). The *theme* control engines generates the visual appearance from the chosen *theme*, the *symbol* control engine encodes information into symbol visuals (not necessarily rectangular), which are overlayed into the *theme*.

## 4 Conclusion

”Informative Art” in one of its earliest appearances was considered as computer augmented pieces of art or computer generated artwork, turning an aesthetical object into an information display [24]. The aim of such displays to deliver information through visuals that are quickly and easily perceived while doing other tasks [19], i.e. provide users with information considered relevant at arbitrary points of work or living engagement, but at the periphery of human (visual) perception [14] is better coined by the more recent term “ambient information system” [29]. In any way, monitoring such a display should cause minimal distraction from the user’s focus of attention.

Several contributions have appeared in the literature, addressing the issue of encoding information of interest in an *aesthetical pleasing* style, using the one or the other design driven approach. In most of these cases, the design work conducts information visualisation concepts, display strategies, as well as decorative, aesthetic and artistic composing, but not involving the user beforehand. Typically, the user is consulted once the informative art display system is ready at hand, and concerned for usability engineering studies (“I-throw-it-out-there-and-watch” design paradigm).

We have collected evidence, that users, based on their cultural background, cognitive skills, situative environment, contextual settings, but most of all their aesthetic appreciation, have dedicated, individual and personal attitudes towards the preferred overall appearance of an informative art display system. We have therefore proposed a *metaphor* driven, participatory design process, that guarantees sovereignty of choice of a display *theme* to the user. Our process identifies *symbols* out of a chosen *theme* according to the metaphor categories *color, space, shape, abstraction, scale* and *dimension*. These metaphors help to find the right connotation of the information of interest and the respective *symbols* of a *theme*. We have used original artwork (C. D. Friedrich, G. Klimt, R. Hausner) to support our arguments for metaphor driven symbol selection. Our informative art design process is supported by a fully functional informative art software framework, within which many display systems have already been built.

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