
Describing Images

This chapter explores relevant insights about the study of images that have been forged within the sciences, humanities, and media studies traditions. Although this book is not about interpreting images, it does take into account research that focuses on material and technological descriptions of images. This is important because we will identify levels of analysis and methodology which in other chapters will be used as strategies to design and produce visual interfaces. In this respect, a brief discussion regarding the notion of interface is also contemplated.

1.1. Light, visual perception and visual imagery

Where do images come from? Where do they take place? Before images are printed or displayed on a computer screen, they are physical and psychological phenomena. A brief account of the processes underlying the formation of images will illuminate the perceptual and cognitive approaches that will inform further sections of this book.

On the one hand, visual perception puts attention on the physical and material aspect of vision. It occurs in the eye and its organic layers. The physical explanation of vision starts when light stimulates the retina. From there, different photoreceptor cells, mainly rods and cones, process signals and send information to the region of the brain called the primary visual cortex. On the other hand, visual imagery is related to mental experiences of representation and simulation; it occurs in the brain. Henceforth, the explanation moves to the domain of cognitive sciences. The cortex identifies basic visual features and redirects information according to two pathways:

visual properties (shape, color) and spatial movement properties (location and motion).

Vision and imagery cooperate whenever we interact with images depicted on the computer screen. As we will note, we do not only perceive and explore visual constituents of images but also think about different things at the same time: maybe a mental scheme of the interface, a subjective critique of design decisions, a memory evoked by a picture, or even our grocery list or plans for the next weekend.

1.1.1. *Physical light*

Light is what allows visible sensation. It is worth starting our account on visual media by considering some physical conditions of light as they have been postulated by sciences. This section will be useful to review basic concepts, properties, units of measure, and applications derived from the study of light.

Optics is the branch of physics concerned with the phenomena of light, particularly its propagation and image formation [TAI 13, p. 485]. Broadly speaking, optics has three subdomains, each one describing light differently: geometrical, wave, and quantum optics.

For geometrical optics, light is understood as a series of rays or beams. Here, the object of interest is not really the physical properties of light, but rather the “controlled manipulations of rays by means of refracting and reflecting surfaces” [HEC 05, p. 156]. The light that arrives from the Sun, for example, crosses the atmosphere, which is composed of air molecules that conform the density of the medium. Light particles interact with these molecules at different moments and angles, varying its diffusion: lateral diffusion produces the blue of sky; low diffusion, when the Sun is closer to the horizon, the red-orange of dusk; and, after 18 degrees below the horizon line, the black of night. This optical phenomenon is also referred to as Rayleigh scattering.

When the light hits more solid substances than air, it is said to be refracted and/or reflected. The former specifies the change of direction as the light traverses a substance. The latter occurs when the light is returned or bounced off the surface. More precisely, reflection can be of two kinds: specular (when the reflecting surface is smooth, creating a mirror image) and

diffuse (when light bounces off in all directions). In the natural world, both phenomena rarely occur in pure manner; the correct behavior lies somewhere between the two [HEC 05, p. 103].

For our purposes, geometrical optics will be further evoked regarding its applications: it has been an integral part of the development and understanding of optical systems (human's eye, glasses, magnifying glasses, binoculars, microscopes, camera lenses, and telescopes); it also provides explanations for peculiar optical phenomena in nature (mirages, rainbows, halos, shadows, etc.)¹, and it has informed the development of software for computer graphics (such as 3D projection techniques like ray tracing).

For wave optics, light is studied as radiation, that is, as energy transmitted in the form of waves. In this respect, signals can be described as a spectrum consisting of frequencies (times per occurrence measured in Hertz, where 1 Hz equals one oscillation per second) and wavelengths (distance between repetitions of the shape measured in meters). From this perspective, light waves are part of the larger electromagnetic spectrum, which includes other types of radiation: gamma, X-ray, ultraviolet, visible light, infrared, T-ray, microwaves, and radio waves.

Visible radiation can be perceived by the human eye and analyzed according to the visible spectrum. It identifies approximate wavelengths for spectrum colors, going from violet (400–450 nm), blue (450–500 nm), green (500–580 nm), yellow (580–590 nm), orange (590–620 nm) and red (620–700 nm) [TAI 13, p. 635]. The other types of radiation can be detected or generated with special instruments, although they are not always of an optical nature.

Wave optics investigates the superposition of waves mainly through polarization, interference and diffraction. The first takes advantage of the fact that natural light waves oscillate in multiple directions, and therefore it is possible to filter and change the direction of the electromagnetic field. Famous cases where we see applications and types of polarized images are in stereoscopy using 3D glasses, photography lens filters, and liquid crystal displays (LCD). Interference and diffraction use barriers and slits of different shapes (rectangular, circular, single and multiple) to describe how waves move around or change when crossing an opening space in the obstacle.

¹ You can find a socially updated list of optical phenomena on Wikipedia: https://en.wikipedia.org/wiki/Optical_phenomena.

Even though it is not always appropriate, interference considers small number of waves, whereas diffraction deals with a big number [HEC 05, p. 459]. Among the applications, we see some effects in fringes of light, interferograms, speckle textures, and Airy rings.

Finally, for quantum optics, light is studied at the subatomic level where the fundamental particle is the photon. It describes the minimal amount of all electromagnetic radiation and is part of the boson classification, together with the gluon, the Z boson and the W boson. The whole picture of elementary particles includes fermions (quarks and leptons that correspond to matter and anti-matter particles)². Among the applications of photons in optical technologies and imagery, we cite the diverse varieties of lasers (acronym of Light Amplification by Stimulated Emission of Radiation, introduced in 1958), the multiple techniques used in holography (holograms by reflection, transmission, volume holograms, interferometry holograms, etc.) [HEC 05, p. 640], and ongoing advances in quantum computing.

1.1.2. Visual perception: Gibson's ecological approach

The ecological approach to visual perception differs from physical studies of light by focusing on the perception of the environment. The approach was initiated by the renowned psychologist James J. Gibson [GIB 86] during the second half of the last century. For him, environment is the physical terrestrial world constituted by substances and surfaces. The latter are the visible faces of the former, inasmuch as substances keep a more or less solid state of matter. In other words, surfaces separate substances. For example, consider your field of view right now. You see different objects, perhaps a chair, a table and a wall. Before calling them by their names, you discern their boundaries and contours because some parts are more or less illuminated; they also have some kind of texture, and they are placed at different positions from your angle of perspective (up, down, in front, behind, aside, etc.).

According to Gibson, what we really put attention to when we perceive the environment are not the properties of the surfaces, objects and places (e.g. their shape, color, composition, size) but their “affordances”, that is, what the object permits one, or not, to do with them. If we come back to the

² At the date of mid-2016, other particles exist in a theoretical form. A comprehensive list with updates and references can be revised at: https://en.wikipedia.org/wiki/List_of_particles.

chair, table and wall, the chair affords sitting (but also standing on it, or even grabbing, lifting, pushing, pulling if it is not too heavy or attached to the ground). The table affords placing other objects on top of it, and the wall affords separating spaces, hanging objects, painting or covering with tapestry. An important aspect of affordances is that they are properties taken in reference to the observer; they are not physical or phenomenal [GIB 86, p. 143]. In this respect, the chair, table and wall afford differently to a child, a cat or a fly.

As we can infer, Gibson was really occupied by perception in the natural world. He introduced notions such as “ecological optics”, “ecological information” and “ecological events” that helped him re-contextualize traditional understandings of psychology. The importance of his approach was to study visual images as a kind of knowledge. Because in nature we do not have descriptors, visual perception is an implicit and direct knowledge that coexists with others: metric knowledge (by means of optical instruments that allow one to change scale), explicit knowledge (by means of languages that define and categorize objects and places) and mediated or indirect knowledge (by means of pictures, images and written-on surfaces).

The work of Gibson inspired the development of computational solutions to capture and record visual information. We will come back to this question in the following chapter. For now, let’s review what images are from the ecological approach to visual perception.

In Gibson’s terms, images and pictures are surfaces, which means they exist as part of the world, within the context of other objects and surfaces. They have the property of specifying something other than what they are [GIB 86, p. 273], in the same line as “displays”, which are surfaces shaped to show information for more than just the surface itself (e.g. the surface of porcelain, which could be molded as a figure or as a traditional lithophone from Limoges). In the words of Gibson, images and pictures are “surfaces so treated that they make available an optic array of arrested structures with underlying invariants of structure” [GIB 86, p. 272].

From this standpoint, drawings, paintings and photographs record a moment from the real world experience. The ambient light is divided into component parts, which are then organized into an optic array made of visual angles. Such angles may vary according to the point of view of the observer, but they form relations of inclusion: smaller parts or details can be seen

within a larger structure (to illustrate, imagine the hierarchy leaves-trees-forest). The so-called “invariants of structure” are elements common to all points of observation. Furthermore, in the specific case of drawings and paintings, where the artist can add imaginary objects, they are also depicted as surfaces. Although previously visualized and abstracted by information processed by the perceptual system, imaginary objects need to be presented in a visual form, with the available material possibilities.

1.1.3. *Visual imagery and cognitive sciences*

We said earlier that visual imagery is related to mental experiences of perception and action in the absence of their external expression. Visual imagery is also referred to in literature as mental imagery, imagination, or seeing with our mind’s eye. In this section, we move from the natural world to the realm of the brain and mind. The intention is twofold. First, we want to revise how both dimensions could converge and provide helpful insights regarding creativity and innovation. Second, it is crucial to evoke notions of “representation”, “description” and “simulation” within the context of cognitive sciences because they have played a central role in the development of digital images.

In contrast to the ecological approach to visual perception, the concept of “representation” becomes central to cognition. For Gibson, representation is misleading because it would imply recreating a whole natural scene. From this point of view, it is of course impossible to represent exactly the same physical conditions in space and time of an event, and that is why invariants record some of its characteristics.

However, in cognitive sciences, “representation” is a form of mental imagery. The notion is associated with interpretation and meaning making. In the case of images, we say that they are “iconic representations” [AND 04, p. 37], and this already suggests that there exist other types of representation systems: language, words, music, mathematics, logics, etc.

Following the cognitive science approach called “connectionism”, the information stored in the brain is not in the form of explicit packages. It is rather distributed and loosely connected. Hence, mental images imply being reassembled and connected, instead of loaded directly from the memory [HOF 85, p. 410]. Moreover, the structure seems to be rather dynamic, since

the elements of a representation system trigger modifications in different parts or processes of the mind (this is what Marvin Minsky refers to as “agents” [MIN 85, p. 196]).

One of the important aspects of regarding mental imagery for our study will be to consider it as a source of creative thinking. This will be decisive when we will talk about designing innovative graphical interfaces. To take a glance at imagination and simulation is also to think reflectively about our experiences. It is a way to visualize new virtual features that could be later implemented in projects and interactive interfaces.

Minsky has noted that “there is an intimate relationship between how we ‘represent’ what we already know and the generalizations that will seem most plausible” [MIN 85, p. 303]. In another strand, Douglas Hofstadter, when relating the work of artists and scientists, mentioned the example of a musical interpreter who establishes a multidimensional cognitive structure that is a mental representation of the song, fed by many other different mental structures related to previous experiences [HOF 85, p. 653]. The meaning of the song emerges in the process. Once again we observe the dynamic and complex situation of elements of the representation system, acting both as triggers and substantial supports of signification.

In more recent studies, Benjamin Bergen has introduced the term “embodied simulation”. He proposes that “maybe we understand language by simulating in our minds what it would be like to experience the things that the language describes” [BER 12, p. 13]. The neurophysiological fact behind this idea is that we use the same parts and mechanisms of the brain for visual perception and for visual imagery. Therefore, whenever we simulate an event in our mind, we activate the same regions of the brain that we use in the physical world. Furthermore, Bergen points out that both kinds of images are indeed integrated. Visual imagery might interfere or enhance actual vision [BER 12, p. 28].

The other aspect that interests our study regarding mental images is the way in which they are understood as representation system. The earlier mentioned “connectionism approach” has found profound applications in computer science, particularly in digital imagery among other domains.

First of all, by the late 1930s, the basic components of computing were already invented (i.e. electrical circuitry, Boolean processing, propositional

logics), and cybernetics established the umbrella field to explore relations soliciting the brain, the mind and the machine. As we can suspect, those different ingredients also constitute different levels of analysis and description. The question was: how to pass or move from one to another?

A simple way to understand a “description” is to think about a different language to describe something. What the computer central unit does can be described in machine language, but this is very difficult for humans because we do not think in binary terms. Thus, we go a step further to think in assembly language, which is easier and can be described in the decimal system. However, we know that, even today, assembly language is hardly taught in any “data visualization” workshop. What we do is go several steps higher. We describe in terms of another language what assembly does (and in consequence, what the machine language does at lower levels). We can now imagine the complexity of imbricated layers required for us to write a document in a word processor or to type a line of code in JavaScript.

Neuroscientist David Marr has defined “description” as “the result of using a representation to describe a given entity” [MAR 10, p. 20]. But then, what is a “representation”? Marr continues: “is a formal system for making explicit certain entities or types of information, together with a specification of how the system does this” [MAR 10, p. 20]. These definitions were formulated with visual information in mind, and we will come back to the work of Marr in the following chapter. For the moment, let’s say that Marr was very aware of the importance of representation mainly because it determines how easy or complicated it is to do things with information: “any particular representation makes certain information explicit at the expense of information that is pushed into the background and may be quite hard to recover” [MAR 10, p. 21].

At the moment of writing these words, the influence of the connectionism or “network approach” is latent in recent advances in machine learning, most notably “neural networks” and “deep learning”. The logic behind this approach remains anchored on the idea that the machine is expected to resemble the brain in the sense that small constituents act in parallel, without any hierarchical control and interconnected by links where the efficiency is modulated by experience, thus “representing” the knowledge or learning of the machine [AND 04, p. 43].

To conclude this section, let's come back to those "small constituents" or formal rules of the system. Given the fact that a computer is a very complex system and that we do not interact with it except at higher levels, it is necessary that the transmissions of information between layers avoid as many errors as possible. This is achieved through formal structures with no ambiguity at all. While natural language is polysemic (i.e. words or images may have several meanings), the machine needs a clear input in the form of 1 or 0. Other examples of formal rules are cardinal numbers, which require a specific syntax and combinatory rules different from Roman numbers.

1.2. Visual media

Visual media will be for us the means to make sense of visual information. Following the precedent sections, where we have tried to describe levels of incidence of visual information, it is obvious to say that visual media are types of mediated images. If direct perception consists of discerning surfaces, textures, objects, places and other visual information within the natural world, then any kind of image is indirect and mediated because it already contains a pre-figured point of view, disposition of elements, and choices of illumination.

While the digital screen is the preferred material support in our study, it is convenient to distinguish between different forms of expression that we encounter. First, we have the *screen as object*: it has sizes, weight, resolutions, electronic components, technologies, mechanics of functions, etc. Second, we have the *image that appears on the screen*. This image is determined by the technical possibilities of the screen as object and, in general terms, it is the image that simulates an existing media: digital photographs, digital cinema, digital magazines. Third, the images that we see on the screen are created with other kinds of images: digital graphical interfaces (or, as we call them, *image interfaces*). Here we are thinking about buttons, sliders, menus, boxes and other elements that facilitate interacting with software. In this section, we explore the latter two forms; the third is the opening section of Chapter 2.

1.2.1. Visual media as mediation

Visual media consists of what is depicted as image and the material support on which it appears. This first approximation is of course too vast

and vague, but it has the advantage of not confining visual media exclusively to digital technologies. Mediation, as a process that connects a message to a cultural form, exists at the level of the depicted image, but also when the material support is used as image. This is the case when drawing pictures on the sand or forming figures with pebbles on the ground or, rather differently, constructing a golem-like sculpture out of TV sets. Furthermore, material supports will continue to develop and different kinds of surfaces are likely to be exploited: projections on physical objects and holograms, to mention a couple of examples.

Literature in visual media is abundant in media studies, media art history, media archaeology, sociology of media, and other related areas. We learn that media often get their names from the relation of techniques and supports. Photography associates the Greek words “photos” (light) with “graphé” (drawing with lines) to stand for “drawing with lines”. The word television puts together “tele” (far) and “visio” (sight). More recently, electronic terms derive from acronyms pointing to technical components: “pixel” stands for “picture element”, “codec” means “coder-decoder” and “modem” refers to “modulator-demulator”.

Although it is not our purpose to elaborate a theory or classification of visual media, it will be useful to consider some of them as entry points. Among many classifications, instances of visual media commonly include: painting, photography, graphic design, comics, magazines, cinema, television, video clips, advertising, video games, virtual/augmented reality and websites. These media first come to mind as they are also the most popular. Three kinds of material supports are observed: canvas, paper and screen. However, a different list can be created if we consider media that remained at the state of visual artifact and technology, that were not produced massively or that became obsolete and forgotten. Oliver Grau, an important media art historian, recalls: peep show, panorama, anamorphosis, myriorama, cyclorama, magic lantern, eidophusikon, diorama, phantasmagoria, silent movies, films with scents, cinéorama [GRA 07, p. 11]. For these instances, the supports explored are not always solid and rigid: smoke, fog, glass, water, etc.

In a similar ecological approach as visual perception, media theorist Marshall McLuhan understood media as environments, as technologies, and as extensions of man [MCL 03]. For him, media are not only about communication, like our lists before, but also about changing effects in

culture. Thus, for him, media was also money, clothing, transportation, weapons and clocks. Gibson's idea of medium relates to McLuhan's inasmuch as both are imperceptible to us because we are immersed in them. A medium is like an environment that allows doing and thinking according to its own conditions. The perceptible traits accessible to us are other media that act as content of the former, for example, one of McLuhan's favorite cases was that movies are the content of TV; literature and theater are the content of movies; and speech is the content of writing.

For McLuhan, we are only aware of the content and not the medium itself. Furthermore, what happens to the medium that acts as content is a "cultural upgrade", from an ordinary form to an art form. By making explicit a previous environment or technology, a medium gets studied, explained and refashioned. In other words, we abstract its properties and components for their comprehension and use. When TV started transmitting moving pictures, cinema left its technological phase and gave birth to TV shows, TV series, advertising, and televisual culture.

Following McLuhan, the arts act as "anti-environments" since they allow us to perceive the environment itself [MCL 03, p. 14]. In the electronic age, technologies move so fast that they also perform as arts. This is true in our context of study: constant innovations in digital imaging make us aware of different constituents and their relationships regarding digital images (new algorithms, new filters, new procedures, new visual designs, new applications). Since old media can be simulated and depicted as digital image, and because different communities tackle similar problems from diverse perspectives, it occurs that digital images advance, evolve and mediate as small fragments distributed along the ecology of software, formats, codecs, domains, disciplines, intentions and experiments. This is to say that an image mediates another one in different manners: it could be that it mediates the depicted image or that it mediates the technique or algorithm used. What we have to do, following McLuhan, is to discover, recognize and re-orchestrate patterns in those small fragments, which are residues of the mechanized environment of the machine revolution.

Therefore we can ask, how does the electronic environment upgrade mechanized parts and processes as art? According to media theorist Friedrich Kittler, who situated digital images in the long tradition of optical media, it is about opening up the total programmability of Turing machines to the users [KIT 10, p. 227]. The main thing to remember about digital

images, contends Kittler, is that they are no longer optics. They are part of a sequence of dimension reductions, going from the 4D space-time of the natural world to 3D sculptures, to 2D paintings, to 1D text, and finally, to 0D bits. At each reduction, the possibilities augment via abstraction and description of the precedent level, that is, there are more possibilities by representing the upper dimension instead of actually working with it (it would be easier to draw a golem made of TV sets than actually constructing it). However, digital images restart the process from the bottom, operating a dimensional growth: from 0D bit to 1D command lines to 2D graphical interfaces to 3D virtual reality interfaces to forthcoming 4D holograms, quantum computing, and non-Euclidean speculative data visualizations.

In their digital form, visual media are mediated by the computer, which is the environment that precisely allows this total programmability. In order to create or manipulate images, we use the language of hardware and software, that is, their conventions and modes of existence. Media theorist Lev Manovich has defined media in the era of software according to the formula “*Medium = algorithms + a data structure*” [MAN 13, p. 207]. For him, data structures are the digital representations of physical materials, while the algorithms relate to tools, techniques, operations and actions on such data structures; examples of data structures are bitmap and vector images, polygonal and NURBS 3D models, and text files.

The relationship between data structures and physical materials is of course not straightforward. Manovich observes that all different material supports that exist (or have existed) to create images (all the types of canvas, papers, celluloid films) are reduced to two data structures: bitmap and vector images. Moreover, the same data structures can be used to simulate different media: photographs, maps, software icons, and, we should add, the whole graphical interface.

As we can see, when visual information enters a process of signification, its understanding broadens in complexity. We encode and decode messages according to our particular experiences, which are framed by social structures (profession, country, religion, institutions). To say it differently, visual media are forms of expressing our thoughts and feelings. Moreover, visual media combines different meanings, styles and codes (not only pictures, but also texts and symbolic elements). Perhaps the difficulty and complexity of describing and defining digital visual media resides in the fact that it is ourselves who are the medium. If mechanized culture was the medium

whose content was agrarian life, and the electronic world is the medium whose content is the machine revolution, we might suspect that humanity and its representation models are the media whose content is the digital life. With software, algorithms and data structures, we are slowly shaping ourselves and changing our culture.

1.2.2. *Metaphors of visual media*

In the last section, we used the notion of “mediation” in a broad sense, as it fits media artifacts: how they function as forms or placeholders when a message needs to be constructed. In this part, however, we present briefly other contemporary views of mediation that, in general, ask to go beyond the material part and to focus on effects and processes. This observation will lead us to open up the kind of metaphors through which we usually understand visual media.

Through a critical reading of Kittler, McLuhan and Manovich, and informed by thinkers such as Louis Althusser, Gilles Deleuze, Alain Badiou and Jacques Rancière, media theorist Alexander Galloway contemplates new media, and particularly computers, not as objects but as processes, techniques, practices, actions and sets of executions. His endeavor is to leave media in favor of investigating modes of mediation. In philosophical terms, his theory invites one to move from the domain of ontology and metaphysics – which describe what media are – towards ethics, pragmatics and politics. Because computers define general principles for action, Galloway suggests studying digital media politically: reading the contemporary world as the actually existing social and historical reality. An example of putting this approach into practice could link formal structures and their realities, that is, what he calls centers and edges: image to frames; representation to metrics; realism to function; text to paratext. As Galloway puts it, “the edges of the work are the politics of the work” [GAL 12a, p. 42].

The political stakes of media and software take into account the institutional, economical, governmental and military origins of computers at the time of the Cold War, economical crisis, and labor organization. Media theorist Matthew Fuller asks in the same strand about the kind of user that is being imagined by software. Which “models of work” have informed a software application like Microsoft Word, for instance? As we have noted, Word cannot order lists alphabetically or produce combinatorial poetry

[FUL 03, pp. 137–165]. In association with the same principle of identifying “edges”, we can consider how the graphical space of Word is organized: it follows an idea of what is most important to have at hand in order to get work done. To think about the interface as edge means to forget for a moment that we are writing a document or a letter; instead, we are using a software dispositive.

Fuller points out that multiple working teams collaborate behind the design of tools available throughout graphical interfaces. To a large extent, this is made possible thanks to the programming paradigm implemented in development and production. As we will see in more detail in the next chapter, object-oriented programming constitutes a synthesis of procedural structurability and functional logic design [HAG 06]. Examples of OOP languages are SMALLTALK, EIFFEL, C++, Java and Ruby. Today, the great majority of software applications are produced and maintained with the latter three, and almost every aspect of industry has been restructured to cope and adapt to “the potentials and vicissitudes of software” [GAL 12b, p. 97].

From a similar perspective, media theorist Wendy Chun situates computers as neoliberal governmental technology and names them “mediums of power”, not only because they simulate to empower users (through easier to use interfaces and the impression of mastering the system) but, more importantly, because their interfaces embody ways to navigate the world: conceptually, metaphorically and virtually. Among such metaphors, we find software as mind, as culture, as society, as the body, as ideology, as biology, as economy and, in fact, as metaphor for metaphor. Software as power has to do with combining something visible (such as images and software on the screen) with something invisible (operations of computation). The result is an “invisible system of visibility, a system of casual pleasure” [CHU 11, p. 18] that we vaguely understand due to its technical layers of complexity, thus carrying sometimes unexpected effects. For us, it will be important to pay attention to those unattended situations that really do not exist in old media and that recall the human construction behind technological innovations: glitches, crashes and “creative bugs” (which refer to noticing behaviors through an error or chance, as is the case with serendipity).

Visibility and invisibility: political questions are closely related to aesthetics. Media theorist Warren Sack has shown, in a very informed manner, how we can trace the origin of computers to the division of labor, as

originally introduced by Adam Smith and accurately identified by Herbert Simon [SAC 14a]. Sack retraces a history of computing in order to understand how computers are language machines before they are numerical: it was through the translations from “work language” into “machine language”, from the machine diagrams of labor depicted by Charles Babbage, to their arithmetical description by Ada Lovelace, to their implementation as the language of computers by Goldstein and von Neumann.

Mediated as it is through the screen, computer code is also commonly understood as image and number [SAC 14b, p. 123]. Besides “visual programming languages”, which will be explored in the next chapter, this is precisely the case in web graphics and data visualizations: we can verify the data URI of a PNG image at the location bar of the browser, or check the X and Y positions of graphical elements in the SVG file. Following Sack, his take on data visualization is to avoid worrying about beautiful or culturally pleasant criteria; it is about asking whether it is aligned to bureaucratic or democratic principles. In short, he calls for an “aesthetics of governance” (where works interpret, organize, articulate subjects and things woven together), which is in tune with the principles and traditions of conceptual art [SAC 06].

In sum, this section intends to serve as a brief account of digital images from a standpoint beyond their material support. Specifically, the relation with social and historical contexts was established through political and ethical mediations, both in a sense more related to Jacques Rancière’s philosophical elaborations [RAN 00, RAN 03]. We observe the importance that is given to effects on the individual subject, the society and the community. Furthermore, these views consider seriously the mediated power and ideologies conveyed by software, artifacts and *dispositifs*, in the sense of Michel Foucault and Gilles Deleuze [DEL 86]. In the second part, we established a link with esthetics not only as a door that opens to material concretizations but also as a pathway towards artistic practices and positions.

Throughout this book, this section will be repeatedly evoked. This is even more important if we accept that more forms of mediation and metaphor can be invited into reflection. For example, what happens with ephemeral data art and data visualizations? Can we archive them when every instance of an image is an original, in the sense of [GRO 16]? What if we consider software, images and interfaces as a spatial and ecological flux that we and

other species inhabit, acclimate and alter during certain moments [SPU 16, ALE 77]? Or, can we approach a phenomenology of other species and object operations in a similar terrain of “flat ontologies” [BOG 12]? In any case, our point of view will be to intend so by making and reflecting on things, to couple theory and practice or, rather, making theory out of our practices.

1.3. Visual interfaces

Visual interfaces are a type of visual media with their own specific characteristics: they convey action and they establish a dynamic space where multiple actors interact at the same time and level (human users, computational procedures, digital media, computer devices). In this section, we explore some characteristics of visual interfaces from the tradition of computer science, history of technology, and media studies.

Media theorists Jay Bolter and Richard Grusin aptly imported what McLuhan called content and medium in terms of new media [BOL 99]. They introduced the notion of “remediation” to indicate the manner in which media, old and new, refashion constantly through two distinct yet interrelated logics. On the one hand, the logic of “immediacy” tends to make us forget the medium: it describes the state where the individual is immersed into the imaginary of the film, the novel, the news, etc. On the other hand, the logic of “hypermediacy” brings forward the medium: it makes us aware that we are immersed in content through the multiplicity and heterogeneity of material supports and configurations of a medium [BOL 99, p. 33]. Besides the examples they provide in their book, hypermediacy can easily be seen through breakouts that happen when we are using or watching a medium: we remember we are reading a book when we suddenly lose the page (so we come back to the page interface); we remember we are using a web browser when we have to locate the back and forth buttons to get out of a web page.

This section is then precisely about the visible, multiple and heterogeneous frames inside media. Visual interfaces organize content in space and also provide help for effectuating operations on it. Moreover, it seems that designing visual interfaces is also about designing momentary lapses of invisibility. We can think about buttons in media players as an

example of small interfaces that disappear when we are not using them, but we know they are there. Something alike happens to our experience within a whole web page: its entire spatial organization is also an interface, a large interface space where we spend some time. Finally, we consider an interface as the place that materializes deeper levels of abstractions: actions, behaviors, algorithms, objects and techniques.

1.3.1. Remediation of machines and media

The origin of the term “interface” has been traced back by cultural theorist Branden Hookway to the domain of fluid dynamics [HOO 14]. In 1869, engineer and physicist James Thomson used the term to “define and separate areas of unequal energy distribution within a fluid in motion” [HOO 14, p. 59]. If we imagine two water currents flowing in different directions, the interface is the form that originates when both currents meet. This creates fluidity. Since fluids (liquids and gases) are studied in motion, it might be difficult to perceive their changes; therefore, the interface also defines the potential forms that might emerge. Examples of complex and remarkable forms are found in a vortex or turbulence.

Among the technological developments based on fluid flows, there are windmills, water mills, and, more recently, turbines designed specifically to transform energy into work. We might observe how technical components such as blades and sails act as interfaces. They are shaped and produced to capture, in the most efficient manner, the flow.

Historian Sigfried Giedion stresses that the method that forms the basis of all mechanization is the human hand. “It can seize, hold, press, pull, mold with ease” [GIE 13, p. 46]. What the hand cannot do is to move permanently, and this is where mechanization becomes determinant. For Giedion, its first phase consisted of transforming into continuous rotation the pushing, pressing and pulling of the hand. The second phase was about the procedures by which mechanical components would be produced. For him, stamping, pressing, embossing, casting, all relied on dies and molds and facilitated standardization and interchangeability of parts.

This brief account is important because the history of inventions and technologies is also a history of interfaces. Through illustrative works such as [GIE 13, LER 73, ECO 61, GLE 17], we have a glance at those moments

and situations where innovations took place. These can also be seen as abstractions or virtualizations. It is about extracting the essence of an act that can be achieved with an object by which we can later communicate its function, even in the absence of the object. Consider the act of hammering. It might have been discovered with a rock, but it certainly can be realized with another object.

For philosopher Pierre Lévy, who identified media as virtualizations of actions, organs and things, inspired by Gilles Deleuze and Henri Bergson [LEV 98], there is, throughout the history of inventions, a small number of virtualizations, but a large number of realizations: how many times has the act of hammering been discovered in contrast to the amount of times people have performed the act of hammering?

When something is made or created, it can be done either creatively or in a more standardized form. This is not to say that there is no creativity in the standard, but only that its focus is on the practical achievement of something. Of course, innovation may rise from standards and, when the standard was first invented, it was once a creative type, but as it is widely adopted, it is more of a repetition and not a difference [DEL 68]. However, when something is created in a creative manner, it explores and approaches a solution in a different manner. This is the actualization. The creative thinking implies refashioning, modifying, remixing and combining elements. And when this creative solution is questioned and re-articulated, it is being virtualized.

To describe stable innovations, philosopher Gilbert Simondon uses the notion of “technical object”, which refers to a seamless communication of the human actor with the technicity: this “is specified by the convergence of structural functions because there is not, at a given epoch or time, an infinite plurality of possible functional systems. Human needs diversify to infinity, but the directions of convergence of technical species are of a limited number” [SIM 69, p. 23].

Giedion points to the fact that the quest of progress and perfection in mechanized societies is related to “rationalism”. It has always been necessary to analyze, describe and represent the endless movement put in practice by the machines, and Giedion retraces the history of the representation

and capture of movement: from Nicolas Oresme, who first created a graphical representation of movement (a kind of proto-bar chart or histogram), to Franck Gilbreth's physical wire models.

From the representation of movement to the capture of movement, Giedion shows us the work of Étienne-Jules Marey, who in the 19th Century invented devices like the spymograph and the myograph to record movement in a graphical form. Later, Marey used photography to register the trajectories and transformations of movement that the naked eye could not perceive. The "chronophotographs", as he called them, traced the movement at the rate of 12 frames per second in the same image. In complement to the work of Eadweard Muybridge, who depicted phases of movement in separated frames, Marey was interested in showing these states in a single frame. Besides his chronophotographs, he also experimented with capturing the movement of an object from different angles (by using three cameras: front, left, top), and he even crafted 3D sculptures of the successive attitudes of a seagull in movement.

These examples of remediation make evident a passage that goes from abstract geometrical figures to figurative images. It was in the late work of Marey and most prominently in the works of Frank Gilbreth that the passage comes back to abstract lines. Gilbreth invented the cyclograph around 1912 with the intention of recording the movement of workers at their posts. The resulting image was also called light curves because they were mainly white lines over black background. Later, Gilbreth also created a physical 3D model of those lines, but this time using wires. Contrary to Marey, whose interest was especially in scientific experimentation and the production of graphical forms, Gilbreth was interested in assisting workers to improve their efficiency. His graphs can also be considered mechanizations of human motion, and its abstraction could then be implemented as a model for a machine.

1.3.2. Conventions and standards in human-computer interaction

Regarding computer-based models of interaction, the kind of interfaces that we will revise are those that came after the era of punched card computers which flourished between the introduction of the ENIAC in 1946 and the 1970s.

In computer sciences, interfaces are not only visual or projected on a screen. A broad typology can be listed as follows [FUL 08, p. 149]:

- users to hardware (input/output devices, etc.);
- hardware to hardware (such as bus systems);
- hardware to software (for instance, device drivers);
- software to software (application programming interfaces or APIs);
- software to users (graphical user interface or GUI).

A more refined and detailed typology of interfaces can also be evoked: command line, WIMP/GUI, multimedia, virtual reality, information visualization, web, consumer appliances, mobile, speech, pen, touch, air-based gesture, haptic, multimodal, shareable, tangible, augmented reality, wearable, robotics and drones, brain computer interaction (BCI) [PRE 15, p. 159].

Although in this part of our study, we mainly focus on graphical and visual interfaces, we can identify a commonality to all those interfaces if we describe them one layer above: they require being created and programmed in a graphical developing environment (also called SDK, or software development kits). We are talking about software to create software. Such environments, we will see in further sections, use a combination of graphical interfaces and programming languages adapted to specific purposes and domains.

After the era of punched card computers, several command-based or command line interfaces (CLI) appeared in the 1980s. At that time, some computer systems had already used a CRT (cathode ray tube) display, as exemplified in the famous demo of the “NLS” system by Douglas Engelbart in 1968. Moreover, virtual reality was being pioneered in that decade as well: the “Sensorama Simulator” by Morton Heiling in 1960 and the “Ultimate Display” by Ivan Sutherland in 1965.

Examples of CLI are DOS/UNIX shells that allow accessing the operating system of a computer. Today, we still use CLI when we manage files or launch batch operations from the Terminal application in OSX, which is based on Bash as Unix shell, or with programming languages that include a CLI mode: Python, R, MATLAB, LISP. Among the issues of interest in CLI, the syntax of commands has been paramount. Should we use

an abbreviation or full name to invoke a command? How can we combine different commands? One of the principles that prevailed is that of consistency: using the first letters of word to abbreviate or adopt a noun-verb/verb-noun logic [RAS 00].

CLI were rapidly challenged by graphical user interfaces (GUI). In 1970, Xerox Corporation established the Xerox Palo Alto Research Center (PARC), and by 1972 they created the Xerox Alto, the first personal computer with a bitmap screen, a pointing device, and a graphical interface. It was their second landmark, the Xerox Star in 1981, in which visual interfaces benefited from extensive research on visible mechanisms, design principles, user-oriented methodology, and empirical testing [WIN 96, pp. 32–36].

Computer scientist Ben Schneiderman explains some aspects that made it easier to understand relations in a visual rather than linguistic form through GUI. With the concept of “direct manipulation”, he states the importance of presenting continuously the object of interest and being able to simulate physical actions on it, which would also immediately inform the user about the result. Direct manipulation can be seen in WYSIWYG (what you see is what you get) interfaces, visual programming, and GUI. One of the important tasks is to build an appropriate representation or model of reality and to keep in mind the simple syntactic/semantic model of human cognition [SHN 83].

On the one hand, syntactic knowledge is ephemeral. It demands that the same operations be constantly reproduced, otherwise they are forgotten. On the other hand, semantic knowledge can be imagined as layers. At the lower level, there are actions similar to command language: copy, paste, insert, delete, etc. These are commonly software agnostic. Subsequent layers would add combinations of series of actions: correct spelling, moving paragraphs among sections of a text, etc.

The basic GUI visual elements that were introduced by the Star were later refined by the Apple Macintosh in 1984 and consolidated by Microsoft Windows in 1995. The elements are windows, scroll bars, checkboxes, panels, palettes, dialog boxes (confirmations, error messages, checklists, forms), buttons; icons depicting tools, applications, and low-level semantic operations (e.g. cut, copy, paste); and different styles of menus: flat lists, drop-down, pop-up, contextual and expanding menus.

Those visual elements have also been the subject of graphic design explorations in style: B&W, color, shadowing, photorealistic images, 3D rendering, animations, flat design [PRE 07, p. 236]. Besides that, inside the space of an interface, they are arranged in visual frameworks [MUR 12, p. 79]: table, columns, flow charts, hierarchy charts, taxonomies, networks, maps, timelines, bubble diagrams, or any other arbitrary form (such as infographics, which might use visual metaphors [BOL 01, p. 52]).

As we know, all those basic elements from the 1980s are still in use today. They have become conventions, in the sense of media theorist Janet Murray: “social practices and communication formats shared by members of a culture or subculture, as well as media formats shared by artifacts within the same genre” [MUR 12, p. 415]. For her, the move towards conventions must follow a direction in which digital media is exploited according to four affordances, each one of them related to concepts and knowledge from special disciplines: encyclopedic (information science), spatial (visual design), procedural (computer science) and participatory (human–computer interaction) [MUR 12].

Perhaps the most advanced efforts to standardize digital media come from guidelines and specifications, best practices, international recommendations, consortiums and, more recently, design patterns. Among the most acclaimed software guidelines, we may cite the Macintosh Human Interface Guidelines, later changed to Apple’s Human Interface Guidelines, and the more recently available iOS Human Interface Guidelines. In those documents, Apple describes its vision of WYSIWYG, metaphors, direct manipulation, and how to use the interface elements (i.e. menus, windows, dialog boxes, controls, icons, colors, behaviors and language) [APP 85a]. Regarding specifications, around the same years, in 1993, the International Organization for Standardization released the ISO 9241 titled “Ergonomic requirements for office work with visual display” starting with requirements for visual displays and keyboards. Today, ISO 9241 covers ergonomics of human–computer interaction on eight levels, going from software ergonomics to environment ergonomics and tactile and haptic interactions [ISO 14]. Another example of standardization is the World Wide Web Consortium (W3C), initiated by Tim Berners-Lee in 1994. Its focus is on the standards for the web: languages, technologies, protocols and guidelines (W3C 2014).

One of the underlying principles that has allowed media software to flourish and expand is the potentiality to interchange files and data between applications and operating systems. This is possible because data structures and data formats are common in several environments. For example, although the Graphics Interchange Format (GIF) started as a proprietary technology developed and owned by CompuServe in 1987, it can be used for free today, that is to say that the technique of compressing data with the algorithm LZW and its packaging in a GIF file can be freely used by developers. As we know, GIF animated images have gained popularity with the explosion of web-based social networks; hence, they can be opened, distributed, embedded and produced with many different software.

1.3.3. Visual space of image interfaces

We have seen that visual interfaces are particular types of visual media that exist on the electronic screen. We understand display devices as material supports that delimit the potential kinds of images to be depicted. Visual interfaces act by organizing commands and operations as representations of such potentialities. For instance, when we use application software, most of them have low-level operations that allow us to copy and paste but, in some cases, the software itself allows us to regroup in a macro, or through a script module or plugins, a bunch of operations that we might use recurrently: crop, adjust levels, and add filters for a series of images. These are abstractions or descriptions of a higher level.

A fundamental critique of standardization has been that it constrains creative and original alternatives. This happens when we want to do something different to what the software confines us to. But why would we be willing to do something different? A possible answer has already been noted with Simondon: because human needs tend to evolve continuously and technical objects have to be rethought, experienced, tested. In short, they have to be used by the society.

Hookway has noted that an interface theory is also a theory of culture. An interface describes a cultural moment: “to use an interface is to participate in culture” [HOO 14, p. 16]. Furthermore, the interface comes into being when it is actively used. The cultural relation between interfaces and human users is a critical part that motivates its creative developments and uses. Of course, today screens are pervasive. They are everywhere, with different sizes and

technical specifications. We use them for different aspects of our life, from work to leisure. As such they are cultural objects that mediate and simulate our physical interactions. Media theorist Lev Manovich named software interfaces as “cultural interfaces”, integrated in “cultural objects” (websites, games, mobile apps) that allow us to access “cultural data” (images, texts, videos, etc.) [MAN 01, p. 70].

The fact that the screen is a visual machine makes us aware that everything projected on it is a digital image. More precisely, this means that multiple visual media cohabit the same space, but also that they can exchange visual properties between them. The text written in a text editor can be, for example, resized, colored, stylized. While the text conserves its linear properties in order to be read, it can also be animated, fragmented, turned over or around, and it might also be deleted, replaced or shaped into another form. More interestingly, as we will see, visual media can also exchange operations.

The interest in challenging predisposed organizations or relations between media is not new. We recall experiments in text by poet Stéphane Mallarmé (*Un coup de dés*, 1914); writer Filippo Marinetti (*Zang tumb tuum*, 1914 or *Mots en liberté*, 1919); and poet Guillaume Apollinaire (*Pablo Picasso SIC*, 1916 or *La cravate et la montre*, 1916 or *Lettre Océan*, 1916). Later, with the advent of video technologies, text was conceived as motion graphics: *Catalog* (1961) by artist John Whitney and movie title sequences such as designer Maurice Binder’s 007 James Bond movies from 1962–1989 or graphic designer Saul Bass’ in *Vertigo* (Hitchcock, 1958). More recently, with classical net art pieces such as *Jodi.org*³ by Joan Heemskerk and Dirk Paesmans in the mid-1990s, or recent exhibitions like *Chercher le texte*⁴ (curated by Philippe Bootz in 2013), text has also become an animated web element. From this point, design of visual interfaces has been influenced by graphic design and modern and contemporary art. One of the motivations behind those explorations is, as digital art pioneer Frieder Nake says, that “aesthetic computing deliberately introduces subjectivism into computing” [NAK 08].

In the academic world, we can also see innovations in the field of digital humanities. Media theorist Johanna Drucker calls on us to rethink our

3 <http://www.wwwwwww.jodi.org/>

4 <http://gallery.dddl.eu/en/home/>

interfaces under the sight of a humanistic design which is subject-oriented [DRU 14]. Her approach consists in taking into account the “subject positions in relation to the act of engagement with media” [DRU 14, p. 151]. By redefining the user as a subject, instead of having pre-defined “needs”, she can also wander around or discover a corpus of data by applying scholarly methodologies (e.g. comparison, interpretation, discussion, suspended conclusions). In this respect, visual interfaces and their graphical organizations might function as provocations to cognition and esthetics.

Some examples of developments created in the digital humanities domain take advantage of the web as a platform. For a person, it is possible to use a website as a web app. That means the design of web pages becomes also a matter of interface design. Consider the popular Wordle⁵, which generates text visualizations in the form of a cloud, where the size of text is not an arbitrary decision but is rather related to the number of frequencies of that word. Another example is the more robust Voyant⁶, which not only has traditional graphical representations of text analysis, but also includes some experimental representations such as Lava and Bubbles.

With this brief description, we learn that the visual space of an interface can be questioned by practice. In order to go beyond a certain model of action or user, it is sometimes necessary to dig down a level below the visual interface, that is, the programming code, data structures, data types and algorithms. However, once we have manipulated and constructed a prototype, we come to the surface by means of standard elements of the interface. However, the new object has the novelty that it has been thought from a different angle, perhaps artistic, experimental, technical, or as a new tool for digital humanities or cultural analytics. In any case, interface designers should be aware of such levels as well as the cultural and structuring regimes in which they takes place.

Graphical organizations are abstractions of “structuring spaces whose relations create value through position, hierarchy, juxtaposition, and other features in an act of interpretation” [DRU 14, p. 177], in a similar manner in which menus, windows, and frames abstract operations and sequences of commands. As we have seen, an abstraction is a model that extracts a mode of operation; therefore, it can also be used in different contexts. Interfaces

5 <http://www.wordle.net/>

6 <http://voyant-tools.org/>

abstract actions, tools and components. What we will put attention on in further parts of this book is how graphical supports of visual information (mainly in digital art and digital humanities) impersonate interchange operations that were dedicated to interface elements before. If translations from one language to another are called intra-linguistic, and if the combination of multiple types of images into the same context (such as collages or websites) is called inter-pictorial, then we will call interface exchanges as inter- and intra-interfacial.

1.4. Visual methods

In this last section of the first chapter, we will deal with the general question: which methods exist to analyze images and how can they help us in the design of graphical information? The intention is to explore existing frameworks that put in practice the description of images through a defined model with its values and components. This section is more focused on research from humanities and social sciences before we study in more detail methods from computer science in the following chapters. The overall objective will be to think about the problem of elaborating and envisioning new methods suited for graphical information and interfaces.

The first observation to make at this point is that the analysis of images depends on the context of use and the type of actors that intervene in the process. Examples of context of use are disciplines and fields. They generally ask the question: why do we need to analyze images? What are the goals and outcomes? It is obvious that analyzing images implies different objectives for a computer scientist specialized in computer vision, whose techniques might include image segmentation and image recognition of objects, than for an art historian who specializes in styles, connotations and themes from one epoch to another. The types of actors that intervene in such examples may be human and technological: an artist, a scholar but maybe also a series of algorithms that extract information, recognize shapes, and take decisions. However, although contexts and actors may differ, the object of study remains the same: it is about studying images and creating models to understand them. We believe that creative forms of graphical information might be found if we adopt a larger point of view regarding the variety of visual methods across different domains.

In the following sections, we cover four main areas where visual methods can be found: 1) the so-called field of visual studies; 2) visual semiotics; 3) diagrams and graphics; and 4) visual analytics and interface design.

1.4.1. *Visual studies*

A large amount of literature that deals with images falls within the domain of visual studies. The area of study has been described in the works of David Mitchell, Nicholas Mirzoeff, James Elkins or Gunalan Nadarajan. A common trait of visual studies is the recognition of the differentiated power of images in several states: when it is being constructed (how the producer imprints desires and messages); when it is already constructed (how it coexists with the ecosystem of images); and when it is consumed (how it talks to the viewer and how it might have an influence).

The largest field that has attracted researchers of visual studies is the history and theory of arts. Traditional types of images that serve as objects of study include paintings and drawings. More recently, with the development of mass media, researchers have diversified these types to include photographs, advertisements, comics, film, television and fashion. The case of scientific imagery, although less prominent in visual studies literature, has also been evoked in some works [ELK 08].

Broadly speaking, the description of images from the standpoint of visual studies represents efforts to adopt a more systematic mode of seeing pictures. They try to structure the gaze of the observer in front of a picture and to relate her insights with the context of the production of the image. The result of an analysis informs about the tools and techniques used, its visual construction, and the social practices that it raises. Such methodologies seem more suited for students and young researchers interested in understanding and interpreting images, documenting and cataloging corpora of images, and collecting qualitative data with techniques such as photo-elicitation: “using photographs to invoke comments, memory and discussion” [BAN 07, p. 65].

Scholars like Gillian Rose or art historians like Laurent Gervereau have defined similar methods that distinguish between the description of the image itself, its context of production, and its context of reception or interpretation. They promote the use of a grid of analysis that helps structure the observations: name of producer, date, type of support, format,

localization, main colors, main objects, theme, what was the purpose of producing the image, how does it fit in its historical context, how was it received, which meaning does it evoke, and the personal appreciations of the observer.

Regarding the gaze of the observer and the image itself, visual studies often use terminology from other disciplines in order to provide strategies of seeing. From the description of the format and dimensions of the image, they identify golden proportions, the movement of the gaze in the surface (linear or circular depending on how figures, colors and tones drive the attention of the eye), symmetrical or asymmetrical compositions (in the form of triangular or diagonal), horizon lines, vantage points, golden sections, and chiaroscuro relationships. It is worth noticing how some authors modify the image analyzed to depict their findings: they often make diagrams or trace marks on top of the image or create simplified models of the main objects of interest in the form of contours (see Figure 1.1).

Taken together, we can ask where the producer, the image itself and its reception come from. It might seem straightforward to relate these kinds of image analysis to the basic model of communication: sender (the producer of the image) – message (the image itself) – receiver (the public or the observer). If we would like to elaborate or construct methods in the same line, we could recall, for example, the work of linguist Roman Jakobson, who extended the communication model into six elements and identified communicative functions for each element:

– *Sender*: the attention is placed on the producer, that is, the actor(s) who create the image or any other message. Jakobson describes the function of the sender as expressive.

– *Receiver*: the public or the observer are seen as performing a conative function as they have to engage in the process of understanding and modifying their behavior based on the expression of the sender.

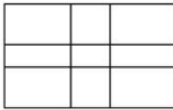
– *Message*: the message itself is regarded as a poetic function based on the many ways to enunciate and express something. Esthetic and rhetorical values are considered when the focus is placed on this element.

– *Code*: the material expression by which a message is realized. The function is metalinguistic in the sense that both the sender and the receiver are expected to understand the expressive form and substance. Examples of code can be language, pictures or sounds.

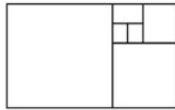
– *Channel*: the attention is put on verifying that the distribution channel works properly. It ensures contact or can also inform about the general atmosphere and conditions for communication. The function is called phatic.

– *Context*: the reference ground in which the communication exists. When attention is given to this element, it can point to historical epochs, themes, places or circuits of distribution, and background environments. Its function is referential.

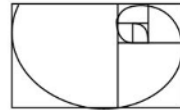
Divine proportions



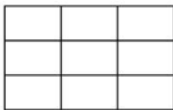
Golden spiral sections



Golden spiral



Rule of thirds



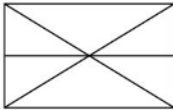
Golden triangles



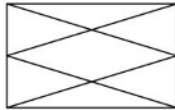
Harmonious triangles



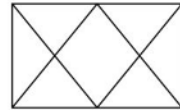
Midpoints



Diagonals



Diagonals to midpoints



Combinations and variations

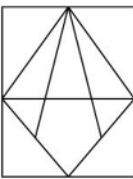
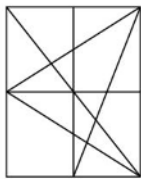
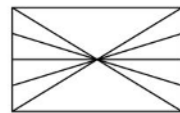
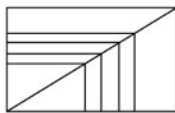
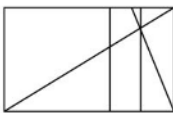


Figure 1.1. Typical composition techniques

The hierarchy of Jakobson's model of communication does not intend to be exhaustive or discriminatory; it is rather a formalism that aims to direct attention. In practice, the situations are more complex than the examples because all the elements can be present in a communicative process or can behave in a dynamic fashion, varying and modulating their position within the hierarchy.

As we have said earlier, this book is not strictly about interpreting images, but rather about discovering strategies to design and implement graphical information. We will refrain from making interpretations or talk about the styles and esthetic effects of images. Visual studies often have the intention of explaining meanings, from symbolisms attached to objects to the historical momentum in which non-figurative images such as abstract art can be understood. In the next section, we turn to models from visual semiotics, which have studied more rigorously the visual aspects of images and tried to describe the mechanisms underlying meaning production.

1.4.2. *Visual semiotics*

Linguistics has influenced in several ways the description of images. Besides Roman Jakobson, major exponents such as Louis Hjelmslev, Algirdas Greimas or Émile Benveniste have drawn on the work of Ferdinand de Saussure, who initiated the field of semiology within the theory of language at the beginning of the 20th Century. However, around the same time as Saussure, the field of semiotics was also conceived by philosopher Charles Peirce with the intention of situating a doctrine of signs within the boundaries of pragmatism. Today, semiotics benefits from both its philosophical and linguistic heritage, and it strives to extend to experimental methods informed by cognitive sciences – a branch known as cognitive semiotics.

The study of images has been widely associated with Peirce's most famous triad that identifies a sign in relation to its object. First, an icon is a sign that keeps a relationship of similarity with its object. Paintings, photographs and drawings can be icons if they resemble the depicted object. Second, an index is a sign that relates to its object by perceptible or perceived directness. Popular examples are footprints in the sand (produced at a moment before perception) and arrows (perceived as direction). All images have indexical properties: they relate to their mode of production (made by hand or using technological means), the material support used

(paper, screen, etc.), the title given by the author, and may have internal directions, such as vectors that direct the movement of the eye. Third, signs are symbols by cultural convention to their object. Here, the observer adds cultural categories to images: a figure of a man with ornaments and accessories can be seen in its social role (a warrior, a sorcerer, a worker, etc.) and, ultimately, it can symbolize an ideology or a greater category (Christianity, capitalism, socialism, etc.).

A more systematic description of images came from the distinction between figurative and plastic signs, which was first observed by Algirdas Greimas and further elaborated by Jean-Marie Floch, Félix Thürlemann and the Groupe Mu. On the one hand, figurative signs constitute the layer of the image that simulates the world as it appears to human perception, also called iconic signs and developed as pictorial signs by semiotician Göran Sonesson [SON 89]. The plastic layer, on the other hand, has emerged from studies of proto-iconical and non-figurative signs, such as abstract art. The Groupe Mu categorizes three main components that exist in this layer: colors, forms and textures. Extensively, in a similar way of linguistics, they decompose each category into basic units of meaning: colorèmes have variations of hue, saturation and brightness; formèmes can be arranged in direction, position and dimension; and texturèmes observe single patterns and their laws of repetition and distribution.

In general, methods for analyzing images have been configured according to two planes: the expression plane and the content plane, which developed from the linguist separation of signifier and signified. Louis Hjelmselv refined each part into planes and proposed that each one has two further dimensions: form and substance. In this respect, there are substance and form of expression on one side, and form and substance of content on the other side. Following this theory, meaning or semiosis arises from the collaboration of both the planes. The importance of such a distinction establishes a systematic focus either on the material or on the interpretative part of a sign. Algirdas Greimas, for example, developed a generative trajectory of content associated with narrative and discursive instances. More recently, semiotician Jacques Fontanille elucidated a possible generative trajectory of expression: going from signs to texts to objects to practices and then to strategies and life forms [FON 08]. The scheme has been useful to determine formal supports that give ground to substance supports. In this view, forms are like syntax vocabularies and rules that delimit how the

substance will be manifested. Accordingly, the substance of one level becomes the form of its upper level (see section 2.1 for a more detailed discussion).

Seminal examples of image analysis in the semiotic field that put in practice plastic and figurative signs, as well as content and expression planes, can be found in Thürlemann and Floch, who have pushed forward historical analyses by semioticians Roland Barthes and Umberto Eco. In his own strand, Sonesson has criticized and studied the possibility of different models that can also be used: the narrative model, the rhetorical model (in its taxonomic and systematic modes), the Laokoon model and experimental models [SON 89, SON 94]. The investigations in pictorial semiotics by Sonesson announce that its goal is not really to analyze images or producers of images, but rather to identify general rules that might apply to particular types of images. His emphasis is on finding the specificities that make an image a kind of visual sign, in all its possible varieties of signification.

An image is then considered as a way to distribute marks on a surface; it is a surface treated in some manner. As an object of study, the image must possess signification for someone and should participate in different pictorial kinds (the picture type, the picture function or the picture circulation channel). Sonesson's concept of sign is taken from phenomenologist Edmund Husserl and psychologist Jean Piaget: a sign is a complex entity that is perceived directly as non-thematic (the expression), while the theme is given indirectly (the content); and the sign must comply with a principle of discontinuity between the signifier and the signified (this is the case with objects represented only by some of their parts, mainly because the rest might be hidden or because the frame of a picture interrupts them). Throughout the exemplary image analysis made by Sonesson in different publications, he makes recourse to structural and textual analysis traditions in order to describe properly the elements of an image. Then, for each observation of figurative and plastic signs, there are series of attributes and values that elaborate meaning when viewed as oppositions and factorialities (relationships between the whole and its parts). Experimental studies in psychology such as Gestalt theory and prototypical (and anti-prototypical) structures also find their place in tackling internal composition and human expectancies in perception where shapes, colors, symbols and picture types conform or do not conform to universal structures.

We believe that visual semiotics can be broadened by taking into account research from different fields and domains. Just as in psychology and cognitive sciences, advances in computer science can contribute to the description of images. The objective would not precisely be to automatize methods, but would rather be to offer the possibility of new and different descriptions, configurations and terminology for the expression plane. We will refer to this section in further parts of this book, especially when we discuss practices of image interfaces in Chapters 4 and 5.

1.4.3. *Diagrams and graphics*

Let's come back to Peirce, as briefly mentioned in the previous part. As is known, much of his reasoning used triads to explain categories. A sign for him is conceived as a relationship of three parts: an object, a sign vehicle, and an interpretant (the latter should not be identified as a person, but rather with interpretative or meaning making mechanisms that provoke an action or reaction in the light of the object). Then for each category, there are special kinds of signs. We have already talked about the types of signs in relation to their object: icons, indexes and symbols. In this section, we want to consider his further typology of icons: images, diagrams and metaphors.

For Peirce, images, in their restricted sense, are icons that share similarity with their objects by means of simple qualities: color, size, tonality, shape. Diagrams are icons that represent “the relations (...) of the parts of one thing by analogous relations in their own parts” [PEI 98, p. 274], for example, mathematical diagrams, maps, statistical diagrams, and certainly different forms of data visualization. Finally, metaphors refer to their object by the intermediary of a third object that relies upon the general understanding of different types of diagram schemas.

In a study devoted to icons and diagrams, semiotician Frederik Stjernfelt shows how diagrammatic reasoning can be used in the analysis of pictorial images. Because diagrams are skeleton-like sketches of their objects (and the author indeed creates sketch versions of art paintings), the relations between their parts follow a rational form of seeing and thinking that allows for obtaining more knowledge about their objects. Moreover, natural perception, explains Stjernfelt, possesses diagrammatic abilities that permit one to perform ideal manipulations on the object. Consider how, for instance, in front of a picture, it is possible to imaginarily simulate being inside of it, or

how we can mentally rotate or scale depicted objects. From this standpoint, all images are also diagrams: “what is gained by realizing the diagrammatical character of picture viewing is not least the close relation between picture and thought” [STJ 07, p. 288].

Of course, diagrams are not only derived from visual phenomena; they can also emerge to chart ideal relationships. In mathematics, different diagrams are used to support proofs or demonstrate relationships between parts of geometric figures: from diagrams in Euclid’s *Elements* to algebra diagrams by René Descartes to complex higher dimensional abstractions such as in Riemann and Klein models. In other sections of this book, we also evoke logic diagrams that represent states of a machine and diagrammatic attributes of the visual programming paradigm, where computing code written in environments such as Max/MSP, Pure Data or NodeBox specify variations of a generative digital image while making the code a diagram as well.

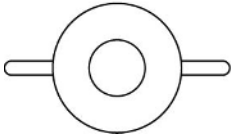
Further cases of diagrams can be found in social sciences and humanities. A prominent example is of “sociograms”, introduced by Jacob Moreno in 1932 to depict social relationships among groups. Sociograms have developed through the work of scientists like Albert Barabási and many more working in the field of network sciences. Artists have extensively used diagrams too, not only as primary sketches of paintings but also as a way of making notes, organizing thinking, or even as pedagogical resource, as was the case for Johann von Goethe, Filippo Marinetti, Wassily Kandinsky and Paul Klee, to mention only a small sample. Although subjective and arbitrary, personal diagrams reflect on the thinking processes and potential knowledge that can be gained from the study of their parts.

One of the differences between functional diagrams and pictures as diagrams are the explicit symbolic set of rules necessary to complete the meaning of relationships. Here, we are thinking about legends, numbers and other symbolic forms which, in their absence, would make diagrams closer to proto-icononical images, such as visual jokes (see Figure 1.2).

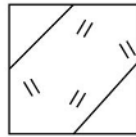
In his seminal work on the semiology of graphics, cartographer Jacques Bertin [BER 05] deals precisely with the study of rational images where the meaning of each sign appearing in a graphical form is conceived before it is observed by its public, that is, elements are previously and carefully arranged according to visual variables and levels of organization. The goal

of Bertin is to provide a method based on visual syntax and combination rules in order to produce meaningful ways of conveying information in a graphical form.

A Mexican on a bike
seen from above



A giraffe crossing a
window



Soldiers marching
behind a wall

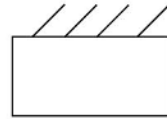


Figure 1.2. *Examples of proto-iconical images (visual jokes)*

The visual variables that Bertin distinguishes are seven: the 2D plane, scale, value (degrees of saturation and brightness), grain (simulated textures), color, orientation and form (circle, rectangle, triangle, glyphs, etc.). He then demonstrates how to use these variables according to four retinal variables [BER 05, p. 48]: 1) selective (signs are perceived as different); 2) associative (signs are perceived as similar); 3) ordered (signs are ranked); and 4) quantitative (signs are perceived as proportional to numeric factors).

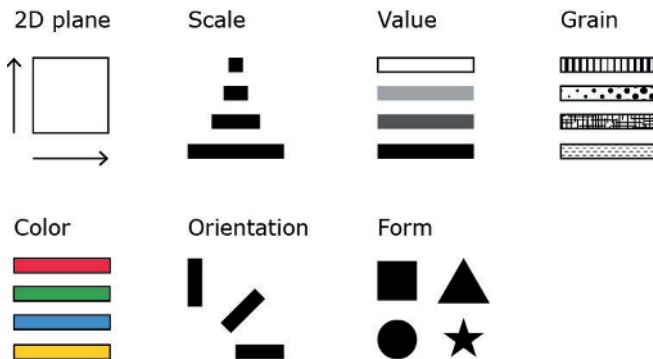


Figure 1.3. *Visual variables according to Jacques Bertin*

Furthermore, Bertin distinguishes what he calls “imposition groups”, which are none other than visualization categories: networks, cartographies, diagrams and signs/symbols. Imposition groups are derived from several imposition types or spatial organization patterns: linear, circular, orthogonal and polar. Special cases occur when more than two components need to be represented: then he adds volume projections in perspective view (Chapter 4 deals with these “imposition types” from a different categorical perspective: charts, plots, network graphs, geometric sets, and variations/combinations).

Although Bertin’s work was done before the use of computers, his lessons are still valid in many contemporary uses of graphics. In historical and recent accounts of graphical information, [TUF 97, LIM 11, MEI 13 DRU 14], we observe how designers use visual variables in creative manners. More recently, with the explosion of computing information visualization, it is exciting to notice models and tools that allow general users to practice with their own sets of data. In the following chapters, we will explore in detail libraries and web apps that support certain kinds of models, but it will be necessary for us to revise how such models are technically and formally implemented in order to challenge them.

1.4.4. Visual computation

Historically, the relationship between computer sciences and images has yielded specialized groups interested in the development of computational and mathematical methods in image processing (IP), computer vision (CV), computer graphics (CGI), and multimedia/hypermedia systems. It has also introduced new methods in established disciplines and fostered the emergence of new fields such as visual analytics, algorithmic architecture, digital art/design, digital humanities, and cultural analytics.

Simply put, the overall functions of computers can be understood from four main operations: to receive, to process, to store, and to emit information (philosopher Michel Serres observes that these operations also apply to living systems, inanimate objects and human associations. Therefore, the computer, as a universal machine, helps erase the gap between social and natural sciences because it simulates the behavior of all the objects in the world [SER 07]). From this classification, we can identify methods and techniques that have been developed for each operation. To receive information relates to digitization, image capture or image acquisition. To

process information includes image representation, analysis, enhancement, generation and compression. To store information relies on bits and bytes organized in data types and formats. Finally, emitting information is concerned with image projection and image transmission through different networks and protocols.

Methods in visual computing are elaborated and used to solve practical problems. Although many foundations, concepts and techniques are shared between the specialized groups (IP, CV, and CGI), there are also specific goals. It is commonly recognized that one of the first uses of IP was in images obtained from particle accelerators and space probes in the early 1960s; the original intention was to improve quality in order to be perceived by humans. More recently, IP is concerned with all the processes that are carried out once the image has been digitized and stored in the digital format. It comprises techniques like image representation and description, image formation (quantization, sampling), image analysis (segmentation, feature extraction), image restoration, color processing, image transformations (pixel processing, geometric transformations) and image compression.

Regarding CV, it concentrates on gathering, describing and analyzing information. As we can see, it also uses image analysis, but strives to go from a syntactical description of objects and scenes to a semantic level where the system would be capable of taking decisions (such as clustering, learning and recognizing shapes). During the 1980s, the approach developed by David Marr introduced the first formalizations of vision for computing purposes. Marr was interested in deriving shape information from images, entering a sequence of representations from what he called the primal sketch (constituted by edge segments, blobs, groups, boundaries) to 2½ D sketch (local surface orientation, distance from viewer, discontinuities in depth and surface) and to 3D model representation (volumetric and surface primitives) [MAR 10, pp. 36–37]. Later, other research has extended Marr's investigations to include the particularities of the observer (human or computerized), changes in the context and evolution of internal structure of the system, such as machine learning and more recently artificial neural networks or “deep learning”.

Finally, CGI deals with producing and synthesizing information. It adopts a somehow inverse direction from CV: it constructs and produces images based on a given computational model, most commonly: polygons, surfaces

and volumes. In the late 1960s, the first uses of CGI appeared in the form of computer modeling, computer animation, virtual worlds, and digital art. Let's remember, for example, the "Sensorama Simulator" by Morton Heiling (1960), the artworks "Aku" (1977) and "Transjovian Pipeline" (1979) by David Em, and "Legible City" (1989) by Jeffrey Shaw.

IP, CGI and CV integrate their methods in applied areas such as scientific visualization, multimedia/hypermedia systems, video games, and digital art. The way in which this integration takes place is in the form of software. While each of the applied areas have dedicated tools, libraries, APIs and SDKs, it is interesting to note that software packages might implement the same techniques and algorithms, but by adapting its functionality according to the domain conventions and vocabulary. Consider how programs like ImageJ, Processing, Unity, Photoshop or QGIS use interface metaphors and organize workflow through their command menus.

In the past 10 years, we have seen emergent areas that have started to use extensively visual methods in their research agendas. In 2005, the well-known report *Illuminating the Path*, edited by Thomas and Cook, introduced the notion of visual analytics and defined it as: "the science of analytical reasoning facilitated by interactive visual interfaces" [THO 05, p. 4]. In the same year, the media editor Tim O'Reilly called for the era of "Web 2.0" [ORE 05], broadening the scope of data mining to the social Internet and into what is called today big data. The massive creation of texts, images and videos by any user with access to a connected computing device accelerated the development of procedures to analyze and visualize information using high-level languages like R, Python and JavaScript. We have seen that fields like "information design" are now labeled "data and information visualization", with dedicated compendiums of creative projects by designers and developers [MEI 13, LIM 11].

In 2008, Lev Manovich oriented his work on software studies towards "cultural analytics" with the aim of studying cultural data (i.e. data that is produced by everybody on an everyday basis, as opposed to scientific data for example) through IP techniques, opening the path to techniques such as media visualizations, image plots, image histograms, and motion structures. Also in 2008, the former field known as "humanities computing" started to redefine itself into "digital humanities" [SCH 08]. While the primary emphasis of scholars and practitioners seemed to be in text analysis and processing, visual methods can be found in metadata descriptors, cartography, and

diagrammatic visualizations of texts (word clouds, word trees, network topologies). Other researchers use image reconstruction techniques with heritage and historical data to produce 3D models and simulations of ancient buildings and cities.

Finally, arts and design have also embraced visual computing. From the early development of CAD systems dedicated to architecture and industrial design, we observe new trends such as “algorithmic architecture” where programming code and scripts are used to create variations and generative design [TER 06, PET 13]. Researchers like Anthony Dunne, Fiona Raby, Johanna Drucker and Bettany Nowviskie have approached speculative and critical visions of design applied to graphical interfaces and devices. In art, visual computing has been considered as a means of expression, of subjectivity, of political contestation, and to represent the complex and contradictory nature of human condition. Finally, the school of pioneering artists such as John Whitney, Saul Bass, John Maeda, Jean-Pierre Balpe, Jean-Louis Boissier and Roy Ascott, among many others, has a strong influence on new generations of scholars that create, code, prototype and teach with their own productions – from artistic visualizations to computer games – as intellectual objects (to mention only a couple of recent examples, the reader can consult the recent volumes of the collection *Digital Tools & Uses* published by ISTE-Wiley [SZO 17, REY 17, BOU 17]).

