

Bild-Ästhetik – Aesthetic Primitives of Images for Visualization

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Abstract

Images play an important role in visualization. As users are more willing to adopt a product if it evokes pleasurable feelings the aesthetic appeal of interfaces becomes more important. Thus, there is a growing need to generate also images which appear aesthetically to the user. Starting with the modularities of the human visual system, we derive six dimensions of visual aesthetics. For each dimension we explore, inspired by principles of the visual arts and insights of cognitive neuroscience, which peculiarities of the dimensions are particularly adequate for an aesthetic impression. Accompanied by a fair number of image examples, these considerations result in an easy to understand guideline for computer scientists and interface designers how to deal with images in terms of aesthetics.

1 Introduction

The roles of images in visualization are manifold. Usually four main benefits are named. Images motivate and attract the attention of the user and have the function to persuade her. They communicate information, which is often exploited in computer-based learning. Furthermore, they have the great power to overcome language barriers, and they support interaction. Images are especially powerful whenever it is difficult to describe the depicted information by words or numbers. This is the paradigm for most human-computer interaction applications. For example, in web design images are utilized mainly for two different purposes. They can have the function to attract the user and may be used as anticipation of the overall topic of the website. On the other hand, small thumbnails promote interaction. In e-learning images usually are the support of the information, that should be conveyed by the course. Other examples of interfaces from several applications of augmented reality (geovisualization, navigati-

on, maintenance and repair) where images are the key components of the visualization, are shown in figures 1. The left picture of figure 1 shows an image of the environment which is augmented by data indicating a possible path for a vehicle.

One could be of the opinion that such a real-time navigation system has to show „just the image the camera captures“. But the interface designer has to decide for the specification of numerous variables that determine how the captured image is presented in the user interface. To name but a few, she has to choose color space, contrast, dynamic range, spatial arrangement of the image components (e.g., the position of the horizon), depth of field, and focal length. The right part of figure 1 shows an example for maintenance instructions for an engine. The previous statements hold true for this example, as well.

In the context of information visualization and human-computer interaction topics such as the importance of aesthetic qualities of graphical elements of user interfaces or the aesthetics of interaction have frequently been addressed. Also the relation between visual and verbal information in presentations has been dealt with. What is underrepresented in the literature is the role of image aesthetics in visualization. This project is an attempt to fill this gap. To identify aesthetic dimensions that, on the one hand, allow for the evaluation of the aesthetic qualities of an image and, on the other hand, enable an interface designer to adapt her tools to the needs of the user, we have to start at the user, i.e., the human, and have to know basics about human visual information processing. The human visual system solves a perceptual problem by filtering out the salient features of an object from the details and varieties of its appearance. This is akin to visual artist's abilities to cull from the sensory manifolds those



Figure 1. Images as key components of visualization: navigation and maintenance.

image features that enhance the clarity of the representation. Thus, cognitive neuroscience as well as artistic principles give us clues to define dimensions of visual aesthetics.

2 Dimensions of visual aesthetics

We start with an overview of the human visual system and draw the conclusion that the basic dimensions that constitute an aesthetic experience can directly be derived from the modularity of our visual system.

2.1. Modularity of the human visual system

The human visual system is organized as a parallel, modular system. It processes different attributes of a visual scene, such as color and motion, in different, specialized subdivisions of the brain. These cortical areas are dedicated to the analysis of a single property of the visual scene, only.

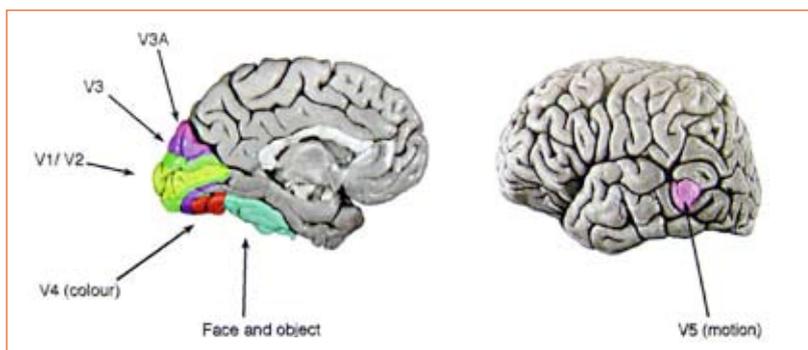


Figure 2. Cortical areas of the human visual system dedicated to different visual modularities. (Images taken from [Zeki, Inner Vision].)

The left part of figure 2 shows a human brain from the medial side with some of these areas. From the retina the visual information is carried along the optic pathway to the primary visual cortex (V1) at the back of the brain. Signals carrying information on color, motion, form, and depth are transported to V1 and are collected into specialized compartments in V1. Both, directly and via an intermediate area called V2, V1 sends this information further on to other specialized areas. A colored stimulus leads to an activation in V1 and in a complex of areas called V4. Analogously, a moving visual pattern activates V1 and an area called V5 located on the outside surface of the hemispheres (right part of figure 2). Another interesting modularity that has its own representation in the brain is the body and parts of it, such as faces and hands. The human fusiform gyrus (in

the left part of figure 2 marked by the turquoise color) is important for the perception of faces.

2.2. Correlation to the aesthetic experience

The above mentioned modules of the visual system (color, motion, body parts) and other not mentioned ones (such as form, depth, and spatial organization) are also attributes that have been important for the formal aspects of visual arts, and thus for aesthetics. We speak of the aesthetics of color or the aesthetics of portrait painting, as if there are also different categories of aesthetics. These categories seem to correspond to the modules of visual perception. Neuroscience studies revealed that the judgement of a painting as beautiful or ugly correlates with specific brain structures. But Zeki suggests that there is not one visual aesthetic „sense“ only but many, each tied to a different specialized processing system. Different attributes of the formal aspect of art excite different groups of cells in the brain, thus there is also a functional specialization in aesthetics. Lattin posed the question as to why some features – aesthetic primitives – of the modularities provoke a stronger aesthetic impression than others. He came to the conclusion that a property of a stimulus is intrinsically interesting if it resonates with mechanisms of the visual system. Aesthetic primitives isolate or exaggerate one of the processes of the human visual system by evoking maximal responses of those cells in the brain dedicated to that special attribute. They are aesthetically moving because they blend with our brains. Summarizing, we suggest the basic dimensions of visual aesthetics to be exactly the different modularities of the human visual system. The most important of them are color, form, spatial organization, motion, depth, and the human body.

3 Aesthetic primitives of vision

Having identified the main dimensions of visual aesthetics, we will consider the question now, which peculiarities of these dimensions are capable of evoking an aesthetic sensation. Those peculiarities we will call aesthetic primitives. Many books have been filled with principles of lay-out and arrangement of color and form in visual arts, whether it is drawing, painting, or photography. For each primitive described in this section we give an example, mostly in form of a photograph, but the described principles hold true for all kinds of images.

3.1 Color

Color is a modularity of the visual system, which just in the context of beauty is an important means

to evoke aesthetic experiences. Here we examine one property of color and its distribution in an image, which is known to appeal to our aesthetic sense. (Two others are described in [iV 2007].)

3.1.1 Only a few strong colors.

Less is more. Two to three strong colors usually are the maximum for an image still to be pleasant to the eyes. If more than a few strong colors occur in an image usually the effect of beauty is lost. (Maybe this corresponds to the isolated process in the human visual system triggered by only one special visual attribute which was mentioned earlier.) In principle, color in an image should correlate with its content. If color is not the salient feature of an object depicted in the image, as it holds true, e.g., for a butterfly, the visual system of the observer is overcharged and an aesthetic impression is missed. An example is shown in the left image of figure 3.



Figure 3. Only a few strong colors.

The orange color of the turbans of the musicians is the dominant property of them in this image. Thus, they are depicted in such a way that the orange color is also the dominant property of the whole image. All other colors are subordinate or even non-colors. Also the right image of figure 3

gets by with only a few strong colors, the yellow of the taxis and the red rear lights of the cars. An exaggeration of this rule is monochromaticity, the deliberate choice of only one main color. Quite aesthetic results can be achieved if only a small range of colors adjacent in the color circle (see figure 4) are chosen, e.g., only red, brown, and orange tones in a picture of autumn foliage. The left images of figure 4 show an example of this principle, where only a brown tone is used. Such a subtle monochrom coloration allows for the accentuation of important elements which come to the fore (such as the bench and the person in these examples).

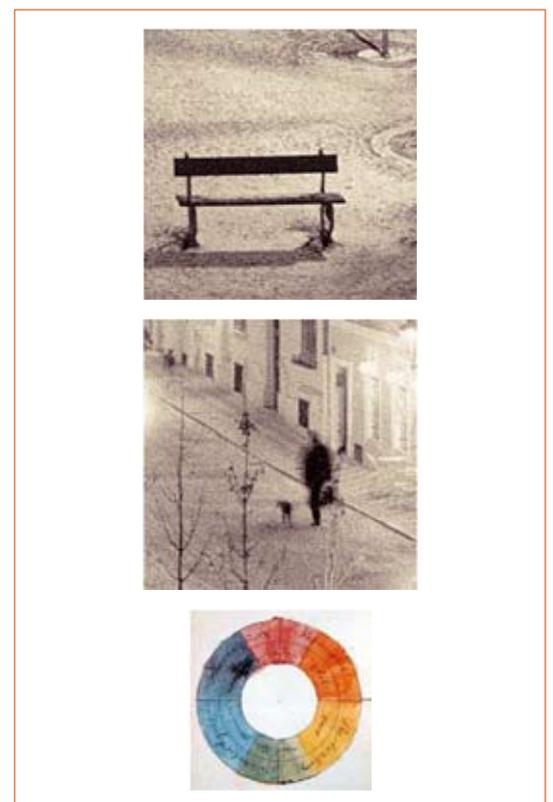


Figure 4. Monochrom coloration and color circle by Goethe.

3.2 Spatial organization

Not only the shapes of the elements constituting an image are of importance for its aesthetic appearance, but also their mutual spatial relations in the two-dimensional surface of the image play a major role for the aesthetics of an image as a whole. We will comment here on the aesthetic primitive clarity of spatial organization and rhythm, repetition, and variation. Other aesthetic primitives of spatial organization are described in [iV 2007].



Figure 5a. Clarity of spatial organization.

3.2.1 Clarity of spatial organization.

Too many objects in a single image cause confusion and derangement. An image should not be overloaded by details, as well. Figure 5a shows an example which demonstrates the power of spatial organization.

The attention of the viewer is focussed on the person in the center, although the visible parts of the boy occupy only a very small portion in the image. This effect is only in part due to the form contrast between curved and straight lines, but mainly due to the spatial arrangement of the image elements. In general, an image appears aesthetically, if no element neither can be omitted nor can be added without destroying the visual balance. There are also some more restrictive rules concerning the distribution of light and dark parts of an image. The usual way to scan an image is supposed to be from the left upper part diagonally to the right lower part. Accordingly, the most important portion of an image is the left upper part, because here the image inspection starts. As humans are more inclined to examine lighter parts of an image rather than darker parts, an image should have its lighter parts in the upper left, its darker parts in the lower right, just as exemplified by the pictures of figure 5b.



Figure 5b. Clarity of spatial organization.

3.2.2 Rhythm, repetition, and variation.

Many visual patterns are strongly related to repeated shapes or objects. These copies can occur in regular spatial distances or they can be arranged arbitrarily. Patterns of largest relevance for animals are those of medium entropy. Regarding aesthetics conditions are similar. Perfect symmetry in images as well as chaos (or noise) are not ranked beautiful. Figure 6 demonstrates the beauty of repetition by copying single slices of an image and combining them without modification.

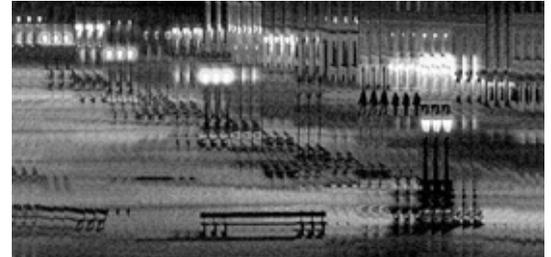


Figure 6. Repetition.

Repeated structures are also present in the images of figure 5b and contribute to their aesthetic appeal. As pure repetition often is said to be monotonous another principle of art consists in variation, which means an instance of change in present structures. This is usually applied to increase the visual interest. Figure 7 shows variations over a theme, namely stripe patterns in animal fur.

Visual rhythm is the last aesthetic primitive of spatial organization we will explain. It is an artistic principle closely connected to repetition and often described by the flow of how the viewer's eye is drawn across an image, for example, whether the eye is forced to jump rapidly or glide smoothly from one image element to the next. There are several types of visual rhythm. These include:

(1) Regular rhythms: $ab\ ab\ \dots$ is the most common type. Another example is $abbb\ abbb\ \dots$. The picture in figure 6 exploits the schema $aaa\ bbb\ ccc\ \dots$

(2) Alternating rhythms: for example: $aba\ cdc\ aba\ efe\ aba\ \dots$

(3) Progressive rhythms: Progression occurs when there is a gradual increase or decrease in the size, number, or some other quality of the elements repeated. A sample pattern would be: $ab\ aabb\ aaabbb\ \dots$. The left image of figure 5b displays a progressive rhythm. In figure 7 the effect of visual rhythm is even more evident: in the upper left image the viewer's gaze is led horizontally from the left to the right by the arrangement of the vertical stripes, whereas in the middle picture of the same row it is directed more smoothly and diagonally from the upper left to the lower right.

3.3 Motion

Motion inherently is an aesthetic cue because it refers to life and action. As this article is about images rather than movies, we will illuminate the means by which motion can be conveyed in

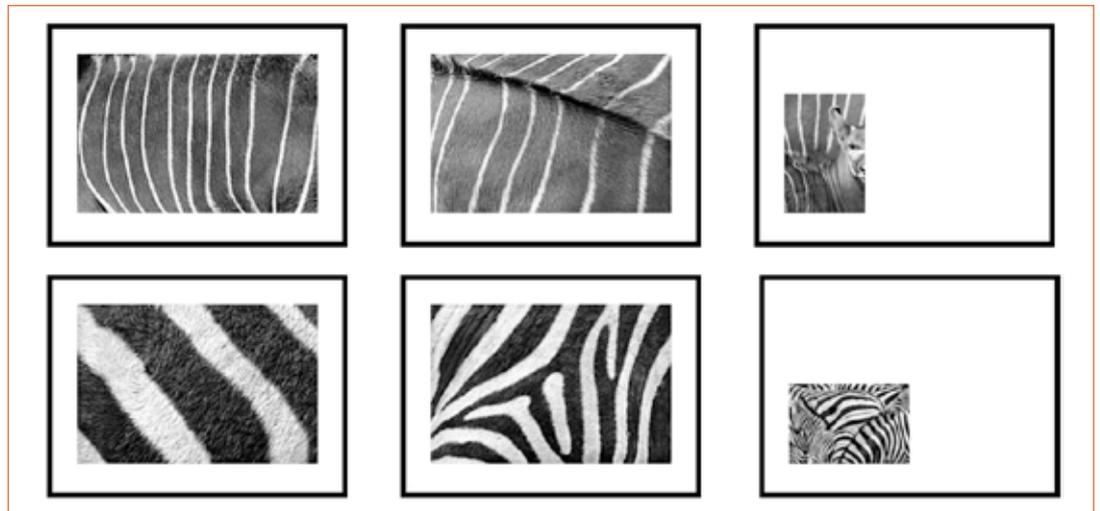


Figure 7. Rhythm and variation.

an image. Calder, most famous for inventing the mobile, used black, white, and red as the only colors for his kinetic sculptures, because he was of the opinion that all other colors would confuse the clarity of motion. This opinion is interesting because of the coincidence with the functional specialization of the color and motion pathways in our visual system, mentioned earlier. According to Calder, motion is most effectively represented by placing highly contrastive surfaces side by side. Translated into images, this means that motion is best expressed in an image (even a color image), if it is based on contrast changes, rather than color. The graphical means by which this can be realized are manifold. We will concentrate here on two of the most expressive motion symbols, blur and the depiction of distinct motion phases.

3.3.1 Blur.

Blur is an indicator for movement. Feininger defines it as „unsharpness in one direction“, namely the direction of the moving object. The stronger the blur, the stronger the impression of speed. In photography it can be achieved either by a static camera taking a moving object (so-called motion blur) or panning the camera with a moving object (so-called panning blur). Blur as an indicator for motion is an aesthetic primitive if the blurred parts of the image contain lines or stripes of high contrast rather than being of homogeneous luminance. The upper row of figure 8 shows two examples of motion blur. Note the high contrast changes in the blurred regions. The same holds true for the images in the lower row. Here the blur was induced by a panning of the camera. In the left image it was panned with the walking woman,

thus she is depicted almost sharply. In the right image the camera was panned with the right car. Again, in both images the blurred regions exhibit high contrasts, which is essential to evoke an aesthetic impression.

3.3.2 Distinct motion phases.

Another technique to illustrate movement in images is the depiction of a number of distinct motion phases simultaneously in a single image. Its high aesthetic appeal is probably partly due to the element of repetition. A series of sharp, slightly different, partly overlapping copies of an object, which is captured in different phases of movement, can symbolize the concept of motion in a graphically smart way. Duchamp practised this principle in his famous painting pictured in figure 9. In photography distinct motion phases are usually obtained by multiple exposures of an object (right image of figure 9).

3.4 Human body

As already mentioned the human body and its parts such as hands and heads take up a special position in visual information processing, which reflects the importance of these visual stimuli for our survival. Also in our aesthetic sensation it seems to be worth to be regarded as a separate category. A concept which is important in this context is that of the principal axes of an object.

3.4.1 Principal axes.

Principal axes are axes of symmetry or elongation around which the local parts of objects are grouped in order to constitute their global form. If an object is enlarged, shrunk, or rotated around its



Figure 8. Blur. Upper row: motion blur, lower row: panning blur.

principal axis the relationship between the parts and the principal axis remains constant across all variations. Principal axes are considered as aesthetic primitives. Supporting arguments for this opinion can be derived from the arts as well as from cognitive neuroscience. Stick figures have been used by artists ever since, even humans in cave paintings have been depicted by means of their principal axes. On the other hand, it has been shown in a study that little animal models

made of pipe-cleaners are sufficient to represent the animals. They are easily recognizable although no information on the surface of the shape is present. Marr et al. supposed, that the success is due to the correspondence between the pipe-cleaners and the axes of the volumes they stand for. To come back to aesthetics, Giacometti provides examples for the thesis that the human body intrinsically is capable of evoking a feeling of beauty. What distinguishes his statues is the fact that they almost only consist of their principal axes. Giacometti reduces the body to its basic shape, and thus we recognize the concept of a human at once (left image of figure 10). Sartre put this as follows: „As soon as I see them [these figures], they spring into my visual field as an idea before my mind; the idea alone is at one stroke all that it is.“. Other examples are given by a motion study of Muybridge in figure 10 (boxing men), and the shapes of humans in figure 11, which illustrate the beauty of the human body defined by its principal axes. It seems that the human body does not appear beautiful arbitrarily, but because its shape, especially in the exaggerated version of principal axes, corresponds to the simplifications and transformations our visual system performs to analyze and represent it.



Figure 9. Distinct motion phases. Left: Marcel Duchamp's "Nude descending a staircase", 1911-12, right: doouble exposure indicating slight movement.

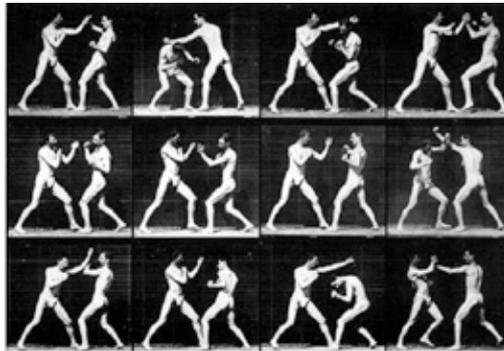


Figure 10. Human body. Left: part of a sculpture by Alberto Giacometti ("Le Place", 1948-49, right: photographs by Eadweard Muybridge).

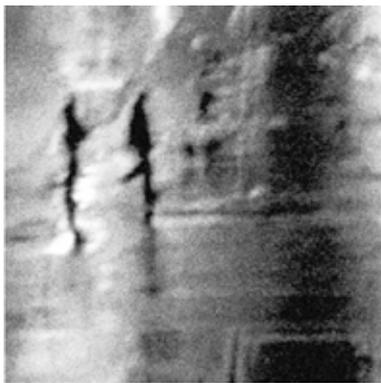


Figure 11. Silhouettes of the human body.

4 Summary

In the context of human-computer interaction users are more willing to adopt a product if it evokes pleasurable feelings. In addition, the acceptance of an application has severe implications for its safety. Disregarded for a long time, the aesthetic appeal of interfaces recently becomes more important. In this project we addressed only one element of interfaces, namely images. The best content of an image does not reach the

recipient, if the image is designed poorly and thus appears confusing or ugly. Motivated by the modularity of the human visual system we have identified six dimensions of visual aesthetics, four of them we described in this article. For each dimension we explored the conditions and properties that enhance the clarity or vividness of the visual presentation. These aesthetic primitives are justified in an interdisciplinary fashion by the way how sensory information is processed by our visual system, as well as by approved practices of artists. Of course, there are exceptions to the stated rules and often just famous works of art break them. But to keep control over the process of generating appealing images it is necessary to break the rules consciously rather than randomly or just by exploration. And for that purpose interface designers have to be aware of the basic aesthetic primitives.

Summarizing, we list here, in striking terms, the directives for image composition for the six identified dimensions of visual aesthetics. These directives should not be adhered to too seriously but rather be regarded as rules of thumb.

Color: use a few strong colors only; often complementary contrasts are effective; exploit the dynamic range

Form: forms should be clear and simple; silhouettes are aesthetic

Spatial organization: spatial organization of image elements should be clear and simple; apply the rule of the golden mean; attain a wholistic impression by textures and patterns; apply variations to patterns and take care for the visual rhythm induced by repetition of elements

Motion: express motion by blur of high contrast; distinct motion phases are aesthetically appealing

Depth: illustrate linear perspective; exploit the contrast between sharpness and unsharpness; the distribution of light and shadow may evoke the impression of depth

Human body: let the principal axes of the human body be clearly visible.

References:

- Gabriele Peters, Aesthetic Primitives of Images for Visualization, 11th International Conference on Information Visualisation (iV 2007), Symposium on Design and Aesthetics in Visualisation (DAViZ), 2007.